

NASA SP-222(08)  
VOLUME II

**NASTRAN<sup>®</sup> USER'S MANUAL**

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Volume II

NASTRAN USER'S MANUAL

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## INTRODUCTION

The User's Manual is one of four manuals that constitute the documentation for NASTRAN, the other three being the Theoretical Manual, the Programmer's Manual and the Demonstration Problem Manual. Although the User's Manual contains all of the information that is directly associated with the solution of problems with NASTRAN, the user will find it desirable to refer to the other manuals for assistance in the solution of specific user problems.

The Theoretical Manual gives an excellent introduction to NASTRAN and presents developments of the analytical and numerical procedures that underlie the program. The User's Manual is instructive and encyclopedic in nature, but is restricted to those items related to the use of NASTRAN that are generally independent of the computing system being used. Computer-dependent topics and information that is required for the maintenance and modification of the program are treated in the Programmer's Manual. The Programmer's Manual also provides a complete description of the program, including the mathematical equations implemented in the code. The Demonstration Problem Manual presents a discussion of the sample problems delivered with NASTRAN, thereby illustrating the formulation of the different types of problems that can be solved with NASTRAN.

In addition to the four manuals described above, there is also a NASTRAN User's Guide that serves as a handbook for users. It describes all of the NASTRAN features and options and illustrates them by examples. Other excellent sources for NASTRAN-related topics are the proceedings of the NASTRAN Users' Colloquia (held normally every year) which provide a large body of information based on user experiences with NASTRAN.

The User's Manual has recently been completely revised and updated. With a view to facilitate easier updating of the manual in the future to keep up with newer releases of NASTRAN, it has now been divided into two volumes.

Volume I consists of seven sections and contains all of the material that was in the old single volume, except Section 3. This section has been re-arranged into four sections and forms Volume II. In order to avoid confusion, Section 3 of Volume I does not contain anything other than a reference to the new Volume II. Also, it should be noted here that, unless explicitly indicated otherwise, all references to sections in each volume refer only to sections in that volume.

NASTRAN uses the finite element approach to structural modeling, wherein the distributed physical properties of a structure are represented by a finite number of structural elements which are interconnected at a finite number of grid points, to which loads are applied and for which displacements are calculated. The procedures for defining and loading a structural model are

described in Volume I, Section 1. This section contains a functional reference for every card that is used for structural modeling.

The NASTRAN Data Deck, including the details for each of the data cards, is described in Volume I, Section 2. This section also discusses the NASTRAN control cards that are associated with the use of the program.

As mentioned earlier, Volume I, Section 3 does not contain anything other than a reference to Volume II.

The procedures for using the NASTRAN plotting capability are described in Volume I, Section 4. Both deformed and undeformed plots of the structural model are available. Response curves are also available for static, transient response, frequency response, modal flutter and modal aeroelastic response analyses.

NASTRAN contains problem solution sequences, called rigid formats. Each of these rigid formats is associated with the solution of problems for a particular type of static or dynamic analysis. In addition to the rigid format procedures, the user may choose to write his own Direct Matrix Abstraction Program (DMAP). This procedure permits the user to execute a series of matrix operations of his choice along with any utility modules or executive operations that he may need. The rules governing the creation of DMAP programs are described in Volume I, Section 5.

The NASTRAN diagnostic messages are documented and explained in Volume I, Section 6. The NASTRAN Dictionary, in Volume I, Section 7, contains descriptions of mnemonics, acronyms, phrases, and other commonly used NASTRAN terms.

Volume II, Section 1 contains a general description of rigid format procedures. Specific instructions and information for the use of each rigid format are given in Volume II, Sections 2, 3 and 4, which deal with the rigid formats associated with the DISPLACEMENT, HEAT and AERØ approaches, respectively.

There is a limited number of sample problems included in the User's Manual. However, a more comprehensive set of demonstration problems, at least one for each of the rigid formats, is described in the NASTRAN Demonstration Problem Manual. The data decks are available on tape for each of the computer systems on which NASTRAN has been implemented. Samples of the printer output and of structure plots and response plots can be obtained by executing these demonstration problems. The printer output for these problems is also available on microfiche.

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## 1. RIGID FORMATS

### 1.1 GENERAL DESCRIPTION OF RIGID FORMATS

The most general way of using NASTRAN is with a user-written Direct Matrix Abstraction Program (DMAP). This procedure permits the user to execute a series of matrix operations of his choice along with any utility modules or executive operations that he may need. The user may even choose to write a module of his own. The rules governing all of these operations are described in Volume I, Section 5.

In order to relieve the user of the necessity of constructing a DMAP sequence for each of his problems, a number of such sequences, called rigid formats, have been included with NASTRAN. All of these rigid formats are resident on a data base called the Rigid Format Data Base, which is described in detail in Section 1.1.7. Each rigid format in this data base consists of a DMAP sequence and the associated restart tables. These restart tables are automatically used by the program to modify the series of DMAP operations to account for any changes that are made in any part of the Data Deck when making a restart, after having previously run all, or a part, of the problem. Without such tables, the user would have to carefully modify his DMAP sequence to account for the conditions surrounding each restart. The chances for error in making these modifications for restart are very great. The restart tables not only relieve the user of the burden of modifying his DMAP sequence, but also assure him of a correct and efficient program execution.

In addition to the DMAP sequence provided with each rigid format, a number of options are available, which are subsets of each complete DMAP sequence. Subsets are selected by specifying the subset numbers (zero for the complete DMAP sequence) along with the rigid format number on the S<sub>0</sub>L card in the Executive Control Deck. See the description of the S<sub>0</sub>L card in Volume I, Section 2.2 for the list of available subsets.

If the user wishes to modify the DMAP sequence of a rigid format in some manner not provided for in the available subsets, he can use the ALTER feature described in Section 2.2. Typical uses are to schedule an EXIT prior to completion, in order to check intermediate output, schedule the printing of a table or a matrix for diagnostic purposes, and to delete or add a functional module to the DMAP sequence. (The manner in which DMAP ALTERs are handled in restarts is discussed in Section 1.1.5.) The user should be familiar with the rules for DMAP programming, as described in Volume I, Section 5, prior to making ALTERs to a rigid format.

The following rigid formats for structural analysis are currently included in NASTRAN:

1. Static Analysis

## RIGID FORMATS

2. Static Analysis with Inertia Relief
3. Normal Modes Analysis
4. Static Analysis with Differential Stiffness
5. Buckling Analysis
6. Piecewise Linear Static Analysis
7. Direct Complex Eigenvalue Analysis
8. Direct Frequency and Random Response
9. Direct Transient Response
10. Modal Complex Eigenvalue Analysis
11. Modal Frequency and Random Response
12. Modal Transient Response
13. Normal Modes Analysis with Differential Stiffness
14. Static Analysis with Cyclic Symmetry
15. Normal Modes Analysis with Cyclic Symmetry
16. Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The following rigid formats for heat transfer analysis are included in NASTRAN:

1. Linear Static Heat Transfer Analysis
3. Nonlinear Static Heat Transfer Analysis
9. Transient Heat Transfer Analysis

The following rigid formats for aeroelastic analysis are included in NASTRAN:

9. Blade Cyclic Modal Flutter Analysis
10. Modal Flutter Analysis
11. Modal Aeroelastic Response

### 1.1.1 Input File Processor

The Input File Processor operates in the Preface prior to the execution of the DMAP operations in the rigid format. A complete description of the operations in the Preface is given in the Programmer's Manual. The main interest here is to indicate the source of data blocks that are created in the Preface and hence appear only as inputs in the DMAP sequences of the rigid formats. None of the data blocks created by the Input File Processor are checkpointed, as they are always regenerated on restart. The Input File Processor is divided into five parts. The first part (IFP1) processes the Case Control Deck, the second part (IFP) processes the Bulk Data Deck,

## GENERAL DESCRIPTION OF RIGID FORMATS

the third part (IFP3) performs additional processing of the bulk data cards associated with the conical shell element, and the fourth part (IFP4) performs additional processing of the bulk data cards associated with the fluid element. The fifth section (IFP5) processes data related to acoustic cavity analysis.

IFP1 processes the Case Control Deck and creates the Case Control Data Block (CASECC), the Plot Control Data Block (PCDB), and the XY-Plot Control Data Block (XYCDB). IFP1 also examines all of the cards, except those associated with plotting, for errors in format or use. If errors are detected, they are classed as either fatal or warning, and suitable error messages are provided. Reference to Volume I, Section 2.3 will assist the user in correcting errors in the Case Control Deck. If the error is fatal, the Executive System will not allow the execution to continue beyond the completion of the Preface.

The Bulk Data Deck is sorted in the Preface, if necessary, before the execution of the second part of the Input File Processor. IFP checks all of the bulk data cards for errors according to the rules given for each card in Volume I, Section 2.4. If errors are detected, suitable messages are provided to the user. If the error is classed as fatal, the Executive System will not allow the execution to continue beyond the completion of the Preface. IFP creates the data blocks that are input to the various part of the Geometry Processor (GEØM1, GEØM2, GEØM3 and GEØM4), the Element Properties Table (EPT), the Material Properties Table (MPT), the Element Deformation Table (EDT), and the Direct Input Table (DIT).

The third part of the Input File Processor (IFP3) converts the information on the special conical shell cards (CCØNEAX, CTRAPAX, CTRIAAX, FØRCEAX, MØMAX, MPCAX, ØMITAX, PCØNEAX, PØINTAX, PRESAX, PTRAPAX, PTRIAAX, RINGAX, SECTAX, SPCAX, SUPAX, and TEMPAX) to reflect the number of harmonics specified by the user on the AXIC card. This converted information is added to any existing information on data blocks GEØM1, GEØM2, GEØM3 and GEØM4.

The fourth part of the input file processor (IFP4) converts the information on the fluid-related cards (AXIF, BDYLIST, CFLUID2, CFLUID3, CFLUID4, DMIAX, FLSYM, FREEPT, FSLIST, GRIDB, PRESPT, and RINGFL) to reflect the desired harmonics, boundaries, and matrix input. This converted information is added to GEØM1, GEØM2, GEØM4 and MATPØØL.

The fifth part of the input file processor (IFP5) converts the information on the acoustic cavity related cards (AXSLØT, CAXIF2, CAXIF3, CAXIF4, CSLØT3, CSLØT4, GRIDF, GRIDS, and SLBDY) to equivalent structural scalar points, elements, scalar springs and plotting elements. This converted information is added to the GEØM1 and GEØM2 data blocks.

1.1.2 Functional Modules and Supporting DMAP Operations

The DMAP listings of the rigid formats currently included with NASTRAN are presented in the following sections. Following each listing are subsections that deal with the following items for each rigid format:

1. Brief description of important DMAP operations for the rigid format
2. Output available from the rigid format
3. Case Control Deck setup for the rigid format
4. Parameters used in the rigid format
5. Automatic ALTERs for Automated Multi-Stage Substructuring (if applicable to the rigid format)
6. Rigid format error messages
7. Any other features peculiar to the rigid format

Descriptions of all major functional modules are given in the Programmer's Manual.

Additional information is also given in the Theoretical Manual. Descriptions of all other NASTRAN modules are given in Volume I, Section 5.

The modules in the following list appear repeatedly in the rigid formats. Since the purpose of these operations in a rigid format is obvious, they are generally omitted from the descriptions of the DMAP operations in the following sections. More complete descriptions of these modules are given in Volume I, Section 5.

1. BEGIN indicates the beginning of the DMAP sequence constituting the rigid format.
2. END indicates the end of the DMAP sequence constituting the rigid format and causes a normal termination when executed.
3. FILE makes declarations relative to a particular file.

ABC = TAPE states that file ABC will be assigned as a sequential file.

DEF = APPEND states that file DEF may be extended as the result of an internal loop in the rigid format.

GHI = SAVE states that file GHI should not be dropped after use as it may be needed for subsequent executions of an internal Toop.

4. LABEL specifies a labeled point in the sequence of DMAP instructions. Labels are referenced by REPT, JUMP and COND instructions.
5. PARAM performs specified operations on integer DMAP parameters.
6. PRECHK actuates the automatic generation of explicit CHKPNT instructions. (PRECHK ALL immediately and automatically CHKPNTs all output data blocks from each functional module, all data blocks mentioned in each PURGE instruction and all secondary data blocks in each EQUIV instruction.)\* The CHKPNT instruction specifies a list of files to be written on

\*The only exceptions to this are the CASESS, CASEI and CASECC data blocks appearing as output in substructure analyses.

## GENERAL DESCRIPTION OF RIGID FORMATS

the new problem tape (NPTP), including files that may have been purged, either because they were not generated in this particular execution or were explicitly purged with a PURGE instruction.

7. PURGE specifies the names of files that are conditionally dropped based on the parameter named.

### 1.1.3 Checkpoint/Restart Procedures

The checkpoint/restart feature available in NASTRAN is a very sophisticated and useful capability. The purpose of this feature is to enable a user to checkpoint a NASTRAN run and then restart it (with or without changes in data) by executing only those modules that need to be executed for the restart.

There are several situations in which the use of the checkpoint/restart feature may be desirable. Some of these are listed below:

1. The user may wish to perform his analysis task in two or more stages by specifying scheduled exits in one or more runs.
2. The user may want to ensure that unscheduled exits (resulting from such causes as data errors, insufficient time, insufficient core or hardware failures) will not require him to repeat his entire analysis.
3. The user may wish to rerun his problem by making limited changes in his data.

Scheduled exits can be requested at any point in a rigid format by means of the ALTER feature. (The manner in which ALTERs are handled in restarts is discussed in Section 1.1.5). An exit is scheduled by inserting the following cards in the Executive Control Deck:

```
ALTER      K1 $  
EXIT       K2 $  
ENDALTER    $
```

where      K1 = DMAP statement number after which exit will take place

and        K2 = Number of times EXIT instruction will be skipped before being executed - default is zero. For use with loops, where the user wishes to execute the loop K2 times before scheduling the exit.

If the user chooses to restart the problem without making any changes, the Executive System will execute an unmodified restart following the last completed checkpoint.

Unscheduled exits are usually caused by errors on input cards or errors in the structural model resulting from missing or inconsistent input data. When such errors are detected, an unscheduled exit is performed accompanied with the output of the applicable user error messages. Following the correction of the input data errors, a modified restart can be performed.

Unscheduled exits may also occur because of machine failure or insufficient time allowance. In these cases, an unmodified restart is usually made following the last completed checkpoint. In some cases, where a portion of the problem has been completed, including the output for the completed portion, a modified restart must be made following an unscheduled exit due to insufficient time allowance. These situations are discussed under Case Control Deck requirements in the sections dealing with the individual rigid formats.

The initial execution of any problem must be made with a complete NASTRAN Data Deck, including all of the bulk data. However, all or part of the bulk data may be assembled from alternate input sources, such as the User's Master File or a module written by the user to generate input. The User's Master File is described in Volume I, Section 2.5 and user generated input is discussed in Volume I, Section 2.6.

For restarts, the Bulk Data Deck consists only of delete cards (see Volume I, Section 2.4) and new cards which the user wishes to add. The previous Bulk Data Deck is read from the Old Problem Tape. All other parts of the NASTRAN Data Deck, including the Executive Control Deck, the Case Control Deck, the BEGIN BULK card and the ENDDATA card must be resubmitted even though no changes are made in the control decks and no new bulk data is added. In addition, the RESTART cards (or dictionary) punched during the previous execution must be included in the Executive Control Deck. When changing rigid formats, the solution number (\$OL) must be changed to the number of the new rigid format.

A New Problem Tape (NPTP) is constructed only when checkpointing is requested (CHKPNT YES) in the Executive Control Deck. The NPTP should be assigned to a physical tape or other storage device that can be dismounted and saved at the conclusion of the execution. At the completion of an initial execution, the NPTP contains the input deck, with the bulk data in sorted form, and all of the files that were checkpointed during the execution.

For restarts, the Old Problem Tape ( $\emptyset$ PTP) is defined as the Problem Tape that was written during the previous execution. The NPTP is defined as the Problem Tape written during the current execution, beginning with the restart. At the completion of an unmodified restart, the NPTP contains the input deck, with the bulk data in sorted form, all files from the  $\emptyset$ PTP that are necessary to complete the solution, and all of the files checkpointed during the current execution. At the completion of a modified restart, the NPTP is similar, except that the input deck is modified according to the information submitted for the restart.

#### 1.1.4 Types of Restarts

The type of a restart is determined automatically by the program by comparing the input data of the restart run with that of the checkpoint run. The user need not be concerned about the manner in which this is done, but may be interested in knowing the resulting type.

The types of restarts presently recognized in NASTRAN are summarized in the following table.

Types of Restarts in NASTRAN

Restart data compared to checkpoint data	Resulting type of restart	Applicable environment	
		Rigid format	DMAP
No effective changes	Unmodified restart	Yes	Yes
Effective changes only to the Case Control Deck and/or the Bulk Data Deck	Modified restart	Yes	Yes
Change in rigid format	Modified restart with rigid format switch	Yes	No

In earlier versions of NASTRAN, an additional type of restart, called the pseudo modified restart, was recognized for cases involving changes only in output requests. This is no longer done since it is now handled as a special case of the modified restart.

The manner in which a restart is handled by the program depends on its type and on its environment (rigid format or DMAP environment). This is discussed in the following sections.

An important term that is frequently encountered in the following discussion is the reentry point for a restart. This is defined as the last reentry point specified in the restart dictionary. It is an integer equal to the instruction number of the DMAP instruction in the checkpoint run at which an unmodified restart will resume execution. (See Volume I, Section 2.2.)

#### 1.1.4.1 Unmodified Restart

An unmodified restart involves no effective changes to the data. The execution in this type of restart resumes at the reentry point. Unmodified restarts in both rigid format and DMAP environments are handled in an identical manner.

It is useful to distinguish between two types of unmodified restarts. These are described below.

- Unmodified restart in which the reentry point is not within a DMAP loop

This is the simplest type of restart possible. In this case, the execution flags for all DMAP instructions prior to the reentry point are turned off and the execution flags for all DMAP instructions from the reentry point onwards are turned on. All input files or data blocks required for the restart already exist on the ØPTP and will be retrieved.

- Unmodified restart in which the reentry point is within a DMAP loop.

In this case, initially, the execution flags for all DMAP instructions prior to the reentry point are turned off and the execution flags for all DMAP instructions from the reentry point onwards are turned on. This is so indicated in the DMAP source listing. However, subsequently, the DMAP instructions prior to the reentry point and within the DMAP loop are recognized and their execution flags are turned on. The user is informed about this in the output. Note, however, that the execution does resume at the reentry point, even though DMAP instructions prior to this point are turned on. DMAP instructions within the DMAP loop and prior to the reentry point are executed only if additional passes in the loop need to be executed. If the restart is within the last pass of the DMAP loop, obviously DMAP instructions within the loop and prior to the reentry point are not executed even though their execution flags are on.

All input files or data blocks required by the restart already exist on the ØPTP and will be retrieved.

#### 1.1.4.2 Modified Restart

This type of restart involves one or more effective changes to the data in the Case Control Deck and/or in the Bulk Data Deck.

The heart of the restart logic for modified restarts in the rigid format environment is the Module Execution Decision Table (MEDT) associated with each rigid format. The MEDT for each rigid format actually comprises three distinct tables. These are the Card Name Restart Table, the Rigid Format Change Restart Table and the File Name Restart Table associated with that rigid format. (See discussion in Section 1.1.7. See also Sections 1.10 and 7 of the Programmer's Manual.)

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In the case of modified restarts in the rigid format environment, all DMAP instructions from the reentry points onwards have their execution flags turned on. In addition, this type of restart generally requires that certain DMAP instructions prior to the reentry point also be turned on, depending on the specific data changes involved. The DMAP instructions that need to be so turned on are determined from the Card Name Restart Table. The DMAP source listing provided in the output indicates all the DMAP instructions whose execution flags are initially turned on by the above procedure.

Once the DMAP instructions are initially turned on as described above, the program checks to see if all of the required input data blocks are either being generated by prior modules or are available on the ØPTP for retrieval. If so, no additional DMAP instructions need to be turned on. If, however, there are any input data blocks that are neither being generated by prior modules nor are available on the ØPTP, the program needs to turn on additional DMAP instructions in order to generate the required data blocks. The DMAP instructions that need to be so turned on are determined from the File Name Restart Table.

After the additional DMAP instructions are turned on as described in the above paragraph, the process is repeated until it is ensured that all of the required input data blocks are either being generated by prior modules or can be retrieved from ØPTP.

All the DMAP instructions that are turned on as per the above logic (by the use of the File Name Restart Table) are identified and listed in the restart output just after the DMAP source listing.

It should be noted that the execution in a modified restart will start at the first module in the DMAP sequence whose execution flag is turned on. Generally, this is before the reentry point.

In the case of modified restarts in the DMAP environment, the effect of changes in the Case Control Deck and/or in the Bulk Data Deck on particular modules cannot be determined since the DMAP itself is, by definition, not predefined. (An MEDT is meaningless for a DMAP.) Hence, it is assumed that the changes will affect the entire DMAP which, therefore, needs to be re-executed. This is accomplished in the program by re-setting the reentry point to zero and treating this case as an unmodified restart. This causes the entire DMAP to be re-executed.

Those input files or data blocks that are needed for the restart and that are available on the ØPTP are retrieved, just as it is done in the case of modified restarts in the rigid format environment.

#### 1.1.4.3 Modified Restart with Rigid Format Switch

This type of restart involves a switch from one rigid format to another. It may or may not involve effective changes to the data in the Case Control Deck and/or in the Bulk Data Deck.

The most important point to recognize in this type of restart is that the reentry point is quite meaningless since it was determined in relation to another rigid format. This is handled in the program by resetting the reentry point to an extremely high value which, for all practical purposes, can be considered to be infinite. As a result, all DMAP instructions in the restart are considered to be before the reentry point and no DMAP instructions are considered to exist after the reentry point.

Once this important change is made, this type of restart is handled in the program in the same manner as a modified restart, with one important modification: the DMAP instructions that are initially turned on are determined not only from the Card Name Restart Table, but also from the Rigid Format Change Restart Table.

#### 1.1.5 Use of DMAP ALTERs in Restarts

Because different types of restarts are handled differently by the program, the user should be careful in the use of DMAP ALTERs in restarts.

In the case of an unmodified restart in which the reentry point is not within a DMAP loop, the only DMAP instructions that are flagged for execution are those that are beyond (and include) the reentry point. Hence, a DMAP ALTER will be flagged for execution only if it is beyond the reentry point and will be ignored if it is before the reentry point.\*

In the case of an unmodified restart in which the reentry point is within a DMAP loop, the only DMAP instructions flagged for execution are those that are beyond (and include) the reentry point and those that are before the reentry point but within the DMAP loop. Hence, a DMAP ALTER will be flagged for execution only if it is beyond the reentry point or before it but within the DMAP loop. Otherwise, it will be ignored.\*

\* The user can ensure that a DMAP ALTER in an unmodified restart is flagged for execution by suitably deleting the latter part of the restart dictionary so that the reentry point is before the DMAP ALTER. This, of course, will cause more modules to be executed in the restart.

## GENERAL DESCRIPTION OF RIGID FORMATS

In the case of a modified restart and a modified restart with rigid format switch, a DMAP ALTER will be flagged for execution regardless of its position in the DMAP with respect to the reentry point.

### 1.1.6 Rigid Format Output

Although most of the rigid format output is optional, some of the printer output is automatic. The printer output is designed for 132 characters per line, with the lines per page controlled by the NLINES keyword on the NASTRAN card (see Volume I, Section 2.1) and the LINE card in the Case Control Deck (see Volume I, Section 2.3). The NLINES and LINE default is set to fit on 11-inch paper. Optional titles are printed at the top of each page from information in the Case Control Deck. These titles may be defined at the subcase level. The pages are automatically dated and numbered.

The output from the data recovery and plot modules is all optional, and its selection is controlled by cards in the Case Control Deck. The details of making selections in the Case Control Deck are described in Volume I, Section 2.3 for printer and punch output, and in Volume I, Section 4 for plotter output. Since the outputs from the data recovery and plot modules vary considerably with the rigid format, a list of available output is included in the section on the Case Control Deck for each rigid format. Information on the force and stress output available for each element type is given in Volume I, Section 1.3.

The first part of the output for a NASTRAN run is prepared during the execution of the Preface, prior to the beginning of the DMAP sequence of the rigid format. The following output is either automatically or optionally provided during the execution of the Preface:

1. NASTRAN title page - Two full pages automatic, unless changed with the TITLEOPT keyword on the NASTRAN card (see Volume I, Section 2.1) before the Executive Control Deck.
2. Executive Control Deck echo - Automatic.
3. Case Control Deck echo - Automatic.
4. Unsorted Bulk Data Deck echo - Optional, selected in Case Control Deck with the ECHØ Card. (Automatic in restart runs and in runs employing the User's Master File, unless suppressed in the Case Control Deck with the ECHØ card.)
5. Sorted Bulk Data Deck echo - Automatic, unless suppressed in the Case Control Deck with the ECHØ Card.
6. DMAP listing - Selected with DIAG 14 (or the LIST option on an XDMAP card) in the Executive Control Deck. Provides the list of DMAP instructions, including those resulting from ALTERs, for the subset of the rigid format being executed. (Automatic in restart runs and in runs using the DMAP approach (APP DMAP) or the substructure capability (APP DISP, SUBS), unless suppressed by the NØLIST option on an XDMAP card in the Executive Control Deck.)

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7. Checkpoint Dictionary - Automatic, when operating in the checkpoint mode. A printed echo (unless suppressed with the DIAG 9 card in the Executive Control Deck) and punched output are prepared for additions to the checkpoint dictionary after the execution of each checkpoint.

When making restarts, the following additional output is automatically prepared during the execution of the Preface:

1. Asterisks (\*) are placed beside the DMAP statement numbers of all instructions that are flagged for execution in the restart. (It should be emphasized that a DMAP instruction marked with the symbol \* is only flagged for execution; whether it actually gets executed or not is decided by the logic in the DMAP.)
2. Pluses (+) are placed beside the DMAP statement numbers of all instructions that are processed only at DMAP compilation time. (DMAP instructions BEGIN, COMP~~O~~FF, COMP~~O~~N, FILE, LABEL, PRECHK and XDMAP are the only instructions that belong to this category.)
3. Message indicating the bit position activated by a rigid format change.
4. Message indicating the type of restart (unmodified, modified or modified with rigid format switch).
5. Table indicating, among other things, the effective data changes (if any) and the associated "packed bit positions" that control the restart. The table distinguishes between effective changes made to the Case Control Deck and those made to the Bulk Data Deck. The reader is referred to the Programmer's Manual for the full interpretation of this table.
6. List of files along with the DMAP instructions that were marked for execution (if any) by the File Name Restart Table.
7. List of files from the Old Problem Tape, including purged files, used to initiate the restart.

A number of fatal errors are detected by the DMAP statements in the various rigid formats.

These messages indicate the presence of fatal user errors that either cannot be determined by the functional modules or can be more effectively detected by the DMAP statements in the rigid format. The detection of such an error causes a transfer to a LABEL instruction near the end of the rigid format. The text of the message is output and the execution is terminated. These messages will always appear at the end of the NASTRAN output. The messages applicable to each rigid format are described under the description of that rigid format.

NASTRAN diagnostic messages are usually identified by numbers. These messages may be either program diagnostics or user diagnostics, and they may contain information, warnings, or an indication of a fatal error. There are also a few unnumbered, self-explanatory messages, for example, the time that the execution of each functional module begins and ends.

The Grid Point Singularity Table (GPST) is automatically output following the execution of the Grid Point Singularity Processor (GPSP) if singularities remain in the stiffness matrix at the grid point level. This table contains all possible combinations of single-point constraints, in the global coordinate system, that can be used to remove the singularities. Entries in this table

## GENERAL DESCRIPTION OF RIGID FORMATS

should only be treated as warnings, because it cannot be determined at the grid point level whether or not the singularities are removed by other means, such as general elements or multipoint constraints. Further information on this matter is given in the Theoretical Manual.

Several items of output are discussed in other sections. Output that is not associated with all of the rigid formats is discussed in the sections treating the individual rigid formats. Some output is under the control of PARAM cards. These items are discussed in Volume I, Section 2.4 (PARAM card). The DIAG card is used to control the printing of some output. A list of the available output under DIAG control is given in the description of the Executive Control Deck in Volume I, Section 2.2.

Any of the matrices or tables that are prepared by the functional modules can be printed by using selected utility modules described in Volume I, Section 5.5. These utility modules can be scheduled at any point in a rigid format by using the ALTER feature. (See Section 1.1.5 for the manner in which ALTERs are handled in restarts.) In general, they should be scheduled immediately after the functional module that generates the table or matrix to be printed. Note that functional modules cannot be separated from a SAVE instruction. However, the user is cautioned to check the calling sequence for the utility module, in order to be certain that all required inputs have been generated prior to this point.

### 1.1.7 Rigid Format Data Base

As indicated earlier, the Rigid Format Data Base contains the DMAP sequences and other information for all of the rigid formats in NASTRAN. Its design allows for convenient maintenance of the existing rigid formats as well as the addition of new rigid formats. Editing of the data base may be done by using standard text editors provided on the host computer systems.

#### 1.1.7.1 Design of the Data Base

The Rigid Format Data Base is a collection of all rigid formats available to the user in NASTRAN. Each Rigid Format is maintained as a separate card-image entry within the data base. The entry for each rigid format consists of three parts. The first part is the DMAP part. It contains the DMAP sequence for the rigid format, the DMAP sequence subset flags, the restart flags (card name, file name and rigid format switch restart flags) and the substructure DMAP ALTER control flags. The second part contains the card name table and the third part contains the file name table. The restart flags in the first part and the name tables comprising the second and third

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parts are not processed by NASTRAN in non-restart runs. Similarly, the substructure control flags in the first part are not processed in non-substructure runs.

The format of the data base is free field. Each of the three parts in a rigid format entry is separated from the other parts by a "\$\*" card. The following fictitious example illustrates a rigid format entry in the data base.

```
APR.86
$$$$ THIS IS A COMMENT
$$$$ ****
M0ODULE1 IN1,IN2,/0UT1,0UT2//*PARM1* $
****SBST 1,3,9-12
****RFMT 188,200-201
****CARD 1-20,30,44
****FILE 100-104,110
****PHS1 I1
****PHS2 DB5
****PHS3 D7
$$$$ ****
M0ODULE2 IN3,IN4/0UT3/*PARM2* $
****CARD 1-40,45
****FILE 101,102
****PHS2 DE5
$$$$ ****
.
.
.

$$$$
$*CARD NAME TABLE
$$$$
1      AXIC    AXIF    CELAS1    CELAS2
2      ADUM1   CDUM1   CRØD
.
.

$$$$
$*FILE NAME TABLE
$$$$
94      SLT     GPTT
95      KGGX   GPST
.
.

$*
```

The very first card of an entry identifies the release of NASTRAN with which the rigid format is associated. In this example, the rigid format is associated with the April 1986 release.

The "\$\*CARD" card separates the card name table from the DMAP part of the entry and the "\$\*FILE" card separates the file name table from the card name table. A "\$\*" card terminates the file name table and the rigid format entry.

Comment cards are identified in the data base by the "\$\$\$\$" identification in the first four columns of the field and control cards are identified by the "\*\*\*\*" identification in the first four columns of the field.

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Comment cards may be placed anywhere in the card name or file name tables (the second and third parts of a rigid format entry). However, comment cards have a required usage and serve a specific purpose in the DMAP part of a rigid format entry. In this part, a comment card is used to distinguish and separate a DMAP entry (that is, a DMAP statement and its associated control cards) from another DMAP entry. Hence, there must be at least one comment card separating a DMAP entry from the next DMAP entry. In the data base supplied with NASTRAN, a comment card with a trailing string of "\*" is used for this purpose to serve as a cosmetic delineation between successive DMAP entries.

All DMAP statements must conform to the rules as specified in Volume I, Section 5.2. Any card in the DMAP part of a rigid format entry that does not begin with "\$\$\$\$" or "\*\*\*\*" in the first four columns of the field is considered to be a DMAP statement or part of a DMAP statement.

Comment and control cards in a rigid format entry can extend up to 80 columns. However, DMAP cards can only extend up to 72 columns.

Control cards (that is, cards that begin with "\*\*\*\*" in the first four columns of the field) are permitted only in the DMAP part of a rigid format entry. A control card must have any one of seven four-character names in columns five through eight. The permissible names are: SBST, RFMT, CARD, FILE, PHS1, PHS2 and PHS3. Control cards follow the corresponding DMAP statement in the entry and may be specified in any order.

The "SBST", "RFMT", "CARD" and "FILE" control cards contain sequences of numbers and/or ranges of numbers in ascending order represented by the use of a dash. A comma is required after each number in a sequence or after a range of numbers, if an additional number or range of numbers is to follow. There may be multiple cards for any one of these control cards for a specific DMAP statement.

The "SBST" control card provides DMAP sequence subset controls. If a user requests a given subset on the S<sub>0</sub>L card of a NASTRAN run and that number is in the sequence of numbers given on the "SBST" card, then the associated DMAP statement is deleted. The range of subset numbers is from 1 to 9 and each number is documented under the description of the S<sub>0</sub>L Executive Control card in Volume I, Section 2.2.

The "RFMT" control card is processed in restart runs and is applicable to cases where a rigid format switch has occurred. Each rigid format has a unique number assigned to it. For APPR<sub>0</sub>A<sub>C</sub>H DISP, rigid formats 1 through 16 are assigned the numbers 187 through 202, respectively. For APPR<sub>0</sub>A<sub>C</sub>H HEAT, rigid formats 1, 3 and 9 are assigned the numbers 207, 208 and 209, respectively.

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For APPRØACH AERØ, rigid formats 9, 10 and 11 are assigned the numbers 216, 214 and 215, respectively. A DMAP statement is flagged for execution in a modified restart if the number associated with the rigid format that was used in the checkpointed run is listed in the sequence of numbers given on the "RFMT" card provided with the DMAP statement.

The "CARD" and "FILE" control cards provide restart information for changes that involve input data or files within the DMAP. For a given rigid format, every type of effective change in the Case Control and Bulk Data Decks and each output file (or data block) in the DMAP is assigned a number as defined in the card name and file name tables in the second and third parts of a rigid format entry. In a modified restart, if the number associated with an input data change or an affected file appears in the sequence of numbers given on the "CARD" or "FILE" cards, then the corresponding DMAP statement is flagged for execution in the restart run.

The information provided by all of the "CARD" control cards in a rigid format entry is collectively referred to as the Card Name Restart Table. Similarly, the information provided by all of the "FILE" and "RFMT" control cards in a rigid format entry is collectively referred to as the File Name Restart Table and the Rigid Format Change Restart Table, respectively. For a given rigid format, these three restart tables compose the Module Execution Decision Table (MEDT) of that rigid format.

The "PHS1", "PHS2" and "PHS3" control cards are used to indicate where substructure DMAP ALTERs are to be generated. The number following the "PHS" refers to the substructure phase number. These cards must have one of the following flags: "In", "Dn", "DBn" or "DEn". The "n" in these flags is an integer that refers to the subroutine governing the substructure run (subroutine ASCM01, ASCM05, ASCM07 or ASCM08) and must have the value "1" for Phase 1 cards, either the value "5" or "8" for Phase 2 cards, and either the value "1" or "7" for Phase 3 cards. The "I" in the "In" flag indicates that a DMAP ALTER is to be inserted after this DMAP statement. The "D" in the "Dn" flag indicates that this DMAP statement is to be deleted and possibly replaced by a DMAP ALTER. The "DB" in the "DBn" flag and the "DE" in the "DEn" flag indicate the beginning and the end of a group of contiguous DMAP statements that are to be deleted and possibly replaced by a DMAP ALTER. Users are cautioned to be very careful in making any changes to these substructure control cards because of their impact on the DMAP ALTERs automatically generated in substructure analyses. (The automated substructure capability is currently implemented only in rigid formats 1, 2, 3, 8 and 9, APPRØACH DISP.)

## GENERAL DESCRIPTION OF RIGID FORMATS

The card name and file name tables assign numbers to every type of effective change in the Case Control and Bulk Data Decks and to every output file (or data block) in the DMAP. Numbers 1 through 93 are allocated to card names and numbers 94 through 186 are allocated to file (or data block) names. This information is used subsequently to determine the DMAP statements to be flagged for execution in modified restarts. The format of these tables is free field. Each entry in these tables must have an integer number in the first field and a list of names in the remaining fields of the entry. All names are to be alphanumeric and may contain up to a maximum of eight characters. No name should appear twice in these tables. Comment cards may be freely used in these tables to facilitate readability.

### 1.1.7.2 Implementation of the Data Base

The Rigid Format Data Base is implemented differently on the CDC, DEC VAX, IBM and UNIVAC versions. On the CDC and DEC VAX versions, each rigid format entry is stored as a separate file. The local names of these files during a NASTRAN execution are: DISP1 through DISP16 for APPR $\varnothing$ ACH DISP; HEAT1, HEAT3 and HEAT9 for APPR $\varnothing$ ACH HEAT; AER $\varnothing$ 9, AER $\varnothing$ 10 and AER $\varnothing$ 11 for APPR $\varnothing$ ACH AER $\varnothing$ . These same files are stored as members of a partitioned data set (PDS) on the IBM version and as elements of the \*NASTRAN file on the UNIVAC version. The member and element names are exactly the same as the local file names on the CDC and DEC VAX versions. On the IBM version, the PDS containing the Rigid Format Data Base must be referred to by a Data Definition card, "DD", with the DDname of RFDATA. On the UNIVAC version, the \*NASTRAN file is the file containing the NASTRAN program absolutes. (See References 1 and 2 for the formats of file names for the CDC and DEC VAX versions, respectively. See Reference 3 for the formats of DDnames and member names for the IBM version. See Reference 4 for the format of UNIVAC file names.)

### 1.1.7.3 Usage of the Data Base

The following examples illustrate the manner in which the Rigid Format Data Base is accessed and used on all of the four versions of NASTRAN.

#### CDC VERSION

```
/J $\varnothing$ B.  
.  
GET,DISP1,DISP2,DISP3,DISP4,DISP5.  
GET,DISP6,DISP7,DISP8,DISP9,DISP10.  
GET,DISP11,DISP12,DISP13,DISP14,DISP15,DISP16.
```

## RIGID FORMATS

```
GET,HEAT1,HEAT3,HEAT9,AERØ9,AERØ10,AERØ11.  
RFL,220000.  
REDUCE,-.  
LINK1,INPUT,ØUTPUT,PUNCH,UT1.  
/EØR  
ID ....  
. .  
ENDDATA  
/EØF
```

### DEC VAX VERSION

```
ASSIGN DDB1:[NASDIR]DISP1.DT DISP1.  
ASSIGN DDB1:[NASDIR]DISP2.DT DISP2.  
. .  
ASSIGN DDB1:[NASDIR]HEAT1.DT HEAT1.  
. .  
ASSIGN DDB1:[NASDIR]AERØ11.DT AERØ11.  
@DDB1:[NASDIR]NASTRAN DEMØ.DT
```

### IBM VERSION

```
// EXEC NASTRAN  
//NS.RFDA DATA DD DSN=RIGID.FORMAT.DATA,DISP=SHR  
//NS.SYSIN DD *  
ID ....  
. .  
ENDDATA  
//
```

### UNIVAC VERSION

```
@ASG,A *NASTRAN.  
@XQT *NASTRAN.LINK1
```

#### 1.1.7.4 Development of User Rigid Formats

In addition to using COSMIC-supplied rigid formats, users may develop their own rigid formats, with restart capabilities included. Rigid formats developed by users must conform to the rules explained earlier and must be similar in content and structure to the COSMIC-supplied rigid formats. Each user-developed rigid format must reside as a separate file on the CDC and DEC VAX versions, as a member of a PDS on the IBM version and as a file or file.element on the UNIVAC version.

Before developing their own rigid formats, users are strongly advised to carefully study and examine the COSMIC-supplied rigid formats, particularly with regard to their use of control cards. The following important guidelines should help users in developing their own rigid formats.

## GENERAL DESCRIPTION OF RIGID FORMATS

1. The DMAP sequence of the user rigid format must be tested for its correctness and logic. This testing may be done either in a DMAP environment or in the environment of an existing rigid format by use of ALTERs.
2. The card name table (the second part of a rigid format entry) must be constructed by assigning numbers 1 through 93 for all types of Case Control and Bulk Data Deck changes that will affect the logic of the rigid format. Normally, those input data changes that have the same effect on the logic of the rigid format are assigned the same number.
3. The file name table (the third part of a rigid format entry) must be constructed by assigning numbers 94 through 186 for all files (or data blocks) that are output by the functional modules in the rigid format. Normally, all files (or data blocks) output from a given functional module are assigned the same number.
4. The DMAP part (the first part of a rigid format entry) must be constructed by following each statement in the DMAP sequence by the appropriate control cards and by ensuring that each DMAP entry (that is, a DMAP statement and its associated control cards) is separated from the next DMAP entry by at least one comment card.
5. A given DMAP statement must be followed by a "SBST" control card if that DMAP statement belongs to one or more of the DMAP subsets. These subset numbers must be specified on the "SBST" card. The acceptable subset numbers and their meanings are documented under the description of the SØL Executive Control card in Volume I, Section 2.2.
6. A "RFMT" control card must follow a DMAP statement if that DMAP instruction is to be flagged for execution on restart from a checkpoint of one of the COSMIC-supplied rigid formats. (It is not possible to have a restart in a COSMIC-supplied rigid format from a checkpoint of an user-developed rigid format.) This will be so if this DMAP instruction is not part of the DMAP sequence of the rigid format that was used in the checkpoint run. The "RFMT" control card must list the numbers of the appropriate COSMIC-supplied rigid formats (187 through 202 for rigid formats 1 through 16, respectively, for APPRØACH DISP; 207, 208 and 209 for rigid formats 1, 3 and 9, respectively, for APPRØACH HEAT; and 216, 214 and 215 for rigid formats 9, 10 and 11, respectively, for APPRØACH AERØ).
7. A DMAP statement must be followed by one or more "CARD" control cards indicating the effective input data changes that require that DMAP instruction to be flagged for execution on restart. Any effective input data change will affect one or more files (or data blocks) or parameters in the DMAP sequence. Therefore, for a given data change, all

## RIGID FORMATS

DMAP instructions that use the affected files (or data blocks) or parameters as input are potential candidates to be flagged for execution on restart. However, the logic of these individual DMAP instructions must be checked further (see the Programmer's Manual) to see if they are really impacted by the given data change. This procedure must be applied in turn to those DMAP instructions that use the output of the affected DMAP instructions as input. This procedure must be repeated until the entire DMAP sequence has been considered.

8. A DMAP statement must be followed by one or more "FILE" control cards indicating the DMAP files (or data blocks) whose generation requires the execution flag for that DMAP statement to be turned on during restart. Normally, for a given DMAP file (or data block) that is required on restart but is not available from the checkpoint run, the DMAP instruction that generated it must be flagged for execution. However, in practice, additional DMAP instructions like PURGE and EQUIV that manipulate the given file (or data block) must also be flagged for execution.
9. The restart flags for a COND DMAP instruction (and its companion LABEL DMAP instruction) must include the restart flags for those DMAP instructions whose execution it controls.
10. "PHS1", "PHS2" and "PHS3" control cards must not be used as the substructure capability is not applicable to user rigid formats.

### 1.1.7.5 Usage of User-Developed Rigid Formats

An user-developed rigid format is referenced through the use of the S0L card in the Executive Control Deck. However, instead of specifying the solution number or the name of the COSMIC-supplied rigid format on this card, the name of the user-developed rigid format is specified. This name is a file name on the CDC and DEC VAX versions, a member name of a PDS on the IBM version and a file or file.element name on the UNIVAC version. The member name given on the IBM version must be in the file referenced on the RFDATA DD statement. The manner in which an user-developed rigid format is accessed and used is similar to that of a COSMIC-supplied rigid format, as explained in the examples given Section 1.1.7.3. Thus, for instance, an user-developed rigid format can be accessed and used on the CDC version in the following manner.

```
/J0B.  
.  
GET,NEWRF.  
RFL,220000.
```

GENERAL DESCRIPTION OF RIGID FORMATS

REDUCE,-.  
LINK1,INPUT,ØUTPUT,PUNCH,UT1.  
/EØR  
ID ....  
SØL NEWRF  
.  
.  
/EØF

RIGID FORMATS

REFERENCES

1. Control Data Corporation NOS 1.0 Reference Manual, Document No. 60435400.
2. VAX/VMS Command Language User's Guide, Digital Equipment Corporation, Order No. AA-D023C-TE.
3. IBM OS/VS2 MVS JCL, Document No. GC28-0692-4.
4. Sperry UNIVAC 1100 Series Executive System EXEC Programmer Reference, Volume 2, Document No. UP-4144.2.

## 2. DISPLACEMENT RIGID FORMATS

### 2.1 STATIC ANALYSIS

#### 2.1.1 DMAP Sequence for Static Analysis

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
  
1 BEGIN DISP 01 - STATIC ANALYSIS - APR.86 $  
2 FILE OOPTP2=SAVE/EST1=SAVE $  
3 FILE QG=APPEND/PGG=APPEND/UGV=APPEND/GM=SAVE/KNN=SAVE $  
4 SETVAL //V,Y,INTERACT/O/V,Y,SYS21/O $  
5 PARAM //*MPY*/CARDNO/O/O $  
6 COMPOFF 1,INTERACT $  
7 PRECHK ALL $  
8 COMPON 1,INTERACT $  
10 COMPOFF LBLINT02,SYS21 $  
11 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/ALWAYS=-1 $  
12 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
13 GP2 GEOM2,EQEXIN/ECT $  
14 PARAML PCDB//*PRES*///JUMPPLOT $  
15 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
16 COND P1,JUMPPLOT $  
17 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
18 PRTMSG PLTSETX// $  
19 PARAM //*MPY*/PLTFLG/1/1 $  
20 PARAM //*MPY*/PFILE/O/O $  
21 COND P1,JUMPPLOT $  
22 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
23 PRTMSG PLOTEX1// $  
24 LABEL P1 $  
25 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV/NEVER=1 $  
26 PARAM ///*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $  
27 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
28 PARAM ///*AND*/NOELMT/NOGENL/NOSIMP $  
29 COND ERROR4,NOELMT $  
30 PURGE KGGX,GPST/NOSIMP/OGPST/GENEL $  
31 OPTPRI MPT,EPT,ECT,DIT,EST/OPTP1/S,N,PRINT/S,N,TSTART/S,N,COUNT $  
32 LABEL LOOPTOP $  
33 COND LBL1,NOSIMP $  
34 PARAM ///*ADD*/NOKGGX/1/O $  
35 EQUIV OOPTP1,OPTP2/NEVER/EST,EST1/NEVER $  
36 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
37 COND JMPKGG,NOKGGX $  
38 EMA GPECT,KDICT,KELM/KGGX,GPST $  
39 LABEL JMPKGG $  
40 PURGE MGG/NOMGG $  
41 COND JMPMGG,NOMGG $  
42 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
43 LABEL JMPMGG $  
44 COND LBL1,GRDPNT $  
45 COND ERROR2,NOMGG $  
46 GPWG BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $
```

STATIC ANALYSIS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
47 OFP      OGPWG,,,,,/S,N,CARDNO $  
48 LABEL    LBL1 $  
49 EQUIV   KGGX,KGG/NOGENL $  
50 COND     LBL11A,NOGENL $  
51 SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
52 LABEL    LBL11A $  
53 PARAM   ///*MPY*/NSKIP/O/O $  
54 LABEL    LBL11 $  
55 GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
56 COND     ERROR3,NOL $  
57 PARAM   ///*AND*/NOSR/SINGLE/REACT $  
58 PURGE   KRR,KLR,QR,DM/REACT/GM/MPCF1/G0,K00,LOO,PO,UOOV,RUOV/OMIT/PS,  
KFS,KSS/SINGLE/QG/NOSR $  
59 COND     LBL4,GENEL $  
60 PARAM   ///*EQ*/GPSPFLG/AUTOSPC/O $  
61 COND     LBL4,GPSPFLG $  
62 GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
63 OFP      OGPST,,,,,/S,N,CARDNO $  
64 LABEL    LBL4 $  
65 EQUIV   KGG,KNN/MPCF1 $  
66 COND     LBL2,MPCF2 $  
67 MCE1    USET,RG/GM $  
68 MCE2    USET,GM,KGG,,,/KNN,,, $  
69 LABEL    LBL2 $  
70 EQUIV   KNN,KFF/SINGLE $  
71 COND     LBL3,SINGLE $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
72 SCE1      USET,KNN,,,/KFF,KFS,KSS,,, $  
73 LABEL     LBL3 $  
74 EQUIV    KFF,KAA/OMIT $  
75 COND      LBL5,DMIT $  
76 SMP1      USET,KFF,,,/GO,KAA,KOD,LOO,,,,, $  
77 LABEL     LBL5 $  
78 EQUIV    KAA,KLL/REACT $  
79 COND      LBL6,REACT $  
80 RBMG1     USET,KAA,/KLL,KLR,KRR,,, $  
81 LABEL     LBL6 $  
82 RBMG2     KLL/LLL $  
83 COND      LBL7,REACT $  
84 RBMG3     LLL,KLR,KRR/DM $  
85 LABEL     LBL7 $  
86 SSG1      SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,/  
           LUSET/NSKIP $  
87 EQUIV    PG,PL/NOSET $  
88 COND      LBL10,NOSET $  
89 SSG2      USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $  
90 LABEL     LBL10 $  
91 SSG3      LLL,KLL,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUV/OMIT/V,Y,IRES=-1/  
           NSKIP/S,N,EPSI $  
92 COND      LBL9,IRES $  
93 MATGPR   GPL,USET,SIL,RULV//*L* $  
94 MATGPR   GPL,USET,SIL,RUOV//*O* $  
95 LABEL     LBL9 $  
96 SDR1      USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/UGV,PGG,QG/NSKIP/  
           *STATICS* $
```

## STATIC ANALYSIS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
97  COND    LBL8,REPEAT $  
98  REPT    LBL11,360 $  
99  JUMP    ERROR1 $  
100 PARAM   /*NOT*/TEST/REPEAT $  
101 COND    ERROR5,TEST $  
102 LABEL   LBL8 $  
103 GPFDR  CASECC,UGV,KELM,KDICT,ECT,EQEXIN,GPECT,PGG,QG/ONRGY1,OGPFB1/  
*STATICS* $  
104 OFP     ONRGY1,OGPFB1,,,//S,N,CARDNO $  
105 COND    NOMPCF,GRDEQ $  
106 EQMCK  CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/  
OQM1/V,Y,OPT=O/V,Y,GRDEQ/NSKIP $  
107 OFP     OQM1,,,,//S,N,CARDNO $  
108 LABEL   NOMPCF $  
109 SDR2   CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,  
XYCDB,PGG/OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS*/S,N,  
NOSORT2/-1/S,N,STRNFLG $  
110 COND    LBLSTRS,STRESS $  
111 CURV   OES1,MPT,CSTM,EST,SIL,GPL/OES1M,OES1G/V,Y,STRESS/  
V,Y,NINTPTS $  
112 LABEL   LBLSTRS $  
113 PURGE  OES1M/STRESS $  
114 COND    LBLSTRN,STRNFLG $  
115 SDR2   CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,,UGV,EST,,/  
,,,OES1A,/*STATICS*//1 $  
116 COND    LBLSTRN,STRAIN $  
117 CURV   OES1A,MPT,CSTM,EST,SIL,GPL/OES1AM,OES1AG/V,Y,STRAIN/  
V,Y,NINTPTS $  
118 LABEL   LBLSTRN $  
119 PURGE  OES1A/STRNFLG $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
120  COND    LBL17,NOSORT2 $  
121  SDR3    OUGV1,OPG1,OQG1,OEF1,OES1,/OUGV2,OPG2,OQG2,OEF2,OES2, $  
122  PARAM   ///*SUB*/PRTSORT2/NOSORT2/1 $  
123  COND    LBLSORT1,PRTSORT2 $  
124  OFP     OUGV2,OPG2,OQG2,OEF2,OES2,//S,N,CARDNO $  
125  SCAN   CASECC,OES2,OEF2/OESF2/*RF* $  
126  OFP     OESF2,,,,//S,N,CARDNO $  
127  JUMP   LBLXYPLT $  
128  LABEL  LBLSORT1 $  
129  OFP     OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $  
130  SCAN   CASECC,OES1,OEF1/OESF1/*RF* $  
131  OFP     OESF1,,,,//S,N,CARDNO $  
132  LABEL  LBLXYPLT $  
133  OFP     OESIM,OES1G,OES1A,OES1AM,OES1AG,//S,N,CARDNO $  
134  XYTRAN XYCDB,OPG2,OQG2,OUGV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/S,N,  
          PFILE/S,N,CARDNO $  
135  XYPLOT XYPLTT// $  
136  JUMP   DPLOT $  
137  LABEL  LBL17 $  
138  PURGE  OUGV2/NOSORT2 $  
139  COND    LBLOFP,COUNT $  
140  OPTPR2  OPTP1,OES1,EST/OPTP2,EST1/S,N,PRINT/TSTART/S,N,COUNT/S,N,  
          CARDNO $  
141  EQUIV  EST1,EST/ALWAYS/OPTP2,OPTP1/ALWAYS $  
142  COND    LOOPEND,PRINT $  
143  LABEL  LBLOFP $  
144  OFP     OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $
```

STATIC ANALYSIS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
145 SCAN    CASECC,OES1,OEF1/OESF1X/*RF* $  
146 OFP     OESFIX,,,,//S,N,CARDNO $  
147 OFP     OES1M,OES1G,OES1A,OES1AM,OES1AG,//S,N,CARDNO $  
148 LABEL   DPLOT $  
149 COND   P2,JUMPPLOT $  
150 PLOT   PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OEST1/  
          PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $  
151 PRTPARM PLOTX2// $  
152 LABEL   P2 $  
153 LABEL   LOOPEND $  
154 COND   FINIS,COUNT $  
155 REPT   LOOPTOP,360 $  
156 JUMP   FINIS $  
157 LABEL   ERROR1 $  
158 PRTPARM //1/*STATICS* $  
159 LABEL   ERROR2 $  
160 PRTPARM //2/*STATICS* $  
161 LABEL   ERROR3 $  
162 PRTPARM //3/*STATICS* $  
163 LABEL   ERROR4 $  
164 PRTPARM //4/*STATICS* $  
165 LABEL   ERROR5 $  
166 PRTPARM //5/*STATICS* $  
167 LABEL   FINIS $  
168 PURGE  DUMMY/ALWAYS $  
169 LABEL   LBLINTO2 $  
170 COMPOIN LBLINTO1,SYS21 $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

224 LABEL LBLINT1 \$

225 END \$

### 2.1.2 Description of Important DMAP Operations for Static Analysis

Note: The DMAP sequence for static analysis involves the use of parameters INTERACT and SYS21 (see Section 2.1.5). These parameters are of relevance only when the primary purpose of the user is to make interactive restart runs. (The two parameters are then specified via the PARAM card in the Bulk Data Deck.) However, these two parameters are not required for normal non-interactive batch runs. Consequently, the rigid format DMAP listing shown in Section 2.1.1 was generated by not specifying these parameters (via the PARAM bulk data card). As a result, the C<sub>O</sub>MPOFF and C<sub>O</sub>MPON instructions using these parameters assume a value of 0 for these parameters (see Volume I, Section 5.7).

6. C<sub>O</sub>MPOFF causes the DMAP compiler to compile the next instruction (DMAP No. 7) as the parameter INTERACT is 0 (see Note above).
8. C<sub>O</sub>MPON causes the DMAP compiler to skip the compilation of the next instruction (DMAP No. 9, not shown) as the parameter INTERACT is 0 (see Note above).
10. C<sub>O</sub>MPOFF causes the DMAP compiler to compile all of the following instructions through LABEL LBLINTO2 (DMAP Nos. 11 through 169) as the parameter SYS21 is 0 (see Note above).
11. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
12. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
13. GP2 generates Element Connection Table with internal indices.
16. Go to DMAP No. 24 if there are no structure plot requests.
17. PLTSET transforms user input into a form used to drive the structure plotter.
18. PRTMSG prints error messages associated with the structure plotter.
21. Go to DMAP No. 24 if no undeformed structure plots are requested.
22. PL<sub>O</sub>T generates all requested undeformed structure plots.
23. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
25. GP3 generates Static Loads Table and Grid Point Temperature Table.
27. TA1 generates element tables for use in matrix assembly and stress recovery.
29. Go to DMAP No. 163 and print Error Message No. 4 if no elements have been defined.
31. OPTPR1 performs phase one property optimization and initialization check.
32. Beginning of loop for property optimization.
33. Go to DMAP No. 48 if there are no structural elements.
36. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
37. Go to DMAP No. 39 if no stiffness matrix is to be assembled.
38. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
41. Go to DMAP No. 43 if no mass matrix is to be assembled.
42. EMA assembles mass matrix  $[M_{gg}]$ .
44. Go to DMAP No. 48 if no weight and balance information is requested.
45. Go to DMAP No. 159 and print Error Message No. 2 if no mass matrix exists.

## DISPLACEMENT RIGID FORMATS

46. GPWG generates weight and balance information.
47. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
49. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if no general elements exist.
50. Go to DMAP No. 52 if no general elements exist.
51. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
54. Beginning of loop for multiple constraint sets.
55. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g] \{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
56. Go to DMAP No. 161 and print Error Message No. 3 if no independent degrees of freedom are defined.
59. Go to DMAP No. 64 if general elements are present.
61. Go to DMAP No. 64 if no potential grid point singularities exist.
62. GPSP generates a table of potential grid point singularities.
63. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
65. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if no multipoint constraints exist.
66. Go to DMAP No. 69 if the MPC set for the current pass is unchanged from that of the previous pass.
67. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m|R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .

68. MCE2 partitions stiffness matrix

$$[K_{gg}] = \begin{bmatrix} & & \\ K_{nn} & | & K_{nm} \\ \hline & + & \\ K_{mn} & | & K_{mm} \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nm}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

70. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  if no single-point constraints exist.

71. Go to DMAP No. 73 if no single-point constraints exist.

72. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & | & K_{fs} \\ \hline & + & \\ K_{sf} & | & K_{ss} \end{bmatrix}.$$

74. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.

75. Go to DMAP No. 77 if no omitted coordinates exist.

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76. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{ao} \\ \frac{K_{aa}}{K_{oa}} + \frac{K_{oo}}{K_{oa}} & \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .

78. Equivalence  $[K_{aa}]$  to  $[K_{\ell\ell}]$  if no free-body supports exist.

79. Go to DMAP No. 81 if no free-body supports exist.

80. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix}.$$

82. RBMG2 decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

83. Go to DMAP No. 85 if no free-body supports exist.

84. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|} .$$

86. SSG1 generates static load vectors  $\{P_g\}$ .

87. Equivalence  $\{P_g\}$  to  $\{P_\ell\}$  if no constraints are applied.

88. Go to DMAP No. 90 if no constraints are applied.

89. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{ \frac{\bar{P}_n}{P_m} \right\} , \quad \{P_n\} = \{P_n\} + [G_m^T]\{P_m\} ,$$

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$$\{P_n\} = \left\{ \frac{\bar{P}_f}{P_s} \right\}, \quad \{P_f\} = \bar{P}_f - [K_{fs}]\{Y_s\},$$

$$\{P_f\} = \left\{ \frac{\bar{P}_a}{P_o} \right\}, \quad \{P_a\} = \bar{P}_a + [G_o^T]\{P_o\},$$

$$\{P_a\} = \left\{ \frac{P_\ell}{P_r} \right\}$$

and calculates determinate forces of reaction  $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$ .

91. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\},$$

solves for displacements of omitted coordinates

$$\{u_o^0\} = [K_{oo}]^{-1}\{P_o\},$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\},$$

$$\epsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RU0V) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^0\},$$

$$\epsilon_o = \frac{\{u_o^0\}\{\delta P_o\}}{\{P_o^T\}\{u_o^0\}}$$

92. Go to DMAP No. 95 if residual vectors are not to be printed.

93. MATGPR prints the residual vector for independent coordinates (RULV).

94. MATGPR prints the residual vector for omitted coordinates (RU0V).

96. SDR1 recovers dependent displacements

$$\left\{ \frac{u_\ell}{u_r} \right\} = \{u_a\}, \quad \{u_o^0\} = [G_o]\{u_a\} + \{u_o^0\},$$

$$\left\{ \frac{u_a}{u_o} \right\} = \{u_f\}, \quad \left\{ \frac{u_f}{Y_s} \right\} = \{u_n\},$$

## STATIC ANALYSIS

$$\{u_m\} = [G_m]\{u_n\}, \quad \left\{ \frac{u_n}{u_m} \right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

97. Go to DMAP No. 102 if all constraint sets have been processed.
98. Go to DMAP No. 54 if additional sets of constraints need to be processed.
99. Go to DMAP No. 157 and print Error Message No. 1 as the number of constraint sets exceeds 360.
101. Go to DMAP No. 165 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.
103. GPFDR calculates the grid point force balance ( $\emptyset GPFB1$ ) and element strain energy ( $\emptyset NRGY1$ ) for requested sets.
104.  $\emptyset FP$  formats the tables prepared by GPFDR and places them on the system output file for printing.
105. Go to DMAP No. 108 if no multipoint constraint force balance is requested.
106. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance ( $\emptyset QM1$ ) for output.
107.  $\emptyset FP$  formats the table prepared by EQMCK and places it on the system output file for printing.
109. SDR2 calculates the element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PPG1$ ), displacement vectors ( $\emptyset UGV1$ ) and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the displacement vectors ( $\emptyset PUGV1$ ).
110. Go to DMAP No. 112 if element stresses in material coordinate system and stresses at the connected grid points are not to be calculated.
111. CURV calculates element stresses in material coordinate system ( $\emptyset ES1M$ ) and stresses at the connected grid points ( $\emptyset ES1G$ ).
114. Go to DMAP No. 118 if element strains/curvatures are not to be calculated.
115. SDR2 calculates element strains/curvatures ( $\emptyset ES1A$ ).
116. Go to DMAP No. 118 if element strains/curvatures in material coordinate system and strains/curvatures at the connected grid points are not to be calculated.
117. CURV calculates element strains/curvatures in material coordinate system ( $\emptyset ES1AM$ ) and strains/curvatures at the connected grid points ( $\emptyset ES1AG$ ).
120. Go to DMAP No. 137 if there are no requests for output sorted by grid point number or element number.
121. SDR3 prepares requested output sorted by grid point number or element number.
123. Go to DMAP No. 128 if printed output sorted by grid point number or element number is not required.
124.  $\emptyset FP$  formats the tables prepared by SDR3 for output sorted by grid point number or element number and places them on the system output file for printing.

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125. SCAN examines the element stresses and forces calculated by SDR3 and generates scanned output that meets the specifications set by the user.
126. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.
127. Go to DMAP No. 132.
129. ØFP formats the tables prepared by SDR2 for output sorted by subcase number and places them on the system output file for printing.
130. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
131. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.
133. ØFP formats the tables prepared by CURV and SDR2 for output sorted by subcase number and places them on the system output file for printing.
134. XYTRAN prepares the input for requested X-Y plots.
135. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. subcase.
136. Go to DMAP No. 148.
139. Go to DMAP No. 143 if there is no phase two property optimization.
140. ØPTPR2 performs phase two property optimization.
141. Equivalence EST1 to EST and ØPTP2 to ØPTP1.
142. Go to DMAP No. 153 if no additional output is to be printed for this loop.
144. ØFP formats the tables prepared by SDR2 for output sorted by subcase number and places them on the system output file for printing.
145. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
146. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.
147. ØFP formats the tables prepared by CURV and SDR2 for output sorted by subcase number and places them on the system output file for printing.
149. Go to DMAP No. 152 if no deformed structure plots are requested.
150. PLØT generates all requested deformed structure and contour plots.
151. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
154. Go to DMAP No. 167 and make normal exit if property optimization is complete.
155. Go to DMAP No. 32 if additional loops for property optimization are needed.
156. Go to DMAP No. 167 and make normal exit.
158. Print Error Message No. 1 and terminate execution.
160. Print Error Message No. 2 and terminate execution.
162. Print Error Message No. 3 and terminate execution.

STATIC ANALYSIS

164. Print Error Message No. 4 and terminate execution.
166. Print Error Message No. 5 and terminate execution.
170. CØMPØN causes the DMAP compiler to skip the compilation of all of the following instructions through LABEL LBLINT01 (DMAP Nos. 171 through 223, not shown) as the parameter SYS21 is 0 (see Note at the beginning of this section).

#### 2.1.3 Output for Static Analysis

The following printed output, sorted by loads (SØRT1) or by grid point number or element number (SØRT2), may be requested for Static Analysis solutions:

1. Displacements and components of static loads and single-point forces of constraint at selected grid points or scalar points.
2. Forces and stresses in selected elements.
3. Strains/curvatures in selected elements (only for TRIA1, IRIA2, QUAD1 and QUAD2 elements).

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model.
2. Contour plots of stresses and displacements.
3. X-Y plot of any component of displacement, static load, or single-point force of constraint for a grid point or scalar point versus subcase.
4. X-Y plot of any stress or force component for an element versus subcase.

#### 2.1.4 Case Control Deck for Static Analysis

The following items relate to subcase definition and data selection for Static Analysis:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a LØAD, TEMPERATURE(LØAD), or DEFØRM selection unless all loading is specified with grid point displacements on SPC cards.
3. An SPC set must be selected for (not necessarily within) each subcase, unless the model is a properly supported free body, or all constraints are specified on GRID cards, Scalar Connection cards, or with General Elements.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets of the same output item.

#### 2.1.5 Parameters for Static Analysis

The following parameters are used in Static Analysis:

1. ASETOUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTOSPC - reserved for future optional use. The default value is -1.
3. COPUMASS - CPBAR, CPRD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCFORCE. If the integer value is zero, the basic origin is used. The default value is -1.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
6. INTERACT - optional. This parameter, like the SYS21 parameter, is of relevance only when the primary purpose of the user is to make interactive restart runs. In such a case, the integer value of this parameter must be set to -1 (via a PARAM bulk data card) in both the batch checkpoint run (that precedes the interactive restart run) as well as in the interactive restart run. If not so specified via a PARAM bulk data card, the COMP OFF and COMP ON instructions in the DMAP sequence that use this parameter assume a value of 0 for this parameter (see Volume I, Section 5.7).
7. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following each execution of the SSG3 module.
8. NINTPTS - optional. A positive integer value of this parameter specifies the number of closest independent points to be used in the interpolation for computing stresses or strains/curvatures at grid points (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). A negative integer value or 0 specifies that all independent points are to be used in the interpolation. The default value is 0.
9. OPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFORCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.

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10. STRAIN - optional. This parameter controls the transformation of element strains/curvatures to the material coordinate system (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). If it is a positive integer, the strains/curvatures for these elements are transformed to the material coordinate system. If it is zero, strains/curvatures at the connected grid points are also computed in addition to the element strains/curvatures in the material coordinate system. A negative integer value results in no transformation of the strains/curvatures. The default value is -1.
11. STRESS - optional. This parameter controls the transformation of element stresses to the material coordinate system (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements). If it is a positive integer, the stresses for these elements are transformed to the material coordinate system. If it is zero, stresses at the connected grid points are also computed in addition to the element stresses in the material coordinate system. A negative integer value results in no transformation of the stresses. The default value is -1.
12. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
13. SYS21 - optional. This parameter, like the INTERACT parameter, is of relevance only when the primary purpose of the user is to make interactive restart runs. In such a case, the integer value of this parameter must be set to -1 (via a PARAM bulk data card) in the interactive restart run (that follows a batch checkpoint run). If not so specified via a PARAM bulk data card, the C~~O~~MP~~O~~FF and C~~O~~MP~~O~~N instructions in the DMAP sequence that use this parameter assume a value of 0 for this parameter (see Volume I, Section 5.7).
14. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
15. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

## STATIC ANALYSIS

### 2.1.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Static Analysis, Rigid Format 1, are ALTERed for automated substructure analyses.

Phase 1: 5, 56, 78-85, 87-153

Phase 2: 5, 11-11, 14-24, 28-29, 35-35, 49-52, 59-64, 103-153

Phase 3: 78-85, 88-95, 96

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

### 2.1.7 Rigid Format Error Messages from Static Analysis

The following fatal errors are detected by the DMAP statements in the Static Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

#### STATIC ANALYSIS ERROR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 different sets of boundary conditions or more than 360 passes in the optimization loop have been attempted. This number may be increased by ALTERing the REPT instruction following SDR1 in the former case and the REPT instruction following the last PRTMSG instruction in the latter case.

#### STATIC ANALYSIS ERROR MESSAGE NØ. 2 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

#### STATIC ANALYSIS ERROR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

#### STATIC ANALYSIS ERROR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

#### STATIC ANALYSIS ERROR MESSAGE NØ. 5 - A LØØPING PRØBLEM RUN ØN A NØN-LØØPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

DISPLACEMENT RIGID FORMATS

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DISPLACEMENT RIGID FORMATS

2.2 STATIC ANALYSIS WITH INERTIA RELIEF

2.2.1 DMAP Sequence for Static Analysis With Inertia Relief

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 2

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 02 - STATIC ANALYSIS WITH INERTIA RELIEF - APR. 1986 $  
2 PRECHK ALL $  
3 FILE QG=APPEND/PGG=APPEND/UGV=APPEND/GM=SAVE/KNN=SAVE/MNN=SAVE $  
4 PARAM //*MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/ALWAYS=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 GP2 GEOM2,EQEXIN/ECT $  
8 PARAML PCDB//*PRES*///JUMPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPLOT $  
10 COND P1,JUMPLOT $  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPLOT $  
12 PRTMSG PLTSETX// $  
13 PARAM //*MPY*/PLTFLG/1/1 $  
14 PARAM //*MPY*/PFILE/O/O $  
15 COND P1,JUMPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPLOT/S,N,PLTFLG/S,N,PFILE $  
17 PRTMSG PLOTX1// $  
18 LABEL P1 $  
19 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $  
20 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
21 COND ERROR6,NOSIMP $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 2

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PURGE    OGPST/GENEL $  
23 PARAM    //*ADD*/NOKGGX/1/0 $  
24 PARAM    //*ADD*/NOMGG/1/0 $  
25 EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
           S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
           C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
           C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
           V,Y,VOLUME/V,Y,SURFACE $  
26 PURGE    KGGX,GPST/NOKGGX $  
27 COND     JMPKGG,NOKGGX $  
28 EMA      GPECT,KDICT,KELM/KGGX,GPST $  
29 LABEL    JMPKGG $  
30 COND     ERROR1,NOMGG $  
31 EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
32 COND     LGPWG,GRDPNT $  
33 GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
34 OFF      OGPWG,.,./S,N,CARDNO $  
35 LABEL    LGPWG $  
36 EQUIV   KGGX,KGG/NOGENL $  
37 COND     LBL11A,NOGENL $  
38 SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
39 LABEL    LBL11A $  
40 PARAM    //*MPY*/NSKIP/0/0 $  
41 LABEL    LBL11 $  
42 GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/  
           LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
           S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
           S,Y,AUTOSPC $  
43 COND     ERROR3,NOL $  
44 COND     ERROR4,REACT $
```

STATIC ANALYSIS WITH INERTIA RELIEF

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 2

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45 PURGE GM/MPCF1/GO,KOO,LOO,MOO,MOA,PO,UOOV,RUOV/OMIT/KSS,KFS,PS/  
SINGLE $  
46 COND LBL4,GENEL $  
47 PARAM //EQ*/GPSPFLG/AUTOSPC/O $  
48 COND LBL4,GPSPFLG $  
49 GPSP GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
50 OFF OGPST,,,./S,N,CARDNO $  
51 LABEL LBL4 $  
52 EQUIV KGG,KNN/MPCF1/MGG,MNN/MPCF1 $  
53 COND LBL2,MPCF2 $  
54 MCE1 USET,RG/GM $  
55 MCE2 USET,GM,KGG,MGG,,/KNN,MNN,, $  
56 LABEL LBL2 $  
57 EQUIV KNN,KFF/SINGLE/MNN,MFF/SINGLE $  
58 COND LBL3,SINGLE $  
59 SCE1 USET,KNN,MNN,,/KFF,KFS,KSS,MFF,, $  
60 LABEL LBL3 $  
61 EQUIV KFF,KAA/OMIT/ MFF,MAA/OMIT $  
62 COND LBL5,OMIT $  
63 SMP1 USET,KFF,MFF,,/GO,KAA,KOO,LOO,MAA,MOO,MOA,, $  
64 LABEL LBL5 $  
65 RBMG1 USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $  
66 RBMG2 KLL/LLL $  
67 RBMG3 LLL,KLR,KRR/DM $  
68 RBMG4 DM,MLL,MLR,MRR/MR $  
69 SSG1 SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,/  
LUSET/NSKIP $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 2

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
70 SSG2      USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $  
71 SSG4      PL,QR,PO,MR,MLR,DM,MLL,MOO,MOA,GO,USET/PLI,POI/OMIT $  
72 SSG3      LLL,KLL,PLI,LOO,KOO,POI/ULV,UOOV,RULV,RUOV/OMIT/V,Y,  
             IRES=-1/NSKIP/S,N,EPSI $  
73 COND      LBL9,IRES $  
74 MATGPR    GPL,USET,SIL,RULV//*L* $  
75 MATGPR    GPL,USET,SIL,RUOV//*0* $  
76 LABEL     LBL9 $  
77 SDR1      USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/UGV,PGG,QG/NSKIP/  
             *STATICS* $  
78 COND      LBL8,REPEAT $  
79 REPT      LBL11,360 $  
80 JUMP      ERROR2 $  
81 PARAM     //*NOT*/TEST/REPEAT $  
82 COND      ERROR5,TEST $  
83 LABEL     LBL8 $  
84 COND      NOMPCF,GRDEQ $  
85 EQMCK    CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/  
             OQM1/V,Y,OPT=0/V,Y,GRDEQ/NSKIP $  
86 OFP       OQM1,,,,,/S,N,CARDNO $  
87 LABEL     NOMPCF $  
88 SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/  
             OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS* $  
89 OFP       OUGV1,OPG1,OQG1,OEF1,OES1,/S,N,CARDNO $  
90 SCAN      CASECC,OES1,OEF1/OESF1/*RF* $  
91 OFP       OESF1,,,,,/S,N,CARDNO $  
92 COND      P2,JUMPPLOT $  
93 PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/  
             PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFFILE $
```

STATIC ANALYSIS WITH INERTIA RELIEF

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 2

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
94 PRTMSG PLOTX2// $  
95 LABEL P2 $  
96 JUMP FINIS $  
97 LABEL ERROR1 $  
98 PRTPARM //-*INERTIA* $  
99 LABEL ERROR2 $  
100 PRTPARM //-*INERTIA* $  
101 LABEL ERROR3 $  
102 PRTPARM //-*INERTIA* $  
103 LABEL ERROR4 $  
104 PRTPARM //-*INERTIA* $  
105 LABEL ERROR5 $  
106 PRTPARM //-*INERTIA* $  
107 LABEL ERROR6 $  
108 PRTPARM //-*INERTIA* $  
109 LABEL FINIS $  
110 PURGE DUMMY/ALWAYS $  
111 END $
```

## DISPLACEMENT RIGID FORMATS

### 2.2.2 Description of Important DMAP Operations for Static Analysis with Inertia Relief

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Static Loads Table and Grid Point Temperature Table.
20. TA1 generates element tables for use in matrix assembly and stress recovery.
21. Go to DMAP No. 107 and print Error Message No. 6 if there are no structural elements.
25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 97 and print Error Message No. 1 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
32. Go to DMAP No. 35 if no weight and balance information is requested.
33. GPWG generates weight and balance information.
34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
36. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if no general elements exist.
37. Go to DMAP No. 39 if no general elements exist.
38. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
41. Beginning of loop for multiple constraint sets.
42. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g]\{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
43. Go to DMAP No. 101 and print Error Message No. 3 if no independent degrees of freedom are defined.
44. Go to DMAP No. 103 and print Error Message No. 4 if no free-body supports exist.
46. Go to DMAP No. 51 if general elements are present.

STATIC ANALYSIS WITH INERTIA RELIEF

48. Go to DMAP No. 51 if no potential grid point singularities exist.
49. GPSP generates a table of potential grid point singularities.
50. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
52. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
53. Go to DMAP No. 56 if the MPC set for the current pass is unchanged from that of the previous pass.
54. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
55. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} & | & K_{nm} \\ \hline K_{nn} & + & K_{nm} \\ K_{mn} & | & K_{mm} \end{bmatrix} \quad \text{and} \quad [M_{gg}] = \begin{bmatrix} - & M_{nn} & | & M_{nm} \\ \hline M_{nn} & + & M_{nm} \\ M_{mn} & | & M_{mm} \end{bmatrix}$$

and performs matrix reductions

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [M_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m].$$

57. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.
58. Go to DMAP No. 60 if no single-point constraints exist.
59. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & | & K_{fs} \\ \hline K_{sf} & + & K_{ss} \end{bmatrix} \quad \text{and} \quad [M_{nn}] = \begin{bmatrix} M_{ff} & | & M_{fs} \\ \hline M_{sf} & + & M_{ss} \end{bmatrix}.$$

61. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  and  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.
62. Go to DMAP No. 64 if no omitted coordinates exist.
63. SMP1 partitions constrained stiffness and mass matrices

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} & | & K_{ao} \\ \hline K_{aa} & + & K_{ao} \\ K_{oa} & | & K_{oo} \end{bmatrix} \quad \text{and} \quad [M_{ff}] = \begin{bmatrix} - & M_{aa} & | & M_{ao} \\ \hline M_{aa} & + & M_{ao} \\ M_{oa} & | & M_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reductions  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$

## DISPLACEMENT RIGID FORMATS

and  $[M_{aa}] = [M_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o]$ .

65. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix} \quad \text{and} \quad [M_{aa}] = \begin{bmatrix} M_{\ell\ell} & M_{\ell r} \\ M_{r\ell} & M_{rr} \end{bmatrix}.$$

66. RBMG2 decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

67. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|}$$

68. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

69. SSG1 generates static load vectors  $\{P_g\}$ .

70. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{ \frac{\bar{P}_n}{P_m} \right\} , \quad \{P_n\} = \left\{ \bar{P}_n \right\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{ \frac{\bar{P}_f}{P_s} \right\} , \quad \{P_f\} = \left\{ \bar{P}_f \right\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{ \frac{\bar{P}_a}{P_o} \right\} , \quad \{P_a\} = \left\{ \bar{P}_a \right\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{ \frac{\bar{P}_{\ell}}{P_r} \right\}$$

and calculates determinate forces of reaction  $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$ .

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71. SSG4 calculates inertia loads and combines them with static loads

$$\{P_{\ell}^i\} = \{P_{\ell}\} + \left( [M_{\ell\ell}] [D] + [M_{\ell r}] \right) [m_r]^{-1} \{q_r\} \quad \text{and}$$

$$\{P_0^i\} = \{P_0\} + \left( [M_{00}] [G_0] + [M_{ao}] \right) \begin{bmatrix} D \\ I \end{bmatrix} [m_r]^{-1} \{q_r\} .$$

72. SSG3 solves for displacements of independent coordinates

$$\{u_{\ell}\} = [K_{\ell\ell}]^{-1} \{P_{\ell}^i\} ,$$

solves for displacements of omitted coordinates

$$\{u_0^0\} = [K_{00}]^{-1} \{P_0^i\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_{\ell}^i\} = \{P_{\ell}^i\} - [K_{\ell\ell}] \{u_{\ell}\}$$

$$\epsilon_{\ell} = \frac{\{u_{\ell}^T\} \{\delta P_{\ell}^i\}}{\{P_{\ell}^i\}^T \{u_{\ell}\}}$$

and calculates residual vector (RU0V) and residual vector error ratio for omitted coordinates

$$\{\delta P_0^i\} = \{P_0^i\} - [K_{00}] \{u_0^0\} ,$$

$$\epsilon_0 = \frac{\{u_0^T\} \{\delta P_0^i\}}{\{P_0^i\}^T \{u_0^0\}} .$$

73. Go to DMAP No. 76 if residual vectors are not to be printed.

74. MATGPR prints the residual vector for independent coordinates (RULV).

75. MATGPR prints the residual vector for omitted coordinates (RU0V).

77. SDR1 recovers dependent displacements

$$\begin{Bmatrix} u_{\ell} \\ -u_r \end{Bmatrix} = \{u_a\} , \quad \{u_0\} = [G_0] \{u_a\} + \{u_0^0\} ,$$

$$\begin{Bmatrix} u_a \\ u_0 \end{Bmatrix} = \{u_f\} , \quad \begin{Bmatrix} u_f \\ Y_s \end{Bmatrix} = \{u_n\} ,$$

$$\{u_m\} = [G_m] \{u_n\} , \quad \begin{Bmatrix} u_n \\ u_m \end{Bmatrix} = \{u_g\}$$

## DISPLACEMENT RIGID FORMATS

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T] \{u_f\} + [K_{ss}] \{Y_s\} .$$

78. Go to DMAP No. 83 if all constraint sets have been processed.
79. Go to DMAP No. 41 if additional sets of constraints need to be processed.
80. Go to DMAP No. 99 and print Error Message No. 2 as the number of constraint sets exceeds 360.
82. Go to DMAP No. 105 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.
84. Go to DMAP No. 87 if no multipoint constraint force balance is requested.
85. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance ( $\emptyset QM1$ ) for output.
86.  $\emptyset FP$  formats the table prepared by EQMCK and places it on the system output file for printing.
88. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PG1$ ), displacement vectors ( $\emptyset UGV1$ ), and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the displacement vector ( $PUGV1$ ).
89.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
90. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
91.  $\emptyset FP$  formats the scanned output table prepared by SCAN and places it on the system output file for printing.
92. Go to DMAP No. 95 if no deformed structure plots are requested.
93. PL $\emptyset T$  generates all requested deformed structure and contour plots.
94. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
96. Go to DMAP No. 109 and make normal exit.
98. Print Error Message No. 1 and terminate execution.
100. Print Error Message No. 2 and terminate execution.
102. Print Error Message No. 3 and terminate execution.
104. Print Error Message No. 4 and terminate execution.
106. Print Error Message No. 5 and terminate execution.
108. Print Error Message No. 6 and terminate execution.

## STATIC ANALYSIS WITH INERTIA RELIEF

### 2.2.3 Output for Static Analysis with Inertia Relief

The following output may be requested for Static Analysis with Inertia Relief:

1. Displacements at selected grid points due to the sum of the applied loads and the inertia loads.
2. Nonzero components of the applied static loads at selected grid points.
3. Reactions on free-body supports due to applied loads (single-point forces of constraint).
4. Forces and stresses in selected elements due to the sum of the applied loads and inertia loads.
5. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model.
2. Contour plots of stresses and displacements.

### 2.2.4 Case Control Deck for Static Analysis with Inertia Relief

The following items relate to subcase definition and data selection for Static Analysis with Inertia Relief:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a LØAD selection.
3. An SPC set may be selected only if used to remove grid point singularities or some, but not all, of the free body motions. At least one free body support must be provided with a SUPØRT card in the Bulk Data Deck.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets for the same output item.

### 2.2.5 Parameters for Static Analysis with Inertia Relief

The following parameters are used in Static Analysis with Inertia Relief:

## DISPLACEMENT RIGID FORMATS

1. ASET $\emptyset$ UT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT $\emptyset$ SPC - reserved for future optional use. The default value is -1.
3. C $\emptyset$ UPMASS - CPBAR, CPR $\emptyset$ D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCF $\emptyset$ RCE. If the integer value is zero, the basic origin is used. The default value is -1.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
6. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
7. OPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCF $\emptyset$ RCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
8. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
10. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

## STATIC ANALYSIS WITH INERTIA RELIEF

### 2.2.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Static Analysis with Inertia Relief, Rigid Format 2, are ALTERed in automated substructure analyses.

Phase 1: 4, 44-44, 65-68, 70-96

Phase 2: 4, 5-5, 8-18, 21-21, 30-30, 36-39, 46-51, 84-98

Phase 3: 65-68, 70-76, 77

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

### 2.2.7 Rigid Format Error Messages from Static Analysis with Inertia Relief

The following fatal errors are detected by the DMAP statements in the Static Analysis with Inertia Relief rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

#### STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR CALCULATION ØF INERTIA LØADS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

#### STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 different sets of boundary conditions. This number may be increased by ALTERing the REPT instruction following SDR1.

#### STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

#### STATIC ANALYSIS WITH INERTIA RELIEF ERRØR MESSAGE NØ. 4 - FREE-BØDY SUPPORTS ARE REQUIRED.

A statically determinate set of supports must be specified on a SUPØRT card in order to determine the rigid body characteristics of the structural model.

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STATIC ANALYSIS WITH INERTIA RELIEF ERROR MESSAGE NØ. 5 - A LØØPING PROBLEM RUN ØN A NØN-LØØPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

STATIC ANALYSIS WITH INERTIA RELIEF ERROR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

## DISPLACEMENT RIGID FORMATS

### 2.3 NORMAL MODES ANALYSIS

#### 2.3.1 DMAP Sequence for Normal Modes Analysis

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 03 - NORMAL MODES ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 FILE LAMA=APPEND/PHIA=APPEND $  
4 PARAM //*MPY*/CARDNO/0/0 $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/ALWAYS=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 GP2 GEOM2,EQEXIN/ECT $  
8 PARAML PCDB//*PRES*///JUMPPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
10 COND P1,JUMPPLOT $  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
12 PRTMSG PLTSETX// $  
13 PARAM //*MPY*/PLTFLG/1/1 $  
14 PARAM //*MPY*/PFILE/0/0 $  
15 COND P1,JUMPPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
17 PRTMSG PLOTX1//$/  
18 LABEL P1 $  
19 GP3 GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $  
20 TAT ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
21 COND ERROR4,NOSIMP $
```

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RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PURGE OGPST/GENEL $  
23 PARAM //*ADD*/NOKGGX/1/0 $  
24 PARAM //*ADD*/NOMGG/1/0 $  
25 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
26 PURGE KGGX,GPST/NOKGGX $  
27 COND JMPKGG,NOKGGX $  
28 EMA GPECT,KDICT,KELM/KGGX,GPST $  
29 LABEL JMPKGG $  
30 COND ERROR1,NOMGG $  
31 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
32 COND LGPWG,GRDPNT $  
33 GPWG BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
34 OFP OGPWG,,,,,/S,N,CARDNO $  
35 LABEL LGPWG $  
36 EQUIV KGGX,KGG/NOGENL $  
37 COND LBL11,NOGENL $  
38 SMA3 GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
39 LABEL LBL11 $  
40 PARAM //*MPY*/NSKIP/0/0 $  
41 GP4 CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
42 COND ERROR3,NOL $  
43 PURGE KRR,KLR,DM,MLR,MR/REACT/GM/MPCF1/GO/OMIT/KFS/SINGLE/QG/NOSET $  
44 COND LBL4,GENEL $
```

NORMAL MODES ANALYSIS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45 PARAM //EQ*/GPSPFLG/AUTOSPC/O $
46 COND LBL4,GPSPFLG $
47 GPSP GPL,GPST,USET,SIL/0GPST/S,N,NOGPST $
48 OFP OGPST,,,./S,N,CARDNO $
49 LABEL LBL4 $
50 EQUIV KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
51 COND LBL2,MPCF1 $
52 MCE1 USET,RG/GM $
53 MCE2 USET,GM,KGG,MGG,,/KNN,MNN,, $
54 LABEL LBL2 $
55 EQUIV KNN,KFF/SINGLE/MNN,MFF/SINGLE $
56 COND LBL3,SINGLE $
57 SCE1 USET,KNN,MNN,,/KFF,KFS,,MFF,, $
58 LABEL LBL3 $
59 EQUIV KFF,KAA/OMIT $
60 EQUIV MFF,MAA/OMIT $
61 COND LBL5,OMIT $
62 SMP1 USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
63 SMP2 USET,GO,MFF/MAA $
64 LABEL LBL5 $
65 COND LBL6,REACT $
66 RBMG1 USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $
67 RBMG2 KLL/LLL $
68 RBMG3 LLL,KLR,KRR/DM $
69 RBMG4 DM,MLL,MLR,MRR/MR $
70 LABEL LBL6 $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
71 DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,EED,EQDYN/
LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
NONLFT/NOTRL/S,N,NOEED//NOUE $

72 COND     ERROR2,NOEED $

73 PARAM    //*MPY*/NEIGV/1/-1 $

74 READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/
S,N,NEIGV $

75 OFP      OEIGS,,,,,/S,N,CARDNO $

76 COND     FINIS,NEIGV $

77 OFP      LAMA,,,,,/S,N,CARDNO $

78 SDR1     USET,,PHIA,,,GO,GM,,KFS,,/PHIG.,QG/1/*REIG* $

79 COND     NOMPCF,GRDEQ $

80 EQMCK    CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,PHIG,LAMA,QG,CSTM/
QQM1/V,Y,OPT=0/V,Y,GRDEQ/-1 $

81 OFP      OQM1,,,,,/S,N,CARDNO $

82 LABEL    NOMPCF $

83 SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,BGPDP,LAMA,QG,PHIG,EST,,/
,OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG* $

84 OFP      OPHIG,OQG1,OEF1,OES1,,/S,N,CARDNO $

85 SCAN     CASECC,OES1,OEF1/OESF1/*RF* $

86 OFP      OESF1,,,,,/S,N,CARDNO $

87 COND     P2,JUMPPLOT $

88 PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,OES1/
PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

89 PRTMSG   PLOTX2// $

90 LABEL    P2 $

91 JUMP     FINIS $

92 LABEL    ERROR1 $

93 PRTPARM //1/*MODES* $
```

NORMAL MODES ANALYSIS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
94 LABEL    ERROR2 $  
95 PRTPARM //2/*MODES* $  
96 LABEL    ERROR3 $  
97 PRTPARM //3/*MODES* $  
98 LABEL    ERROR4 $  
99 PRTPARM //4/*MODES* $  
100 LABEL   FINIS $  
101 PURGE  DUMMY/ALWAYS $  
102 END    $
```

### 2.3.2 Description of Important DMAP Operations for Normal Modes Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Grid Point Temperature Table.
20. TA1 generates element tables for use in matrix assembly and stress recovery.
21. Go to DMAP No. 98 and print Error Message No. 4 if there are no structural elements.
25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 92 and print Error Message No. 1 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
32. Go to DMAP No. 35 if no weight and balance information is requested.
33. GPWG generates weight and balance information.
34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
36. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if no general elements exist.
37. Go to DMAP No. 39 if no general elements exist.
38. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
42. Go to DMAP No. 96 and print Error Message No. 3 if no independent degrees of freedom are defined.
44. Go to DMAP No. 49 if general elements are present.
46. Go to DMAP No. 49 if no potential grid point singularities exist.
47. GPSP generates a table of potential grid point singularities.

## NORMAL MODES ANALYSIS

48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
50. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
51. Go to DMAP No. 54 if no multipoint constraints exist.
52. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \begin{bmatrix} K_{nn} & K_{nm} \\ K_{mn} & K_{mm} \end{bmatrix} \quad \text{and} \quad [M_{gg}] = \begin{bmatrix} M_{nn} & M_{nm} \\ M_{mn} & M_{mm} \end{bmatrix}$$

and performs matrix reductions

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [M_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m].$$

55. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.
56. Go to DMAP No. 58 if no single-point constraints exist.
57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & K_{fs} \\ K_{sf} & K_{ss} \end{bmatrix} \quad \text{and} \quad [M_{nn}] = \begin{bmatrix} M_{ff} & M_{fs} \\ M_{sf} & M_{ss} \end{bmatrix}.$$

59. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
60. Equivalence  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.
61. Go to DMAP No. 64 if no omitted coordinates exist.
62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} K_{aa} & K_{ao} \\ K_{oa} & K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .

63. SMP2 partitions constrained mass matrix

DISPLACEMENT RIGID FORMATS

$$[M_{ff}] = \begin{bmatrix} - & M_{aa} & M_{ao} \\ \frac{M_{aa}}{M_{ao}} + & M_{ao} \\ M_{ao} & M_{oo} \end{bmatrix},$$

and performs matrix reduction

$$[M_{aa}] = [M_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o].$$

65. Go to DMAP No. 70 if no free-body supports exist.

66. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix} \text{ and } [M_{aa}] = \begin{bmatrix} M_{\ell\ell} & M_{\ell r} \\ M_{r\ell} & M_{rr} \end{bmatrix}$$

67. RBMG2 decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

68. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|}.$$

69. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

71. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

72. Go to DMAP No. 94 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

74. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0,$$

calculates rigid body modes by finding a square matrix  $[\phi_{ro}]$  such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} D\phi_{ro} \\ \phi_{ro} \end{bmatrix},$$

## NORMAL MODES ANALYSIS

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit value of a selected component
- 2) Unit value of the largest component
- 3) Unit value of the generalized mass.

75. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.
76. Go to DMAP No. 100 and make normal exit if no eigenvalues were found.
77. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.
78. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o] \{\phi_a\} , \quad \left\{ \frac{\phi_a}{\phi_o} \right\} = \{\phi_f\} ,$$

$$\left\{ \frac{\phi_f}{\phi_s} \right\} = \{\phi_n\} , \quad \{\phi_m\} = [G_m] \{\phi_n\} ,$$

$$\left\{ \frac{\phi_n}{\phi_m} \right\} = \{\phi_g\}$$

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}]^T \{\phi_f\}$ .

79. Go to DMAP No. 82 if no multipoint constraint force balance is requested.
80. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance (ØQM1) for output.
81. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.
83. SDR2 calculates element forces (ØEF1) and stresses (ØES1) and prepares eigenvectors (ØPHIG) and single-point forces of constraint (ØQG1) for output and translation components of the eigenvectors (PPHIG).
84. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.
85. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
86. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.
87. Go to DMAP No. 90 if no deformed structure plots are requested.

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88. PL0T generates all requested deformed structure and contour plots.
89. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
91. Go to DMAP No. 100 and make normal exit.
93. Print Error Message No. 1 and terminate execution.
95. Print Error Message No. 2 and terminate execution.
97. Print Error Message No. 3 and terminate execution.
99. Print Error Message No. 4 and terminate execution.

### 2.3.3 Output for Normal Modes Analysis

Each eigenvalue is identified with a mode number determined by sorting the eigenvalues by their algebraic magnitude. The following summary of the eigenvalues extracted is automatically printed:

1. Mode Number
2. Extraction Order
3. Eigenvalue
4. Radian Frequency
5. Cyclic Frequency
6. Generalized Mass
7. Generalized Stiffness

The following summary of the eigenvalue analysis performed, using the Inverse Power method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of starting points used.
3. Number of starting point moves.
4. Number of triangular decompositions.
5. Number of vector iterations.
6. Reason for termination.
  - (1) Two consecutive singularities encountered while performing triangular decomposition.
  - (2) Four shift points while tracking a single root.
  - (3) All eigenvalues found in the frequency range specified.
  - (4) Three times the number of roots estimated in the frequency range have been extracted.
  - (5) All eigenvalues that exist in the problem have been found.
  - (6) The number of roots desired have been found.
  - (7) One or more eigenvalues have been found outside the frequency range specified.
  - (8) Insufficient time to find another root.
  - (9) Unable to converge
7. Largest off-diagonal modal mass term and the number failing the criterion.

## DISPLACEMENT RIGID FORMATS

The following summary of the eigenvalue analysis performed, using the Determinant method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of passes through starting points.
3. Number of criteria changes.
4. Number of starting point moves.
5. Number of triangular decompositions.
6. Number of failures to iterate to a root.
7. Reason for termination.
  - (1) The number of roots desired have been found.
  - (2) All predictions for eigenvalues are outside the frequency range specified.
  - (3) Insufficient time to find another root.
  - (4) Matrix is singular at first three starting points.
8. Largest off-diagonal modal mass term and the number failing the criterion.
9. Swept determinant function for each starting point.

The following summary of the eigenvalue analysis performed, using the Givens method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of eigenvectors computed.
3. Number of eigenvalue convergence failures.
4. Number of eigenvector convergence failures.
5. Reason for termination.
  - (1) Normal termination.
  - (2) Insufficient time to calculate eigenvalues and number of eigenvectors requested.
  - (3) Insufficient time to find additional eigenvectors.
6. Largest off-diagonal modal mass term and the number failing the criterion.

The following summary of the eigenvalue analysis performed, using the Tridiagonal Reduction (FEER - Fast Eigenvalue Extraction Routine) method, is automatically printed.

1. Number of eigenvalues extracted.
2. Number of starting points used.

This corresponds to the total number of random starting and restart vectors used by the FEER process.

## NORMAL MODES ANALYSIS

3. Number of starting point moves.

Not used in FEER (set equal to zero).

4. Number of triangular decompositions.

Always equal to one, except for unshifted vibration problems (roots starting from the lowest requested). In this case, a maximum of three shifts and three decompositions are employed to remove possible stiffness matrix singularities.

5. Total number of vector iterations.

The total number of reorthogonalizations of all the trial vectors employed.

6. Reason for termination.

(0) Normal termination.

(1) Fewer than the requested number of eigenvalues and eigenvectors have been extracted.

(3) The problem size has been reduced. However, the desired number of accurate eigensolutions specified on the EIGB or EIGR card may have been obtained. A detailed list of the computed error bounds can be obtained by requesting DIAG 16 in the Executive Control Deck.

7. Largest off-diagonal modal mass term and the number failing the mass orthogonality criterion.

The following output may be requested:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed plot of the structural model and mode shapes for selected modes.
2. Contour plots of stresses and displacements for selected modes.

### **2.3.4 Case Control Deck for Normal Modes Analysis**

The following items relate to subcase definition and data selection for Normal Modes Analysis:

1. METHOD must be used to select an EIGR card that exists in the Bulk Data Deck.

## DISPLACEMENT RIGID FORMATS

2. On restart, the current EIGR card controls the eigenvalue extraction, regardless of what calculations were made in the previous execution. Consequently, when making restarts with either the Determinant method, the Inverse Power method or the Tridiagonal Reduction (FEER) method, METH<sub>00</sub> should be changed to select an EIGR card that avoids the extraction of previously found eigenvalues. This is particularly important following unscheduled exits due to insufficient time to find all eigenvalues in the range of interest.
3. An SPC set must be selected unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. Multiple subcases are used only to control output requests. A single subcase is sufficient if the same output is desired for all modes. If multiple subcases are present, the output requests will be honored in succession for increasing mode numbers. M<sub>00</sub>DES may be used to repeat subcases in order to make the same output request for several consecutive modes.

### 2.3.5 Parameters for Normal Modes Analysis

The following parameters are used in Normal Modes Analysis:

1. ASET<sub>00</sub>OUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT<sub>00</sub>SPC - reserved for future optional use. The default value is -1.
3. C<sub>00</sub>UPMASS - CPBAR, CPR<sub>00</sub>, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCF<sub>00</sub>RCE. If the integer value is zero, the basic origin is used. The default value is -1.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.

6. OPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFORCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
7. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

### 2.3.6 Optional Diagnostic Output for FEER

Special detailed information related to the generation of the reduced problem size, the elements of the reduced tridiagonal matrix, computed error bounds and other numerical tests can be obtained by requesting DIAG 16 in the NASTRAN Executive Control Deck.

The meaning of this information is explained below in the order in which it appears in the DIAG 16 output.

<u>ORDER</u>	- The order of the unreduced problem (size of the $[K_{aa}]$ matrix)
<u>MAX RANK</u>	- The maximum number of existing finite eigensolutions as initially detected by FEER
<u>RED ORDER</u>	- The order of the reduced eigenproblem which will be solved to obtain the number of accurate solutions requested by the user
<u>ORTH VCT</u>	- The number of previously computed accurate eigenvectors on the eigenvector file which were generated prior to a restart or by the NASTRAN rigid body mode generator
<u>USER SHIFT</u>	- The user specified shift after conversion from cycles to radians - squared (used only in frequency problems).
<u>INTERNAL SHIFT</u>	- A small positive value automatically computed to remove singularities if the user has specified a zero shift. Otherwise, the negative of the user shift (used only in frequency problems).

## DISPLACEMENT RIGID FORMATS

SINGULARITY CHECK - PASS: the shifted stiffness matrix is non-singular  
- \*\*\*\*: the number of internal shifts needed to remove stiffness matrix singularities

TRIDIAGONAL ELEMENTS ROW j, \*\*, \*\*\*, \*\*\*\* - The computed tridiagonal elements of the reduced eigenmatrix:

- j - Matrix row
- \*\* - Diagonal element
- \*\*\* - Off-diagonal element
- \*\*\*\* - First estimate of off-diagonal element in the next row

ØRTH ITER - The number of times a reorthogonalization of a trial vector has been performed.

MAX PRØJ - The maximum projection of the above trial vector on the previously computed accurate trial vectors (prior to the current reorthogonalization)

NORMAL FACT - The normalization factor for the reorthogonalized trial vector

ØPEN CØRE NØT USED \*\*\* FEER3 - Open core not used by Subroutine FEER3, in single-precision words

FEER QRW ELEMENT \*, ITER \*\*, \*\*\*, RATIØ \*\*\*\*, PRØJ \*\*\*\*\*:

- \*
- \*\* - The number of inverse power iterations performed to extract the associated eigenvector of the reduced system (this is not a physical eigenvector)
- \*\*\* - If a multiple root has been detected, the number of times that the previous multiple-root, reduced-system eigenvectors have been projected out of the current multiple-root eigenvector before repeating the inverse power iterations
- \*\*\*\* - The absolute ratio of maximum, reduced-system eigenvector elements for successive inverse power iterations
- \*\*\*\*\* - The maximum projection of a current multiple-root eigenvector on previously computed eigenvectors for the same root

PHYSICAL EIGENVALUE \*, \*\*, THEØR ERRØR \*\*\* PERCENT, PASS ØR FAIL:

- \*
- \*\* - The associated physical eigenvalue ( $\lambda$  for buckling problems,  $\omega^2$  for frequency problems)
- \*\*\* - Theoretical upper bound on the relative eigenvalue error
- PASS - The computed error is less than or equal to the allowable specified on the EIGB or EIGR bulk data card (default is .001/n where n is the order of the stiffness matrix)
- FAIL - The computed error is greater than the allowable and this mode is not accepted for further processing

ØPEN CØRE NØT USED \*\*\* FEER4 - Open core not used by Subroutine FEER4, in single-precision words

FEER CØMPLETE \*, \*\*, \*\*\*, \*\*\*\*

- \*
- \*\* - The remaining CPU time available following decomposition of the shifted stiffness matrix, in seconds (the total time is specified on the TIME card in the Executive Control Deck)
- \*\*\* - The remaining CPU time, in seconds after completing Subroutine FEER3
- \*\*\*\* - The remaining CPU time, in seconds after completing Subroutine FEER4

## NORMAL MODES ANALYSIS

- \*\*\*\* - The total operation count for FEER after decomposition of the shifted stiffness matrix. One operation is considered to be a multiplication or division followed by an addition

### 2.3.7 The APPEND Feature

In real eigenvalue analysis, it is frequently necessary to add new eigenvalues and eigenvectors to those already computed in a previous run. The APPEND feature (see Section 9.2.2 of the Theoretical Manual for details) makes it possible to do this without re-executing the entire problem. It is available when using the Inverse Power, Determinant and Tridiagonal Reduction (FEER) methods of eigenvalue extraction.

In order to use the APPEND feature, the user should employ the following steps:

1. Request a checkpoint of an eigenvalue problem by employing either the Inverse Power, Determinant or Tridiagonal Reduction (FEER) method.
2. Check to ensure that at least one eigenvalue and one eigenvector are computed in this run and that the LAMA (eigenvalue) and PHIA (eigenvector) files are successfully checkpointerd.
3. Restart the problem by changing either the METHOD card in the Case Control Deck and/or the EIGR card in the Bulk Data Deck and ensuring that the following conditions are satisfied:
  - a. The structural model and the constraint data for the restart must be the same as that used in the checkpoint run.
  - b. The method of eigenvalue extraction employed in the restart need not be the same as that used in the checkpoint run, but the range of eigenvalues specified on the EIGR Bulk Data card should not include the eigenvalues already checkpointed in Step 1.
  - c. If the user wishes to retrieve only a subset of the checkpointed eigenvalues and eigenvectors, a DMAP alter should be employed in the Executive Control Deck to reset the parameter NEIGV to the desired value by means of a PARAM statement just before the READ module in the DMAP sequence. (See Section 9.2.2 of the Theoretical Manual for details.)

## DISPLACEMENT RIGID FORMATS

4. Note that the eigenvalues and eigenvectors output by the restart include those retrieved from the checkpointed run of Step 1. Also, the resulting eigenvectors are normalized according to the method of normalization specified in the restart.

### 2.3.8 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Normal Modes Analysis, Rigid Format 3, are ALTEREd in automated substructure analyses.

Phase 1: 4, 42, 65-70, 71-91

Phase 2: 4, 5-5, 8-18, 21-21, 30-30, 36-39, 44-49, 79-93

Phase 3: 65-70, 71-77, 78

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

### 2.3.9 Rigid Format Error Messages from Normal Modes Analysis

The following fatal errors are detected by the DMAP statements in the Normal Modes Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHOD in the Case Control Deck must select an EIGR set.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

NØRMAL MØDE ANALYSIS ERRØR MESSAGE NØ. 4 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

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2.4 STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

2.4.1 DMAP Sequence for Static Analysis With Differential Stiffness

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 04 - DIFFERENTIAL STIFFNESS ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 PARAM //*MPY*/CARDNO/0/0 $  
4 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
S,N,NOGPDT/MINUS1=-1 $  
5 COND ERROR3,NOGPDT $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 GP2 GEOM2,EQEXIN/ECT $  
8 PARAML PCDB//*PRES*///JUMPPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
10 COND P1,JUMPPLOT $  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
12 PRTMSG PLTSETX// $  
13 PARAM //*MPY*/PLTFLG/1/1 $  
14 PARAM //*MPY*/PFILE/0/0 $  
15 COND P1,JUMPPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
17 PRTMSG PLOTX1// $  
18 LABEL P1 $  
19 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $  
20 PARAM //*AND*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 $  
21 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22  COND      ERROR1,NOSIMP $  
23  PURGE     OGPST/GENEL $  
24  PARAM     //**ADD*/NOKGGX/I/O $  
25  EMG       EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
           S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
           C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
           C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
           V,Y,VOLUME/V,Y,SURFACE $  
26  PURGE     KGGX,GPST/NOKGGX/MGG/NOMGG $  
27  COND      JMPKGG,NOKGGX $  
28  EMA       GPECT,KDICT,KELM/KGGX,GPST $  
29  LABEL     JMPKGG $  
30  COND      JMPMGG,NOMGG $  
31  EMA       GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
32  LABEL     JMPMGG $  
33  COND      LBL1,GRDPNT $  
34  COND      ERROR4,NOMGG $  
35  GPWG     BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $  
36  OFP      OGPWG,.,./S,N,CARDNO $  
37  LABEL     LBL1 $  
38  EQUIV    KGGX,KGG/NOGENL $  
39  COND      LBL11,NOGENL $  
40  SMA3     GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
41  LABEL     LBL11 $  
42  PARAM     //**MPY*/NSKIP/0/0 $  
43  CASE     CASECC,/CASEXX/*TRANRESP*/0/NOLOOP $  
44  GP4      CASEXX,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/  
           LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/S,N,  
           NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
           S,Y,AUTOSPC $
```

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45  COND    ERROR5,NOL $  
46  PURGE   GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,KFS,KSS,QG,  
           YBS,PBS,KBFS,KBSS,KDFS,KDSS/SINGLE $  
47  COND    LBL4D,REACT $  
48  JUMP    ERROR2 $  
49  LABEL   LBL4D $  
50  COND    LBL4,GENEL$  
51  PARAM   //EQ*/GPSPFLG/AUTOSPC/O $  
52  COND    LBL4,GPSPFLG $  
53  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
54  OFP     OGPST,/,//S,N,CARDNO $  
55  LABEL   LBL4 $  
56  EQUIV   KGG,KNN/MPCF1 $  
57  COND    LBL2,MPCF1 $  
58  MCE1    USET,RG/GM $  
59  MCE2    USET,GM,KGG,,,/KNN,,, $  
60  LABEL   LBL2 $  
61  EQUIV   KNN,KFF/SINGLE $  
62  COND    LBL3,SINGLE $  
63  SCE1    USET,KNN,,,/KFF,KFS,KSS,,, $  
64  LABEL   LBL3 $  
65  EQUIV   KFF,KAA/OMIT $  
66  COND    LBL5,OMIT $  
67  SMP1    USET,KFF,,,/GO,KAA,KOO,LOO,,,$  
68  LABEL   LBL5 $  
69  RBMG2   KAA/LLL $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
70 SSG1      SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASEXX,DIT,/PG,,,/LUSET/1 $  
71 EQUIV    PG,PL/NOSET $  
72 COND     LBL10,NOSET $  
73 SSG2     USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $  
74 LABEL    LBL10 $  
75 SSG3     LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/1/S,N,EPST $  
76 COND     LBL9,IRES $  
77 MATGPR   GPL,USET,SIL,RULV//*L* $  
78 MATGPR   GPL,USET,SIL,RUOV//*0* $  
79 LABEL    LBL9 $  
80 SDR1     USET,,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PG1,QG/1/*DSO* $  
81 SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PG/OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*DSO* $  
82 OFP      OUGV1,OPG1,OQG1,OEF1,OES1,,/S,N,CARDNO $  
83 SCAN    CASECC,OES1,OEF1/OESF1/*RF* $  
84 OFP      OESF1,,,,/S,N,CARDNO $  
85 COND    P2,JUMPPLOT $  
86 PLOT    PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $  
87 PRTMSG  PLOTX2// $  
88 LABEL    P2 $  
89 TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/NOSIMP/0/NOGENL/GENEL $  
90 DSMG1    CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/DSCOSET $  
91 PARAM    /*ADD*/SHIFT/-1/0 $  
92 PARAM    /*ADD*/COUNT/ALWAYS=-1/NEVER= 1 $
```

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
93 PARAMR ///*ADD*/DSEPS1/0.0/0.0 $  
94 PARAML YS///*NULL*///NOYS $  
95 LABEL OUTLPTOP $  
96 EQUIV PG,PG1/NOYS $  
97 PARAM ///*KLOCK*/TO $  
98 EQUIV KDGG,KDNN/MPCF1 $  
99 COND LBL2D,MPCF1 $  
100 MCE2 USET,GM,KDGG,,,/KDNN,,, $  
101 LABEL LBL2D $  
102 EQUIV KDNN,KDFF/SINGLE $  
103 COND LBL3D,SINGLE $  
104 SCE1 USET,KDNN,,,/KDFF,KDFS,KDSS,,, $  
105 LABEL LBL3D $  
106 EQUIV KDFF,KDAA/OMIT $  
107 COND LBL5D,OMIT $  
108 SMP2 USET,GO,KDFF/KDAA $  
109 LABEL LBL5D $  
110 ADD KAA,KDAA/KBLL $  
111 ADD KFS,KDFS/KBFS $  
112 ADD KSS,KDSS/KBSS $  
113 COND PGOK,NOYS $  
114 MPYAD KBSS,YS,/PSS/0/1/1/1 $  
115 MPYAD KBFS,YS,/PFS/0/1/1/1 $  
116 UMERGE USET,PFS,PSS/PN/*N*//*F*//*S* $  
117 EQUIV PN,PGX/MPCF1 $  
118 COND LBL6D,MPCF1 $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
119 UMERGE  USET,PN,/PGX/*G*/*N*/*M* $  
120 LABEL    LBL6D $  
121 ADD      PGX,PG/PGG/(-1.0,0.0) $  
122 EQUIV   PGG,PG1/ALWAYS $  
123 LABEL    PGOK $  
124 ADD      PG1,/PGO/ $  
125 RBMG2    KBLL/LBLL/S,N,POWER/S,N,DET $  
126 PRTPARM  //0/*DET* $  
127 PRTPARM  //0/*POWER* $  
128 LABEL    INLPTOP $  
129 PARAM    ///*KLOCK*/TI $  
130 SSG2     USET,GM,YS,KDFS,GO,,PG1/,PBO,PBS,PBL $  
131 SSG3     LBLL,KBLL,PBL,,,UBLV,,RUBLV,/-1/V,Y,IRES/NDSKIP/S,N,  
EPSI $  
132 COND    LBL9D,IRES $  
133 MATGPR   GPL,USET,SIL,RUBLV//*L* $  
134 LABEL    LBL9D $  
135 SDR1     USET,,UBLV,,YS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/1/*DS1* $  
136 ADD      UBGV,UGV/DUGV/(-1.0,0.0) $  
137 DSMG1    CASECC,GPTT,SIL,EDT,DUGV,CSTM,MPT,ECPT,GPCT,DIT/DKDGG/  
DSCOSET $  
138 MPYAD   DKDGG,UBGV,PGO/PG11/0/1/1/0 $  
139 DSCHK   PG1,PG11,UBGV//C,Y,EPS10=1.E-5/S,N,DSEPSI/C,Y,NT=10/T0/  
TI/S,N,DONE/S,N,SHIFT/S,N,COUNT/C,Y,BETAD=4 $  
140 COND    DONE,DONE $  
141 COND    SHIFT,SHIFT $  
142 EQUIV   PG,PG1/NEVER/PG11,PG1/ALWAYS/PG1,PG11/NEVER $  
143 REPT    INLPTOP,1000 $
```

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
144 TABPT PG11,PG1,PG,,// $  
145 LABEL SHIFT $  
146 ADD DKDGG,KDGG/KDGG1/(-1.0,0.0) $  
147 EQUIV UBGV,UGV/ALWAYS/KDGG1,KDGG/ALWAYS $  
148 EQUIV KDGG,KDGG1/NEVER/UGV,UBGV/NEVER $  
149 REPT OUTLPTOP,1000 $  
150 TABPT KDGG1,KDGG,UGV,,// $  
151 LABEL DONE $  
152 SDR2 CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QBG,UBGV,EST,,/  
,QBG1,OUBGV1,OESB1,OEFB1,PUBGV1/*DS1* $  
153 OFP OUBGV1,QBG1,OEFB1,OESB1,,//S,N,CARDNO $  
154 COND P3,JUMPLOT $  
155 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUBGV1,,GPECT,  
OESB1/PLOTX3/NSIL/LUSEP/JUMPLOT/PLTFLG/S,N,  
PFILE $  
156 PRTPARM PLOTX3// $  
157 LABEL P3 $  
158 JUMP FINIS $  
159 LABEL ERROR1 $  
160 PRTPARM //1/*DIFFSTIF* $  
161 LABEL ERROR2 $  
162 PRTPARM //2/*DIFFSTIF* $  
163 LABEL ERROR3 $  
164 PRTPARM //3/*DIFFSTIF* $  
165 LABEL ERROR4 $  
166 PRTPARM //4/*DIFFSTIF* $  
167 LABEL ERROR5 $  
168 PRTPARM //5/*DIFFSTIF* $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 4

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
169 LABEL    FINIS $  
170 PURGE    DUMMY/MINUS1 $  
171 END      $
```

## STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

### 2.4.2 Description of Important DMAP Operations for Static Analysis with Differential Stiffness

4. G1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
5. Go to DMAP No. 163 and print Error Message No. 3 if there is no Grid Point Definition Table.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Static Loads Table and Grid Point Temperature Table.
21. TA1 generates element tables for use in matrix assembly and stress recovery.
22. Go to DMAP No. 159 and print Error Message No. 1 if there are no structural elements.
25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 32 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
33. Go to DMAP No. 37 if no weight and balance information is requested.
34. Go to DMAP No. 165 and print Error Message No. 4 if no mass matrix exists.
35. GPWG generates weight and balance information.
36. OFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
38. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if no general elements exist.
39. Go to DMAP No. 41 if no general elements exist.
40. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
43. CASE copies the first record of CASECC to CASEXX.
44. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g] \{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
45. Go to DMAP No. 167 and print Error Message No. 5 if no independent degrees of freedom are defined.

DISPLACEMENT RIGID FORMATS

47. Go to DMAP No. 49 if no free-body supports are supplied.
48. Go to DMAP No. 161 and print Error Message No. 2.
50. Go to DMAP No. 55 if general elements are present.
52. Go to DMAP No. 55 if no potential grid point singularities exist.
53. GPSP generates a table of potential grid point singularities.
54. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
56. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if no multipoint constraints exist.
57. Go to DMAP No. 60 if no multipoint constraints exist.
58. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
59. MCE2 partitions stiffness matrix

$$[K_{gg}] = \begin{bmatrix} - & \\ K_{nn} & | K_{nm} \\ \hline K_{mn} & + \\ K_{mm} & | K_{mm} \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

61. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  if no single-point constraints exist.
62. Go to DMAP No. 64 if no single-point constraints exist.
63. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & | K_{fs} \\ \hline K_{sf} & | K_{ss} \end{bmatrix}.$$

65. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
66. Go to DMAP No. 68 if no omitted coordinates exist.
67. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & \\ K_{aa} & | K_{ao} \\ \hline K_{oa} & + \\ K_{oo} & | K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .

69. RMBG2 decomposes constrained stiffness matrix  $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

70. SSG1 generates static load vectors  $\{P_g\}$ .
71. Equivalence  $\{P_g\}$  to  $\{P_\ell\}$  if no constraints are applied.
72. Go to DMAP No. 74 if no constraints are applied.
73. SSG2 applies constraints to static load vectors

$$\begin{aligned}\{P_g\} &= \left\{ \frac{\bar{P}_n}{\bar{P}_m} \right\}, & \{P_n\} &= \bar{P}_n + [G_m^T] \{P_m\}, \\ \{P_n\} &= \left\{ \frac{\bar{P}_f}{\bar{P}_s} \right\}, & \{P_f\} &= \bar{P}_f - [K_{fs}] \{Y_s\}, \\ \{P_f\} &= \left\{ \frac{\bar{P}_a}{\bar{P}_o} \right\} \quad \text{and} \quad \{P_\ell\} = \{P_a\} + [G_o^T] \{P_o\}.\end{aligned}$$

75. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{aa}]^{-1} \{P_\ell\},$$

solves for displacements of omitted coordinates

$$\{u_o^0\} = [K_{oo}]^{-1} \{P_o\},$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{aa}] \{u_\ell\},$$

$$\epsilon_\ell = \frac{\{u_\ell^T\} \{\delta P_\ell\}}{\{P_\ell^T\} \{u_\ell\}},$$

and calculates residual vector (RUOV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}] \{u_o^0\},$$

$$\epsilon_o = \frac{\{u_o^T\} \{\delta P_o\}}{\{P_o^T\} \{u_o^0\}}.$$

76. Go to DMAP No. 79 if residual vectors are not to be printed.
77. MATGPR prints the residual vector for independent coordinates (RULV).
78. MATGPR prints the residual vector for omitted coordinates (RUOV).

## DISPLACEMENT RIGID FORMATS

80. SDR1 recovers dependent displacements

$$\{u_0\} = [G_0]\{u_g\} + \{u_0^0\},$$

$$\left\{ \frac{u_a}{u_0} \right\} = \{u_f\}, \quad \left\{ \frac{u_f}{Y_s} \right\} = \{u_n\},$$

$$\{u_m\} = [G_m]\{u_n\}, \quad \left\{ \frac{u_n}{u_m} \right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

81. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PG1$ ), displacement vectors ( $\emptyset UGV1$ ) and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the displacement vector ( $PUGV1$ ) for the static solution.
82.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
83. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
84.  $\emptyset FP$  formats the scanned output table prepared by SCAN and places it on the system output file for printing.
85. Go to DMAP No. 88 if no deformed static solution structure plots are requested.
86. PL $\emptyset T$  generates all requested static solution deformed structure and contour plots.
87. PRTMSG prints plotter data, engineering data, and contour data for each deformed static solution plot generated.
89. TA1 generates element tables for use in differential stiffness matrix assembly.
90. DSMG1 generates differential stiffness matrix  $[K_{gg}^d]$ .
95. Beginning of outer (stiffness adjustment) loop for differential stiffness iteration.
96. Equivalence  $\{P_g\}$  to  $\{P_{g1}\}$  if no enforced displacements are specified.
98. Equivalence  $[K_{gg}^d]$  to  $[K_{nn}^d]$  if no multipoint constraints exist.
99. Go to DMAP No. 101 if no multipoint constraints exist.
100. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \begin{bmatrix} K_{nn}^d & K_{nm}^d \\ \hline K_{mn}^d & K_{mm}^d \end{bmatrix}$$

and performs matrix reduction

## STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

$$[K_{nn}^d] = [K_{nn}^d] + [G_m^T][K_{mn}^d] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

102. Equivalence  $[K_{nn}^d]$  to  $[K_{ff}^d]$  if no single-point constraints exist.

103. Go to DMAP No. 105 if no single-point constraints exist.

104. SCE1 partitions out single-point constraints

$$[K_{nn}^d] = \begin{bmatrix} K_{ff}^d & K_{fs}^d \\ K_{sf}^d & K_{ss}^d \end{bmatrix}.$$

106. Equivalence  $[K_{ff}^d]$  to  $[K_{aa}^d]$  if no omitted coordinates exist.

107. Go to DMAP No. 109 if no omitted coordinates exist.

108. SMP2 partitions constrained differential stiffness matrix

$$[K_{ff}^d] = \begin{bmatrix} K_{aa}^d & K_{ao}^d \\ K_{oa}^d & K_{oo}^d \end{bmatrix}.$$

and performs matrix reduction

$$[K_{aa}^d] = [K_{aa}^d] + [K_{oa}^d]^T[G_o] + [G_o]^T[K_{oa}^d] + [G_o]^T[K_{oo}^d][G_o].$$

110. ADD  $[K_{aa}^d]$  and  $[K_{aa}^d]$  to form  $[K_{\ell\ell}^b]$ .

111. ADD  $[K_{fs}^d]$  and  $[K_{fs}^d]$  to form  $[K_{fs}^b]$ .

112. ADD  $[K_{ss}^d]$  and  $[K_{ss}^d]$  to form  $[K_{ss}^b]$ .

113. Go to DMAP No. 123 if no enforced displacements are specified.

114. MPYAD multiplies  $[K_{ss}^b]$  and  $\{Y_s\}$  to form  $\{P_{ss}\}$ .

115. MYPAD multiplies  $[K_{fs}^b]$  and  $\{Y_s\}$  to form  $\{P_{fs}\}$ .

116. UMERGE combines  $\{P_{fs}\}$  and  $\{P_{ss}\}$  to form  $\{P_n\}$ .

117. Equivalence  $\{P_n\}$  to  $\{P_g^X\}$  if no multipoint constraints exist.

118. Go to DMAP No. 120 if no multipoint constraints exist.

119. UMERGE expands  $\{P_n\}$  to form  $\{P_g^X\}$ .

121. ADD  $-\{P_g^X\}$  and  $\{P_g\}$  to form  $\{P_{gg}\}$ .

122. Equivalence  $\{P_{gg}\}$  to  $\{P_{g1}\}$ .

124. ADD  $\{P_{g1}\}$  and nothing to create  $\{P_{go}\}$ .

125. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix

$$[K_{\ell\ell}^b] = [L_{\ell\ell}^b][U_{\ell\ell}^b].$$

126. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

## DISPLACEMENT RIGID FORMATS

127. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.
128. Beginning of inner (load correction) loop for differential stiffness iteration.
130. SSG2 applies constraints to static load vectors

$$\{P_{g1}^b\} = \begin{Bmatrix} \bar{P}_n^b \\ P_m^b \end{Bmatrix}, \quad \{P_n^b\} = \bar{P}_n^b + [G_m^T] \{P_m^b\},$$

$$\{P_n^b\} = \begin{Bmatrix} \bar{P}_f^b \\ P_s^b \end{Bmatrix}, \quad \{P_f^b\} = \bar{P}_f^b - [K_{fs}^d] \{Y_s\},$$

$$\{P_f^b\} = \begin{Bmatrix} \bar{P}_a^b \\ P_o^b \end{Bmatrix} \quad \text{and} \quad \{P_\ell^b\} = \{P_a^b\} + [G_o^T] \{P_o^b\}.$$

131. SSG3 solves for displacements of independent coordinates for current differential stiffness load vector

$$\{u_\ell^b\} = [K_{\ell\ell}^b]^{-1} \{P_\ell^b\},$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

$$\{\delta P_\ell^b\} = \{P_\ell^b\} - [K_{\ell\ell}^b] \{u_\ell^b\},$$

$$\epsilon_\ell^b = \frac{\{u_\ell^b\}^T \{\delta P_\ell^b\}}{\{P_\ell^b\}^T \{u_\ell^b\}}$$

132. Go to DMAP No. 134 if the residual vector for current differential stiffness solution is not to be printed.
133. MATGPR prints the residual vector for current differential stiffness solution.
135. SDR1 recovers dependent displacements for the current differential stiffness solution

$$\{u_o^b\} = [G_o] \{u_\ell^b\} + \{u_o^{ob}\}, \quad \begin{Bmatrix} u_\ell^b \\ u_o^b \end{Bmatrix} = \{u_f\},$$

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

$$\left\{ \frac{u_f^b}{\gamma_s^b} \right\} = \{u_n^b\} , \quad \{u_m^b\} = [G_m] \{u_n^b\} ,$$

$$\left\{ \frac{u_n^b}{u_m^b} \right\} = \{u_g^b\}$$

and recovers single-point forces of constraint for the current differential stiffness solution

$$\{q_s^b\} = -\{P_s^b\} + [K_{sf}^b] \{u_f^b\} + [K_{ff}^b] \{\gamma_s^b\} .$$

136. ADD  $\{-U_g^b\}$  and  $\{U_g\}$  to form  $\{U_g^d\}$ .

137. DSMG1 generates differential stiffness matrix  $[\delta K_{gg}^d]$ .

138. MYPAD forms the load vector for inner loop iteration

$$\{P_{g_{I1}}\} = [\delta K_{gg}^d] \{U_g^d\} + \{P_{go}\}.$$

139. DSCHK performs differential stiffness convergence checks.

140. Go to DMAP No. 151 if differential stiffness iteration is complete.

141. Go to DMAP No. 145 if additional differential stiffness matrix changes are necessary for further iteration.

142. Break the previous equivalence of  $\{P_g\}$  to  $\{P_{g1}\}$  and  $\{P_{g1}\}$  to  $\{P_{g_{I1}}\}$  and establish equivalence of  $\{P_{g_{I1}}\}$  to  $\{P_{g1}\}$ .

143. Go to DMAP No. 128 for an additional inner loop differential stiffness iteration.

144. TABPT table prints vectors  $\{P_{g_{I1}}\}$ ,  $\{P_{g1}\}$ , and  $\{P_g\}$ .

146. ADD  $-[\delta K_{gg}^d]$  and  $[K_{gg}^d]$  to form  $[K_{gg1}^d]$ .

147. Equivalence  $\{U_g^b\}$  to  $\{U_g\}$  and  $[K_{gg1}^d]$  to  $[K_{gg}^d]$ .

148. Break the previous equivalence of  $[K_{gg}^d]$  to  $[K_{gg1}^d]$  and  $\{U_g\}$  to  $\{U_g^b\}$ .

149. Go to DMAP No. 95 for an additional outer loop differential stiffness iteration.

150. TABPT table prints  $[K_{gg1}^d]$ ,  $[K_{gg}^d]$ , and  $\{U_g\}$ .

152. SDR2 calculates element forces ( $\emptyset EFB1$ ) and stresses ( $\emptyset ESB1$ ) and prepares displacement vectors ( $\emptyset UBGV1$ ) and single-point forces of constraint ( $\emptyset QBG1$ ) for output and translation components of the displacement vector ( $PUBGV1$ ) for the differential stiffness solution.

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153. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.
154. Go to DMAP No. 157 if no differential stiffness solution deformed plots are requested.
155. PLØT generates all requested differential stiffness solution deformed structure and contour plots.
156. PRTMSG prints plotter data, engineering data, and contour data for each differential stiffness solution deformed plot generated.
158. Go to DMAP No. 169 and make normal exit.
160. Print Error Message No. 1 and terminate execution.
162. Print Error Message No. 2 and terminate execution.
164. Print Error Message No. 3 and terminate execution.
166. Print Error Message No. 4 and terminate execution.
168. Print Error Message No. 5 and terminate execution.

## STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

### 2.4.3 Output for Static Analysis with Differential Stiffness

The value of the determinant of the sum of the elastic stiffness and the differential stiffness is automatically printed for each differential stiffness loading condition.

Iterative differential stiffness computations are terminated for one of five reasons. Iteration termination reasons are automatically printed in an information message. These reasons have the following meanings:

1. REASON 0 means the iteration procedure was incomplete at the time of exit. This is caused by either an unexpected interruption of the iteration procedure (i.e., system abort) or termination is not scheduled (for the other four reasons) at the completion of the current iteration.
2. REASON 1 means the iteration procedure converged to the EPSI $\emptyset$  value supplied by the user on a PARAM bulk data card. (The default value of EPSI $\emptyset$  is 1.0E-5.)
3. REASON 2 means the iteration procedure is diverging from the EPSI $\emptyset$  value supplied by the user on a PARAM bulk data card. (The default value of EPSI $\emptyset$  is 1.0E-5.)
4. REASON 3 means insufficient time remaining to achieve convergence to the EPSI $\emptyset$  value supplied by the user on a PARAM bulk data card. (The default value of EPSI $\emptyset$  is 1.0E-5.)
5. REASON 4 means the number of iterations supplied by the user on a PARAM bulk data card has been met. (The default number of iterations is 10.)

Parameter values at the time of exit are automatically output as follows:

1. Parameter D $\emptyset$ NE: -1 is normal; + N is the estimate of the number of iterations required to achieve convergence.
2. Parameter SHIFT: +1 indicates a return to the top of the inner loop was scheduled; -1 indicates a return to top of the outer loop was scheduled following the current iteration.
3. Parameter DSEPSI: the value of the ratio of energy error to total energy at the time of exit.

The following output may be requested:

1. Nonzero Components of the applied static load for the linear solution at selected grid points.
2. Displacements and nonzero components of the single-point forces of constraint, with and without differential stiffness, at selected grid points.
3. Forces and stresses in selected elements, with and without differential stiffness.

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4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undefomed and deformed plots of the structural model.
2. Contour plots of stresses and displacements.

### 2.4.4 Case Control Deck for Static Analysis with Differential Stiffness

The following items relate to subcase definition and data selection for Static Analysis with Differential Stiffness:

1. The Case Control Deck must contain two subcases.
2. A static loading condition must be defined above the subcase level with a LØAD, TEMPERATURE (LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
3. An SPC set must be selected above the subcase level unless all constraints are specified on GRID cards.
4. Output requests that apply only to the linear solution must appear in the first subcase.
5. Output requests that apply only to the solution with differential stiffness must be placed in the second subcase.
6. Output requests that apply to both solutions, with and without differential stiffness, may be placed above the subcase level.

### 2.4.5 Parameters for Static Analysis with Differential Stiffness

The following parameters are used in Static Analysis with Differential Stiffness:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. BETAD - optional. The integer value of this parameter is the number of iterations allowed for computing the load correction in the inner (load) loop before shifting to the outer (stiffness) loop, which adjusts the differential stiffness. The default value is 4 iterations.
4. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT,

## STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS

CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

5. EPSI0 - optional. The real value of this parameter is used to test the convergence of the iterated differential stiffness. The default value is  $10^{-5}$ .
6. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
7. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
8. NT - optional. The integer value of this parameter limits the cumulative number of iterations in both loops. The default value is 10 iterations.
9. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
10. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
11. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

### 2.4.6 Rigid Format Error Messages from Static Analysis with Differential Stiffness

The following fatal errors are detected by the DMAP statements in the Static Analysis with Differential Stiffness rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPORTS NØT ALLØWED.

Free bodies are not allowed in Static Analysis with Differential Stiffness. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

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STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 3 - NØ GRID PØINT DATA IS SPECIFIED.

No points have been defined with GRID or SPØINT cards.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

STATIC ANALYSIS WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 5 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

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2.5 BUCKLING ANALYSIS

2.5.1 DMAP Sequence for Buckling Analysis

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

-----  
1 BEGIN DISP 05 - BUCKLING ANALYSIS - APR. 1986 \$  
2 PRECHK ALL \$  
3 FILE LAMA=APPEND/PHIA=APPEND \$  
4 PARAM ///\*MPY\*/CARDNO/0/0 \$  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/MINUS1=-1 \$  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP \$  
7 GP2 GEOM2,EQEXIN/ECT \$  
8 PARAML PCDB///\*PRES\*///JUMPPLOT \$  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT \$  
10 COND P1,JUMPPLOT \$  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT \$  
12 PRTMSG PLTSETX// \$  
13 PARAM ///\*MPY\*/PLTFLG/1/1 \$  
14 PARAM ///\*MPY\*/PFILE/0/0 \$  
15 COND P1,JUMPPLOT \$  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE \$  
17 PRTMSG PLOTX1// \$  
18 LABEL P1 \$  
19 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV \$  
20 PARAM ///\*AND\*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 \$  
21 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL \$

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```
22  COND    ERROR1,NOSIMP $  
23  PURGE   OGPST/GENEL $  
24  PARAM   //ADD*/NOKGGX/I/O $  
25  EMG     EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
           S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
           C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
           C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
           V,Y,VOLUME/V,Y,SURFACE $  
26  PURGE   KGGX,GPST/NOKGGX/MGG/NOMGG $  
27  COND    JMPKG,G,NOKGGX $  
28  EMA     GPECT,KDICT,KELM/KGGX,GPST $  
29  LABEL   JMPKG $  
30  COND    JMPMGG,NOMGG $  
31  EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
32  LABEL   JMPMGG $  
33  COND    LBL1,GRDPNT $  
34  COND    ERROR5,NOMGG $  
35  GPWG   BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $  
36  OFP    OGPWG,.,./S,N,CARDNO $  
37  LABEL   LBL1 $  
38  EQUIV  KGGX,KGG/NOGENL $  
39  COND    LBL11,NOGENL $  
40  SMA3   GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
41  LABEL   LBL11 $  
42  PARAM   //MPY*/NSKIP/0/0 $  
43  GP4    CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/  
           LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
           S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
           S,Y,AUTOSPC $  
44  COND    ERROR6,NOL $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45 PARAM ///*AND*/NOSR/SINGLE/REACT $  
46 PURGE GM/MPCF1/G0,K00,L00,P0,U00V,RUOV/OMIT/PS,KFS,KSS,KDFS/SINGLE/  
QG/NOSR $  
47 COND LBL4D,REACT $  
48 JUMP ERROR2 $  
49 LABEL LBL4D $  
50 COND LBL4,GENEL $  
51 PARAM ///*EQ*/GPSPFLG/AUTOSPC/O $  
52 COND LBL4,GPSPFLG $  
53 GPSP GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
54 OFP OGPST,,,,,/S,N,CARDNO $  
55 LABEL LBL4 $  
56 EQUIV KGG,KNN/MPCF1 $  
57 COND LBL2,MPCF1 $  
58 MCE1 USET,RG/GM $  
59 MCE2 USET,GM,KGG,,,/KNN,,, $  
60 LABEL LBL2 $  
61 EQUIV KNN,KFF/SINGLE $  
62 COND LBL3,SINGLE $  
63 SCE1 USET,KNN,,,/KFF,KFS,KSS,,, $  
64 LABEL LBL3 $  
65 EQUIV KFF,KAA/OMIT $  
66 COND LBL5,OMIT $  
67 SMP1 USET,KFF,,,/GO,KAA,K00,L00,,,,, $  
68 LABEL LBL5 $  
69 RBMG2 KAA/LLL $  
70 SSG1 SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/  
PG,,,,/LUSET/1 $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
71 EQUIV PG,PL/NOSET $  
72 COND LBL10,NOSET $  
73 SSG2 USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $  
74 LABEL LBL10 $  
75 SSG3 LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/  
1/S,N,EPSI $  
76 COND LBL9,IRES $  
77 MATGPR GPL,USET,SIL,RULV//*L* $  
78 MATGPR GPL,USET,SIL,RUOV//*0* $  
79 LABEL LBL9 $  
80 SDR1 USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/1/  
*BKLO* $  
81 SDR2 CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/  
OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*BKLO* $  
82 OFP OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $  
83 SCAN CASECC,OES1,OEF1/OESF1/*RF* $  
84 OFP OESF1,///S,N,CARDNO $  
85 COND P2,JUMPPLOT $  
86 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/  
PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFIL $  
87 PRTMSG PLOTX2// $  
88 LABEL P2 $  
89 TAI ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/  
NOSIMP/O/NOGENL/GENEL $  
90 DSMG1 CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/  
DSCOSET $  
91 EQUIV KDGG,KDNN/MPCF1 $  
92 COND LBL2D,MPCF1 $  
93 MCE2 USET,GM,KDGG,,,/KDNN,,, $  
94 LABEL LBL2D $
```

## BUCKLING ANALYSIS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
95 EQUIV KDNM,KDFF/SINGLE $
96 COND LBL3D,SINGLE $
97 SCE1 USET,KDNM,,,/KDFF,KDFS,,,,$
98 LABEL LBL3D $
99 EQUIV KDFF,KDAA/OMIT $
101 SMP2 USET,GO,KDFF/KDAA $
102 LABEL LBL5D $
103 ADD KDAAM/(-1.0,0.0)/(0.0,0.0) $
104 DPD DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,EED,EQDYN/
LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/
NONLFT/NOTRL/S,N,NOEED//NOUE $
105 COND ERROR3,NOEED $
106 PARAM ///*MPY*/NEIGV/1/-1 $
107 READ KAA,KDAAM,,,EED,USET,CASECC/LAMA,PHIA,,OEIGS/*BUCKLING*/
S,N,NEIGV/2 $
108 OFP OEIGS,LAMA,,,//S,N,CARDNO $
109 COND ERROR4,NEIGV $
110 SDR1 USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,BQG/1/*BKL1* $
111 SDR2 CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,LAMA,BQG,PHIG,EST,,/
,OBQG1,OPHIG,OBES1,OBEF1,PPHIG/*BKL1* $
112 OFP OPHIG,OBQG1,OBEF1,OBES1,,/S,N,CARDNO $
113 COND P3,JUMPPLOT $
114 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,
OBES1/PLTX3/NSIL/LUSEP/JUMPPLOT/PLTFLG/
S,N,PFILE $
115 .PRTMSG PLTX3// $
116 LABEL P3 $
117 JUMP FINIS $
118 LABEL ERROR1 $
119 PRTPARM ///*BUCKLING* $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
120  LABEL    ERROR2 $  
121  PRTPARM // -2/*BUCKLING* $  
122  LABEL    ERROR3 $  
123  PRTPARM // -3/*BUCKLING* $  
124  LABEL    ERROR4 $  
125  PRTPARM // -4/*BUCKLING* $  
126  LABEL    ERROR5 $  
127  PRTPARM // -5/*BUCKLING* $  
128  LABEL    ERROR6 $  
129  PRTPARM // -6/*BUCKLING* $  
130  LABEL    FINIS $  
131  PURGE   DUMMY/MINUS1 $  
132  END     $
```

2.5.2 Description of Important DMAP Operations for Buckling Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Static Loads Table and Grid Point Temperature Table.
21. TA1 generates element tables for use in matrix assembly and stress recovery.
22. Go to DMAP No. 118 and print Error Message No. 1 if no structural elements have been defined.
25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 32 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
33. Go to DMAP No. 37 if no weight and balance information is requested.
34. Go to DMAP No. 126 and print Error Message No. 5 if no mass matrix exists.
35. GPWG generates weight and balance information.
36. OFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
38. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
39. Go to DMAP No. 41 if there are no general elements.
40. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
43. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g] \{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
44. Go to DMAP No. 128 and print Error Message No. 6 if no independent degrees of freedom are defined.
47. Go to DMAP No. 49 if there are no free-body supports.
48. Go to DMAP No. 120 and print Error Message No. 2.

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50. Go to DMAP No. 55 if general elements are present.
52. Go to DMAP No. 55 if no potential grid point singularities exist.
53. GPSP generates a table of potential grid point singularities.
54. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
56. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if there are no multipoint constraints.
57. Go to DMAP No. 60 if there are no multipoint constraints.
58. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
59. MCE2 partitions stiffness matrix

$$[K_{gg}] = \begin{bmatrix} - \\ K_{nn} + K_{mm} \\ \hline K_{mn} + K_{nm} \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

61. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  if no single-point constraints exist.
62. Go to DMAP No. 64 if no single-point constraints exist.
63. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} + K_{fs} \\ \hline K_{sf} + K_{ss} \end{bmatrix}.$$

65. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
66. Go to DMAP No. 68 if no omitted coordinates exist.
67. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - \\ K_{aa} + K_{ao} \\ \hline K_{oa} + K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{co}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .

69. RMBG2 decomposes constrained stiffness matrix  $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$ .
70. SSG1 generates static load vectors  $\{P_g\}$ .
71. Equivalence  $\{P_g\}$  to  $\{P_\ell\}$  if no constraints are applied.

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72. Go to DMAP No. 74 if no constraints are applied.

73. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{ \frac{\bar{P}_n}{P_m} \right\}, \quad \{P_n\} = \bar{P}_n + [G_m^T]\{P_m\},$$

$$\{P_n\} = \left\{ \frac{\bar{P}_f}{P_s} \right\}, \quad \{P_f\} = \bar{P}_f - [K_{fs}]\{Y_s\}$$

$$\text{and } \{P_f\} = \left\{ \frac{P_a}{P_o} \right\} \text{ and } \{P_\ell\} = \{P_a\} + [G_o^T]\{P_o\}.$$

75. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\},$$

solves for displacements of omitted coordinates

$$\{u_0^0\} = [K_{00}]^{-1}\{P_o\},$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\},$$

$$\epsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

and calculates residual vector (RU0V) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{00}]\{u_0^0\},$$

$$\epsilon_0 = \frac{\{u_0^T\}\{\delta P_o\}}{\{P_o^T\}\{u_0^0\}}.$$

76. Go to DMAP No. 79 if residual vectors are not to be printed.

77. MATGPR prints the residual vector for independent coordinates (RULV).

78. MATGPR prints the residual vector for omitted coordinates (RU0V).

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80. SDR1 recovers dependent displacements

$$\{u_0\} = [G_0]\{u_g\} + \{u_0^0\},$$

$$\left\{ \frac{u_a}{u_0} \right\} = \{u_f\}, \quad \left\{ \frac{u_f}{Y_s} \right\} = \{u_n\},$$

$$\{u_m\} = [G_m]\{u_n\}, \quad \left\{ \frac{u_n}{u_m} \right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

81. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PG1$ ), displacement vectors ( $\emptyset UGV1$ ) and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the displacement vector ( $PUGV1$ ) for the static solution.
82.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
83. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
84.  $\emptyset FP$  formats the scanned output table prepared by SCAN and places it on the system output file for printing.
85. Go to DMAP No. 88 if no static solution deformed structure plots are requested.
86. PL $\emptyset T$  generates all requested static solution deformed structure and contour plots.
87. PRTMSG prints plotter data, engineering data, and contour data for each static solution deformed plot generated.
89. TA1 generates element tables for use in differential stiffness matrix assembly.
90. DSMG1 generates differential stiffness matrix  $[K_{gg}^d]$ .
91. Equivalence  $[K_{gg}^d]$  to  $[K_{nn}^d]$  if no multipoint constraints exist.
92. Go to DMAP No. 94 if no multipoint constraints exist.
93. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \begin{bmatrix} \bar{K}_{nn}^d & K_{nm}^d \\ \hline K_{nn}^d & + & K_{nm}^d \\ \hline K_{mn}^d & | & K_{mm}^d \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}^d] = [\bar{K}_{nn}^d] + [G_m^T][K_{mn}^d] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

95. Equivalence  $[K_{nn}^d]$  to  $[K_{ff}^d]$  if no single-point constraints exist.
96. Go to DMAP No. 98 if no single-point constraints exist.

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97. SCE1 partitions out single-point constraints

$$[K_{nn}^d] = \begin{bmatrix} K_{ff}^d & | & K_{fs}^d \\ \hline & + & \\ K_{sf}^d & | & K_{ss}^d \end{bmatrix}.$$

99. Equivalence  $[K_{ff}^d]$  to  $[K_{aa}^d]$  if no omitted coordinates exist.

100. Go to DMAP No. 102 if no omitted coordinates exist.

101. SMP2 partitions constrained differential stiffness matrix

$$[K_{ff}^d] = \begin{bmatrix} K_{aa}^d & | & K_{ao}^d \\ \hline & + & \\ K_{oa}^d & | & K_{oo}^d \end{bmatrix}.$$

and performs matrix reduction

$$[K_{aa}^d] = [K_{aa}^d] + [K_{oa}^d]^T [G_0] + [G_0]^T [K_{oa}^d] + [G_0]^T [K_{oo}^d] [G_0].$$

103. ADD  $-[K_{aa}^d]$  and nothing to create  $[K_{aa}^{dm}]$ .

104. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

105. Go to DMAP No. 122 and print Error Message No. 3 if there is no Eigenvalue Extraction Data.

107. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} + \lambda K_{aa}^{dm}] \{u_a\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit value of a selected component
- 2) Unit value of the largest component.

108. ØFP formats the eigenvalues (LAMA) and summary of eigenvalue extraction information (ØEIGS) prepared by READ and places them on the system output file for printing.

109. Go to DMAP No. 124 and print Error Message No. 4 if no eigenvalues were found.

110. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o] \{\phi_a\}, \quad \left\{ \frac{\phi_a}{\phi_o} \right\} = \{\phi_f\},$$

$$\left\{ \frac{\phi_f}{\phi_s} \right\} = \{\phi_n\}, \quad \{\phi_m\} = [G_m] \{\phi_n\},$$

$$\left\{ \frac{\phi_n}{\phi_m} \right\} = \{\phi_g\}$$

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and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}^T] \{\phi_f\}$ .

111. SDR2 calculates element forces ( $\emptyset BEF1$ ) and stresses ( $\emptyset BES1$ ) and prepares eigenvectors ( $\emptyset PHIG$ ) and single-point forces of constraint ( $\emptyset BQG1$ ) for output and translation components of the eigenvectors ( $\emptyset PHIG$ ) for the buckling solution.
112.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
113. Go to DMAP No. 116 if no buckling solution deformed structure plots are requested.
114. PL $\emptyset T$  generates all requested buckling solution deformed structure and contour plots.
115. PRTMSG prints plotter data, engineering data, and contour data for each buckling solution deformed plot generated.
117. Go to DMAP No. 130 and make normal exit.
119. Print Error Message No. 1 and terminate execution.
121. Print Error Message No. 2 and terminate execution.
123. Print Error Message No. 3 and terminate execution.
125. Print Error Message No. 4 and terminate execution.
127. Print Error Message No. 5 and terminate execution.
129. Print Error Message No. 6 and terminate execution.

### 2.5.3 Output for Buckling Analysis

The summary of the eigenvalues associated with the buckling modes and the summary of the eigenvalue analysis performed, as described in the Normal Mode Analysis rigid format (see Section 2.3.3), are automatically printed.

The following output may be requested:

1. Displacements and nonzero components of the static loads and single-point forces of constraint at selected grid points for the static analysis.
2. Forces and stresses in selected elements for the static loading condition.
3. Mode shapes and nonzero components of the single-point forces of constraint at selected grid points for selected modes.
4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed plot of the structural model and mode shapes for selected buckling modes.
2. Contour plots of stresses and displacements for selected buckling modes.

### 2.5.4 Case Control Deck for Buckling Analysis

The following items relate to subcase definition and data selection for Buckling Analysis:

1. The Case Control Deck must contain at least two subcases. Subcases beyond the second are used only for output selection.
2. METHØD must appear in the second subcase to select an EIGB card from the Bulk Data Deck.
3. A static loading condition must be defined in the first subcase with a LØAD, TEMPERATURE (LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
4. An SPC set must be selected above the subcase level, unless all constraints are specified on GRID cards.
5. Output requests that apply only to the solution under static load must be placed in the first subcase.
6. Output requests that apply to the buckling solution only must be placed in the second and succeeding subcases. If only two subcases exist, the output requests in the second subcase will be honored for all buckling modes.
7. Output requests that apply to both the static solution and the buckling modes may be placed above the subcase level.

#### 2.5.5 Parameters for Buckling Analysis

The following parameters are used in Buckling Analysis:

1. ASETOUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTOSPC - reserved for future optional use. The default value is -1.
3. COUPMASS - CPBAR, CPRD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
5. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
6. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

#### 2.5.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

## BUCKLING ANALYSIS

### 2.5.7 Rigid Format Error Messages from Buckling Analysis

The following fatal errors are detected by the DMAP statements in the Buckling Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

#### BUCKLING ANALYSIS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

#### BUCKLING ANALYSIS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPORTS NOT ALLOWED.

Free bodies are not allowed in Buckling Analysis. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

#### BUCKLING ANALYSIS ERRØR MESSAGE NØ. 3 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGB card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGB set.

#### BUCKLING ANALYSIS ERRØR MESSAGE NØ. 4 - NØ EIGENVALUES FØUND.

No buckling modes exist in the range specified by the user.

#### BUCKLING ANALYSIS ERRØR MESSAGE NØ. 5 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

#### BUCKLING ANALYSIS ERRØR MESSAGE NØ. 6 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

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## 2.6 PIECEWISE LINEAR STATIC ANALYSIS

### 2.6.1 DMAP Sequence for Piecewise Linear Static Analysis

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 06 - PIECEWISE LINEAR STATIC ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 FILE QG1=APPEND/UGV1=APPEND/KGGSUM=SAVE/PGV1=APPEND $  
4 PARAM ///*MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/MINUS1=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 GP2 GEOM2,EQEXIN/ECT $  
8 PARAML PCDB///*PRES*///JUMPPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
10 COND P1,JUMPPLOT $  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
12 PRMSG PLTSETX// $  
13 PARAM ///*MPY*/PLTFLG/1/1 $  
14 PARAM ///*MPY*/PFILE/O/O $  
15 COND P1,JUMPPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
17 PRMSG PLOTX1// $  
18 LABEL P1 $  
19 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $  
20 PARAM ///*AND*/SKPMGG/NOGRAV/V,Y,GRDPNT $  
21 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,ECPT,GPCT/  
LUSET/S,N,NOSIMP/2/S,N,NOGENL/S,N,GENEL $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PARAM ///*AND*//NOELMT/NOGENL/NOSIMP $  
23 COND ERROR4,NOELMT $  
24 PURGE KGGX,GPST/NOSIMP/OGPST/GENEL $  
25 COND LBL1,NOSIMP $  
26 PARAM ///*ADD*//NOKGGX/1/0 $  
27 PARAM ///*ADD*//NOMGG/1/0 $  
28 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/  
C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/  
C,Y,CPQDPLT/C,Y,CTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
29 PURGE KGGX,GPST/NOKGGX/MGG/NOMGG $  
30 COND JMPKGG,NOKGGX $  
31 EMA GPECT,KDICT,KELM/KGGX,GPST $  
32 LABEL JMPMGG $  
33 COND JMPMGG,NOMGG $  
34 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
35 LABEL JMPMGG $  
36 COND LBL1,GRDPNT $  
37 COND ERROR3,NOMGG $  
38 GPWG BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/V,Y,WTMASS $  
39 OFP OGPWG,,,,,/S,N,CARDNO $  
40 LABEL LBL1 $  
41 PLA1 CSTM,MPT,ECPT,GPCT,DIT,CASECC,EST/KGGXL,ECPTNL,ESTL,ESTNL/S,N,  
KGGLPG/S,N,NPLALIM/S,N,ECPTNLPG/S,N,PLSETNO/S,N,NONLSTR/S,N,  
PLFACT $  
42 COND ERROR1,ECPTNLPG $  
43 PURGE ONLES,ESTNL1/NONLSTR $  
44 PARAM ///*ADD*//ALWAYS/-1/0 $
```

PIECEWISE LINEAR STATIC ANALYSIS

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45 PARAM //**ADD*/NEVER/1/0 $  
46 EQUIV KGGX,KGG/NOGENL/KGGXL,KGGL/NOGENL $  
47 COND LBL11,NOGENL $  
48 SMA3 GE1,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
49 SMA3 GE1,KGGXL/KGGL/LUSET/NOGENL/KGGLPG $  
50 LABEL LBL11 $  
51 PARAM //**MPY*/NSKIP/0/0 $  
52 GP4 CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
53 PARAM //**ANO*/NOSR/SINGLE/REACT $  
54 PURGE KRR,KLR,QR,DM/REACT/GM/MPCF1/G0,K00,L00,P0,U00V,RU0V/OMIT/PS,  
KFS,KSS/SINGLE/QG/NOSR $  
55 SSG1 SLT,BGPDT,CSTM,SIL,EST,MPT,,,MGG,CASECC,DIT,/PG1,,,/  
LUSET/1 $  
56 EQUIV PG1,PL/NOSET $  
57 COND LBL4,GENEL $  
58 PARAM //**EQ*/GPSPFLG/AUTOSPC/0 $  
59 COND LBL4,GPSPFLG $  
60 GPSP GPL,GPST,USET,SIL/0GPST/S,N,NOGPST $  
61 OFF OGPST,,,,//S,N,CARDNO $  
62 LABEL LBL4 $  
63 PARAM //**ADD*/PLACOUNT/1/0 $  
64 EQUIV KGG,KNN/MPCF1 $  
65 COND LBL2,MPCF1 $  
66 MCE1 USET,RG/GM $  
67 LABEL LOOPBGN $  
68 EQUIV KGG,KNN/MPCF1 $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
69  COND      LBL2,MPCF1 $  
70  MCE2      USET,GM,KGG,,,/KNN,,, $  
71  LABEL     LBL2 $  
72  EQUIV    KNN,KFF/SINGLE $  
73  COND      LBL3,SINGLE $  
74  SCE1      USET,KNN,,,/KFF,KFS,KSS,,, $  
75  LABEL     LBL3 $  
76  EQUIV    KFF,KAA/OMIT $  
77  COND      LBL5,OMIT $  
78  SMP1      USET,KFF,,,/GO,KAA,KOO,L00,,,,, $  
79  LABEL     LBL5 $  
80  EQUIV    KAA,KLL/REACT $  
81  COND      LBL6,REACT $  
82  RBMG1    USET,KAA,/KLL,KLR,KRR,,, $  
83  LABEL     LBL6 $  
84  DECOMP   KLL/LLL,/1/0/MINDIAGK/DETKLLXX/IDETKLLX/  
           S,N,SINGKLLX $  
85  COND      PLALBL4,SINGKLLX $  
86  COND      LBL7,REACT $  
87  RBMG3    LLL,KLR,KRR/DM $  
88  LABEL     LBL7 $  
89  ADD       PG1,/PG/PLFACT $  
90  COND      LBL10,NOSET $  
91  SSG2      USET,GM,YS,KFS,GO,DM,PG/QR,PO,PS,PL $  
92  LABEL     LBL10 $  
93  SSG3      LLL,KLL,PL,LOO,KOO,PO/ULV,U00V,RULV,RUOV/OMIT/V,Y,IRES=-1/  
           PLACOUNT/S,N,EPSI $
```

## PIECEWISE LINEAR STATIC ANALYSIS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
94  COND    LBL9,IRES   $  
95  MATGPR   GPL,USET,SIL,RULV//*L* $  
96  MATGPR   GPL,USET,SIL,RUOV//*O* $  
97  LABEL    LBL9  $  
98  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/DELTAVG,DELTAPG,  
           DELTAQG///*STATIC$* $  
99  PLA2     DELTAVG,DELTAPG,DETAQG/UGV1,PGV1,QG1/S,N,PLACOUNT $  
100 EQUIV    ESTNL,ESTNL1/NEVER/ECPTNL,ECPTNL1/NEVER $  
101 COND    PLALBL2A,NONLSTR $  
102 PLA3     CSTM,MPT,DIT,DELTAVG,ESTNL,CASECC/ONLES,ESTNL1/PLACOUNT/  
           PLSETNO $  
103 OFFP    ONLES,,,,//S,N,CARDNO $  
104 LABEL    PLALBL2A $  
105 PARAM    ///*SUB*/DIFF/NPLALIM/PLACOUNT $  
106 COND    PLALBL5,DIFF $  
107 PLA4     CSTM,MPT,ECPTNL,GPCT,DIT,DELTAVG/KGGNL,ECPTNL1/S,N,PLACOUNT/S,  
           N,PLSETNO/S,N,PLFACT $  
108 EQUIV    KGGNL,KGGSUM/KGGLPG $  
109 COND    PLALBL3,KGGLPG $  
110 ADD     KGGNL,KGGL/KGGSUM $  
111 LABEL    PLALBL3 $  
112 EQUIV    ESTNL1,ESTNL/ALWAYS/ECPTNL1,ECPTNL/ALWAYS/KGGSUM,KGG/ALWAYS $  
113 REPT    LOOPBGN,360 $  
114 JUMP    ERROR2 $  
115 LABEL    PLALBL4 $  
116 PRTPARM ///*PLA* $  
117 LABEL    PLALBL5 $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
118 SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG1,UGV1,ESTL,,  
          PGV1/OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*PLA* $  
119 OFP       OUGV1,OPG1,OQG1,OEF1,OES1,//S,N,CARDNO $  
120 SCAN      CASECC,OES1,OEF1/OESF1/*RF* $  
121 OFF       OESF1,,,,//S,N,CARDNO $  
122 COND      P2,JUMPPLOT $  
123 PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,ECPT,OES1/  
          PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFIL $  
124 PRTPARM   PLOTX2// $  
125 LABEL     P2 $  
126 JUMP      FINIS $  
127 LABEL     ERROR1 $  
128 PRTPARM   //1/*PLA* $  
129 LABEL     ERROR2 $  
130 PRTPARM   //2/*PLA* $  
131 LABEL     ERROR3 $  
132 PRTPARM   //3/*PLA* $  
133 LABEL     ERROR4 $  
134 PRTPARM   //4/*PLA* $  
135 LABEL     FINIS $  
136 PURGE    DUMMY/MINUS1 $  
137 END      $
```

## PIECEWISE LINEAR STATIC ANALYSIS

### 2.6.2 Description of Important DMAP Operations for Piecewise Linear Static Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Static Loads Table and Grid Point Temperature Table.
21. TA1 generates element tables for use in matrix assembly and stress recovery.
23. Go to DMAP No. 133 and print Error Message No. 4 if no elements have been defined.
25. Go to DMAP No. 40 if there are no structural elements.
28. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
30. Go to DMAP No. 32 if no stiffness matrix is to be assembled.
31. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
33. Go to DMAP No. 35 if no mass matrix is to be assembled.
34. EMA assembles mass matrix  $[M_{gg}]$ .
36. Go to DMAP No. 40 if no weight and balance information is requested.
37. Go to DMAP No. 131 and print Error Message No. 3 if no mass matrix exists.
38. GPWG generates weight and balance information.
39. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
41. PLA1 extracts the linear terms from  $[K_{gg}^X]$  to give  $[K_{gg}^{XL}]$ , extracts the nonlinear entries from the Element Connection and Properties Table to give ECPTNL, and separates the linear and nonlinear entries in the Element Summary Table to give ESTL and ESTNL.
42. Go to DMAP No. 127 and print Error Message No. 1 if no elements have a stress-dependent modulus of elasticity.
46. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  and  $[K_{gg}^{XL}]$  to  $[K_{gg}^L]$  if there are no general elements.
47. Go to DMAP No. 50 if there are no general elements.
48. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .

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49. SMA3 adds general elements to  $[K_{gg}^{X\ell}]$  to obtain stiffness matrix of linear elements  $[K_{gg}^\ell]$ .
52. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
55. SSG1 generates total static load vector  $\{P_g^1\}$ .
56. Equivalence  $\{P_g^1\}$  to  $\{P_\ell\}$  if no constraints are applied.
57. Go to DMAP No. 62 if general elements are present.
59. Go to DMAP No. 62 if no potential grid point singularities exist.
60. GPSP generates a table of potential grid point singularities.
61. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
64. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if no multipoint constraints exist.
65. Go to DMAP No. 71 if no multipoint constraints exist.
66. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m | R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
67. Beginning of loop for additional load increments.
68. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if no multipoint constraints exist.
69. Go to DMAP No. 71 if no multipoint constraints exist.
70. MCE2 partitions stiffness matrix

$$[K_{gg}] = \begin{bmatrix} - \\ K_{nn} + K_{nm} \\ - \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

72. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  if no single-point constraints exist.
73. Go to DMAP No. 75 if no single-point constraints exist.
74. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} + K_{fs} \\ - \\ K_{sf} + K_{ss} \end{bmatrix}.$$

76. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
77. Go to DMAP No. 79 if no omitted coordinates exist.
78. SMP1 partitions constrained stiffness matrix

## PIECEWISE LINEAR STATIC ANALYSIS

$$[K_{ff}] = \begin{bmatrix} - & K_{ao} \\ \frac{K_{aa}}{K_{oa}} + \frac{K_{ao}}{K_{oo}} & \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .

- 80. Equivalence  $[K_{aa}]$  to  $[K_{\ell\ell}]$  if no free-body supports exist.
- 81. Go to DMAP No. 83 if no free-body supports exist.
- 82. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix}$$

- 84. DECOMP decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .
- 85. Go to DMAP No. 115 and print Error Message No. 5 if stiffness matrix  $[K_{\ell\ell}]$  is singular (i.e., local plasticity).
- 86. Go to DMAP No. 88 if no free-body supports exist.
- 87. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}]^T + [K_{\ell r}][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|}.$$

- 89. ADD multiplies total load vector  $\{P_g^1\}$  by factor, PLFACT, and adds it to nothing to obtain applied load vector  $\{P_g\}$  for current loop.
- 90. Go to DMAP No. 92 if no constraints are applied.
- 91. SSG2 applies constraints to static load vectors for current loop

$$\{P_g\} = \left\{ \frac{\bar{P}_n}{\bar{P}_m} \right\}, \quad \{P_n\} = \{P_n\} + [G_m^T]\{P_m\},$$

$$\{P_n\} = \left\{ \frac{\bar{P}_f}{\bar{P}_s} \right\}, \quad \{P_f\} = \{P_f\} - [K_{fs}]\{Y_s\},$$

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$$\{P_f\} = \left\{ \begin{array}{c} P_a \\ P_o \end{array} \right\}, \quad \{P_a\} = \left\{ \begin{array}{c} P_a \\ P_o \end{array} \right\} + [G_o^T] \{P_o\},$$

$$\{P_a\} = \left\{ \begin{array}{c} P_\ell \\ P_r \end{array} \right\}$$

and calculates incremental determinate forces of reaction for current loop

$$\{q_r\} = -\{P_r\} - [D^T] \{P_\ell\}.$$

93. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1} \{P_\ell\},$$

solves for displacements of omitted coordinates

$$\{u_o^0\} = [K_{oo}]^{-1} \{P_o\},$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}] \{u_\ell\},$$

$$\epsilon_\ell = \frac{\{u_\ell^T\} \{\delta P_\ell\}}{\{P_\ell^T\} \{u_\ell\}}$$

and calculates residual vector (RUOV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}] \{u_o^0\},$$

$$\text{and } \epsilon_o = \frac{\{u_o^T\} \{\delta P_o\}}{\{P_o^T\} \{u_o^0\}}$$

94. Go to DMAP No. 97 if residual vectors are not to be printed.

95. MATGPR prints the residual vector for independent coordinates (RULV).

96. MATGPR prints the residual vector for omitted coordinates (RUOV).

## PIECEWISE LINEAR STATIC ANALYSIS

98. SDR1 recovers dependent displacements for current loop

$$\left\{ \frac{u_\ell}{u_r} \right\} = \{u_a\} \quad \{u_0\} = [G_0]\{u_a\} + \{u_0^0\} ,$$

$$\left\{ \frac{u_a}{u_0} \right\} = \{u_f\} , \quad \left\{ \frac{u_f}{Y_s} \right\} = \{u_n\} ,$$

$$\{u_m\} = [G_m]\{u_n\} , \quad \left\{ \frac{u_n}{u_m} \right\} = \{u_g\}$$

and recovers single-point forces of constraint for current loop

$$\{\delta q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\}.$$

99. PLA2 adds the incremental displacement vector (DELT AUGV) and the incremental single-point forces of constraint vector (DELT AQG) for the current loop to the accumulated sum of these vectors (DELT APG).

$$\{u_{g_{i+1}}\} = \{\delta u_{g_i}\} + \{u_{g_i}\} \text{ and}$$

$$\{q_{g_{i+1}}\} = \{\delta q_{g_i}\} + \{q_{g_i}\} .$$

100. Allocate separate files for ESTNL and ESTNL1 and for ECPTNL and ECPTNL1.  
 101. Go to DMAP No. 104 if no stress output is requested for nonlinear elements.  
 102. PLA3 calculates incremental stresses in nonlinear elements ( $\emptyset$ NLES) for which an output request has been made and updates the accumulated stresses (ESTNL1) in these elements.  
 103.  $\emptyset$ FP formats the accumulated stresses in nonlinear elements prepared by PLA3 and places them on the system output file for printing.  
 106. Go to DMAP No. 117 if all loading increments have been completed.  
 107. PLA4 generates stiffness matrix for nonlinear elements  $[K_{gg}^{nl}]$  and updates stress information.  
 108. Equivalence  $[K_{gg}^{nl}]$  to  $[K_{gg}]$  if all elements are nonlinear.  
 109. Go to DMAP No. 111 if all elements are nonlinear.  
 110. Add stiffness matrix for nonlinear elements (KGGNL) to stiffness matrix for linear elements (KGGL)
- $$[K_{gg}^{nl}] + [K_{gg}^l] + [K_{gg}^{sum}]$$
112. Equivalence existing element tables to updated tables and equivalence  $[K_{gg}^{sum}]$  to  $[K_{gg}]$  for next pass through loop.  
 113. Go to DMAP No. 67 if additional load increments need to be processed.

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114. Go to DMAP No. 129 and print Error Message No. 2 as the number of load increments exceeds 360.
116. Print Error Message No. 5 and terminate execution.
118. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses for linear elements ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PG1$ ), displacement vectors ( $\emptyset UGV1$ ) and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the displacement vector ( $PUGV1$ ).
119.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
120. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
121.  $\emptyset FP$  formats the scanned output table prepared by SCAN and places it on the system output file for printing.
122. Go to DMAP No. 125 if no deformed structure plots are requested.
123. PL $\emptyset T$  generates all requested deformed structure and contour plots.
124. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
126. Go to DMAP No. 135 and make normal exit.
128. Print Error Message No. 1 and terminate execution.
130. Print Error Message No. 2 and terminate execution.
132. Print Error Message No. 3 and terminate execution.
134. Print Error Message No. 4 and terminate execution.

## PIECEWISE LINEAR STATIC ANALYSIS

### 2.6.3 Output for Piecewise Linear Static Analysis

The following output may be requested for Piecewise Linear Static Analysis:

1. Accumulated sums of displacements and nonzero components of the static loads and single-point forces of constraint at selected grid points for each load increment.
2. Stresses in selected elements. If an element is composed of a nonlinear material, the accumulated stress will be output for each load increment. Stresses in linear elements are only calculated for the total load.
3. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed plot of the structural model and deformed plots for each load increment.
2. Contour plots of stresses and displacements for each load increment.

### 2.6.4 Case Control Deck for Piecewise Linear Static Analysis

The following items relate to subcase definition and data selection for Piecewise Linear Static Analysis:

1. The Case Control Deck must contain one and only one subcase.
2. A static loading condition must be defined with a LOAD selection.
3. An SPC set must be selected unless all constraints are specified on GRID cards.
4. PLC $\emptyset$ EFFICIENT must appear either to select a PLFACT set from the Bulk Data Deck or to explicitly select the default value of unity.

### 2.6.5 Parameters for Piecewise Linear Static Analysis

The following parameters are used in Piecewise Linear Static Analysis:

1. ASET $\emptyset$ UT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT $\emptyset$ SPC - reserved for future optional use. The default value is -1.
3. C $\emptyset$ UPMASS - CPBAR, CPR $\emptyset$ D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.

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4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
5. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
6. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

### 2.6.6 Rigid Format Error Messages from Piecewise Linear Static Analysis

The following fatal errors are detected by the DMAP statements in the Piecewise Linear Static Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

#### PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 1 - NØ NØNLINÆR ELEMENTS HAVE BEEN DEFINED.

A piecewise linear problem has not been formulated because none of the elements has a stress dependent modulus of elasticity defined on a Material card.

#### PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØØPS.

An attempt has been made to use more than 360 load increments. This number may be increased by ALTERING the REPT instruction preceding SDR2.

#### PIECEWISE LINEAR STATIC ANALYSIS ERRØR MESSAGE NØ. 3 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

PIECEWISE LINEAR STATIC ANALYSIS

PIECEWISE LINEAR STATIC ANALYSIS ERROR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

PIECEWISE LINEAR STATIC ANALYSIS ERROR MESSAGE NØ. 5 - STIFFNESS MATRIX SINGULAR DUE TØ MATERIAL PLASTICITY.

The stiffness matrix is singular due either to one or more grid point singularities or element material plasticity.

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2.6-16 (05/30/86)

# DISPLACEMENT RIGID FORMATS

## 2.7 DIRECT COMPLEX EIGENVALUE ANALYSIS

### 2.7.1 DMAP Sequence for Direct Complex Eigenvalue Analysis

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 7

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 07 - DIRECT COMPLEX EIGENVALUE ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 FILE GOD=SAVE/GMD=SAVE $  
4 PARAM //*MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
S,N,NOGPDT/MINUS1=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 PURGE USET,GM,GO,KAA,BAA,MAA,K4AA,KFS,EST,ECT,PLTSETX,PLTPAR,GPSETS,  
ELSETS/NOGPDT $  
8 COND LBL5,NOGPDT $  
9 GP2 GEOM2,EQEXIN/ECT $  
10 PARAML PCDB//*PRES*///JUMPPLOT $  
11 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
12 COND P1,JUMPPLOT $  
13 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
14 PRMSG PLTSETX// $  
15 PARAM //*MPY*/PLTFLG/1/1 $  
16 PARAM //*MPY*/PFILE/O/O $  
17 COND P1,JUMPPLOT $  
18 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $  
19 PRMSG PLOTX1// $  
20 LABEL P1 $  
21 GP3 GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 7

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 TAI      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
           LUSET/S,N,NOSIMP=-1/1/S,N,NOGENL=-1/S,N,GENEL $  
23 PURGE    K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,  
           KGGX/NOSIMP / OGPST/GENEL $  
24 COND     LBL1,NOSIMP $  
25 PARAM    ///*ADD*/NOKGGX/1/O $  
26 PARAM    ///*ADD*/NOMGG/1/O $  
27 PARAM    ///*ADD*/NOBGG=-1/1/O $  
28 PARAM    ///*ADD*/NOK4GG/1/O $  
29 EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT,/S,N,  
           NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/  
           C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/  
           C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
           V,Y,VOLUME/V,Y,SURFACE $  
30 PURGE    KGGX,GPST/NOKGGX/MGG/NOMGG $  
31 COND     LBLKGGX,NOKGGX $  
32 EMA      GPECT,KDICT,KELM/KGGX,GPST $  
33 LABEL    LBLKGGX $  
34 COND     LBLMGG,NOMGG $  
35 EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
36 LABEL    LBLMGG $  
37 COND     LBLBGG,NOBGG $  
38 EMA      GPECT,BDICT,BELM/BGG, $  
39 LABEL    LBLBGG $  
40 COND     LBLK4GG,NOK4GG $  
41 EMA      GPECT,KDICT,KELM/K4GG,/NOK4GG $  
42 LABEL    LBLK4GG $  
43 PURGE    MNN,MFF,MAA/NOMGG $  
44 PURGE    BNN,BFF,BAA/NOBGG $
```

## DIRECT COMPLEX EIGENVALUE ANALYSIS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 7

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45  COND    LBL1,GRDPNT $  
46  COND    ERROR3,NOMGG $  
47  GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $  
48  OFP     OGPWG,,,,,/S,N,CARDNO $  
49  LABEL   LBL1 $  
50  EQUIV   KGGX,KGG/NOGENL $  
51  COND    LBL11,NOGENL $  
52  SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
53  LABEL   LBL11 $  
54  PARAM   ///*MPY*/NSKIP/O/O $  
55  GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/  
           LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
           S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/  
           C,Y,ASETOUT/S,Y,AUTOSPC $  
56  PURGE   GM,GMD/MPCF1/GO,GOD/OMIT/KFS,QPC/SINGLE $  
57  COND    LBL4,GENEL $  
58  COND    LBL4,NOSIMP $  
59  PARAM   ///*EQ*/GPSPFLG/AUTOSPC/O $  
60  COND    LBL4,GPSPFLG $  
61  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
62  OFP     OGPST,,,,,/S,N,CARDNO $  
63  LABEL   LBL4 $  
64  EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $  
65  COND    LBL2,MPCF1 $  
66  MCE1    USET,RG/GM $  
67  MCE2    USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $  
68  LABEL   LBL2 $  
69  EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 7

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
70  COND    LBL3,SINGLE $  
71  SCE1    USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $  
72  LABEL   LBL3 $  
73  EQUIV   KFF,KAA/OMIT/ MFF,MAA/OMIT/BFF,BAA/OMIT/K4FF,K4AA/OMIT $  
74  COND    LBL5, OMIT $  
75  SMP1    USET,KFF,,,GO,KAA,KOO,LOO,,,,, $  
76  COND    LBLM,NOMGG $  
77  SMP2    USET,GO,MFF/MAA $  
78  LABEL   LBLM $  
79  COND    LBLB,NOBGG $  
80  SMP2    USET,GO,BFF/BAA $  
81  LABEL   LBLB $  
82  COND    LBL5,NOK4GG $  
83  SMP2    USET,GO,K4FF/K4AA $  
84  LABEL   LBL5 $  
85  DPD     DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,EED,EQDYN/  
LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  
NONLFT/NOTRL/S,N,NOEED/123/S,N,NOUE $  
86  COND    ERROR1,NOEED $  
87  EQUIV   GO,GOD/NOUE/GM,GMD/NOUE $  
88  PARAM   //*ADD*/NEVER/1/0 $  
89  PARAM   //*MPY*/REPEAT/1/-1 $  
90  BMG    MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/  
S,N,MFACT $  
91  PARAM   //*AND*/NOFL/NOABFL/NOKBFL $  
92  PURGE  KBFL/NOKBFL/ ABFL/NOABFL $  
93  COND    LBL13,NOFL $  
94  MTRXIN, ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/  
0 $
```

## DIRECT COMPLEX EIGENVALUE ANALYSIS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 7

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
95  LABEL    LBL13 $  
96  PURGE   PHID,CLAMA,OPHID,OQPC1,OPHIP,OESC1,OEFC1,CPHIP,QPC,  
           K2PP,M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $  
97  CASE     CASEXX,/CASEXX/*CEIGN*/S,N,REPEATE/S,N,NOLOOP $  
98  MTRXIN  CASEXX,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,  
           NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $  
99  PARAM    //*AND*/NOM2PP/NOABFL/NOM2DPP $  
100 PARAM   //*AND*/NOK2PP/NOFL /NOK2DPP $  
101 EQUIV   K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $  
102 COND    LBLFL2,NOFL $  
103 ADD5    ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $  
104 COND    LBLFL2,NOABFL $  
105 TRNSP   ABFL/ABFLT $  
106 ADD     ABFLT,M2DPP/M2PP/MFACT $  
107 LABEL   LBLFL2 $  
108 PARAM   //*AND*/BDEBA/NOUE/NOB2PP $  
109 PARAM   //*AND*/MDEMA/NOUE/NOM2PP $  
110 PARAM   //*AND*/KDEK2/NOGENL/NOSIMP $  
111 PURGE   K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $  
112 EQUIV   M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/  
           MAA,MDD/MDEMA/BAA,BDD/BDEBA $  
113 COND    LBL18,NOGPDT $  
114 GKAD    USETD,GM,GO,CAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,  
           GOD,K2DD,M2DD,B2DD/*CMPLEV/*/*DISP/*/*DIRECT*/C,Y,G=0.0/  
           0.0/0.0/NOK2PP/NOM2PP/NOB2PP/  
           MPCF1/SINGLE/OMIT/NOUE/NOK4GG/NOBGG/  
           KDEK2/-1 $  
115 LABEL   LBL18 $  
116 EQUIV   B2DD,BDD/NOBGG/ M2DD,MDD/NOSIMP/ K2DD,KDD/KDEK2 $  
117 CEAD    KDD,BDD,MDD,EED,CASEXX/PHID,CLAMA,OCEIGS,/S,N,EIGVS $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 7

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
118 OFP      OCEIGS,CLAMA,,,//S,N,CARDNO $  
119 COND     LBL16,EIGVS $  
120 VDR      CASEXX,EQDYN,USETD,PHID,CLAMA,,/OPHID,//*CEIGN*/*DIRECT*/  
              O/S,N,NOD/S,N,NOP/O $  
121 COND     LBL15,NOD $  
122 OFP      OPHID,,,,//S,N,CARDNO $  
123 LABEL    LBL15 $  
124 COND     LBL16,NOP $  
125 EQUIV   PHID,CPHIP/NOA $  
126 COND     LBL17,NOA $  
127 SDR1    USETD,, PHID,,,GOD,GMD,,KFS,,/CPHIP,,QPC/1/*DYNAMICS* $  
128 LABEL    LBL17 $  
129 SDR2    CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,CLAMA,QPC,CPHIP,EST,,/,OQPC1,  
              OCPHIP,OESC1,OEFC1,//*CEIG* $  
130 OFP      OCPHIP,OQPC1,OEFC1,OESC1,,//S,N,CARDNO $  
131 LABEL    LBL16 $  
132 COND     FINIS,REPEAT $  
133 REPT    LBL13,100 $  
134 PRTPARM //2/*DIRCEAD* $  
135 JUMP    FINIS $  
136 LABEL    ERROR1 $  
137 PRTPARM //1/*DIRCEAD* $  
138 LABEL    ERROR3 $  
139 PRTPARM //3/*DIRCEAD* $  
140 LABEL    FINIS $  
141 PURGE   DUMMY/MINUS1 $  
142 END     $
```

2.7.2 Description of Important DMAP Operations for Direct Complex Eigenvalue Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
8. Go to DMAP No. 84 if there is only Direct Matrix Input.
9. GP2 generates Element Connection Table with internal indices.
12. Go to DMAP No. 20 if there are no structure plot requests.
13. PLTSET transforms user input into a form used to drive the structure plotter.
14. PRTMSG prints error messages associated with the structure plotter.
17. Go to DMAP No. 20 if no undeformed structure plots are requested.
18. PL0T generates all requested undeformed structure plots.
19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
21. GP3 generates Grid Point Temperature Table.
22. TA1 generates element tables for use in matrix assembly and stress recovery.
24. Go to DMAP No. 49 if there are no structural elements.
29. EMG generates structural element stiffness, mass and damping matrix tables and dictionaries for later assembly by the EMA module.
31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.
32. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
34. Go to DMAP No. 36 if no mass matrix is to be assembled.
35. EMA assembles mass matrix  $[M_{gg}]$ .
37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.
38. EMA assembles viscous damping matrix  $[B_{gg}]$ .
40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.
41. EMA assembles structural damping matrix  $[K_{gg}^4]$ .
45. Go to DMAP No. 49 if no weight and balance information is requested.
46. Go to DMAP No. 138 and print Error Message No. 3 if no mass matrix exists.
47. GPWG generates weight and balance information.
48. OFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
50. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
51. Go to DMAP No. 53 if there are no general elements.
52. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .

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55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
57. Go to DMAP No. 63 if general elements are present.
58. Go to DMAP No. 63 if there are no structural elements.
60. Go to DMAP No. 63 if no potential grid point singularities exist.
61. GPSP generates a table of potential grid point singularities.
62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
64. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$ ,  $[M_{gg}]$  to  $[M_{nn}]$ ,  $[B_{gg}]$  to  $[B_{nn}]$  and  $[K_{gg}^4]$  to  $[K_{nn}^4]$  if no multipoint constraints exist.
65. Go to DMAP No. 68 if no multipoint constraints exist.
66. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
67. MCE2 partitions stiffness, mass and damping matrices

$$\begin{aligned} [K_{gg}] &= \begin{bmatrix} - & K_{nn} \mid K_{nm} \\ \hline K_{nn} \mid K_{mn} & + \end{bmatrix}, & [M_{gg}] &= \begin{bmatrix} - & M_{nn} \mid M_{nm} \\ \hline M_{mn} \mid M_{mm} & + \end{bmatrix} \\ [B_{gg}] &= \begin{bmatrix} - & B_{nn} \mid B_{nm} \\ \hline B_{mn} \mid B_{mm} & + \end{bmatrix} \quad \text{and} \quad [K_{gg}^4] &= \begin{bmatrix} - & K_{nn}^4 \mid K_{nm}^4 \\ \hline K_{mn}^4 \mid K_{mm}^4 & + \end{bmatrix} \end{aligned}$$

and performs matrix reductions

$$\begin{aligned} [K_{nn}] &= [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] , \\ [M_{nn}] &= [M_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] , \\ [B_{nn}] &= [B_{nn}] + [G_m^T][B_{mn}] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m] , \\ [K_{nn}^4] &= [K_{nn}^4] + [G_m^T][K_{mn}^4] + [K_{mn}^4]^T[G_m] + [G_m^T][K_{mm}^4][G_m] . \end{aligned}$$

69. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$ ,  $[M_{nn}]$  to  $[M_{ff}]$ ,  $[B_{nn}]$  to  $[B_{ff}]$  and  $[K_{nn}^4]$  to  $[K_{ff}^4]$  if no single-point constraints exist.
70. Go to DMAP No. 72 if no single-point constraints exist.

DIRECT COMPLEX EIGENVALUE ANALYSIS

71. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & | & K_{fs} \\ \hline K_{sf} & + & K_{ss} \end{bmatrix}, \quad [M_{nn}] = \begin{bmatrix} M_{ff} & | & M_{fs} \\ \hline M_{sf} & + & M_{ss} \end{bmatrix},$$

$$[B_{nn}] = \begin{bmatrix} B_{ff} & | & B_{fs} \\ \hline B_{sf} & + & B_{ss} \end{bmatrix} \text{ and } [K_{nn}^4] = \begin{bmatrix} K_{ff}^4 & | & K_{fs}^4 \\ \hline K_{sf}^4 & + & K_{ss}^4 \end{bmatrix}.$$

73. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$ ,  $[M_{ff}]$  to  $[M_{aa}]$ ,  $[B_{ff}]$  to  $[B_{aa}]$  and  $[K_{ff}]^4$  to  $[K_{aa}^4]$  if no omitted coordinates exist.

74. Go to DMAP No. 84 if no omitted coordinates exist.

75. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & | & K_{ao} \\ \hline K_{aa} & + & K_{ao} \\ K_{oa} & | & K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{ao}][G_o]$ .

76. Go to DMAP No. 78 if no mass matrix exists.

77. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} - & | & M_{ao} \\ \hline M_{aa} & + & M_{ao} \\ M_{oa} & | & M_{oo} \end{bmatrix},$$

and performs matrix reduction

$$[M_{aa}] = [M_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o]$$

79. Go to DMAP No. 84 if no viscous damping matrix exists.

80. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \begin{bmatrix} - & | & B_{ao} \\ \hline B_{aa} & + & B_{ao} \\ B_{oa} & | & B_{oo} \end{bmatrix},$$

and performs matrix reduction

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$$[B_{aa}] = [\bar{B}_{aa}] + [B_{ao}][G_0] + [B_{ao}G_0]^T + [G_0^T][B_{oo}][G_0] .$$

82. Go to DMAP No. 84 if no structural damping matrix exists.

83. SMP2 partitions constrained structural damping matrix

$$[K_{ff}^4] = \begin{bmatrix} K_{aa}^4 & K_{ao}^4 \\ \hline K_{ao}^4 & K_{oo}^4 \end{bmatrix},$$

and performs matrix reduction

$$[K_{aa}^4] = [K_{aa}^4] + [K_{ao}^4][G_0] + [K_{ao}^4G_0]^T + [G_0^T][K_{oo}^4][G_0]$$

85. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).
86. Go to DMAP No. 136 and print Error Message No. 1 if there is no Eigenvalue Extraction Data.
87. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for dynamic analysis.
90. BMG generates DMIG card images describing the interconnection of the fluid and the structure.
93. Go to DMAP No. 95 if no fluid-structure interface is defined.
94. MTRXIN generates fluid boundary matrices  $[A_{b,f\ell}]$  and  $[K_{b,f\ell}]$ . The matrix  $[K_{b,f\ell}]$  is generated only for a nonzero gravity in the fluid.
95. Beginning of loop for additional sets of direct input matrices.
97. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.
98. MTRXIN selects the direct input matrices  $[K_{pp}^{2d}]$ ,  $[M_{pp}^{2d}]$  and  $[B_{pp}^2]$  for the current loop.
101. Equivalence  $[K_{pp}^2]$  to  $[K_{pp}^{2d}]$  if no fluid-structure interface is defined and equivalence  $[M_{pp}^2]$  to  $[M_{pp}^{2d}]$  if there is no  $[A_{b,f\ell}]$ .
102. Go to DMAP No. 107 if no fluid-structure interface is defined.
103. ADD5 adds  $[K_{b,f\ell}]$  and  $[K_{pp}^{2d}]$  and subtracts  $[A_{b,f\ell}]$  from them to form  $[K_{pp}^2]$ .
104. Go to DMAP No. 107 if there is no  $[A_{b,f\ell}]$ .
105. Transpose  $[A_{b,f\ell}]$  to obtain  $[A_{b,f\ell}]^T$ .
106. ADD assembles input matrix  $[M_{pp}^2] = \text{MFACT } [A_{b,f\ell}]^T + [M_{pp}^{2d}]$ .

## DIRECT COMPLEX EIGENVALUE ANALYSIS

112. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^2]$  if no constraints are applied,  $[M_{aa}]$  to  $[M_{dd}]$  if there are no direct input mass matrices and no extra points, and  $[B_{aa}]$  to  $[B_{dd}]$  if there are no direct input damping matrices and no extra points.
113. Go to DMAP No. 115 if only extra points are defined.
114. GKAD assembles stiffness, mass and damping matrices for use in Direct Complex Eigenvalue Analysis

$$[K_{dd}] = (1 + ig)[K_{dd}^1] + [K_{dd}^2] + i[K_{dd}^4],$$

$$[M_{dd}] = [M_{dd}^1] + [M_{dd}^2] \quad \text{and}$$

$$[B_{dd}] = [B_{dd}^1] + [B_{dd}^2].$$

Direct input matrices may be complex.

116. Equivalence  $[K_{dd}^2]$  to  $[K_{dd}]$  if all stiffness is Direct Matrix Input,  $[M_{dd}^2]$  to  $[M_{dd}]$  if all mass is Direct Matrix Input and  $[B_{dd}^2]$  to  $[B_{dd}]$  if all damping is Direct Matrix Input.
117. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M_{dd}p^2 + B_{dd}p + K_{dd}] \{u_d\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit magnitude of a selected component
- 2) Unit magnitude of the largest component.

118. ØFP formats the summary of complex eigenvalues (CLAMA) and summary of eigenvalue extraction information (ØCEIGS) prepared by CEAD and places them on the system output file for printing.
119. Go to DMAP No. 131 if no eigenvalues were found.
120. VDR prepares eigenvectors for output, using only the independent degrees of freedom.
121. Go to DMAP No. 123 if there is no output request for independent degrees of freedom.
122. ØFP formats the eigenvectors for independent degrees of freedom prepared by VDR and places them on the system output file for printing.
124. Go to DMAP No. 131 if there is no output request involving dependent degrees of freedom or forces and stresses.
125. Equivalence  $\{\phi_d\}$  to  $\{\phi_p\}$  if no constraints are applied.
126. Go to DMAP No. 128 if no constraints are applied.

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127. SDR1 recovers dependent components of eigenvectors

$$\begin{aligned}\{\phi_0\} &= [G_0^d] \{\phi_d\} , & \left\{ \frac{\phi_d}{\phi_0} \right\} &= \{\phi_f + \phi_e\} , \\ \left\{ \frac{\phi_f + \phi_e}{\phi_s} \right\} &= \{\phi_n + \phi_e\} , & \{\phi_m\} &= [G_m^d] \{\phi_n + \phi_e\} , \\ \left\{ \frac{\phi_n + \phi_e}{\phi_m} \right\} &= \{\phi_p\}\end{aligned}$$

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}^T] \{\phi_f\}$ .

129. SDR2 calculates element forces ( $\emptyset EFC1$ ) and stresses ( $\emptyset ESC1$ ) and prepares eigenvectors ( $\emptyset CPHIP$ ) and single-point forces of constraint ( $\emptyset QPC1$ ) for output.
130.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
132. Go to DMAP No. 140 if no additional sets of direct input matrices need to be processed.
133. Go to DMAP No. 95 if additional sets of direct input matrices need to be processed.
134. Print Error Message No. 2 and terminate execution.
135. Go to DMAP No. 140 and make normal exit.
137. Print Error Message No. 1 and terminate execution.
139. Print Error Message No. 3 and terminate execution.

## DIRECT COMPLEX EIGENVALUE ANALYSIS

### 2.7.3 Output for Direct Complex Eigenvalue Analysis

Each complex eigenvalue is identified with a root number determined by sorting the complex eigenvalues according to the magnitude of the imaginary part, with positive values considered as a group ahead of all negative values. The following summary of the complex eigenvalues extracted is automatically printed for each set of direct input matrices:

1. Root Number
2. Extraction Order
3. Real and Imaginary Parts of the Eigenvalue
4. The coefficients  $f_j$  (frequency) and  $g_j$  (damping coefficient) in the following representation of the eigenvalue

$$P_j = 2\pi f_j (i - \frac{1}{2} g_j)$$

The following summary of the eigenvalue analysis performed, using the Determinant method, is automatically printed for each set of direct input matrices:

1. Number of eigenvalues extracted
2. Number of passes through starting points.
3. Number of criteria changes.
4. Number of starting point moves.
5. Number of triangular decompositions.
6. Number of failures to iterate to a root.
7. Number of predictions outside region.
8. Reason for termination:
  - (1) The number of roots desired have been found.
  - (2) All predictions for eigenvalues are outside the regions specified.
  - (3) Insufficient time to find another root.
  - (4) Matrix is singular at first three starting points.
9. Swept determinant functions for each starting point.

The following summary of the eigenvalue analysis performed, using the Inverse Power method, is automatically printed for each region specified:

1. Number of eigenvalues extracted.
2. Number of starting points used.
3. Number of starting point moves.
4. Number of triangular decompositions.

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5. Number of vector iterations.
6. Reason for termination.
  - (1) Two consecutive singularities encountered while performing triangular decomposition.
  - (2) Four starting point moves while tracking a single root.
  - (3) All eigenvalues found in the region specified.
  - (4) Three times the number of roots estimated in the region have been extracted.
  - (5) All eigenvalues that exist in the problem have been found.
  - (6) The number of roots desired have been found.
  - (7) One or more eigenvalues have been found outside the region specified.
  - (8) Insufficient time to find another root.
  - (9) Unable to converge.

The following summary of the eigenvalue analysis performed, using the complex Tridiagonal Reduction (FEER) method, is automatically printed:

1. Number of eigenvalues extracted.
2. Number of starting points used.

This corresponds to the total number of random starting and restart vectors used by the complex FEER process for all neighborhoods.

3. Number of starting point moves.

Not used in FEER (set equal to zero).

4. Number of triangular decompositions.

Always equal to the number of points of interest (neighborhoods) in the complex plane processed by FEER, since ordinarily only one triangular decomposition is required by FEER for each point of interest, unless the dynamic matrix is singular at a given point of interest, in which case an additional decomposition is required (obtained by moving the point of interest slightly).

5. Total number of vector iterations.

The total number of reorthogonalizations of all the trial vectors employed.

6. Reason for termination.

(0) All, or more solutions than the number requested by the user, have been determined (normal termination).

## DIRECT COMPLEX EIGENVALUE ANALYSIS

- (1) All neighborhoods have been processed, but FEER has not obtained the desired number of roots in each neighborhood, possibly because they have already been found in other neighborhoods.
- (2) Abnormal termination - either no roots found or none passes the FEER error test.

The following printed output, sorted by complex eigenvalue root number (SORT1), may be requested for any complex eigenvalue extracted, as either real and imaginary parts or magnitude and phase angle ( $0^\circ$  -  $360^\circ$  lead):

1. The eigenvector for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SOLUTION points (points used in the formulation of the dynamic equation).
2. Nonzero components of the single-point forces of constraint for a list of PHYSICAL points.
3. Stresses and forces in selected elements.

In addition, an undeformed plot of the structural model may be requested.

### 2.7.4 Case Control Deck for Direct Complex Eigenvalue Analysis

The following items relate to subcase definition and data selection for Direct Complex Eigenvalue Analysis:

1. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP).
2. Multiple subcases for each set of direct input matrices are used only to control output requests. A single subcase for each set of direct input matrices is sufficient if the same output is desired for all modes. If consecutive multiple subcases are present for a single set of direct input matrices, the output requests will be honored in succession for increasing mode numbers. MODES may be used to repeat subcases in order to make the same output request for several consecutive modes.
3. CMETHOD must be used to select an EIGC card from the Bulk Data Deck for each set of direct input matrices.
4. On restart following an unscheduled exit due to insufficient time, the subcase structure must be changed to reflect the sets of direct input matrices that were completed, and either CMETHOD must be changed to select an EIGC card that reflects any complex eigenvalues found in the previous execution or EIGP cards must be used to insert poles

## DISPLACEMENT RIGID FORMATS

for previously found eigenvalues. Otherwise, the previously found eigenvalues will be extracted again.

5. Constraints must be defined above the subcase level.

### 2.7.5 Parameters for Direct Complex Eigenvalue Analysis

The following parameters are used in Direct Complex Eigenvalue Analysis:

1. ASETOUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT0SPC - reserved for future optional use. The default value is -1.
3. C0UPMASS - CPBAR, CPR0D, CPQUAD1, CPQUAD2, CPTRIA1, CPIRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems (see Section 9.3.3 of the Theoretical Manual). Not recommended for use in hydroelastic problems.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
6. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

## DIRECT COMPLEX EIGENVALUE ANALYSIS

### 2.7.6 Rigid Format Error Messages from Direct Complex Eigenvalue Analysis

The following fatal errors are detected by the DMAP statements in the Direct Complex Eigenvalue Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 1 - EIGENVALUE EXTRACTION DATA REQUIRED FØR CØMPLEX EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGC card in the Bulk Data Deck and CMETHOD in the Case Control Deck must select an EIGC set.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØOPS.

An attempt has been made to use more than 100 sets of direct input matrices. This number may be increased by ALTERing the REPT instruction following SDR2.

DIRECT CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 3 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATØNS.

The mass matrix is null because either no elements were defined on Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

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2.7-18 (05/30/86)

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2.8 DIRECT FREQUENCY AND RANDOM RESPONSE

2.8.1 DMAP Sequence for Direct Frequency and Random Response

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OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 08 - DIRECT FREQUENCY/RANDOM RESPONSE ANALYSIS-APR. 1986 $  
2 PRECHK ALL $  
3 FILE KGGX=TAPE/KGG=TAPE/GOD=SAVE/GMD=SAVE/MDD=SAVE/BDD=SAVE $  
4 PARAM //*MPY*/CARDNO/0/0 $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
S,N,NOGPDT/ALWAYS=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 PURGE USET,GM,GO,KAA,BAA,MAA,K4AA,KFS,PSF,QPC,EST,ECT,PLTSETX,PLTPAR,  
GPSETS,ELSETS/NOGPDT $  
8 COND LBL5,NOGPDT $  
9 GP2 GEOM2,EQEXIN/ECT $  
10 PARAML PCDB//*PRES*///JUMPPLOT $  
11 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
12 COND P1,JUMPPLOT $  
13 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
14 PRTMSG PLTSETX// $  
15 PARAM //*MPY*/PLTFLG/1/1 $  
16 PARAM //*MPY*/PFILE/0/0 $  
17 COND P1,JUMPPLOT $  
18 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT.,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
19 PRTMSG PLOTX1//$/  
20 LABEL P1 $  
21 GP3 GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $
```

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```
22 TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
  
23 PURGE    K4GG,GPST,OGPST,MGG,BGG,K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,  
KGGX/NOSIMP/OGPST/GENEL $  
  
24 COND     LBL1,NOSIMP $  
  
25 PARAM    //*ADD*/NOKGGX/1/0 $  
  
26 PARAM    //*ADD*/NOMGG/1/0 $  
  
27 PARAM    //*ADD*/NOBGG=-1/1/0 $  
  
28 PARAM    //*ADD*/NOK4GG/1/0 $  
  
29 EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,BELM,BDICT,/S,N,NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/V,Y,VOLUME/V,Y,SURFACE $  
  
30 PURGE    GPST/NOKGGX/MGG/NOMGG $  
  
31 COND     LBLKGGX,NOKGGX $  
  
32 EMA      GPECT,KDICT,KELM/KGGX,GPST $  
  
33 LABEL    LBLKGGX $  
  
34 COND     LBLMGG,NOMGG $  
  
35 EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
  
36 LABEL    LBLMGG $  
  
37 COND     LBLBGG,NOBGG $  
  
38 EMA      GPECT,BDICT,BELM/BGG, $  
  
39 LABEL    LBLBGG $  
  
40 COND     LBLK4GG,NOK4GG $  
  
41 EMA      GPECT,KDICT,KELM/K4GG,/NOK4GG $  
  
42 LABEL    LBLK4GG $  
  
43 PURGE    MNN,MFF,MAA/NOMGG $  
  
44 PURGE    BNN,BFF,BAA/NOBGG $
```

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```
45  COND      LBL1,GRDPNT $  
46  COND      ERROR4,NOMGG $  
47  GPWG      BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
48  OFP       OGPWG,///S,N,CARDNO $  
49  LABEL     LBL1 $  
50  EQUIV    KGGX,KGG/NOGENL $  
51  COND      LBL11,NOGENL $  
52  SMA3      GE1,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
53  LABEL     LBL11 $  
54  PARAM     ///*MPY*/NSKIP/0/0 $  
55  GP4       CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
56  PURGE    GM,GMD/MPCF1/G0,GOD/OMIT/KFS,PSF,QPC/SINGLE $  
57  COND      LBL4,GENEL $  
58  COND      LBL4,NOSIMP $  
59  PARAM     ///*EQ*/GPSPFLG/AUTOSPC/0 $  
60  COND      LBL4,GPSPFLG $  
61  GPSP      GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
62  OFP       OGPST,///S,N,CARDNO $  
63  LABEL     LBL4 $  
64  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $  
65  COND      LBL2,MPCF1 $  
66  MCE1      USET,RG/GM $  
67  MCE2      USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $  
68  LABEL     LBL2 $  
69  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
```

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```
70  COND      LBL3,SINGLE $  
71  SCE1      USET,KNN,MNN,BNN,K4NN/KFF,KFS,,MFF,BFF,K4FF $  
72  LABEL     LBL3 $  
73  EQUIV    KFF,KAA/OMIT $  
74  EQUIV    MFF,MAA/OMIT $  
75  EQUIV    BFF,BAA/OMIT $  
76  EQUIV    K4FF,K4AA/OMIT $  
77  COND      LBL5, OMIT $.  
78  SMP1      USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $  
79  COND      LBLM,NOMGG $  
80  SMP2      USET,GO,MFF/MAA $  
81  LABEL     LBLM $  
82  COND      LBLB,NOBGG $  
83  SMP2      USET,GO,BFF/BAA $  
84  LABEL     LBLB $  
85  COND      LBL5,NOK4GG $  
86  SMP2      USET,GO,K4FF/K4AA $  
87  LABEL     LBL5 $  
88  DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,,  
EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/S,N,NOPSDL/S,N,  
NOFRL/NONLFT/NOTRL/NOEED//S,N,NOUE $  
89  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $  
90  PARAM     ///*ADD*/NEVER/I/O $  
91  PARAM     ///*MPY*/REPEATF/-1/1 $  
92  BMG       MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/  
S,N,MFACT $  
93  PARAM     ///*AND*/NOFL/NOABFL/NOKBFL $  
94  PURGE    KBFL/NOKBFL/ ABFL/NOABFL $
```

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```
95  COND      LBL13,NOFL $  
96  MTRXIN,   ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/  
     0 $  
97  LABEL     LBL13 $  
98  PURGE    OUDVC1,OUDVC2,XYPLTFA,OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OPPC2,  
             OQPC2,OUPVC2,OESC2,OEFC2,XYPLTF,PSDF,AUTO,XYPLTR,  
             K2PP,M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $  
99  CASE      CASEXX,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $  
100 MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,  
           NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $  
101 PARAM    //*AND*/NOM2PP/NOABFL/NOM2DPP $  
102 PARAM    //*AND*/NOK2PP/NOFL /NOK2DPP $  
103 EQUIV    K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $  
104 COND      LBLFL2,NOFL $  
105 ADD5     ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $  
106 COND      LBLFL2,NOABFL $  
107 TRNSP    ABFL/ABFLT $  
108 ADD      ABFLT,M2DPP/M2PP/MFACT $  
109 LABEL     LBLFL2 $  
110 PARAM    //*AND*/BDEBA/NOUE/NOB2PP $  
111 PARAM    //*AND*/KDEK2/NOGENL/NOSIMP $  
112 PARAM    //*AND*/MDEMA/NOUE/NOM2PP $  
113 PURGE    K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $  
114 EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/  
             MAA,MDD/MDEMA/BAA,BDD/BDEBA $  
115 COND      LBL18,NOGPDT $  
116 GKAD     USETD,GM,GO,KAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,  
             GOD,K2DD,M2DD,B2DD/*FREQRESP*/*DISP*/*DIRECT*/C,Y,G=0.0/  
             0.0/0.0/NOK2PP/NOM2PP/NOB2PP/  
             MPCF1/SINGLE/OMIT/NOUE/NOK4GG/NOBGG/  
             KDEK2/-1 $
```

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```
117 LABEL    LBL18 $  
118 EQUIV    B2DD,BDD/NOBGG/ M2DD,MDD/NOSIMP/ K2DD,KDD/KDEK2 $  
119 COND     ERROR1,NOFRL $  
120 COND     ERROR2,NODLT $  
121 FRRD     CASEXX,USETD,DLT,FRL,GMD,GOD,KDD,BDD,MDD,,DIT/UDVF,PSF,PDF,PPF/  
*DISP*/*DIRECT*/LUSETD/MPCF1/SINGLE/ OMIT/  
NONCUP/FRQSET $  
122 EQUIV    PPF,PDF/NOSET $  
123 VDR      CASEXX,EQDYN,USETD,UDVF,PPF,XYCDB,/OUDVC1,/ *FREQRESP*/  
*DIRECT*/S,N,NOSORT2/S,N,NOD/S,N,NOP/O $  
124 COND     LBL15,NOD $  
125 COND     LBL15A,NOSORT2 $  
126 SDR3     OUDVC1,,,,,/OUDVC2,,,,, $  
127 OFP      OUDVC2,,,,,/S,N,CARDNO $  
128 XYTRAN   XYCDB,OUDVC2,,,,/XYPLTFA/*FREQ*/*DSET*/S,N,PFILE/  
S,N,CARDNO $  
129 XYPLOT   XYPLTFA// $  
130 JUMP     LBL15 $  
131 LABEL    LBL15A $  
132 OFP      OUDVC1,,,,,/S,N,CARDNO $  
133 LABEL    LBL15 $  
134 COND     LBL20,NOP $  
135 EQUIV    UDVF,UPVC/NOA $  
136 COND     LBL19,NOA $  
137 SDR1     USETD,,UDVF,,,GOD,GMD,PSF,KFS,,/UPVC,,QPC/1/*DYNAMICS* $  
138 LABEL    LBL19 $  
139 SDR2     CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,PPF,QPC,UPVC,EST,XYCDB,  
PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUPVC1/*FREQRESP*/  
S,N,NOSORT2 $
```

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```
140  COND    LBL17,NOSORT2 $  
141  SDR3    OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,/OPPC2,OQPC2,OUPVC2,OESC2,  
          OEFC2, $  
142  OFP     OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,//S,N,CARDNO $  
143  XYTRAN  XYCDB,OPPC2,OQPC2,OUPVC2,OESC2,OEFC2/XYPLTF/*FREQ*/*PSET*/  
          S,N,PFILE/S,N,CARDNO $  
144  XYPLOT  XYPLTF// $  
145  COND    LBL16,NOPSDL $  
146  RANDOM  XYCDB,DIT,PSDL,OUPVC2,OPPC2,OQPC2,OESC2,OEFC2,CASEXX/PSDF,AUTO/  
          S,N,NORD $  
147  COND    LBL16,NORD $  
148  XYTRAN  XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND*/*PSET*/S,N,PFILE/  
          S,N,CARDNO $  
149  XYPLOT  XYPLTR// $  
150  JUMP    LBL16 $  
151  LABEL   LBL17 $  
152  PURGE   PSDF/NOSORT2 $  
153  OFP     OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,//S,N,CARDNO $  
154  LABEL   LBL16 $  
155  PURGE   PSDF/NOPSDL $  
156  COND    LBL20,JUMPPLOT $  
157  PLOT    PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUPVC1,  
          GPECT,OESC1/PLOTX2/NS1/LUSEP/JUMPPLOT/PLTFLG/  
          S,N,PFILE $  
158  PRTPARM PLOTX2// $  
159  LABEL   LBL20 $  
160  COND    FINIS,REPEATF $  
161  REPT    LBL13,100 $  
162  PRTPARM //3/*DIRFRRD* $
```

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```
163 JUMP    FINIS $  
164 LABEL   ERROR2 $  
165 PRTPARM //2/*DIRFRRD* $  
166 LABEL   ERROR1 $  
167 PRTPARM //1/*DIRFRRD* $  
168 LABEL   ERROR4 $  
169 PRTPARM //4/*DIRFRRD* $  
170 LABEL   FINIS $  
171 PURGE  DUMMY/ALWAYS $  
172 END    $
```

## DIRECT FREQUENCY AND RANDOM RESPONSE

### 2.8.2 Description of Important DMAP Operations for Direct Frequency and Random Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
8. Go to DMAP No. 87 if there is only Direct Matrix Input.
9. GP2 generates Element Connection Table with internal indices.
12. Go to DMAP No. 20 if there are no structure plot requests.
13. PLTSET transforms user input into a form used to drive the structure plotter.
14. PRTMSG prints error messages associated with the structure plotter.
17. Go to DMAP No. 20 if no undeformed structure plots are requested.
18. PL0T generates all requested undeformed structure plots.
19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
21. GP3 generates Grid Point Temperature Table.
22. TA1 generates element tables for use in matrix assembly and stress recovery.
24. Go to DMAP No. 49 if there are no structural elements.
29. EMG generates structural element stiffness, mass and damping matrix tables and dictionaries for later assembly by the EMA module.
31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.
32. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
34. Go to DMAP No. 36 if no mass matrix is to be assembled.
35. EMA assembles mass matrix  $[M_{gg}]$ .
37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.
38. EMA assembles viscous damping matrix  $[B_{gg}]$ .
40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.
41. EMA assembles structural damping matrix  $[K_{gg}^4]$ .
45. Go to DMAP No. 49 if no weight and balance information is requested.
46. Go to DMAP No. 168 and print Error Message No. 4 if no mass matrix exists.
47. GPWG generates weight and balance information.
48. OFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
50. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
51. Go to DMAP No. 53 if there are no general elements.
52. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .

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55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
57. Go to DMAP No. 63 if general elements are present.
58. Go to DMAP No. 63 if there are no structural elements.
60. Go to DMAP No. 63 if no potential grid point singularities exist.
61. GPSP generates a table of potential grid point singularities.
62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
64. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$ ,  $[M_{gg}]$  to  $[M_{nn}]$ ,  $[B_{gg}]$  to  $[B_{nn}]$  and  $[K_{gg}^4]$  to  $[K_{nn}^4]$  if no multipoint constraints exist.
65. Go to DMAP No. 68 if no multipoint constraints exist.
66. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
67. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} & | & K_{nm} \\ K_{mn} & + & K_{mm} \end{bmatrix}, \quad [M_{gg}] = \begin{bmatrix} - & M_{nn} & | & M_{nm} \\ M_{mn} & + & M_{mm} \end{bmatrix},$$

$$[B_{gg}] = \begin{bmatrix} - & B_{nn} & | & B_{nm} \\ B_{mn} & + & B_{mm} \end{bmatrix} \text{ and } [K_{gg}^4] = \begin{bmatrix} - & K_{nn}^4 & | & K_{nm}^4 \\ K_{mn}^4 & + & K_{mm}^4 \end{bmatrix}$$

and performs matrix reductions

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m],$$

$$[M_{nn}] = [M_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m],$$

$$[B_{nn}] = [B_{nn}] + [G_m^T][B_{mn}] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m],$$

$$[K_{nn}^4] = [K_{nn}^4] + [G_m^T][K_{mn}^4] + [K_{mn}^4]^T[G_m] + [G_m^T][K_{mm}^4][G_m].$$

69. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$ ,  $[M_{nn}]$  to  $[M_{ff}]$ ,  $[B_{nn}]$  to  $[B_{ff}]$  and  $[K_{nn}]^4$  to  $[K_{ff}^4]$  if no single-point constraints exist.
70. Go to DMAP No. 72 if no single-point constraints exist.

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71. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & | & K_{fs} \\ \hline K_{sf} & | & K_{ss} \end{bmatrix}, \quad [M_{nn}] = \begin{bmatrix} M_{ff} & | & M_{fs} \\ \hline M_{sf} & | & M_{ss} \end{bmatrix},$$

$$[B_{nn}] = \begin{bmatrix} B_{ff} & | & B_{fs} \\ \hline B_{sf} & | & B_{ss} \end{bmatrix} \text{ and } [K_{nn}^4] = \begin{bmatrix} K_{ff}^4 & | & K_{fs}^4 \\ \hline K_{sf}^4 & | & K_{ss}^4 \end{bmatrix}.$$

73. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.

74. Equivalence  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.

75. Equivalence  $[B_{ff}]$  to  $[B_{aa}]$  if no omitted coordinates exist.

76. Equivalence  $[K_{ff}^4]$  to  $[K_{aa}^4]$  if no omitted coordinates exist.

77. Go to DMAP No. 87 if no omitted coordinates exist.

78. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} -K_{aa} & | & K_{ao} \\ \hline K_{oa} & | & K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{ao}][G_o]$ .

79. Go to DMAP No. 81 if no mass matrix exists.

80. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} -M_{aa} & | & M_{ao} \\ \hline M_{oa} & | & M_{oo} \end{bmatrix},$$

and performs matrix reduction

$$[M_{aa}] = [M_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o]$$

82. Go to DMAP No. 84 if no viscous damping matrix exists.

83. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \begin{bmatrix} -B_{aa} & | & B_{ao} \\ \hline B_{oa} & | & B_{oo} \end{bmatrix},$$

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and performs matrix reduction

$$[B_{aa}] = [B_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o^T][B_{oo}][G_o]$$

85. Go to DMAP No. 87 if no structural damping matrix exists.

86. SMP2 partitions constrained structural damping matrix

$$[K_{ff}^4] = \begin{bmatrix} -4 & K_{ao}^4 \\ \hline K_{aa}^4 & | & K_{ao}^4 \\ \hline K_{oa}^4 & | & K_{oo}^4 \end{bmatrix}$$

and performs matrix reduction

$$[K_{aa}^4] = [K_{aa}^4] + [K_{ao}^4][G_o] + [K_{ao}^4G_o]^T + [G_o^T][K_{oo}^4][G_o]$$

88. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers, including extra points introduced for dynamic analysis, and prepares Transfer Function Pool, Dynamics Load Table, Power Spectral Density List and Frequency Response List.

- 89. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for dynamic analysis.
- 92. BMG generates DMIG card images describing the interconnection of the fluid and the structure.
- 95. Go to DMAP No. 97 if no fluid-structure interface is defined.
- 96. MTRXIN generates fluid boundary matrices  $[A_{b,f\ell}]$  and  $[K_{b,f\ell}]$ . The matrix  $[K_{b,f\ell}]$  is generated only for a nonzero gravity in the fluid.
- 97. Beginning of loop for additional sets of direct input matrices.
- 99. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.
- 100. MTRXIN selects the direct input matrices  $[K_{pp}^{2d}]$ ,  $[M_{pp}^{2d}]$  and  $[B_{pp}^2]$  for the current loop.
- 103. Equivalence  $[K_{pp}^2]$  to  $[K_{pp}^{2d}]$  if no fluid-structure interface is defined and equivalence  $[M_{pp}^2]$  to  $[M_{pp}^{2d}]$  if there is no  $[A_{b,f\ell}]$ .
- 104. Go to DMAP No. 109 if no fluid-structure interface is defined.
- 105. ADD5 adds  $[K_{b,f\ell}]$  and  $[K_{pp}^{2d}]$  and subtracts  $[A_{b,f\ell}]$  from them to form  $[K_{pp}^2]$ .
- 106. Go to DMAP No. 109 if there is no  $[A_{b,f\ell}]$ .
- 107. Transpose  $[A_{b,f\ell}]$  to obtain  $[A_{b,f\ell}]^T$ .
- 108. ADD assembles input matrix  $[M_{pp}^2] = MFACT [A_{b,f\ell}]^T + [M_{pp}^{2d}]$ .

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114. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^2]$  if no constraints are applied,  $[M_{aa}]$  to  $[M_{dd}]$  if there are no direct input mass matrices and no extra points, and  $[B_{aa}]$  to  $[B_{dd}]$  if there are no direct input damping matrices and no extra points.
115. Go to DMAP No. 117 if only extra points are defined.
116. GKAD assembles stiffness, mass and damping matrices for use in Direct Frequency Response:

$$[K_{dd}] = (1 + ig)[K_{dd}^1] + [K_{dd}^2] + i[K_{dd}^4],$$

$$[M_{dd}] = [M_{dd}^1] + [M_{dd}^2] \quad \text{and}$$

$$[B_{dd}] = [B_{dd}^1] + [B_{dd}^2].$$

Direct input matrices may be complex.

118. Equivalence  $[K_{dd}^2]$  to  $[K_{dd}]$  if all stiffness is Direct Matrix Input,  $[M_{dd}^2]$  to  $[M_{dd}]$  if all mass is Direct Matrix Input and  $[B_{dd}^2]$  to  $[B_{dd}]$  is all damping is Direct Matrix Input.
119. Go to DMAP No. 166 and print Error Message No. 1 if there is no Frequency Response List.
120. Go to DMAP No. 164 and print Error Message No. 2 if there is no Dynamics Load Table.
121. FRRD forms the dynamic load vectors  $\{P_d\}$  and solves for the displacements using the following equation

$$[-M_{dd}\omega^2 + iB_{dd}\omega + K_{dd}] \{u_d\} = \{P_d\} .$$

122. Equivalence  $\{P_p\}$  to  $\{P_d\}$  if no constraints are applied.
123. VDR prepares solution set displacements, sorted by frequency, for output.
124. Go to DMAP No. 133 if there is no output request for the solution set.
125. Go to DMAP No. 131 if there is no output request for solution set displacements sorted by point number.
126. SDR3 sorts the solution set displacements by point number.
127. ØFP formats the requested solution set displacements, sorted by point number, prepared by SDR3 and places them on the system output file for printing.
128. XYTRAN prepares the input for requested X-Y plots of the solution set displacements vs. frequency.
129. XYPLØT prepares the requested X-Y plots of the solution set displacements vs. frequency.
130. Go to DMAP No. 133.

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132. ØFP formats the requested solution set displacements, sorted by frequency, prepared by VDR and places them on the system output file for printing.
134. Go to DMAP No. 159 if there is no output request involving dependent degrees of freedom or forces and stresses.
135. Equivalence  $\{u_d\}$  to  $\{u_p\}$  if no constraints are applied.
136. Go to DMAP No. 138 if no constraints are applied.
137. SDR1 recovers dependent components of displacements

$$\begin{aligned} \{u_o\} &= [G_o^d]\{u_d\} , & \left\{ \frac{u_d}{u_o} \right\} &= \{u_f + u_e\} , \\ \left\{ \frac{u_f + u_e}{u_s} \right\} &= \{u_n + u_e\} , & \{u_m\} &= [G_m^d]\{u_f + u_e\} , \\ \left\{ \frac{u_n + u_e}{u_m} \right\} &= \{u_p\} \end{aligned}$$

and recovers single-point forces of constraint  $\{q_s\} = -\{P_s\} + [K_{fs}^T] \{u_f\}$ .

139. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares load vectors (ØPPC1), displacement vectors (ØUPVC1) and single-point forces of constraint (ØQPC1) for output and translation components of the displacement vector (PUGVC1), sorted by frequency.
140. Go to DMAP No. 151 if there are no output requests sorted by point number or element number.
141. SDR3 prepares requested output sorted by point number or element number.
142. ØFP formats the tables prepared by SDR3 sorted by point number or element number, and places them on the system output file for printing.
143. XYTRAN prepares the input for requested X-Y plots.
144. XYPLØT prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. frequency.
145. Go to DMAP No. 154 if there is no Power Spectral Density List.
146. RANDØM calculates power spectral density functions (PSDF) and autocorrelation functions (AUTØ) using the previously calculated frequency response.
147. Go to DMAP No. 154 if no RANDØM calculations are requested.
148. XYTRAN prepares the input for requested X-Y plots of the RANDØM output.
149. XYPLØT prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.
150. Go to DMAP No. 154.
153. ØFP formats the frequency response output requests prepared by SDR2, sorted by frequency, and places them on the system output file for printing.
156. Go to DMAP No. 159 if no deformed structure plots are requested.

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157. PL0T prepares all requested deformed structure and contour plots.
158. PRTMSG prints plotter data, engineering data and contour data for each deformed plot generated.
160. Go to DMAP No. 170 if no additional sets of direct input matrices need to be processed.
161. Go to DMAP No. 97 if additional sets of direct input matrices need to be processed.
162. Print Error Message No. 3 and terminate execution.
163. Go to DMAP No. 170 and make normal exit.
165. Print Error Message No. 2 and terminate execution.
167. Print Error Message No. 1 and terminate execution.
169. Print Error Message No. 4 and terminate execution.

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### 2.8.3 Output for Direct Frequency and Random Response

The following printed output, sorted by frequency (SØRT1) or by point number or element number (SØRT2), is available, either as real and imaginary parts or magnitude and phase angle (0° - 360° lead), for the list of frequencies specified by ØFREQUENCY:

1. Displacements, velocities and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points.
3. Stresses and forces in selected elements (ALL available only for SØRT1).

The following plotter output is available for Frequency Response calculations:

1. Undeformed plot of the structural model.
2. Deformed shapes of the structural model for selected frequencies.
3. Contour plots of stresses and displacements for selected frequencies.
4. X-Y plot of any component of displacement, velocity or acceleration of a PHYSICAL point or SØLUTIØN point.
5. X-Y plot of any component of the applied load vector or single-point force of constraint.
6. X-Y plot of any stress or force component for an element.

The following plotter output is available for Random Response calculations:

1. X-Y plot of the power spectral density versus frequency for the response of selected components for points or elements.
2. X-Y plot of the autocorrelation versus time lag for the response of selected components for points or elements.

The data used for preparing the X-Y plots may be punched or printed in tabular form (see Section 4.3). This is the only form of printed output that is available for Random Response. Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

### 2.8.4 Case Control Deck for Direct Frequency and Random Response

The following items relate to subcase definition and data selection for Direct Frequency and Random Response:

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1. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP) or frequencies.
2. Consecutive subcases for each set of direct input matrices or frequencies are used to define the loading conditions - one subcase for each dynamic loading condition.
3. Constraints must be defined above the subcase level.
4. DL $\emptyset$ AD must be used to define a frequency-dependent loading condition for each subcase.
5. FREQUENCY must be used to select one, and only one, FREQ, FREQ1, or FREQ2 card from the Bulk Data Deck for each unique set of direct input matrices.
6. On restart following an unscheduled exit due to insufficient time, the subcase structure must be changed to reflect the sets of direct input matrices that were completed, and FREQUENCY must be changed to select a FREQ, FREQ1, or FREQ2 card that reflects any frequencies for which the response has already been determined. Otherwise, the previous calculations will be repeated.
7.  $\emptyset$ FREQUENCY may be used above the subcase level or within each subcase to select a subset of the solution frequencies for output requests. The default is to use all solution frequencies.
8. If Random Response calculations are desired, RAND $\emptyset$ M must be used to select RANDPS and RANDTi cards from the Bulk Data Deck. Only one  $\emptyset$ FREQUENCY and FREQUENCY card can be used for each set of direct input matrices.

### 2.8.5 Parameters for Direct Frequency and Random Response

The following parameters are used in Direct Frequency and Random Response:

1. ASET $\emptyset$ OUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT $\emptyset$ SPC - reserved for future optional use. The default value is -1.
3. C $\emptyset$ UPMASS - CPBAR, CPR $\emptyset$ D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems (see Section 9.3.3 of the Theoretical Manual). Not recommended for use in hydroelastic problems.

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5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
6. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

### 2.8.6 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Direct Frequency and Random Response, Rigid Format 8, are ALTERed in automated substructure analyses.

Phase 1: 4, 56, 88-120, 121-162

Phase 2: 4, 5-5, 10-20, 23-24, 43-53, 111-112, 118-118, 135-158

Phase 3: 87, 90-136, 138, 160-162

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

### 2.8.7 Rigid Format Error Messages from Direct Frequency and Random Response

The following fatal errors are detected by the DMAP statements in the Direct Frequency and Random Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT FREQUENCY AND RANDOM RESPONSE ERROR MESSAGE NO. 1 - FREQUENCY RESPONSE LIST REQUIRED FOR FREQUENCY RESPONSE CALCULATIONS.

Frequencies to be used in the solution of frequency response problems must be supplied on a FREQ,

DIRECT FREQUENCY AND RANDOM RESPONSE

FREQ1, or FREQ2 card in the Bulk Data Deck and FREQ in the Case Control Deck must select a frequency response set.

DIRECT FREQUENCY AND RANDOM RESPONSE ERROR MESSAGE NO. 2 - DYNAMIC LOADS TABLE REQUIRED FOR FREQUENCY RESPONSE CALCULATIONS.

Dynamic loads to be used in the solution of frequency response problems must be specified on an RLAD1 or RLAD2 card in the Bulk Data Deck and DLAD in the Case Control Deck must select a dynamic load set.

DIRECT FREQUENCY AND RANDOM RESPONSE ERROR MESSAGE NO. 3 - ATTEMPT TO EXECUTE MORE THAN 100 LOADS.

An attempt has been made to use more than 100 sets of direct input matrices. This number may be increased by ALTERING the REPT instruction following the last OFP instruction.

DIRECT FREQUENCY AND RANDOM RESPONSE ERROR MESSAGE NO. 4 - MASS MATRIX REQUIRED FOR WEIGHT AND BALANCE CALCULATIONS.

The mass matrix is null because either no elements were defined on Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

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2.9 DIRECT TRANSIENT RESPONSE

2.9.1 DMAP Sequence for Direct Transient Response

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OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 09 - DIRECT TRANSIENT RESPONSE ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 FILE UDV=APPEND/TOL=APPEND $  
4 PARAM //MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
S,N,NOGPDT/ALWAYS=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 PURGE USET,GM,GO,KAA,BAA,MAA,K4AA,PST,KFS,QP,EST,ECT,PLTSETX,PLTPAR,  
GPSETS,ELSETS/NOGPDT $  
8 COND LBL5,NOGPDT $  
9 GP2 GEOM2,EQEXIN/ECT $  
10 PARAML PCDB//PRES///JUMPPLOT $  
11 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
12 COND P1,JUMPPLOT $  
13 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
14 PRTMSG PLTSETX// $  
15 PARAM //MPY*/PLTFLG/1/1 $  
16 PARAM //MPY*/PFILE/O/O $  
17 COND P1,JUMPPLOT $  
18 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
19 PRTMSG PLOTX1// $  
20 LABEL P1 $  
21 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $
```

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```
22 TAI      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GE1,GPECT,,/  
           LUSET/S,N,NOSIMP=-1/1/S,N,NOGENL=-1/S,N,GENEL $  
  
23 PURGE    K4GG,GPST,OGPST,MGG,BGG,  
           K4NN,K4FF,K4AA,MNN,MFF,MAA,BNN,BFF,BAA,KGGX/NOSIMP/  
           OGPST/GENEL $  
  
24 COND     LBL1,NOSIMP $  
  
25 PARAM    //**ADD*/NOKGGX/1/0 $  
  
26 PARAM    //**ADD*/NOMGG/1/0 $  
  
27 PARAM    //**ADD*/NOBGG=-1/1/0 $  
  
28 PARAM    //**ADD*/NOK4GG/1/0 $  
  
29 EMG      EST,CSTM,MPT,DIT,GEOM2./KELM,KDICT,MELM,MDICT,BELM,BDICT,/S,N,NOKGGX/S,N,NOMGG/S,N,NOBGG/S,N,NOK4GG//C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/V,Y,VOLUME/V,Y,SURFACE $  
  
30 PURGE    KGGX,GPST/NOKGGX/MGG/NOMGG $  
  
31 COND     LBLKGGX,NOKGGX $  
  
32 EMA      GPECT,KDICT,KELM/KGGX,GPST $  
  
33 LABEL    LBLKGGX $  
  
34 COND     LBLMGG,NOMGG $  
  
35 EMA      GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
  
36 LABEL    LBLMGG $  
  
37 COND     LBLBGG,NOBGG $  
  
38 EMA      GPECT,BDICT,BELM/BGG, $  
  
39 LABEL    LBLBGG $  
  
40 COND     LBLK4GG,NOK4GG $  
  
41 EMA      GPECT,KDICT,KELM/K4GG,/NOK4GG $  
  
42 LABEL    LBLK4GG $  
  
43 PURGE    MNN,MFF,MAA/NOMGG $  
  
44 PURGE    BNN,BFF,BAA/NOBGG $
```

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```
45  COND    LBL1,GRDPNT $  
46  COND    ERROR3,NOMGG $  
47  GPWG    BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
48  OFP     OGPWG,,,,,/S,N,CARDNO $  
49  LABEL   LBL1 $  
50  EQUIV   KGGX,KGG/NOGENL $  
51  COND    LBL11,NOGENL $  
52  SMA3    GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
53  LABEL   LBL11 $  
54  PARAM   ///*MPY*/NSKIP/0/0 $  
55  GP4     CASECC,GEOM4,EQEXIN,GPD,GPDT,CSTM,GPST/RG,,USET,ASET/  
           LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
           S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
           S,Y,AUTOSPC $  
56  PURGE   GM,GMD/MPCF1/G0,GOD/OMIT/KFS,PST,QP/SINGLE $  
57  COND    LBL4,GENEL $  
58  COND    LBL4,NOSIMP $  
59  PARAM   ///*EQ*/GPSPFLG/AUTOSPC/O $  
60  COND    LBL4,GPSPFLG $  
61  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
62  OFP     OGPST,,,,,/S,N,CARDNO $  
63  LABEL   LBL4 $  
64  EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1/ BGG,BNN/MPCF1/K4GG,K4NN/MPCF1 $  
65  COND    LBL2,MPCF1 $  
66  MCE1    USET,RG/GM $  
67  MCE2    USET,GM,KGG,MGG,BGG,K4GG/KNN,MNN,BNN,K4NN $  
68  LABEL   LBL2 $  
69  EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE/BNN,BFF/SINGLE/K4NN,K4FF/SINGLE $
```

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```
70  COND    LBL3,SINGLE $  
71  SCE1    USET,KNN,MNN,BNN,K4NN/KFF,KFS,      ,MFF,BFF,K4FF $  
72  LABEL   LBL3 $  
73  EQUIV   KFF,KAA/OMIT $  
74  EQUIV   MFF,MAA/OMIT $  
75  EQUIV   BFF,BAA/OMIT $  
76  EQUIV   K4FF,K4AA/OMIT $  
77  COND    LBL5, OMIT $  
78  SMP1    USET,KFF,,,GO,KAA,KOO,LOO,,,,, $  
79  COND    LBLM,NOMGG $  
80  SMP2    USET,GO,MFF/MAA $  
81  LABEL   LBLM $  
82  COND    LBLB,NOBGG $  
83  SMP2    USET,GO,BFF/BAA $  
84  LABEL   LBLB $  
85  COND    LBL5,NOK4GG $  
86  SMP2    USET,GO,K4FF/K4AA $  
87  LABEL   LBL5 $  
88  DPD     DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,,,NLFT,TRL,,  
           EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/NOPSDL/  
           NOFRL/S,N,NONLFT/S,N,NOTRL/NOEED//S,N,NOUE $  
89  COND    ERROR1,NOTRL $  
90  PURGE  PNLD/NONLFT$  
91  EQUIV   GO,GOD/NOUE/GM,GMD/NOUE $  
92  BMG    MATPOOL,BGPDT,EQEXIN,CSTM/BDPOOL/S,N,NOKBFL/S,N,NOABFL/  
           S,N,MFACT $  
93  PARAM   ///*AND*//NOFL/NOABFL/NOKBFL $  
94  PURGE  KBFL/NOKBFL/ ABFL/NOABFL $
```

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```
95  COND    LBLFL3,NOFL $  
96  MTRXIN, ,BDPOOL,EQDYN,,/ABFL,KBFL,/LUSETD/S,N,NOABFL/S,N,NOKBFL/  
    0 $  
97  LABEL   LBLFL3 $  
98  MTRXIN  CASECC,MATPOOL,EQDYN,,TFPOOL/K2DPP,M2DPP,B2PP/LUSETD/S,N,  
    NOK2DPP/S,N,NOM2DPP/S,N,NOB2PP $  
99  PARAM   //*AND*/NOM2PP/NOABFL/NOM2DPP $  
100  PARAM  //*AND*/NOK2PP/NOFL /NOK2DPP $  
101  EQUIV  K2DPP,K2PP/NOFL/M2DPP,M2PP/NOABFL $  
102  COND   LBLFL2,NOFL $  
103  ADD5   ABFL,KBFL,K2DPP,,/K2PP/(-1.0,0.0) $  
104  COND   LBLFL2,NOABFL $  
105  TRNSP  ABFL/ABFLT $  
106  ADD    ABFLT,M2DPP/M2PP/MFACT $  
107  LABEL   LBLFL2 $  
108  PARAM   //*AND*/KDEKA/NOUE/NOK2PP $  
109  PARAM   //*AND*/MDEMA/NOUE/NOM2PP $  
110  PARAM   //*AND*/KDEK2/NOGENL/NOSIMP $  
111  PURGE  K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $  
112  EQUIV  M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA/  
    KAA,KDD/KDEKA $  
113  COND   LBL16,NOGPDT $  
114  GKAD   USETD,GM,GO,CAA,BAA,MAA,K4AA,K2PP,M2PP,B2PP/KDD,BDD,MDD,GMD,  
    GOD,K2DD,M2DD,B2DD/*TRANRESP*/*DISP*/*DIRECT*/C,Y,G=0.0/  
    C,Y,W3=0.0/C,Y,W4=0.0/NOK2PP/NOM2PP/NOB2PP/  
    MPCF1/SINGLE/OMIT/NOUE/NOK4GG/NOBGG/  
    KDEK2/-1 $  
115  LABEL   LBL16 $  
116  EQUIV  M2DD,MDD/NOSIMP/B2DD,BDD/NOGPDT/K2DD,KDD/KDEK2 $  
117  PARAM   //*ADD*/NEVER/I/O $
```

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```
118 PARAM ///*MPY*//REPEATT/1/-1 $  
119 LABEL LBL13 $  
120 PURGE PNLD,OUDV1,OPNL1,OUDV2,OPNL2,XYPLTTA,OPP1,OQP1,OUPV1,OES1,  
OEF1,OPP2,OQP2,OUPV2,OES2,OEF2,PLOTX2,XYPLTT/NEVER $  
121 CASE CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $  
122 PARAM ///*MPY*//NCOL/0/1 $  
123 TRLG CASEXX,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,,EST,MGG,  
MPT/PPT,PST,PDT,PD,,TOL/S,N,NOSET/NCOL $  
124 EQUIV PPT,PDT/NOSET $  
125 TRD CASEXX,TRL,NLFT,DIT,KDD,BDD,MDD,PD/UVT,PNLD/*DIRECT*/  
NOUE/NONCUP/S,N,NCOL/C,Y,ISTART $  
126 VDR CASEXX,EQDYN,USETD,UVT,TOL,XYCDB,PNLD/OUDV1,OPNL1/  
*TRANRESP*//*DIRECT*//0/S,N,NOD/S,N,NOP/0 $  
127 COND LBL15,NOD $  
128 SDR3 OUDV1,OPNL1,,,./OUDV2,OPNL2,,, $  
129 OFP OUDV2,OPNL2,,,./S,N,CARDNO $  
130 XYTRAN XYCDB,OUDV2,OPNL2,,,./XYPLTTA/*TRAN*//*DSET*/S,N,PFIE/  
S,N,CARDNO $  
131 XYPLOT XYPLTTA// $  
132 LABEL LBL15 $  
133 PARAM ///*AND*/PJUMP/NOP/JUMPPLOT $  
134 COND LBL18,PJUMP $  
135 EQUIV UVT,UPV/NOA $  
136 COND LBL17,NOA $  
137 SDR1 USETD,,UVT,,,GOD,GMD,PST,KFS,,/UPV,,QP/1/*DYNAMICS* $  
138 LABEL LBL17 $  
139 SDR2 CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,TOL,QP,UPV,EST,XYCDB,  
PPT/OPP1,OQP1,OUPV1,OES1,OEF1,PUGV/*TRANRESP* $  
140 SDR3 OPP1,OQP1,OUPV1,OES1,OEF1,/OPP2,OQP2,OUPV2,OES2,OEF2, $
```

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```
141  OFF      OPP2,OQP2,OUPV2,OEF2,OES2,//S,N,CARDNO $  
142  SCAN     CASECC,OES2,OEF2/OESF2/*RF* $  
143  OFF      OESF2,,,//S,N,CARDNO $  
144  COND     P2,JUMPPLOT $  
145  PLOT     PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,GPECT,OES1/  
              PLOTX2/NS1/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $  
146  PRTMSG   PLOTX2// $  
147  LABEL    P2 $  
148  XYTRAN   XYCDB,OPP2,OQP2,OUPV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/  
              S,N,PFILE/S,N,CARDNO $  
149  XYPLOT   XYPLTT// $  
150  LABEL    LBL18 $  
151  COND     FINIS,REPEATT $  
152  REPT     LBL13,100 $  
153  PRTPARM  // -2/*DIRTRD* $  
154  JUMP     FINIS $  
155  LABEL    ERROR1 $  
156  PRTPARM  // -1/*DIRTRD* $  
157  LABEL    ERROR3 $  
158  PRTPARM  // -3/*DIRTRD* $  
159  LABEL    FINIS $  
160  PURGE   DUMMY/ALWAYS $  
161  END      $
```

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### 2.9.2 Description of Important DMAP Operations for Direct Transient Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
8. Go to DMAP No. 87 if there is only Direct Matrix Input.
9. GP2 generates Element Connection Table with internal indices.
12. Go to DMAP No. 20 if there are no structure plot requests.
13. PLTSET transforms user input into a form used to drive the structure plotter.
14. PRTMSG prints error messages associated with the structure plotter.
17. Go to DMAP No. 20 if no undeformed structure plots are requested.
18. PL0T generates all requested undeformed structure plots.
19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
21. GP3 generates Grid Point Temperature Table.
22. TA1 generates element tables for use in matrix assembly and stress recovery.
24. Go to DMAP No. 49 if there are no structural elements.
29. EMG generates structural element stiffness, mass, and damping matrix tables and dictionaries for later assembly by the EMA module.
31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.
32. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
34. Go to DMAP No. 36 if no mass matrix is to be assembled.
35. EMA assembles mass matrix  $[M_{gg}]$ .
37. Go to DMAP No. 39 if no viscous damping matrix is to be assembled.
38. EMA assembles viscous damping matrix  $[B_{gg}]$ .
40. Go to DMAP No. 42 if no structural damping matrix is to be assembled.
41. EMA assembles structural damping matrix  $[K_{gg}^4]$ .
45. Go to DMAP No. 49 if no weight and balance information is requested.
46. Go to DMAP No. 157 and print Error Message No. 3 if no mass matrix exists.
47. GPWG generates weight and balance information.
48. OFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
50. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
51. Go to DMAP No. 53 if there are no general elements.
52. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .

## DIRECT TRANSIENT RESPONSE

55. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
57. Go to DMAP No. 63 if general elements are present.
58. Go to DMAP No. 63 if there are no structural elements.
60. Go to DMAP No. 63 if no potential grid point singularities exist.
61. GPSP generates a table of potential grid point singularities.
62. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
64. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$ ,  $[M_{gg}]$  to  $[M_{nn}]$ ,  $[B_{gg}]$  to  $[B_{nn}]$  and  $[K_{gg}^4]$  to  $[K_{nn}^4]$  if no multipoint constraints exist.
65. Go to DMAP No. 68 if no multipoint constraints exist.
66. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m | R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
67. MCE2 partitions stiffness, mass and damping matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} & K_{nm} \\ K_{mn} & + & K_{mm} \\ K_{mn} & + & K_{mm} \end{bmatrix}, \quad [M_{gg}] = \begin{bmatrix} - & M_{nn} & M_{nm} \\ M_{mn} & + & M_{mm} \\ M_{mn} & + & M_{mm} \end{bmatrix}$$

$$[B_{gg}] = \begin{bmatrix} - & B_{nn} & B_{nm} \\ B_{mn} & + & B_{mm} \\ B_{mn} & + & B_{mm} \end{bmatrix} \text{ and } [K_{gg}^4] = \begin{bmatrix} - & K_{nn}^4 & K_{nm}^4 \\ K_{mn}^4 & + & K_{mm}^4 \\ K_{mn}^4 & + & K_{mm}^4 \end{bmatrix}$$

and performs matrix reductions

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}][G_m] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m],$$

$$[M_{nn}] = [M_{nn}] + [G_m^T][M_{mn}][G_m] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m],$$

$$[B_{nn}] = [B_{nn}] + [G_m^T][B_{mn}][G_m] + [B_{mn}^T][G_m] + [G_m^T][B_{mm}][G_m],$$

$$[K_{nn}^4] = [K_{nn}^4] + [G_m^T][K_{mn}^4][G_m] + [K_{mn}^4]^T[G_m] + [G_m^T][K_{mm}^4][G_m].$$

69. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$ ,  $[M_{nn}]$  to  $[M_{ff}]$ ,  $[B_{nn}]$  to  $[B_{ff}]$  and  $[K_{nn}^4]$  to  $[K_{ff}^4]$  if no single-point constraints exist.
70. Go to DMAP No. 72 if no single-point constraints exist.
71. SCE1 partitions out single-point constraints

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$$[K_{nn}] = \begin{bmatrix} K_{ff} & K_{fs} \\ K_{sf} & K_{ss} \end{bmatrix}, \quad [M_{nn}] = \begin{bmatrix} M_{ff} & M_{fs} \\ M_{sf} & M_{ss} \end{bmatrix},$$

$$[B_{nn}] = \begin{bmatrix} B_{ff} & B_{fs} \\ B_{sf} & B_{ss} \end{bmatrix} \text{ and } [K_{nn}^4] = \begin{bmatrix} K_{ff}^4 & K_{fs}^4 \\ K_{sf}^4 & K_{ss}^4 \end{bmatrix}.$$

- 73. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
- 74. Equivalence  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.
- 75. Equivalence  $[B_{ff}]$  to  $[B_{aa}]$  if no omitted coordinates exist.
- 76. Equivalence  $[K_{ff}^4]$  to  $[K_{aa}^4]$  if no omitted coordinates exist.
- 77. Go to DMAP No. 87 if no omitted coordinates exist.
- 78. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} & K_{ao} \\ K_{aa} & + & \\ K_{oa} & & K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}^1] = [K_{aa}] + [K_{ao}][G_o]$ .

- 79. Go to DMAP No. 81 if there is no mass matrix.
- 80. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} M_{aa} & M_{ao} \\ M_{oa} & M_{oo} \end{bmatrix},$$

and performs matrix reduction

$$[M_{aa}^1] = [M_{aa}] + [M_{ao}][G_o] + [M_{ao}G_o]^T + [G_o^T][M_{oo}][G_o].$$

- 82. Go to DMAP No. 84 if there is no viscous damping matrix.
- 83. SMP2 partitions constrained viscous damping matrix

$$[B_{ff}] = \begin{bmatrix} B_{aa} & B_{ao} \\ B_{oa} & B_{oo} \end{bmatrix},$$

and performs matrix reduction

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$$[B_{aa}^1] = [B_{aa}] + [B_{ao}][G_o] + [B_{ao}G_o]^T + [G_o^T][B_{oo}][G_o]$$

85. Go to DMAP No. 87 if there is no structural damping matrix.

86. SMP2 partitions constrained structural damping matrix.

$$[K_{ff}^4] = \begin{bmatrix} K_{aa}^4 & | & K_{ao}^4 \\ \hline K_{oa}^4 & | & K_{oo}^4 \end{bmatrix},$$

and performs matrix reduction

$$[K_{aa}^4] = [K_{aa}^4] + [K_{ao}^4][G_o] + [K_{ao}^4G_o]^T + [G_o^T][K_{oo}^4][G_o]$$

88. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFP00L), Dynamics Load Table (DLT), Nonlinear Function Table (NLFT), and Transient Response List (TRL).

89. Go to DMAP No. 63 if no potential grid point singularities exist.

91. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for dynamic analysis.

92. BMG generates DMIG card images describing the interconnection of the fluid and the structure.

95. Go to DMAP No. 97 if no fluid-structure interface is defined.

96. MTRXIN generates fluid boundary matrices  $[A_{b,f\ell}]$  and  $[K_{b,f\ell}]$  if a fluid-structure interface is defined. The matrix  $[K_{b,f\ell}]$  is generated only for a nonzero gravity in the field.

98. MTRXIN selects the direct input matrices  $[k_{pp}^{2d}]$ ,  $[M_{pp}^{2d}]$  and  $[B_{pp}^2]$ .

101. Equivalence  $[k_{pp}^2]$  to  $[k_{pp}^{2d}]$  if no fluid-structure interface is defined and equivalence  $[M_{pp}^2]$  to  $[M_{pp}^{2d}]$  if there is no  $[A_{b,f\ell}]$ .

102. Go to DMAP No. 107 if no fluid-structure interface is defined.

103. ADD5 adds  $[K_{b,f\ell}]$  and  $[k_{pp}^{2d}]$  and subtracts  $[A_{b,f\ell}]$  from them to form  $[K_{pp}^2]$ .

104. Go to DMAP No. 107 if there is no  $[A_{b,f\ell}]$ .

105. Transpose  $[A_{b,f\ell}]$  to obtain  $[A_{b,f\ell}]^T$ .

106. ADD assembles input matrix  $[M_{pp}^2] = MFACT [A_{b,f\ell}]^T + [M_{pp}^{2d}]$ .

112. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^2]$  if no constraints

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are applied,  $[M_{aa}]$  to  $[M_{dd}]$  if there are no direct input mass matrices and no extra points, and  $[K_{aa}]$  to  $[K_{dd}]$  if there are no direct input stiffness matrices and no extra points.

113. Go to DMAP No. 115 if only extra points are defined.
114. GKAD assembles stiffness, mass, and damping matrices for use in Direct Transient Response:

$$[K_{dd}] = [K_{dd}^1] + [K_{dd}^2],$$

$$[M_{dd}] = [M_{dd}^1] + [M_{dd}^2],$$

and  $[B_{dd}] = [B_{dd}^1] + [B_{dd}^2] + \frac{g}{\omega_3} [K_{dd}^1] + \frac{1}{\omega_4} [K_{dd}^4],$

where

$$\begin{bmatrix} K_{aa} & | & 0 \\ \hline 0 & | & 0 \end{bmatrix} \Rightarrow [K_{dd}^1],$$

$$\begin{bmatrix} M_{aa} & | & 0 \\ \hline 0 & | & 0 \end{bmatrix} \Rightarrow [M_{dd}^1],$$

$$\begin{bmatrix} B_{aa} & | & 0 \\ \hline 0 & | & 0 \end{bmatrix} \Rightarrow [B_{dd}^1],$$

and

$$\begin{bmatrix} K_{aa}^4 & | & 0 \\ \hline 0 & | & 0 \end{bmatrix} \Rightarrow [K_{dd}^4].$$

All matrices are real.

116. Equivalence  $[B_{dd}^2]$  to  $[B_{dd}]$  if all damping is Direct Matrix Input,  $[M_{dd}^2]$  to  $[M_{dd}]$  if all mass is Direct Matrix Input and  $[K_{dd}^2]$  to  $[K_{dd}]$  is all stiffness is Direct Matrix Input.
119. Beginning of loop for additional dynamic load sets.
121. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.
123. TRLG generates matrices of loads versus time.  $\{P_p^t\}$ ,  $\{P_s^t\}$ , and  $\{P_d^t\}$  are generated with one column per output time step.  $\{P_d\}$  is generated with one column per solution time step, and the Transient Output List (TOL) is a list of output time steps.
124. Equivalence  $\{P_p^t\}$  to  $\{P_d^t\}$  if the d and p sets are the same.

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125. TRD forms the linear,  $\{P_d\}$ , and nonlinear,  $\{P_d^{nl}\}$ , dynamic load vectors and integrates the equations of motion (using the standard or alternate starting procedure) over specified time periods to solve for the displacements, velocities, and accelerations, using the following equation

$$[M_{dd}p^2 + B_{dd}p + K_{dd}] \{u_d\} = \{P_d\} + \{P_d^{nl}\} .$$

126. VDR prepares displacements, velocities and accelerations, sorted by time step, for output using only the solution set degrees of freedom.
127. Go to DMAP No. 132 if there is no output request for the solution set.
128. SDR3 prepares the requested output of the solution set displacements, velocities, accelerations and nonlinear load vectors sorted by point number of element number.
129. ØFP formats the tables prepared by SDR3 sorted by point number or element number and places them on the system output file for printing.
130. XYTRAN prepares the input for requested X-Y plots of the solution set quantities.
131. XYPLØT prepares the requested X-Y plots of the solution set displacements, velocities, accelerations and nonlinear load vectors vs. time..
134. Go to DMAP No. 150 if no further output is requested.
135. Equivalence  $\{u_d\}$  to  $\{u_p\}$  if no constraints are applied.
136. Go to DMAP No. 138 if no constraints are applied.
137. SDR1 recovers dependent components of displacements

$$\begin{aligned} \{u_o\} &= [G_o^d]\{u_d\} , & \left\{ \frac{u_d}{u_o} \right\} &= \{u_f + u_e\} , \\ \left\{ \frac{u_f + u_e}{u_s} \right\} &= \{u_n + u_e\} , & \{u_m\} &= [G_m^d]\{u_f + u_e\} , \\ \left\{ \frac{u_n + u_e}{u_m} \right\} &= \{u_p\} \end{aligned}$$

and recovers single-point forces of constraint  $\{q_s\} = -\{P_s\} + [K_{fs}^T] \{u_f\}$ .

139. SDR2 calculates element forces ( $\{\bar{P}_{EF1}\}$ ) and stresses ( $\{\bar{P}_{ES1}\}$ ) and prepares load vectors ( $\{\bar{P}_{PP1}\}$ ), displacement, velocity and acceleration vectors ( $\{\bar{P}_{UPV1}\}$ ) and single-point forces of constraint ( $\{\bar{P}_{QP1}\}$ ) for output and translation components of the displacement vector (PUGV) sorted by time step.
140. SDR3 prepares requested output sorted by point number of element number.
141. ØFP formats the tables prepared by SDR3 for output sorted by point number of element number and places them on the system output file for printing.
142. SCAN examines the element stresses and forces calculated by SDR3 and generates scanned output that meets the specifications set by the user.

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143. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.
144. Go to DMAP No. 147 if no deformed structure plots are requested.
145. PLØT prepares all requested deformed structure and contour plots.
146. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
148. XYTRAN prepares the input for requested X-Y plots.
149. XYPLØT prepares the requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads and single-point forces of constraint versus time.
150. Go to DMAP No. 159 if no additional dynamic load sets need to be processed.
152. Go to DMAP No. 119 if additional dynamic load sets need to be processed.
153. Print Error Message No. 2 and terminate execution.
154. Go to DMAP No. 159 and make normal exit.
156. Print Error Message No. 1 and terminate execution.
158. Print Error Message No. 3 and terminate execution.

## DIRECT TRANSIENT RESPONSE

### 2.9.3 Output for Direct Transient Response

The following printed output, sorted by point number or element number (SORT2), is available at selected multiples of the integration time step:

1. Displacements, velocities, and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SOLUTION points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points.
3. Nonlinear force vector for a list of SOLUTION points.
4. Stresses and forces in selected elements (All not allowed).
5. Scanned output of forces and elements in selected elements.

The following plotter output is available:

1. Undeformed plot of the structural model.
2. Deformed shapes of the structural model for selected time intervals.
3. Contour plots of stresses and displacements for selected time intervals.
4. X-Y plot of any component of displacement, velocity, or acceleration of a PHYSICAL point or a SOLUTION point.
5. X-Y plot of any component of the applied load vector, nonlinear force vector, or single-point force of constraint.
6. X-Y plot of any stress or force component for an element.

The data used for preparing the X-Y plots may be punched or printed in tabular form (see Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

### 2.9.4 Case Control Deck for Direct Transient Response

The following items relate to subcase definition and data selection for Direct Transient Response:

1. One subcase must be defined for each dynamic loading condition.
2. DLØAD and/or NØNLINÆR must be used to define a time-dependent loading condition for each subcase.
3. All constraints must be defined above the subcase level.
4. TSTEP must be used to select the time-step intervals to be used for integration and output in each subcase.

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5. If nonzero initial conditions are desired, IC must be used to select a TIC card in the Bulk Data Deck.
6. On restart following an unscheduled exit due to insufficient time, the subcase structure should be changed to reflect any completed loading conditions. The TSTEP selections must be changed if it is desired to resume the integration at the point terminated.

### 2.9.5 Parameters for Direct Transient Response

The following parameters are used in Direct Transient Response:

1. ASETOUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTSPC - reserved for future optional use. The default value is -1.
3. COUPMASS - CPBAR, CPRD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. G - optional. The real value of this parameter is used as a uniform structural damping coefficient in the direct formulation of dynamics problems (see Section 9.3.3 of the Theoretical Manual). Not recommended for use in hydroelastic problems.
5. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
6. ISTART - optional. A positive value of this parameter causes the TRD module to use the second (or alternate) starting method (see Section 11.4 of the Theoretical Manual). The alternate starting method is recommended when initial accelerations are significant and when the mass matrix is non-singular. The default value is -1 and causes the first starting method to be used.
7. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in

## DIRECT TRANSIENT RESPONSE

- the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. W3 and W4 - optional. The real values (radians/unit time) of these parameters are used as pivotal frequencies for uniform structural damping and element structural damping, respectively (see Section 9.3.3 of the Theoretical Manual). Parameter W3 is required if uniform structural damping is desired. Parameter W4 is required if structural damping is desired for any of the structural elements. Parameter W3 should not be used for hydroelastic problems.
  10. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

### 2.9.6 The CONTINUE Feature

In transient analysis, it is frequently necessary to continue the integration of the coupled equations beyond the last (or from any earlier intermediate) output time for which the solution was obtained in a previous run. The CONTINUE feature (see Section 11.4.2 of the Theoretical Manual for details) makes it possible to do this without re-executing the entire problem.

In order to use the CONTINUE feature, the user should employ the following steps:

1. Request a checkpoint of a coupled transient analysis problem.
2. Check to ensure that the solution for at least one output time is computed in this run and that the TOL (list of output times) and UDVT (displacement - velocity - acceleration) files are successfully checkpointerd.
3. Restart the problem by changing any one or more of several cards either in the Case Control Deck (DLLOAD, NOLINEAR, TSTEP cards) and/or in the Bulk Data Deck (TSTEP, DAREA, DLLOAD, FORCE, etc.) that define either the dynamic loading and/or the time step selection. Ensure that the following conditions are satisfied.
  - a. The structural model and the constraint data for the restart must be the same as that used in the checkpoint run.
  - b. The dynamic loading and/or the time step selection in the restart need not be the same as that used in the checkpoint run.
  - c. If the user wishes to continue the integration from an intermediate (rather than from the last) output time of the checkpoint run, a DMAP alter should be employed in the Executive Control Deck to reset the parameter NCOL to the appropriate value by

## DISPLACEMENT RIGID FORMATS

means of a PARAM statement just before the TRLG module in the DMAP sequence. (See Section 11.4.2 of the Theoretical Manual for details).

4. Note that the output of the restart does not include the solutions of the checkpoint run, but only those solutions that are computed by the restart. Also, any initial conditions specified in the data for the restart are ignored since the solution is continued by using the displacements, velocities and accelerations corresponding to the specified output time of the checkpoint run as initial conditions.

### 2.9.7 Automatic ALTERs for Automated Multi-stage Substructuring

The following lines of the Direct Transient Response, Rigid Format 9, are ALTERed in automated substructure analyses.

Phase 1: 4, 56, 88-124, 125-153

Phase 2: 4, 5-5, 10-20, 23-24, 43-53, 109-110, 116-116, 135-149

Phase 3: 87, 92-136, 138, 151-153

If APP DISP, SUBS is used, the user may also specify ALTERs. However, these must not interfere with the automatically generated DMAP statement ALTERs listed above. See Volume I, Section 5.9 for a description and listing of the ALTERs which are automatically generated for substructuring.

### 2.9.8 Rigid Format Error Messages from Direct Transient Response

The following fatal errors are detected by the DMAP statements in the Direct Transient Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

DIRECT TRANSIENT RESPONSE ERROR MESSAGE NO. 1 - TRANSIENT RESPONSE LIST REQUIRED FOR TRANSIENT RESPONSE CALCULATIONS.

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

DIRECT TRANSIENT RESPONSE ERROR MESSAGE NO. 2 - ATTEMPT TO EXECUTE MORE THAN 100 LOOPS.

An attempt has been made to use more than 100 dynamic load sets. This number may be increased by ALTERing the REPT instruction following the last XYPLOT instruction.

DIRECT TRANSIENT RESPONSE ERROR MESSAGE NO. 3 - MASS MATRIX REQUIRED FOR WEIGHT AND BALANCE CALCULATON.S.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

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2.10 MODAL COMPLEX EIGENVALUE ANALYSIS

2.10.1 DMAP Sequence for Modal Complex Eigenvalue Analysis

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 10 - MODAL COMPLEX EIGENVALUE ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 FILE G0D=SAVE/GMD=SAVE/LAMA=APPEND/PHIA=APPEND $  
4 PARAM //*MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/MINUS1=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 GP2 GEOM2,EQEXIN/ECT $  
8 PARAML PCDB//*PRES*///JUMPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPLOT $  
10 COND P1,JUMPLOT $  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPLOT $  
12 PRTMSG PLTSETX// $  
13 PARAM //*MPY*/PLTFLG/1/1 $  
14 PARAM //*MPY*/PFILE/O/O $  
15 COND P1,JUMPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/JUMPLOT/PLTFLG/S,N,PFILE $  
17 PRTMSG PLOTX1// $  
18 LABEL P1 $  
19 GP3 GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $  
20 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
21 COND ERROR5,NOSIMP $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PURGE OGPST/GENEL $  
23 PARAM //*ADD*/NOKGGX/1/0 $  
24 PARAM //*ADD*/NOMGG/1/0 $  
25 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
26 PURGE KGGX,GPST/NOKGGX $  
27 COND JMPKGGX,NOKGGX $  
28 EMA GPECT,KDICT,KELM/KGGX,GPST $  
29 LABEL JMPKGGX $  
30 COND ERROR1,NOMGG $  
31 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
32 COND LGPWG,GRDPNT $  
33 GPWG BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
34 OFP OGPWG,,,,,/S,N,CARDNO $  
35 LABEL LGPWG $  
36 EQUIV KGGX,KGG/NOGENL $  
37 COND LBL11,NOGENL $  
38 SMA3 GE1,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
39 LABEL LBL11 $  
40 PARAM //*MPY*/NSKIP/0/0 $  
41 GP4 CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
42 PARAM //*AND*/NOSR/REACT/SINGLE $  
43 PURGE GM,GMD/MPCF1/G0,GOD/OMIT/KFS/SINGLE/QPC/NOSR/KLR,KRR,MLR,MRR,  
DM,MR/REACT $
```

MODAL COMPLEX EIGENVALUE ANALYSIS

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
44  COND    LBL4,GENEL $  
45  PARAM   //EQ*/GPSPFLG/AUTOSPC/0 $  
46  COND    LBL4,GPSPFLG $  
47  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
48  OFP     OGPST,,,./S,N,CARDNO $  
49  LABEL   LBL4 $  
50  EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1 $  
51  COND    LBL2,MPCF1 $  
52  MCE1    USET,RG/GM $  
53  MCE2    USET,GM,KGG,MGG,,/KNN,MNN,, $  
54  LABEL   LBL2 $  
55  EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE $  
56  COND    LBL3,SINGLE $  
57  SCE1    USET,KNN,MNN,,/KFF,KFS,,MFF,, $  
58  LABEL   LBL3 $  
59  EQUIV   KFF,KAA/OMIT $  
60  EQUIV   MFF,MAA/OMIT $  
61  COND    LBL5,OMIT $  
62  SMP1    USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $  
63  SMP2    USET,GO,MFF/MAA $  
64  LABEL   LBL5 $  
65  COND    LBL6,REACT $  
66  RBMG1   USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $  
67  RBMG2   KLL/LLL $  
68  RBMG3   LLL,KLR,KRR/DM $  
69  RBMG4   DM,MLL,MLR,MRR/MR $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
70  LABEL    LBL6 $  
71  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,EED,EQDYN/  
          LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/  
          NOFRL/NONLFT/NOTRL/S,N,NOEED//S,N,NOUE $  
72  COND     ERROR2,NOEED $  
73  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $  
74  PARAM    ///*MPY*/NEIGV/1/-1 $  
75  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,  
          NEIGV $  
76  OFP      OEIGS,,,//S,N,CARDNO $  
77  COND     ERROR4,NEIGV $  
78  OFP      LAMA,,,//S,N,CARDNO $  
79  PARAM    ///*ADD*/NEVER/1/0 $  
80  PARAM    ///*MPY*/REPEAT/E/1/-1 $  
81  LABEL    LBL13 $  
82  PURGE   PHIH,CLAMA,OPHIH,CPHID,CPHIP,QPC,OQPC1,OCPHIP,OESC1,OEFC1,  
          K2PP,M2PP,B2PP,K2DD,M2DD,B2DD/NEVER $  
83  CASE     CASEXX,/CASEXX/*CEIGN*/S,N,REPEAT/E/S,N,NOLOOP $  
84  MTRXIN  CASEXX,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,  
          NOK2PP/S,N,NOM2PP/S,N,NOB2PP $  
85  PURGE   K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $  
86  EQUIV    M2PP,M2DD/NOSET/B2PP,B2DD/NOSET/K2PP,K2DD/NOSET $  
87  GKAD     USETD,GM,GO,,,K2PP,M2PP,B2PP/,,GMD,GOD,K2DD,  
          M2DD,B2DD/*CMPELEV*//*DISP*//*MODAL*/O.O/  
          O.O/O.O/NOK2PP/NOM2PP/NOB2PP/  
          MPCF1/SINGLE/OMIT/NOUE/-1/-1/  
          -1/-1 $  
88  GKAM     USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASEXX/MHH,BHH,KHH,PHIDH/  
          NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/  
          NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE $  
89  CEAD     KHH,BHH,MHH,EED,CASEXX/PHIH,CLAMA,OCEIGS,/S,N,EIGVS $  
90  OFP      OCEIGS,,,//S,N,CARDNO $
```

MODAL COMPLEX EIGENVALUE ANALYSIS

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
91  COND      LBL17,EIGVS $  
92  OFP       CLAMA,,,,//S,N,CARDNO $  
93  VDR       CASEXX,EQDYN,USETD,PHIH,CLAMA,,OPHIH,*CEIGEN*/*MODAL*/  
          NOSORT2/S,N,NOH/S,N,NOP/FMODE $  
94  COND      LBL16,NOH $  
95  OFP       OPHIH,,,,//S,N,CARDNO $  
96  LABEL     LBL16 $  
97  COND      LBL17,NOP $  
98  DDR1      PHIH,PHIDH/CPHID $  
99  EQUIV    CPHID,CPHIP/NOA $  
100 COND     LBLNOA,NOA $  
101 SDR1      USETD,,CPHID,,,GOD,GMD,,KFS,,CPHIP,,QPC///*DYNAMICS* $  
102 LABEL     LBLNOA $  
103 SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,CLAMA,QPC,CPHIP,EST,,/  
          ,OQPC1,OCPHIP,OESC1,OEFC1, /*CEIGEN* $  
104 OFP       OCPHIP,OQPC1,OEFC1,OESC1,,//S,N,CARDNO $  
105 LABEL     LBL17 $  
106 COND      FINIS,REPEAT $  
107 REPT     LBL13,100 $  
108 PRTPARM   //-*MDLCEAD* $  
109 JUMP      FINIS $  
110 LABEL     ERROR2 $  
111 PRTPARM   //-*MDLCEAD* $  
112 LABEL     ERROR1 $  
113 PRTPARM   //-*MDLCEAD* $  
114 LABEL     ERROR4 $  
115 PRTPARM   //-*MDLCEAD* $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
116 LABEL    ERROR5 $  
117 PRTPARM //--5/*MDLCEAD* $  
118 LABEL    FINIS $  
119 PURGE   DUMMY/MINUS1 $  
120 END      $
```

## MODAL COMPLEX EIGENVALUE ANALYSIS

### 2.10.2 Description of Important DMAP Operations for Modal Complex Eigenvalue Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Grid Point Temperature Table.
20. TA1 generates element tables for use in matrix assembly and stress recovery.
21. Go to DMAP No. 116 and print Error Message No. 5 if there are no structural elements.
25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 112 and print Error Message No. 1 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
32. Go to DMAP No. 35 if no weight and balance information is requested.
33. GPWG generates weight and balance information.
34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
36. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if no general elements exist.
37. Go to DMAP No. 39 if no general elements exist.
38. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
44. Go to DMAP No. 49 if general elements are present.
46. Go to DMAP No. 49 if no potential grid point singularities exist.
47. GPSP generates a table of potential grid point singularities.
48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

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50. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
51. Go to DMAP No. 54 if no multipoint constraints exist.
52. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \quad R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} \\ \frac{K_{nn}}{K_{mn}} + \frac{K_{nm}}{K_{mm}} & \end{bmatrix} \quad \text{and} \quad [M_{gg}] = \begin{bmatrix} - & M_{nn} \\ \frac{M_{nn}}{M_{mn}} + \frac{M_{nm}}{M_{mm}} & \end{bmatrix}$$

and performs matrix reductions

$$\begin{aligned} [K_{nn}] &= [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and} \\ [M_{nn}] &= [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] . \end{aligned}$$

55. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.
56. Go to DMAP No. 58 if no single-point constraints exist.
57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & K_{fs} \\ \frac{K_{sf}}{K_{ss}} + \frac{K_{ss}}{K_{ff}} & \end{bmatrix} \quad \text{and} \quad [M_{nn}] = \begin{bmatrix} M_{ff} & M_{fs} \\ \frac{M_{sf}}{M_{ss}} + \frac{M_{ss}}{M_{ff}} & \end{bmatrix} .$$

59. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
60. Equivalence  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.
61. Go to DMAP No. 64 if no omitted coordinates exist.
62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} & K_{ao} \\ \frac{K_{aa}}{K_{oa}} + \frac{K_{ao}}{K_{oo}} & \end{bmatrix} ,$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$  .

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} - & M_{aa} & M_{ao} \\ \frac{M_{aa}}{M_{oa}} + \frac{M_{ao}}{M_{oo}} & \end{bmatrix}$$

# MODAL COMPLEX EIGENVALUE ANALYSIS

and performs matrix reduction

$$[M_{aa}] = [M_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. Go to DMAP No. 70 if there are no free-body supports.

66. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & | & K_{\ell r} \\ \hline K_{r\ell} & | & K_{rr} \end{bmatrix} \quad \text{and} \quad [M_{aa}] = \begin{bmatrix} M_{\ell\ell} & | & M_{\ell r} \\ \hline M_{r\ell} & | & M_{rr} \end{bmatrix} .$$

67. RBMG2 decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

68. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|}$$

69. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

71. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFP00L), and Eigenvalue Extraction Data (EED).

72. Go to DMAP No. 110 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

73. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for

dynamic analysis.

75. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 ,$$

calculates rigid body modes by finding a square matrix  $[\phi_{ro}]$  such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} D & \phi_{ro} \\ \hline \phi_{ro} & \phi_{ro} \end{bmatrix} ,$$

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calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit value of a selected component
- 2) Unit value of the largest component
- 3) Unit value of the generalized mass.

76. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.
77. Go to DMAP No. 114 and print Error Message No. 4 if no eigenvalues were found.
78. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.
81. Beginning of loop for additional sets of direct input matrices.
83. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.
84. MTRXIN selects the direct input matrices for the current loop,  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ .
86. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^2]$  if no constraints are applied.
87. GKAD applies constraints to direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ , forming  $[K_{dd}^2]$ ,  $[M_{dd}^2]$  and  $[B_{dd}^2]$ .
88. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Complex Eigenvalue Analysis:

$$[K_{hh}] = [k] + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}] ,$$

$$[M_{hh}] = [m] + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}]$$

$$\text{and } [B_{hh}] = [b] + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}] ,$$

where  $m_i$  = modal masses ,

$$b_i = m_i 2\pi f_i g(f_i)$$

$$\text{and } k_i = m_i 4\pi^2 f_i^2 .$$

Direct input matrices may be complex.

89. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M_{hh}p^2 + B_{hh}p + K_{hh}] \{u_h\} = 0$$

and normalizes eigenvectors according to one of the following user requests:

## MODAL COMPLEX EIGENVALUE ANALYSIS

- 1) Unit magnitude of a selected component
- 2) Unit magnitude of the largest component.
90. ØFP formats the summary of eigenvalue extraction information (ØCEIGS) prepared by CEAD and places it on the system output file for printing.
91. Go to DMAP No. 105 if no complex eigenvalues were found.
92. ØFP formats the complex eigenvalues (CLAMA) prepared by CEAD and places them on the system output file for printing.
93. VDR prepares eigenvectors (ØPHIH) for output, using only the extra points introduced for dynamic analysis and modal coordinates.
94. Go to DMAP No. 96 if there is no output request for the extra points introduced for dynamic analysis or modal coordinates.
95. ØFP formats the table of eigenvectors for extra points introduced for dynamic analysis and modal coordinates prepared by VDR and places it on the system output file for printing.
97. Go to DMAP No. 105 if there is no output request involving dependent degrees of freedom or forces and stresses.
98. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$[\phi_d] = [\phi_{dh}][\phi_h].$$

99. Equivalence  $[\phi_d]$  to  $[\phi_p]$  if no constraints are applied.

100. Go to DMAP No. 102 if no constraints are applied.

101. SDR1 recovers dependent components of eigenvectors

$$\{\phi_0\} = [G_0^\phi]\{\phi_d\}, \quad \left\{ \frac{\phi_d}{\phi_0} \right\} = \{\phi_f + \phi_e\},$$

$$\left\{ \frac{\phi_f + \phi_e}{\phi_s} \right\} = \{\phi_n + \phi_e\}, \quad \{\phi_m\} = [G_m^d]\{\phi_n + \phi_e\},$$

$$\left\{ \frac{\phi_n + \phi_e}{\phi_m} \right\} = \{\phi_p\}$$

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}^T]\{\phi_f\}$ .

103. SDR2 calculates element forces (ØEFC1) and stresses (ØESC1) and prepares eigenvectors (ØCPHIP) and single-point forces of constraint (ØQPC1) for output.
104. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.
106. Go to DMAP No. 118 and make normal exit if no additional sets of direct input matrices need to be processed.
107. Go to DMAP No. 81 if additional sets of direct input matrices need to be processed.
108. Print Error Message No. 3 and terminate execution.

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109. Got to DMAP No. 118 and make normal exit.
111. Print Error Message No. 2 and terminate execution.
113. Print Error Message No. 1 and terminate execution.
115. Print Error Message No. 4 and terminate execution.
117. Print Error Message No. 5 and terminate execution.

## MODAL COMPLEX EIGENVALUE ANALYSIS

### 2.10.3 Output for Modal Complex Eigenvalue Analysis

The real Eigenvalue Summary Table and the real Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

The complex Eigenvalue Summary Table and the complex Eigenvalue Analysis Summary, as described under Direct Complex Eigenvalue Analysis (see Section 2.7.3), are automatically printed for each set of direct input matrices.

Output that may be requested is the same as that described under Direct Complex Eigenvalue Analysis. Output for **SOLUTION** points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the **SOLUTION** points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Modes Analysis Rigid Format or by making a modified restart using the Normal Modes Analysis rigid format.

### 2.10.4 Case Control Deck for Modal Complex Eigenvalue Analysis

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Complex Eigenvalue Analysis:

1. **METHOD** must appear above the subcase level to select an **EIGR** card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An **SPC** set must be selected above the subcase level unless the model is a free body or all constraints are specified on **GRID** cards, Scalar Connection cards or with General Elements.
4. **SDAMPING** must be used to select a **TABDMP1** table if structural damping is desired.

### 2.10.5 Parameters for Modal Complex Eigenvalue Analysis

The following parameters are used in Modal Complex Eigenvalue Analysis:

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1. ASET $\emptyset$ UT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT $\emptyset$ SPC - reserved for future optional use. The default value is -1.
3. COUPMASS - CPBAR, CPR $\emptyset$ D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. LFREQ and HFREQ - required, unless parameter LM $\emptyset$ DES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LM $\emptyset$ DES must be set to 0.
6. LM $\emptyset$ ODES - required, unless parameters LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
7. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
8. V $\emptyset$ LUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

### 2.10.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

2.10.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Complex Eigenvalue Analysis. See Section 2.3.7 for details.

2.10.8 Rigid Format Error Messages from Modal Complex Eigenvalue Analysis

The following fatal errors are detected by the DMAP statements in the Modal Complex Eigenvalue Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATØRN.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØOPS.

An attempt has been made to use more than 100 different sets of direct input matrices. This number can be increased by ALTERing the REPT instruction following the last ØFP instruction.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATØRN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL CØMPLEX EIGENVALUE ANALYSIS ERRØR MESSAGE NØ. 5 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

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2.11 MODAL FREQUENCY AND RANDOM RESPONSE

2.11.1 DMAP Sequence for Modal Frequency and Random Response

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OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 11 - MODAL FREQUENCY/RANDOM RESPONSE ANALYSIS-APR. 1986 $  
2 PRECHK ALL $  
3 FILE GOD=SAVE/GMD=SAVE/LAMA=APPEND/PHIA=APPEND $  
4 PARAM //*MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/MINUS1=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 GP2 GEOM2,EQEXIN/ECT $  
8 PARAML PCDB//*PRES*///JUMPPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
10 COND P1,JUMPPLOT $  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
12 PRTMSG PLTSETX// $  
13 PARAM //*MPY*/PLTFLG/1/1 $  
14 PARAM //*MPY*/PFILE/O/O $  
15 COND P1,JUMPPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT.,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
17 PRTMSG PLOTX1// $  
18 LABEL P1 $  
19 GP3 GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $  
20 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
21 COND ERROR7,NOSIMP $
```

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```
22 PURGE OGPST/GENEL $  
23 PARAM ///*ADD*/NOKGGX/1/0 $  
24 PARAM ///*ADD*/NOMGG/1/0 $  
25 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIAL/C,Y,CPTRIAL2/  
C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
26 PURGE KGGX,GPST/NOKGGX $  
27 COND JMPKGGX,NOKGGX $  
28 EMA GPECT,KDICT,KELM/KGGX,GPST $  
29 LABEL JMPKGGX $  
30 COND ERROR1,NOMGG $  
31 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
32 COND LGPWG,GRDPNT $  
33 GPWG BGPD,CSYM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
34 OFF OGPWG,,,,,/S,N,CARDNO $  
35 LABEL LGPWG $  
36 EQUIV KGGX,KGG/NOGENL $  
37 COND LBL11,NOGENL $  
38 SMA3 GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
39 LABEL LBL11 $  
40 PARAM ///*MPY*/NSKIP/0/0 $  
41 GP4 CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSYM,GPST/RG,,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
42 PARAM ///*AND*/NOSR/REACT/SINGLE $  
43 PURGE GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PSF/SINGLE/QPC/NOSR/KLR,KRR,MLR,  
MRR,DM,MR/REACT/MDD/MODACC $
```

MODAL FREQUENCY AND RANDOM RESPONSE

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```
44  COND    LBL4,GENEL $  
45  PARAM   //EQ*/GPSPFLG/AUTOSPC/O $  
46  COND    LBL4,GPSPFLG $  
47  GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
48  OFFP   OGPST,,,//S,N,CARDNO $  
49  LABEL   LBL4 $  
50  EQUIV  KGG,KNN/MPCF1/MGG,MNN/MPCF1 $  
51  COND    LBL2,MPCF1 $  
52  MCE1    USET,RG/GM $  
53  MCE2    USET,GM,KGG,MGG,,/KNN,MNN,, $  
54  LABEL   LBL2 $  
55  EQUIV  KNN,KFF/SINGLE/MNN,MFF/SINGLE $  
56  COND    LBL3,SINGLE $  
57  SCE1    USET,KNN,MNN,,/KFF,KFS,,MFF,, $  
58  LABEL   LBL3 $  
59  EQUIV  KFF,KAA/OMIT $  
60  EQUIV  MFF,MAA/OMIT $  
61  COND    LBL5,OMIT $  
62  SMP1    USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $  
63  SMP2    USET,GO,MFF/MAA $  
64  LABEL   LBL5 $  
65  EQUIV  KAA,KLL/REACT $  
66  COND    LBL6,REACT $  
67  RBMG1   USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $  
68  JUMP   LBL8 $  
69  LABEL   LBL6 $
```

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```
70  COND      LBL7,MODACC $  
71  LABEL     LBL8 $  
72  RBMG2     KLL/LLL $  
73  COND      LBL7,REACT $  
74  RBMG3     LLL,KLR,KRR/DM $  
75  RBMG4     DM,MLL,MLR,MRR/MR $  
76  LABEL     LBL7 $  
77  DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,,  
           EED,EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/S,N,NOPSDL/  
           S,N,NOFRL/NONLFT/NOTRL/S,N,NOEED//S,N,NOUE $  
78  COND      ERROR2,NOEED $  
79  PURGE    UEVF/NOUE $  
80  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $  
81  PARAM    //*MPY*/NEIGV/1/-1 $  
82  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,  
           NEIGV $  
83  OFP      OEIGS,,,,//S,N,CARDNO $  
84  COND      ERROR4,NEIGV $  
85  OFP      LAMA,,,,//S,N,CARDNO $  
86  PARAM    //*ADD*/NEVER/1/0 $  
87  PARAM    //*MPY*/REPEATF/1/-1 $  
88  LABEL     LBL13 $  
89  PURGE    OUHVC1,OUHVC2,XYPLTFA,OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,OPPC2,  
           OQPC2,OUPVC2,OESC2,OEFC2,XYPLTF,PSDF,AUTO,XYPLTR,K2PP,M2PP,  
           B2PP,K2DD,M2DD,B2DD,OPPCA,IQP1,IPHIP1,IES1,IEF1,OPPCB,IQP2,  
           IPHIP2,IES2,IEF2,ZQPC2,ZUPVC2,ZESC2,ZEFC2,ZQPC1,ZUPVC1,ZESC1,  
           ZEFC1/NEVER $  
90  CASE     CASECC,PSDL/CASEXX/*FREQ*/S,N,REPEATF/S,N,NOLOOP $  
91  MTRXIN   CASEXX,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,  
           NOK2PP/S,N,NOM2PP/S,N,NOB2PP $
```

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```
92 PURGE K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $
93 PARAM ///*AND*//MDEMA/NOUE/NOM2PP $
94 EQUIV M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA $
95 GKAD USETD,GM,GO,,,MAA,,K2PP,M2PP,B2PP/,,MDD,GMD,
      GOD,K2DD,M2DD,B2DD/*FREQRESP*//*DISP*//*MODAL*//0.0/
      0.0/0.0/NOK2PP/NOM2PP/NOB2PP/
      MPCF1/SINGLE/OMIT/NOUE/-1/-1/
      1/V,Y,MODACC = -1 $
96 GKAM USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASEXX/MHH,BHH,KHH,PHIDH/
      NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/
      NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE $
97 COND ERROR5,NOFRL $
98 COND ERROR6,NODLT $
99 FRRD CASEXX,USETD,DLT,FRL,GMD,GOD,KHH,BHH,MHH,PHIDH,DIT/UHVF,PSF,
      PDF,PPF/*DISP*//*MODAL*//LUSSETD/MPCF1/SINGLE/
      OMIT/NONCUP/S,N,FRQSET $
100 EQUIV PPF,PDF/NOSET $
101 VDR CASEXX,EQDYN,USETD,UHVF,PPF,XYCDB,/OUHVC1,/*FREQRESP*/
      /*MODAL*//S,N,NOSORT2/S,N,NOH/S,N,NOP/FMODE $
102 COND LBL16,NOH $
103 COND LBL16A,NOSORT2 $
104 SDR3 OUHVC1,,,,,/OUHVC2,,,,,$
105 OFP OUHVC2,,,,//S,N,CARDNO $
106 XYTRAN XYCDB,OUHVC2,,,,/XYPLTFA/*FREQ*//*HSET*//S,N,PFILE/
      S,N,CARDNO $
107 XYPLOT XYPLTFA // $
108 JUMP LBL16 $
109 LABEL LBL16A $
110 OFP OUHVC1,,,,//S,N,CARDNO $
111 LABEL LBL16 $
112 COND LBL14,NOP $
```

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```
113 PARAM ///*NOT*//NOMOD/V,Y,MODACC $  
114 COND LBDDRM,MODACC $  
115 DDR1 UHVF,PHIDH/UDV1F $  
116 DDR2 USETD,UDV1F,PDF,K2DD,B2DD,MDD,PPF,LLL,DM/UDV2F,UEVF,PAF/  
*FREQRESP*/NOUE/REACT/FRQSET $  
117 EQUIV UDV2F,UDV1F/NOMOD $  
118 EQUIV UDV1F,UPVC/NOA $  
119 COND LBLNOA,NOA $  
120 SDR1 USETD,,UDV1F,,,GOD,GMD,PSF,KFS,,/UPVC,,QPC/1/*DYNAMICS* $  
121 LABEL LBLNOA $  
122 SDR2 CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,PPF,QPC,UPVC,EST,  
XYCDB,PPF/OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,PUGV/*FREQ*/  
S,N,NOSORT2 $  
123 COND LBL18,NOSORT2 $  
124 SDR3 OPPC1,OQPC1,OUPVC1,OESC1,OEFC1,/OPPC2,OQPC2,OUPVC2,OESC2,  
OEFC2, $  
125 JUMP P2A $  
126 LABEL LBDDRM $  
127 SDR1 USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIPH,,QPH/1/*DYNAMICS* $  
128 SDR2 CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,LAMA,QPH,PHIPH,EST,XYCDB,/br  
IQP1,IPHIP1,IES1,IEF1,/MMREIG*/S,N,NOSORT2 $  
129 SDR2 CASEXX,,,EQDYN,SILD,,,PPF,,,XYCDB,PPF/OPPCA,,,,/*FREQ* $  
130 EQUIV OPPCA,OPPC1/MODACC $  
131 COND LBLSORT,NOSORT2 $  
132 SDR3 IQP1,IPHIP1,IES1,IEF1,OPPCA,/IQP2,IPHIP2,IES2,IEF2,OPPCB, $  
133 EQUIV OPPCB,OPPC2/MODACC $  
134 DDRMM CASEXX,UHVF,PPF,IPHIP2,IQP2,IES2,IEF2,XYCDB,EST,MPT,DIT/  
ZUPVC2,ZQPC2,ZESC2,ZEFC2, $  
135 EQUIV ZUPVC2,OUPVC2/MODACC/ZQPC2,OQPC2/MODACC/ZESC2,OESC2/MODACC/  
ZEFC2,OEFC2/MODACC $
```

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```
136 JUMP    P2A $  
137 LABEL   LBLSORT $  
138 DDRMM   CASEXX,UHVF,PPF,IPHIP1,IQP1,IES1,IEF1,,EST,MPT,DIT/  
ZUPVC1,ZQPC1,ZESC1,ZEFC1,$  
139 EQUIV   ZUPVC1,OUPVC1/MODACC/ZQPC1,OQPC1/MODACC/ZESC1,OESC1/MODACC/  
ZEFC1,OEFC1/MODACC $  
140 JUMP    LBL18 $  
141 LABEL   P2A $  
142 OFP     OPPC2,OQPC2,OUPVC2,OEFC2,OESC2,//S,N,CARDNO $  
143 XYTRAN  XYCDB,OPPC2,OQPC2,OUPVC2,OESC2,OEFC2/XYPLTF/*FREQ*//*PSET*/  
S,N,PFILE/S,N,CARDNO $  
144 XYPLOT  XYPLTF// $  
145 COND    LBL21,JUMPPLOT $  
146 PLOT    PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,,/  
PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $  
147 PRTMSG  PLOTX2// $  
148 LABEL   LBL21 $  
149 COND    LBL14,NOPSDL $  
150 RANDOM  XYCDB,DIT,PSDL,OUPVC2,OPPC2,OQPC2,OESC2,OEFC2,CASEXX/PSDF,AUTO/  
S,N,NORD $  
151 COND    LBL14,NORD $  
152 XYTRAN  XYCDB,PSDF,AUTO,,,XYPLTR/*RAND*//*PSET*/S,N,PFILE/  
S,N,CARDNO $  
153 XYPLOT  XYPLTR// $  
154 JUMP    LBL14 $  
155 LABEL   LBL18 $  
156 OFP     OUPVC1,OPPC1,OQPC1,OEFC1,OESC1,//S,N,CARDNO $  
157 LABEL   LBL14 $  
158 COND    FINIS,REPEATF $
```

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```
159 REPT     LBL13,100 $  
160 PRTPARM  //-*MDLFRRD* $  
161 JUMP     FINIS $  
162 LABEL    ERROR2 $  
163 PRTPARM  //-*MDLFRRD* $  
164 LABEL    ERROR1 $  
165 PRTPARM  //-*MDLFRRD* $  
166 LABEL    ERROR4 $  
167 PRTPARM  //-*MDLFRRD* $  
168 LABEL    ERROR5 $  
169 PRTPARM  //-*MDLFRRD* $  
170 LABEL    ERROR6 $  
171 PRTPARM  //-*MDLFRRD* $  
172 LABEL    ERROR7 $  
173 PRTPARM  //-*MDLFRRD* $  
174 LABEL    FINIS $  
175 PURGE   DUMMY/MINUS1 $  
176 END     $
```

## MODAL FREQUENCY AND RANDOM RESPONSE

### 2.11.2 Description of Important DMAP Operations for Modal Frequency and Random Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Grid Point Temperature Table.
20. TA1 generates element tables for use in matrix assembly and stress recovery.
21. Go to DMAP No. 172 and print Error Message No. 7 if there are no structural elements.
25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 164 and print Error Message No. 1 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
32. Go to DMAP No. 35 if no weight and balance information is requested.
33. GPWG generates weight and balance information.
34. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
36. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if no general elements exist.
37. Go to DMAP No. 39 if no general elements exist.
38. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
44. Go to DMAP No. 49 if general elements are present.
46. Go to DMAP No. 49 if no potential grid point singularities exist.
47. GPSP generates a table of potential grid point singularities.
48. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

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50. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
51. Go to DMAP No. 54 if no multipoint constraints exist.
52. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} \mid K_{nm} \\ K_{mn} \mid K_{mm} & \end{bmatrix} \quad \text{and} \quad [M_{gg}] = \begin{bmatrix} - & M_{nn} \mid M_{nm} \\ M_{mn} \mid M_{mm} & \end{bmatrix}$$

and performs matrix reductions

$$\begin{aligned} [K_{nn}] &= [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and} \\ [M_{nn}] &= [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] . \end{aligned}$$

55. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.
56. Go to DMAP No. 58 if no single-point constraints exist.
57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} \mid K_{fs} \\ K_{sf} \mid K_{ss} \end{bmatrix} \quad \text{and} \quad [M_{nn}] = \begin{bmatrix} M_{ff} \mid M_{fs} \\ M_{sf} \mid M_{ss} \end{bmatrix} .$$

59. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
60. Equivalence  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.
61. Go to DMAP No. 64 if no omitted coordinates exist.
62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} \mid K_{ao} \\ K_{oa} \mid K_{oo} & \end{bmatrix} ,$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$  .

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} - & M_{aa} \mid M_{ao} \\ M_{oa} \mid M_{oo} & \end{bmatrix}$$

## MODAL FREQUENCY AND RANDOM RESPONSE

and performs matrix reduction

$$[M_{aa}] = [M_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. Equivalence  $[K_{aa}]$  to  $[K_{\ell\ell}]$  if no free-body supports exist.

66. Go to DMAP No. 69 if no free-body supports exist.

67. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix} \text{ and } [M_{aa}] = \begin{bmatrix} M_{\ell\ell} & M_{\ell r} \\ M_{r\ell} & M_{rr} \end{bmatrix} .$$

68. Go to DMAP No. 71.

70. Go to DMAP No. 76 if there is no request for mode acceleration data recovery.

72. RBMG2 decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

73. Go to DMAP No. 76 if no free-body supports exist.

74. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|} .$$

75. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

77. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFP00L), Dynamic Loads Table (DLT), Power Spectral Density List (PSDL), Frequency Response List (FRL), and Eigenvalue Extraction Data (EED).

78. Go to DMAP No. 162 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

80. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for dynamic analysis.

82. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 ,$$

calculates rigid body modes by finding a square matrix  $[\phi_{r0}]$  such that

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$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} D\phi_{ro} \\ \phi_{ro} \end{bmatrix},$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit value of a selected component
  - 2) Unit value of the largest component
  - 3) Unit value of the generalized mass.
83. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.
84. Go to DMAP No. 166 and print Error Message No. 4 if no eigenvalues were found.
85. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.
88. Beginning of loop for additional sets of direct input matrices.
90. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.
91. MTRXIN selects the direct input matrices for the current loop,  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ .
94. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^2]$  if no constraints are applied, and  $[M_{aa}]$  to  $[M_{dd}]$  if there are no direct input mass matrices and no extra points introduced for dynamic analysis.
95. GKAD applies constraints to direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ , forming  $[K_{dd}^2]$ ,  $[M_{dd}^2]$  and  $[B_{dd}^2]$ .
96. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Frequency Response:

$$[K_{hh}] = [k] + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}],$$

$$[M_{hh}] = [m] + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}]$$

$$\text{and } [B_{hh}] = [b] + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}],$$

where  $m_i$  = modal masses ,

$$b_i = m_i 2\pi f_i g(f_i)$$

## MODAL FREQUENCY AND RANDOM RESPONSE

$$\text{and } k_i = m_i 4\pi^2 f_i^2 .$$

Direct input matrices may be complex.

97. Go to DMAP No. 168 and print Error Message No. 5 if there is no Frequency Response List.

98. Go to DMAP No. 170 and print Error Message No. 6 if there is no Dynamic Loads Table.

99. FRRD forms the dynamic load vectors  $\{P_h\}$  and solves for the displacements using the following equation

$$[-M_{hh}\omega^2 + iB_{hh}\omega + K_{hh}]\{u_h\} = \{P_h\}.$$

100. Equivalence  $\{P_p\}$  to  $\{P_d\}$  if no constraints are applied.

101. VDR prepares displacements ( $\emptyset UHVC1$ ), sorted by frequency, for output using only the extra points introduced for dynamic analysis and modal coordinates (solution points).

102. Go to DMAP No. 111 if there is no output request for solution points.

103. Go to DMAP No. 109 if there is no output request for solution points sorted by extra point or mode number.

104. SDR3 sorts the solution point displacements by extra point or mode number.

105. ØFP formats the requested solution point displacements prepared by SDR3 and places them on the system output file for printing.

106. XYTRAN prepares the input for requested X-Y plots of the solution point displacements vs. frequency.

107. XYPLØT prepares the requested X-Y plots of the solution point displacements vs. frequency.

108. Go to DMAP No. 111.

110. ØFP formats the requested solution point displacements prepared by VDR and places them on the system output file for printing.

112. Go to DMAP No. 157 if there is no output request involving dependent degrees of freedom or forces and stresses.

114. Go to DMAP No. 126 if the mode acceleration technique is not requested.

115. DDR1 transforms the solution vector of displacements from modal to physical coordinates

$$\{u_d\} = [\phi_{dh}]\{u_h\} .$$

116. DDR2 calculates an improved displacement vector using the mode acceleration technique.

117. Equivalence  $\{u_d\}$  to the improved displacement vector. (Flag NØMØD is negative since the mode acceleration technique is requested).

118. Equivalence  $\{u_d\}$  to  $\{u_p\}$  if no constraints are applied.

119. Go to DMAP No. 121 if no constraints are applied.

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120. SDR1 recovers dependent components of displacements

$$\begin{aligned}\{u_o\} &= [G_o^d]\{u_a\} \quad , \quad \left\{ \frac{u_d}{u_o} \right\} = \{u_f + u_e\} \quad , \\ \left\{ \frac{u_f + u_e}{u_s} \right\} &= \{u_n + u_e\} \quad , \quad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad , \\ \left\{ \frac{u_n + u_e}{u_m} \right\} &= \{u_p\}\end{aligned}$$

and recovers single-point forces of constraint  $\{q_s\} = -\{P_s\} + [K_{fs}^T] \{u_f\}$ .

122. SDR2 calculates element forces ( $\emptyset EFC1$ ) and stresses ( $\emptyset ESC1$ ) and prepares load vectors ( $\emptyset PPC1$ ), displacement vectors ( $\emptyset UPVC1$ ) and single-point forces of constraint ( $\emptyset QPC1$ ) for output and translation components of the displacement vector (PUGV), sorted by frequency.
123. Go to DMAP No. 155 if there are no requests for output sorted by point number or element number.
124. SDR3 prepares the requested output sorted by point number of element number.
125. Go to DMAP No. 141.
127. SDR1 recovers dependent components of eigenvectors

$$\begin{aligned}\{\phi_o\} &= [G_o^d]\{\phi_n\} \quad , \quad \left\{ \frac{\phi_n}{\phi_o} \right\} = \{\phi_f + u_e\} \quad , \\ \left\{ \frac{\phi_f + u_e}{\phi_s} \right\} &= \{\phi_n + u_e\} \quad , \quad \{\phi_m\} = [G_m^d]\{\phi_n + u_e\} \quad , \\ \left\{ \frac{\phi_n + u_e}{\phi_m} \right\} &= \{\phi_g + u_e\} = \{\phi_p\}\end{aligned}$$

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}]^T \{\phi_f\}$ .

128. SDR2 calculates element forces (IEF1) and stresses (IES1) and prepares eigenvectors (IPHIP1) and single-point forces of constraint (IQP1) for output sorted by frequency.
129. SDR2 prepares load vectors for output ( $\emptyset PPCA$ ) sorted by frequency.
130. Equivalence  $\emptyset PPCA$  to  $\emptyset PPC1$ . (Flag M0DACC is negative since the mode acceleration technique is not requested).
131. Go to DMAP No. 137 if there are no requests for output sorted by point number or element number.
132. SDR3 prepares the requested output sorted by point number or element number.

## MODAL FREQUENCY AND RANDOM RESPONSE

133. Equivalence  $\emptyset$ PPCB to  $\emptyset$ PPC2. (Flag M $\emptyset$ DACC is negative since the mode acceleration technique is not requested).
134. DDRMM prepares a subset of the element forces (ZEFC2) and stresses (ZESC2), and displacement vectors (ZUPVC2) and single-point forces of constraint (ZQPC2) for output sorted by point number or element number.
135. Equivalence ZUPVC2 to  $\emptyset$ UPVC2, ZQPC2 to  $\emptyset$ QPC2, ZESC2 to  $\emptyset$ ESC2, and ZEFC2 to  $\emptyset$ EFC2. (Flag M $\emptyset$ DACC is negative since the mode acceleration technique is not requested).
136. Go to DMAP No. 141.
138. DDRMM prepares a subset of the element forces (ZEFC1) and stresses (ZESC1), and displacement vectors (ZUPVC1) and single-point forces of constraint (ZQPC1) for output sorted by frequency.
139. Equivalence ZUPVC1 to  $\emptyset$ UPVC1, ZQPC1 to  $\emptyset$ QPC1, ZESC1 to  $\emptyset$ ESC1, and ZEFC1 to  $\emptyset$ EFC1. (Flag M $\emptyset$ DACC is negative since the mode acceleration technique is not requested).
140. Go to DMAP No. 155.
142.  $\emptyset$ FP formats the requested output prepared by SDR3 (with mode acceleration) or DDRMM (no mode acceleration) and places it on the system output file for printing.
143. XYTRAN prepares the input for requested X-Y plots.
144. XYPL $\emptyset$ T prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of constraint vs. frequency.
145. Go to DMAP No. 148 if no deformed structure plots are requested.
146. PL $\emptyset$ T generates all requested deformed structure and contour plots.
147. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
149. Go to DMAP No. 157 if no power spectral density functions or autocorrelation functions are requested.
150. RAND $\emptyset$ M calculates power spectral density functions (PSDF) and autocorrelation functions (AUT $\emptyset$ ) using the previously calculated frequency response.
151. Go to DMAP No. 157 if no X-Y plots of RAND $\emptyset$ M calculations are requested.
152. XYTRAN prepares the input for requested X-Y plots of the RAND $\emptyset$ M output.
153. XYPL $\emptyset$ T prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.
154. Go to DMAP No. 157.
156.  $\emptyset$ FP formats the frequency response output requests prepared by SDR2 (with mode acceleration) or DDRMM (no mode acceleration) and places them on the system output file for printing.
158. Go to DMAP No. 174 and make normal exit if no additional sets of direct input matrices need to be processed.
159. Go to DMAP No. 88 if additional sets of direct input matrices need to be processed.
160. Print Error Message No. 3 and terminate execution.
161. Go to DMAP No. 174 and make normal exit.

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163. Print Error Message No. 2 and terminate execution.
165. Print Error Message No. 1 and terminate execution.
167. Print Error Message No. 4 and terminate execution.
169. Print Error Message No. 5 and terminate execution.
171. Print Error Message No. 6 and terminate execution.
173. Print Error Message No. 7 and terminate execution.

## MODAL FREQUENCY AND RANDOM RESPONSE

### 2.11.3 Output for Modal Frequency and Random Response

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

Output that may be requested is the same as that described under Direct Frequency and Random Response. Output for **SOLUTION** points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the **SOLUTION** points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Modes Analysis rigid format or by making a modified restart using the Normal Modes Analysis rigid format.

### 2.11.4 Case Control Deck for Modal Frequency and Random Response

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Frequency and Random Response:

1. **METHOD** must appear above the subcase level to select an EIGR card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An SPC set must be selected above the subcase level unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
4. SDAMPING must be used to select a TABDMPI table if structural damping is desired.

### 2.11.5 Parameters for Modal Frequency and Random Response

The following parameters are used in Modal Frequency and Random Response:

1. **ASETOUT** - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. **AUTOSPC** - reserved for future optional use. The default value is -1.

## DISPLACEMENT RIGID FORMATS

3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. LFREQ and HFREQ - required, unless parameter LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LMØDES must be set to 0.
6. LMØDES - required, unless parameters LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
7. MØDACC - optional. A positive integer value of this parameter causes the Dynamic Data Recovery module to use the mode acceleration method. Not recommended for use in hydroelastic problems.
8. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
9. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
10. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

### 2.11.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

## MODAL FREQUENCY AND RANDOM RESPONSE

### 2.11.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Frequency and Random Response. See Section 2.3.7 for details.

### 2.11.8 Rigid Format Error Messages from Modal Frequency and Random Response

The following fatal errors are detected by the Modal Frequency and Random Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

#### MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATØRN.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

#### MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

#### MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MORE THAN 100 LØOPS.

An attempt has been made to use more than 100 sets of direct input matrices. This number can be increased by ALTERing the REPT instruction following the last ØFP instruction.

#### MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATØRN.

No real eigenvalues were found in the frequency range specified by the user.

#### MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 5 - FREQUENCY RESPONSE LIST REQUIRED FØR FREQUENCY RESPØNSE CALCULATØNS.

Frequencies to be used in the solution of frequency response problems must be supplied on a FREQ, FREQ1 or FREQ2 card in the Bulk Data Deck and FREQ in the Case Control Deck must select a frequency response set.

#### MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 6 - DYNAMIC LØADS TABLE REQUIRED FØR FREQUENCY RESPØNSE CALCULATØNS.

Dynamic loads to be used in the solution of frequency response problems must be specified on an RLØAD1 or RLØAD2 card in the Bulk Data Deck and DLØAD in the Case Control Deck must select a dynamic load set.

#### MØDAL FREQUENCY AND RANDØM RESPØNSE ERRØR MESSAGE NØ. 7 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

DISPLACEMENT RIGID FORMATS

2.11-20 (05/30/86)

# DISPLACEMENT RIGID FORMATS

## 2.12 MODAL TRANSIENT RESPONSE

### 2.12.1 DMAP Sequence for Modal Transient Response

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 12

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 12 - MODAL TRANSIENT RESPONSE ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 FILE LAMA=APPEND/PHIA=APPEND/UHVT=APPEND/TOL=APPEND $  
4 PARAM ///*MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/MINUS1=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP $  
7 GP2 GEOM2,EQEXIN/ECT $  
8 PARAML PCDB///*PRES*///JUMPPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
10 COND P1,JUMPPLOT $  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
12 PRTMSG PLTSETX// $  
13 PARAM ///*MPY*/PLTFLG/1/1 $  
14 PARAM ///*MPY*/PFILE/O/O $  
15 COND P1,JUMPPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT.,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
17 PRTMSG PLOTX1// $  
18 LABEL P1 $  
19 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $  
20 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
21 COND ERROR6,NOSIMP $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 12

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PURGE OGPST/GENEL $  
23 PARAM //*ADD*/NOKGGX/1/0 $  
24 PARAM //*ADD*/NOMGG/1/0 $  
25 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
C,Y,CPRDD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
26 PURGE KGGX,GPST/NOKGGX $  
27 COND JMPKGGX,NOKGGX $  
28 EMA GPECT,KDICT,KELM/KGGX,GPST $  
29 LABEL JMPKGGX $  
30 COND ERROR1,NOMGG $  
31 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
32 COND LGPWG,GRDPNT $  
33 GPWG BGPD,CSYM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
34 OFP OGPWG,,,,/S,N,CARDNO $  
35 LABEL LGPWG $  
36 EQUIV KGGX,KGG/NOGENL $  
37 COND LBL11,NOGENL $  
38 SMA3 GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
39 LABEL LBL11 $  
40 PARAM //*MPY*/NSKIP/O/O $  
41 GP4 CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSYM,GPST/RG,,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
42 PARAM //*AND*/NOSR/REACT/SINGLE $  
43 PURGE GM,GMD/MPCF1/GO,GOD/OMIT/KFS,PST/SINGLE/QP/NOSR/KLR,KRR,MLR,MR,  
MRR,DM/REACT $
```

MODAL TRANSIENT RESPONSE

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 12

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
44  COND    LBL4,GENEL $  
45  PARAM   //EQ*/GPSPFLG/AUTOSPC/O $  
46  COND    LBL4,GPSPFLG $  
47  GPSP    GPL,GPST,USET,SIL/0GPST/S,N,NOGPST $  
48  OFP     OGPST,,,,,/S,N,CARDNO $  
49  LABEL   LBL4 $  
50  EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1 $  
51  COND    LBL2,MPCF1 $  
52  MCE1    USET,RG/GM $  
53  MCE2    USET,GM,KGG,MGG,,/KNN,MNN,, $  
54  LABEL   LBL2 $  
55  EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE $  
56  COND    LBL3,SINGLE $  
57  SCE1    USET,KNN,MNN,,/KFF,KFS,,MFF,, $  
58  LABEL   LBL3 $  
59  EQUIV   KFF,KAA/OMIT $  
60  EQUIV   MFF,MAA/OMIT $  
61  COND    LBL5,OMIT $  
62  SMP1    USET,KFF,,,/GO,KAA,KOO,L00,,,,, $  
63  SMP2    USET,GO,MFF/MAA $  
64  LABEL   LBL5 $  
65  EQUIV   KAA,KLL/REACT $  
66  COND    LBL6,REACT $  
67  RBMG1   USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $  
68  JUMP    LBL8 $  
69  LABEL   LBL6 $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 12

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
70  COND    LBL7,MODACC $  
71  LABEL   LBL8 $  
72  RBMG2   KLL/LLL $  
73  COND    LBL7,REACT $  
74  RBMG3   LLL,KLR,KRR/DM $  
75  RBMG4   DM,MLL,MLR,MRR/MR $  
76  LABEL   LBL7 $  
77  DPD     DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,,,NLFT,TRL,  
           EED,EQDYN/LUSET/S,N,LUSETD/NOTFL/S,N,NODLT/NOPSDL/  
           NOFRL/S,N,NONLFT/S,N,NOTRL/S,N,NOEED//S,N,NOUE $  
78  COND    ERROR2,NOEED $  
79  PURGE  UEVT/NOUE/PNLH/NONLFT $  
80  EQUIV  GO,GOD/NOUE/GM,GMD/NOUE $  
81  PARAM  ///*MPY*/NEIGV/1/-1 $  
82  READ   KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,  
           NEIGV $  
83  OFP    OEIGS,///S,N,CARDNO $  
84  COND    ERROR4,NEIGV $  
85  OFP    LAMA,///S,N,CARDNO $  
86  MTRXIN CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,  
           NOK2PP/S,N,NOM2PP/S,N,NOB2PP $  
87  PURGE  K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $  
88  PARAM  ///*AND*/MDEMA/NOUE/NOM2PP $  
89  EQUIV  M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA/MAA,MDD/MDEMA $  
90  GKAD   USETD,GM,GO,,,MAA,,K2PP,M2PP,B2PP//,MDD,GMD,  
           GOD,K2DD,M2DD,B2DD/*TRANRESP*/*DISP*/*MODAL*/0.0/  
           0.0/0.0/NOK2PP/NOM2PP/NOB2PP/  
           MPCF1/SINGLE/OMIT/NOUE/-1/-1/  
           1/V,Y,MODACC = -1 $
```

MODAL TRANSIENT RESPONSE

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 12

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
91  GKAM    USETD,PHIA,MI,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,PHIDH/
      NOUE/C,Y,LMODES=0/C,Y,LFREQ=0.0/C,Y,HFREQ=-1.0/
      NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE $

92  COND    ERROR5,NOTRL $

93  PARAM   ///*ADD*/NEVER/1/0 $

94  PARAM   ///*MPY*/REPEATT/1/-1 $

95  LABEL   LBL13 $

96  PURGE   PNLLH,OUHV1,OPNL1,OUHV2,OPNL2,XYPLTTA,OPP1,OQP1,OUPV1,OES1,OEF1,
            OPP2,OQP2,OUPV2,OES2,OEF2,PLOTX2,XYPLTT,OPPA,IQP1,IPHIP1,IES1,
            IEF1,OPPB,IQP2,IPHIP2,IES2,IEF2,ZQP2,ZUPV2,ZES2,ZEF2/NEVER $

97  CASE    CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $

98  PARAM   ///*MPY*/NCOL/0/1 $

99  TRLG    CASEXX,USETD,DLT,SLT,BGPDT,SIL,CSTM,TRL,DIT,GMD,GOD,PHIDH,
            EST,MGG,/PPT,PST,PDT,PD,PH,TOL/S,N,NOSET/NCOL $

100  EQUIV  PPT,PDT/NOSET $

101  TRD    CASEXX,TRL,NLFT,DIT,KHH,BHH,MHH,PH/UHVT,PNLH/*MODAL*/
            NOUE/NONCUP/S,N,NCOL/C,Y,ISTART $

102  VDR    CASEXX,EQDYN,USETD,UHVT,TOL,XYCDB,PNLH/OUHV1,OPNL1/
            *TRANRESP/*MODAL*/O/S,N,NOH/S,N,NOP/FMODE $

103  COND    LBL16,NOH $

104  SDR3   OUHV1,OPNL1,,,./OUHV2,OPNL2,,, $

105  OFP    OUHV2,OPNL2,,,./S,N,CARDNO $

106  XYTRAN  XYCDB,OUHV2,OPNL2,,,XYPLTTA/*TRAN*//*HSET*/S,N,PFFILE/
            S,N,CARDNO $

107  XYPLOT  XYPLTTA// $

108  LABEL   LBL16 $

109  PARAM   ///*AND*/PJUMP/NOP/JUMPPLOT $

110  COND    LBL15,PJUMP $

111  PARAM   ///*NOT*/NOMOD/V,Y,MODACC $

112  PARAM   ///*AND*/MPJUMP/V,Y,MODACC/JUMPPLOT $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 12

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
113  COND      LBDDRM,MPJUMP $  
114  DDR1      UHVT,PHIDH/UDVIT $  
115  COND      LBLMOD,MODACC $  
116  DDR2      USETD,UDV1T,PDT,K2DD,B2DD,MDD,,LLL,DM/UDV2T,UEVT,PAF/  
*TRANRESP*/NOUE/REACT/O $  
117  EQUIV     UDV2T,UDV1T/NOMOD $  
118  LABEL     LBLMOD $  
119  EQUIV     UDV1T,UPV/NOA $  
120  COND      LBL14,NOA $  
121  SDR1      USETD,,UDV1T,,,GOD,GMD,PST,KFS,,/UPV,,QP/1/*DYNAMICS* $  
122  LABEL     LBL14 $  
123  SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDP,TOL,QP,UPV,EST,XYCDB,  
PPT/OPP1,OQP1,OUPV1,OES1,OEF1,PUGV/*TRANRESP* $  
124  SDR3      OPP1,OQP1,OUPV1,OES1,OEF1,/OPP2,OQP2,OUPV2,OES2,OEF2, $  
125  JUMP      P2A $  
126  LABEL     LBDDRM $  
127  SDR1      USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIPH,,QPH/1/*DYNAMICS* $  
128  SDR2      CASEXX,CSTM,MPT,DIT,EQDYN,SILD,,,LAMA,QPH,PHIPH,EST,XYCDB,/br  
,IQP1,IPHIP1,IES1,IEF1,/MMREIG* $  
129  SDR2      CASEXX,,,EQDYN,SILD,,,TOL,,,XYCDB,PPT/OPPA,,,/  
*TRANRESP* $  
130  SDR3      OPPA,IQP1,IPHIP1,IES1,IEF1,/OPPB,IQP2,IPHIP2,IES2,IEF2, $  
131  EQUIV     OPPB,OPP2/MODACC $  
132  DDRMM     CASEXX,UHVT,TOL,IPHIP2,IQP2,IES2,IEF2,,EST,MPT,DIT/  
ZUPV2,ZQP2,ZES2,ZEF2, $  
133  EQUIV     ZUPV2,OUPV2/MODACC/ZQP2,OQP2/MODACC/ZEF2,OEF2/MODACC/ZES2,OES2/  
MODACC $  
134  LABEL     P2A $  
135  OFP       OUPV2,OPP2,OQP2,OEF2,OES2,//S,N,CARDNO $
```

MODAL TRANSIENT RESPONSE

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 12

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
136 SCAN    CASECC,OES2,OEF2/OESF2/*RF* $  
137 OFP     OESF2,,,./S,N,CARDNO $  
138 COND    P2,JUMPLOT $  
139 PLOT    PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,EQEXIN,SIP,,PUGV,,/PLOTX2/  
NSIL/LUSEP/JUMPLOT/PLTFLG/S,N,PFILE $  
140 PRTPARM PLOTX2// $  
141 LABEL   P2 $  
142 XYTRAN  XYCDB,OPP2,OQP2,OUPV2,OES2,OEF2/XYPLTT/*TRAN*/*PSET*/  
S,N,PFILE/S,N,CARDNO $  
143 XYPLOT  XYPLTT// $  
144 LABEL   LBL15 $  
145 COND    FINIS,REPEATT $  
146 REPT    LBL13,100 $  
147 PRTPARM //-*MDLTRD* $  
148 JUMP    FINIS $  
149 LABEL   ERROR2 $  
150 PRTPARM //-*MDLTRD* $  
151 LABEL   ERROR1 $  
152 PRTPARM //-*MDLTRD* $  
153 LABEL   ERROR4 $  
154 PRTPARM //-*MDLTRD* $  
155 LABEL   ERROR5 $  
156 PRTPARM //-*MDLTRD* $  
157 LABEL   ERROR6 $  
158 PRTPARM //-*MDLTRD* $  
159 LABEL   FINIS $  
160 PURGE  DUMMY/MINUS1 $  
161 END    $
```

## DISPLACEMENT RIGID FORMATS

### 2.12.2 Description of Important DMAP Operations for Modal Transient Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Grid Point Temperature Table.
20. TA1 generates element tables for use in matrix assembly and stress recovery.
21. Go to DMAP No. 157 and print Error Message No. 6 if there are no structural elements.
25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 151 and print Error Message No. 1 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
32. Go to DMAP No. 35 if no weight and balance information is requested.
33. GPWG generates weight and balance information.
34. OFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
36. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if no general elements exist.
37. Go to DMAP No. 39 if no general elements exist.
38. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
41. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
44. Go to DMAP No. 49 if general elements are present.
46. Go to DMAP No. 49 if no potential grid point singularities exist.
47. GPSP generates a table of potential grid point singularities.
48. OFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

MODAL TRANSIENT RESPONSE

50. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
51. Go to DMAP No. 54 if no multipoint constraints exist.
52. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
53. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} \mid K_{nm} \\ \frac{K_{nn}}{K_{mn}} + & \end{bmatrix} \quad \text{and} \quad [M_{gg}] = \begin{bmatrix} - & M_{nn} \mid M_{nm} \\ \frac{M_{nn}}{M_{mn}} + & \end{bmatrix}$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m].$$

55. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.
56. Go to DMAP No. 58 if no single-point constraints exist.
57. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} \mid K_{fs} \\ \frac{K_{sf}}{K_{ss}} + & \end{bmatrix} \quad \text{and} \quad [M_{nn}] = \begin{bmatrix} M_{ff} \mid M_{fs} \\ \frac{M_{sf}}{M_{ss}} + & \end{bmatrix}.$$

59. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
60. Equivalence  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.
61. Go to DMAP No. 64 if no omitted coordinates exist.
62. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} \mid K_{ao} \\ \frac{K_{aa}}{K_{oa}} + & \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$ .

63. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} - & M_{aa} \mid M_{ao} \\ \frac{M_{aa}}{M_{oa}} + & \end{bmatrix}$$

## DISPLACEMENT RIGID FORMATS

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o] .$$

65. Equivalence  $[K_{aa}]$  to  $[K_{\ell\ell}]$  if no free-body supports exist.

66. Go to DMAP No. 69 if no free-body supports exist.

67. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix} \text{ and } [M_{aa}] = \frac{M_{\ell\ell} & M_{\ell r} \\ M_{r\ell} & M_{rr} \end{bmatrix} .$$

68. Go to DMAP No. 71.

70. Go to DMAP No. 76 if there is no request for mode acceleration data recovery.

72. RBMG2 decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

73. Go to DMAP No. 76 if no free-body supports exist.

74. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|} .$$

75. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

77. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFP00L), Dynamic Loads Table (DLT), Nonlinear Function Table (NLFT), Transient Response List (TRL).

78. Go to DMAP No. 149 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

80. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for dynamic analysis.

82. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{u_a\} = 0 ,$$

calculates rigid body modes by finding a square matrix  $[\phi_{r0}]$  such that

## MODAL TRANSIENT RESPONSE

$$[m_0] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} D\phi_{ro} \\ \phi_{ro} \end{bmatrix},$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit value of a selected component
- 2) Unit value of the largest component
- 3) Unit value of the generalized mass.

83. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.
84. Go to DMAP No. 153 and print Error Message No. 4 if no eigenvalues were found.
85. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.
86. MTRXIN selects the direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ .
89. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^2]$  if no constraints are applied, and  $[M_{aa}]$  to  $[M_{dd}]$  if there are no direct input mass matrices and no extra points introduced for dynamic analysis.
90. GKAD applies constraints to direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ , forming  $[K_{dd}^2]$ ,  $[M_{dd}^2]$  and  $[B_{dd}^2]$ .
91. GKAM assembles stiffness, mass and damping matrices in modal coordinates for use in Transient Response:

$$[K_{hh}] = [k] + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}],$$

$$[M_{hh}] = [m] + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}]$$

$$\text{and } [B_{hh}] = [b] + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}],$$

where  $m_i$  = modal masses ,

$$b_i = m_i 2\pi f_i g(f_i)$$

$$\text{and } k_i = m_i 4\pi^2 f_i^2 .$$

All matrices are real.

92. Go to DMAP No. 155 and print Error Message No. 5 if there is no Transient Response List.

## DISPLACEMENT RIGID FORMATS

95. Beginning of loop for additional dynamic load sets.
97. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.
99. TRLG generates matrices of loads versus time.  $\{P_p^t\}$ ,  $\{P_s^t\}$  and  $\{P_d^t\}$  are generated with one column per output time step.  $\{P_d\}$  and  $\{P_h\}$  are generated with one column per solution time step, and the Transient Output List (TOL) is a list of output time steps.
100. Equivalence  $\{P_d^t\}$  to  $\{P_p^t\}$  if the d and p sets are the same.
101. TRD forms the linear,  $\{P_d\}$ , and nonlinear,  $\{P_d^{NL}\}$ , dynamic load vectors and integrates the equations of motion over specified time periods to solve for the displacements, velocities and accelerations, using the following equation

$$[M_{hh}p^2 + B_{hh}p + K_{hh}]\{u_h\} = \{P_h\} + \{P_h^{NL}\} .$$

102. VDR prepares displacements, velocities and accelerations, sorted by time step, for output using only the extra points introduced for dynamic analysis and modal coordinates (solution points).
103. Go to DMAP No. 108 if there is no output request for the solution points.
104. SDR3 sorts the solution point displacements, velocities, accelerations and nonlinear load vectors by extra point or mode number.
105. ØFP formats the requested solution point displacements, velocities, accelerations and nonlinear load vectors prepared by SDR3 and places them on the system output file for printing.
106. XYTRAN prepares the input for X-Y plotting of the solution point displacements, velocities, accelerations and nonlinear load vectors vs. time.
107. XYPLØT prepares the requested X-Y plots of the solution point displacements, velocities, accelerations and nonlinear load vectors vs. time.
110. Go to DMAP No. 144 if there is no output request involving dependent degrees of freedom, forces and stresses, or deformed structure plots.
113. Go to DMAP No. 126 if the mode acceleration technique is not requested and if there are no requests for deformed structure plots.
114. DDR1 transforms the solution vector displacements from modal to physical coordinates

$$\{u_d\} = [\phi_{dh}]\{u_h\} .$$

115. Go to DMAP No. 118 if the mode acceleration technique is not requested.
116. DDR2 calculates an improved displacement vector using the mode acceleration technique.
117. Equivalence  $\{u_d\}$  to the improved displacement vector. (Flag NØMOD is negative since the mode acceleration technique is requested).
119. Equivalence  $\{u_d\}$  to  $\{u_p\}$  if no constraints are applied.
120. Go to DMAP No. 122 if no constraints are applied.

## MODAL TRANSIENT RESPONSE

121. SDR1 recovers dependent components of displacements

$$\begin{aligned}\{u_o\} &= [G_o^d]\{u_d\} \quad , \quad \left\{ \frac{u_d}{u_o} \right\} = \{u_f + u_e\} \quad , \\ \left\{ \frac{u_f + u_e}{u_s} \right\} &= \{u_n + u_e\} \quad , \quad \{u_m\} = [G_m^d]\{u_f + u_e\} \quad , \\ \left\{ \frac{u_n + u_e}{u_m} \right\} &= \{u_p\}\end{aligned}$$

and recovers single-point forces of constraint  $\{q_s\} = -\{P_s\} + [K_{fs}^T] \{u_f\}$ .

123. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PP1$ ), displacement, velocity and acceleration vectors ( $\emptyset UPV1$ ) and single-point forces of constraint ( $\emptyset QP1$ ) for output and translation components of the displacement vector (PUGV), sorted by time step.
124. SDR3 prepares requested output sorted by point number or element number.
125. Go to DMAP No. 134.
127. SDR1 recovers dependent components of eigenvectors

$$\begin{aligned}\{\phi_o\} &= [G_o^d]\{\phi_n\} \quad , \quad \left\{ \frac{\phi_h}{\phi_o} \right\} = \{\phi_f + u_e\} \quad , \\ \left\{ \frac{\phi_f + u_e}{\phi_s} \right\} &= \{\phi_n + \phi_e\} \quad , \quad \{\phi_m\} = [G_m^d]\{\phi_n + \phi_e\} \quad , \\ \left\{ \frac{\phi_n + \phi_e}{\phi_m} \right\} &= \{\phi_g + u_e\} = \{\phi_p\}\end{aligned}$$

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}]^T \{\phi_f\}$ .

128. SDR2 calculates element forces (IEF1) and stresses (IES1) and prepares eigenvectors (IPHIP1) and single-point forces of constraint (IQP1) for output sorted by time step.
129. SDR2 prepares load vectors for output ( $\emptyset PPA$ ) sorted by time step.
130. SDR3 prepares the requested output sorted by point number or element number.
131. Equivalence  $\emptyset PPB$  to  $\emptyset PP2$ . (Flag M<sub>0</sub>DACC is negative since the mode acceleration technique is not requested).
132. DDRMM prepares a subset of the element forces (ZEF2) and stresses (ZES2), and displacement vectors (ZUPV2) and single-point forces of constraint (ZQP2) for output sorted by point number or element number.

## DISPLACEMENT RIGID FORMATS

133. Equivalence ZUPV2 to ØUPV2, ZQP2 to ØQP2, ZES2 to ØES2 and ZEF2 to ØEF2. (Flag MØDACC is negative since the mode acceleration technique is not requested).
135. ØFP formats the requested output prepared by SDR3 (with mode acceleration) or DDRMM (no mode acceleration) and places it on the system output file for printing.
136. SCAN examines the element stresses and forces calculated by SDR3 or DDRMM and generates scanned output that meets the specifications set by the user.
137. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.
138. Go to DMAP No. 141 if no deformed structure plots are requested.
139. PLØT prepares all requested deformed structure and contour plots.
140. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
142. XYTRAN prepares the input for requested X-Y plots.
143. XYPLØT prepares the requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads and single-point forces of constraint vs. time.
145. Go to DMAP No. 159 and make normal exit if no additional dynamic load sets need to be processed.
146. Go to DMAP No. 95 if additional dynamic load sets need to be processed.
147. Print Error Message No. 3 and terminate execution.
148. Go to DMAP No. 159 and make normal exit.
150. Print Error Message No. 2 and terminate execution.
152. Print Error Message No. 1 and terminate execution.
154. Print Error Message No. 4 and terminate execution.
156. Print Error Message No. 5 and terminate execution.
158. Print Error Message No. 6 and terminate execution.

## MODAL TRANSIENT RESPONSE

### 2.12.3 Output for Modal Transient Response

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues extracted are included even though not all are used in the modal formulation.

Output that may be requested is the same as that described under Direct Transient Response. Output for **SOLUTION** points will have the modal coordinates identified by the mode number determined in real eigenvalue analysis.

The eigenvectors used in the modal formulation may be obtained for the **SOLUTION** points by using the **ALTER** feature to print the matrix of eigenvectors following the execution of **READ**. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Modes Analysis rigid format or by making a modified restart using the Normal Modes Analysis rigid format.

### 2.12.4 Case Control Deck for Modal Transient Response

The following items related to subcase definition and data selection must be considered in addition to the list presented with Direct Transient Response:

1. **METHOD** must appear above the subcase level to select an **EIGR** card that exists in the Bulk Data Deck.
2. All of the eigenvectors used in the modal formulation must be determined in a single execution.
3. An **SPC** set must be selected above the subcase level unless the model is a free body or all constraints are specified on **GRID** cards, Scalar Connection cards or with General Elements.
4. **SDAMPING** must be used to select a **TABDMP1** table if structural damping is desired.

### 2.12.5 Parameters for Modal Transient Response

The following parameters are used in Modal Transient Response:

1. **ASETOUT** - optional. A positive integer value of this parameter causes the **ASET** output data block to be generated by the **GP4** module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. **AUTOSPC** - reserved for future optional use. The default value is -1.

## DISPLACEMENT RIGID FORMATS

3. C0UPMASS - CPBAR, CPR0D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. ISTART - optional. A positive value of this parameter causes the TRD module to use the second (or alternate) starting method (see Section 11.4 of the Theoretical Manual). The alternate starting method is recommended when initial accelerations are significant and when the mass matrix is non-singular. The default value is -1 and causes the first starting method to be used.
6. LFREQ and HFREQ - required, unless parameter LM0DES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LM0DES must be set to 0.
7. LM0DES - required, unless parameters LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
8. M0DACC - optional. A positive integer value of this parameter causes the Dynamic Data Recovery module to use the mode acceleration method. Not recommended for use in hydroelastic problems.
9. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
10. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
11. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

## MODAL TRANSIENT RESPONSE

### 2.12.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

### 2.12.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Transient Response. See Section 2.3.7 for details.

### 2.12.8 The CONTINUE Feature

The CONTINUE feature can be used for coupled transient analysis in Modal Transient Response. See Section 2.9.6 for details.

### 2.12.9 Rigid Format Error Messages from Modal Transient Response

The following fatal errors are detected by the DMAP statements in the Modal Transient Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

#### MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FORMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

#### MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

#### MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

An attempt has been made to use more than 100 dynamic load sets. This number can be increased by ALTERING the REPT instruction following the last XYPLØT instruction.

#### MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FORMULATION.

No real eigenvalues were found in the frequency range specified by the user.

#### MØDAL TRANSIENT RESPØNSE ERRØR MESSAGE NØ. 5 - TRANSIENT RESPØNSE LIST REQUIRED FØR TRANSIENT RESPØNSE CALCULATIØNS.

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

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MØDAL TRANSIENT RESPØNSE ERROR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

## DISPLACEMENT RIGID FORMATS

### 2.13 NORMAL MODES WITH DIFFERENTIAL STIFFNESS

#### 2.13.1 DMAP Sequence for Normal Modes With Differential Stiffness

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OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 13 - NORMAL MODES WITH DIFFERENTIAL STIFFNESS-APR. 1986 $  
2 PRECHK ALL $  
3 FILE LAMA=APPEND/PHIA=APPEND $  
4 PARAM //*MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDTCSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/MINUS1=-1 $  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/$,N,LUSEP $  
7 GP2 GEOM2,EQEXIN/ECT $  
8 PARAML PCDB//*PRES*///JUMPPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
10 COND P1,JUMPPLOT $  
11 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
12 PRTMSG PLTSETX// $  
13 PARAM //*MPY*/PLTFLG/1/1 $  
14 PARAM //*MPY*/PFILE/O/O $  
15 COND P1,JUMPPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
17 PRTMSG PLOTX1// $  
18 LABEL P1 $  
19 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/NOGRAV $  
20 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
21 COND ERROR1,NOSIMP $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PURGE OGPST/GENEL $  
23 PARAM ///*ADD*/NOKGGX/1/0 $  
24 PARAM ///*ADD*/NOMGG/1/0 $  
25 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
26 PURGE KGGX,GPST/NOKGGX $  
27 COND JMPKGG,NOKGGX $  
28 EMA GPECT,KDICT,KELM/KGGX,GPST $  
29 LABEL JMPKGG $  
30 COND ERROR5,NOMGG $  
31 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
32 COND LBL1,GRDPNT $  
33 GPWG BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $  
34 OFP OGPWG, , , , /S,N,CARDNO $  
35 LABEL LBL1 $  
36 EQUIV KGGX,KGG/NOGENL $  
37 COND LBL11,NOGENL $  
38 SMA3 GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
39 LABEL LBL11 $  
40 PARAM ///*MPY*/NSKIP/0/0 $  
41 GP4 CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
42 COND ERROR6,NOL $  
43 PARAM ///*AND*/NOSR/SINGLE/REACT $
```

NORMAL MODES WITH DIFFERENTIAL STIFFNESS

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
44 PURGE GM/MPCF1/G0,K00,L00,P0,U00V,RU0V/0MIT/PS,KFS,KSS/SINGLE/
QG/NOSR $

45 COND LBL4D,REACT $

46 JUMP ERROR2 $

47 LABEL LBL4D $

48 COND LBL4,GENEL $

49 PARAM //EQ*/GPSPFLG/AUTOSPC/O $

50 COND LBL4,GPSPFLG $

51 GPSP GPL,GPST,USET,SIL/0GPST/S,N,NOGPST $

52 OFP OGPST,,,//S,N,CARDNO $

53 LABEL LBL4 $

54 EQUIV KGG,KNN/MPCF1 $

55 COND LBL2,MPCF1 $

56 MCE1 USET,RG/GM $

57 MCE2 USET,GM,KGG,,,/KNN,,, $

58 LABEL LBL2 $

59 EQUIV KNN,KFF/SINGLE $

60 COND LBL3,SINGLE $

61 SCE1 USET,KNN,,,/KFF,KFS,KSS,,, $

62 LABEL LBL3 $

63 EQUIV KFF,KAA/0MIT $

64 COND LBL5,0MIT $

65 SMP1 USET,KFF,,,/G0,KAA,K00,L00,,,,, $

66 LABEL LBL5 $

67 RBMG2 KAA/LLL $

68 SSG1 SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,/
LUSET/1 $
```

## DISPLACEMENT RIGID FORMATS

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```
69 EQUIV PG,PL/NOSET $  
70 COND LBL10,NOSET $  
71 SSG2 USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $  
72 LABEL LBL10 $  
73 SSG3 LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/  
1/S,N,EPSI $  
74 COND LBL9,IRES $  
75 MATGPR GPL,USET,SIL,RULV//*L* $  
76 MATGPR GPL,USET,SIL,RUOV//*0* $  
77 LABEL LBL9 $  
78 SDR1 USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/1/  
*BKLO* $  
79 SDR2 CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/  
OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*BKLO* $  
80 OFP OUGV1,OPG1,OQG1,OEF1,OES1./S,N,CARDNO $  
81 SCAN CASECC,OES1,OEF1/OESF1/C,N,*RF* $  
82 OFP OESF1,,,./S,N,CARDNO $  
83 COND P2,JUMPPLOT $  
84 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/  
PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $  
85 PRMSG PLOTX2// $  
86 LABEL P2 $  
87 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/  
NOSIMP/O/NOGENL/GENEL $  
88 DSMG1 CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/  
S,N,DSCOSET $  
89 EQUIV KDGG,KDNN/MPCF2 / MGG,MNN/MPCF2 $  
90 COND LBL2D,MPCF2 $  
91 MCE2 USET,GM,KDGG,MGG,,/KDNN,MNN,, $
```

NORMAL MODES WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING  
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```
92  LABEL    LBL2D $  
93  EQUIV   KDNN,KDFF/SINGLE / MNN,MFF/SINGLE $  
94  COND     LBL3D,SINGLE $  
95  SCE1     USET,KDNN,MNN,,/KDFF,KDFS,KDSS,MFF,, $  
96  LABEL    LBL3D $  
97  EQUIV   KDFF,KDAA/OMIT / MFF,MAA/OMIT $  
98  COND     LBL5D,OMIT $  
99  SMP2     USET,GO,KDFF/KDAA $  
100 SMP2    USET,GO,MFF/MAA $  
101 LABEL    LBL5D $  
102 PARAM   ///*ADD*/DSCOSET/-1/0 $  
103 EQUIV   PL,PBL/DSCOSET/PS,PBS/DSCOSET/YS,YBS/DSCOSET/UOOV,UBOOV/  
           DSCOSET $  
104 PARAM   ///*MPY*/NDSKIP/0/0 $  
105 DSMG2    MPT,KAA,KDAA,KFS,KDFS,KSS,KDSS,PL,PS,YS,UOOV/KBLL,KBFS,KBSS,  
           PBL,PBS,YBS,UBOOV/S,N,NDSKIP/S,N,REPEATD/DSCOSET $  
106 RBMG2    KBLL/LBLL/S,N,POWER/S,N,DET $  
107 PRTPARM //0/*DET* $  
108 PRTPARM //0/*POWER* $  
109 SSG3     LBLL,KBLL,PBL,,,/UBLV,,RUBLV,/-1/V,Y,IRES/NDSKIP/  
           S,N,EPSI $  
110 COND     LBL9D,IRES $  
111 MATGPR   GPL,USET,SIL,RUBLV//*L* $  
112 LABEL    LBL9D $  
113 SDR1     USET,,UBLV,UBOOV,YBS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/NDSKIP/  
           *DS1* $  
114 SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QBG,UBGV,EST,,,/  
           0QBG1,0UBGV1,0ESB1,0EFB1,PUBGV1/*DS1* $
```

## DISPLACEMENT RIGID FORMATS

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
115 OFP      OQBG1,OUBGV1,OESB1,OEFB1,,//S,N,CARDNO $  
116 DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,EED,EQDYN/  
LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  
NONLFT/NOTRL/S,N,NOEED//NOUE $  
117 COND     ERROR3,NOEED $  
118 PARAM    ///*MPY*/NEIGV/1/-1 $  
119 READ     KBLL,MAA,,,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/  
S,N,NEIGV/3 $  
120 OFP      OEIGS,,,//S,N,CARDNO $  
121 COND     ERROR4,NEIGV $  
122 OFP      LAMA,,,//S,N,CARDNO $  
123 SDR1     USET,,PHIA,,,GO,GM,,KDFS,,/PHIG,,BQG/1/*REIG* $  
124 CASE     CASECC,/CASEXX/*TRANRESP*/KEPEAT=3/LOOP $  
125 SDR2     CASEXX,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,BQG,PHIG,EST,,/,  
OBQG1,OPHIG,OBES1,OBEF1,PPHIG/*REIG* $  
126 OFP      OPHIG,OBQG1,OBEF1,OBES1,,//S,N,CARDNO $  
127 COND     P3,JUMPPLOT $  
128 PLOT    PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,  
OBES1/PLOTX3/NSIL/LUSEP/JUMPPLOT/PLTFLG/  
S,N,PFFILE $  
129 PRTPARM  PLOTX3// $  
130 LABEL    P3 $  
131 JUMP     FINIS $  
132 LABEL    ERROR1 $  
133 PRTPARM  //~-1/*NMDS* $  
134 LABEL    ERROR2 $  
135 PRTPARM  //~-2/*NMDS* $  
136 LABEL    ERROR3 $  
137 PRTPARM  //~-3/*NMDS* $
```

NORMAL MODES WITH DIFFERENTIAL STIFFNESS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
138 LABEL    ERROR4 $  
139 PRTPARM //4/*NMDS* $  
140 LABEL    ERROR5 $  
141 PRTPARM //5/*NMDS* $  
142 LABEL    ERROR6 $  
143 PRTPARM //6/*NMDS* $  
144 LABEL    FINIS $  
145 PURGE    DUMMY/MINUS1 $  
146 END      $
```

## DISPLACEMENT RIGID FORMATS

### 2.13.2 Description of Important DMAP Operations for Normal Modes with Differential Stiffness

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go to DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no undeformed structure plots are requested.
16. PL0T generates all requested undeformed structure plots.
17. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
19. GP3 generates Static Loads Table and Grid Point Temperature Table.
20. TA1 generates element tables for use in matrix assembly and stress recovery.
21. Go to DMAP No. 132 and print Error Message No. 1 if no structural elements have been defined.
25. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 140 and print Error Message No. 5 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
32. Go to DMAP No. 35 if no weight and balance information is requested.
33. GPWG generates weight and balance information.
34. OFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
36. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
37. Go to DMAP No. 39 if there are no general elements.
38. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
41. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g] \{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
42. Go to DMAP No. 142 and print Error Message No. 6 if no independent degrees of freedom are defined.
45. Go to DMAP No. 47 if there are no support cards.
46. Go to DMAP No. 134 and print Error Message No. 2.
48. Go to DMAP No. 53 if general elements are present.

NORMAL MODES WITH DIFFERENTIAL STIFFNESS

50. Go to DMAP No. 53 if no potential grid point singularities exist.
51. GPSP generates a table of potential grid point singularities.
52. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
54. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if no multipoint constraints exist.
55. Go to DMAP No. 58 if no multipoint constraints exist.
56. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
57. MCE2 partitions stiffness matrix

$$[K_{gg}] = \begin{bmatrix} - \\ K_{nn} \mid K_{nm} \\ \hline K_{mn} \mid K_{mm} \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

59. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  if no single-point constraints exist.
60. Go to DMAP No. 62 if no single-point constraints exist.
61. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} \mid K_{fs} \\ \hline K_{sf} \mid K_{ss} \end{bmatrix}.$$

63. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
64. Go to DMAP No. 66 if no omitted coordinates exist.
65. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - \\ K_{aa} \mid K_{ao} \\ \hline K_{oa} \mid K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

- and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .
67. RBMG2 decomposes constrained stiffness matrix  $[K_{aa}] = [L_{aa}][U_{aa}]$ .
  68. SSG1 generates static load vectors  $\{P_g\}$ .
  69. Equivalence  $\{P_g\}$  to  $\{P_g\}$  if no constraints are applied.
  70. Go to DMAP No. 72 if no constraints are applied.

DISPLACEMENT RIGID FORMATS

71. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{ \frac{\bar{P}_n}{P_m} \right\} , \quad \{P_n\} = \bar{P}_n + [G_m^T] \{P_m\} ,$$

$$\{P_n\} = \left\{ \frac{\bar{P}_f}{P_s} \right\} , \quad \{P_f\} = \bar{P}_f - [K_{fs}] \{Y_s\} ,$$

$$\{P_f\} = \left\{ \frac{P_a}{P_o} \right\} \text{ and } \{P_g\} = \{P_a\} + [G_o^T] \{P_o\} .$$

73. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1} \{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^0\} = [K_{oo}]^{-1} \{P_o\} ,$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}] \{u_\ell\} ,$$

$$\epsilon_\ell = \frac{\{u_\ell^T\} \{\delta P_\ell\}}{\{P_\ell^T\} \{u_\ell\}} ,$$

and calculates residual vector (RU0V) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}] \{u_o^0\} ,$$

$$\epsilon_o = \frac{\{u_o^T\} \{\delta P_o\}}{\{P_o^T\} \{u_o^0\}} .$$

74. Go to DMAP No. 77 if residual vectors are not to be printed.

75. MATGPR prints the residual vector for independent coordinates (RULV).

76. MATGPR prints the residual vector for omitted coordinates (RU0V).

## NORMAL MODES WITH DIFFERENTIAL STIFFNESS

78. SDR1 recovers dependent displacements

$$\begin{aligned}\{u_0\} &= [G_0]\{u_g\} + \{u_0^0\} , \\ \left\{ \frac{u_a}{u_0} \right\} &= \{u_f\} , \quad \left\{ \frac{u_f}{Y_s} \right\} = \{u_n\} , \\ \{u_m\} &= [G_m]\{u_n\} , \quad \left\{ \frac{u_n}{u_m} \right\} = \{u_g\}\end{aligned}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\} .$$

- 79. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PG1$ ), displacement vectors ( $\emptyset UGV1$ ) and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the displacement vector ( $PUGV1$ ) for the static solution.
- 80.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
- 81. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
- 82.  $\emptyset FP$  formats the scanned output table prepared by SCAN and places it on the system output file for printing.
- 83. Go to DMAP No. 86 if no static solution deformed structure plots are requested.
- 84. PL $\emptyset T$  generates all requested static solution deformed structure and contour plots.
- 85. PRTMSG prints plotter data, engineering data, and contour data for each static solution deformed plot generated.
- 87. TA1 generates element tables for use in differential stiffness matrix assembly.
- 88. DSMG1 generates differential stiffness matrix  $[K_{gg}^d]$ .
- 89. Equivalence  $[K_{gg}^d]$  to  $[K_{nn}^d]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
- 90. Go to DMAP No. 92 if no multipoint constraints exist.
- 91. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \begin{bmatrix} \bar{K}_{nn}^d & K_{nm}^d \\ \hline \bar{K}_{mn}^d & \bar{K}_{mm}^d \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}^d] = [\bar{K}_{nn}^d] + [G_m^T][K_{mn}^d] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

- 93. Equivalence  $[K_{nn}^d]$  to  $[K_{ff}^d]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.

DISPLACEMENT RIGID FORMATS

94. Go to DMAP No. 96 if no single-point constraints exist.

95. SCE1 partitions out single-point constraints

$$[K_{nn}^d] = \begin{bmatrix} K_{ff}^d & K_{fs}^d \\ \hline \hline - & + \\ K_{sf}^d & K_{ss}^d \end{bmatrix} \text{ and } [M_{nn}] = \begin{bmatrix} M_{ff} & M_{fs} \\ \hline \hline - & + \\ M_{sf} & M_{ss} \end{bmatrix} .$$

97. Equivalence  $[K_{ff}^d]$  to  $[K_{aa}^d]$  and  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.

98. Go to DMAP No. 101 if no omitted coordinates exist.

99. SMP2 partitions constrained differential stiffness matrix

$$[K_{ff}^d] = \begin{bmatrix} - & K_{aa}^d & K_{ao}^d \\ \hline \hline K_{aa}^d & - & + \\ K_{ao}^d & + & K_{oo}^d \end{bmatrix}$$

and performs matrix reduction  $[K_{aa}^d] = [K_{aa}^d] + [K_{ao}^d][G_o]$ .

100. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} - & M_{aa} & M_{ao} \\ \hline \hline M_{aa} & - & + \\ M_{ao} & + & M_{oo} \end{bmatrix} ,$$

and performs matrix reduction

$$[M_{aa}] = [M_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o]$$

103. Equivalence  $\{P_\ell^b\}$  to  $\{P_\ell^b\}$ ,  $\{P_s\}$  to  $\{P_s^b\}$ ,  $\{Y_s\}$  to  $\{Y_s^b\}$  and  $\{u_0^0\}$  to  $\{u_0^{ob}\}$  if a scale factor is not specified on a DSFACT card.

105. DSMG2 adds partitions of stiffness matrix to similar partitions of differential stiffness matrix

$$[K_{\ell\ell}^b] = [K_{aa}] + \beta[K_{aa}^d] ,$$

$$[K_{fs}^b] = [K_{fs}] + \beta[K_{fs}^d] \text{ and}$$

$$[K_{ss}^b] = [K_{ss}] + \beta[K_{ss}^d]$$

and multiplies partitions of load vectors and displacement vectors by the value of the differential stiffness scale factor ( $\beta$ )

$$\{P_\ell^b\} = \beta\{P_\ell\} , \quad \{P_s^b\} = \beta\{P_s\} ,$$

$$\{Y_s^b\} = \beta\{Y_s\} \text{ and } \{u_0^{bo}\} = \beta\{u_0^0\} .$$

## NORMAL MODES WITH DIFFERENTIAL STIFFNESS

106. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix

$$[K_{\ell\ell}^b] = [L_{\ell\ell}^b][U_{\ell\ell}^b].$$

107. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.

108. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and the elastic stiffness matrix.

109. SSG3 solves for displacements of independent coordinates for the value of differential stiffness scale factor ( $\beta$ )

$$\{u_{\ell}^b\} = [K_{\ell\ell}^b]^{-1}\{P_{\ell}^b\}$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

$$\{\delta P_{\ell}^b\} = \{P_{\ell}^b\} - [K_{\ell\ell}^b]\{u_{\ell}^b\},$$

$$\epsilon_{\ell}^b = \frac{\{u_{\ell}^b\}^T \{\delta P_{\ell}^b\}}{\{P_{\ell}^b\}^T \{u_{\ell}^b\}}.$$

110. Go to DMAP No. 112 if the residual vector for current differential stiffness load factor is not to be printed.

111. MATGPR prints the residual vector for current differential stiffness load factor.

113. SDR1 recovers dependent displacements for the current differential stiffness scale factor

$$\{u_0^b\} = [G_0] \{u_{\ell}^b\} + \{u_0^{ob}\}, \quad \left\{ \begin{array}{c} u_{\ell}^b \\ u_0^b \end{array} \right\} = \{u_f^b\},$$

$$\left\{ \begin{array}{c} u_f^b \\ \gamma_s^b \end{array} \right\} = \{u_n^b\}, \quad \{u_m^b\} = [G_m] \{u_n^b\},$$

$$\left\{ \begin{array}{c} u_n^b \\ u_m^b \end{array} \right\} = \{u_g^b\}$$

and recovers single-point forces of constraint for the current differential stiffness scale factor

$$\{q_s^b\} = -\{P_s^b\} + [K_{sf}^b]\{u_f^b\} + [K_{ff}^b]\{\gamma_s^b\}.$$

## DISPLACEMENT RIGID FORMATS

114. SDR2 calculates element forces ( $\emptyset EFB1$ ) and stresses ( $\emptyset ESB1$ ) and prepares displacement vectors ( $\emptyset UBGV1$ ) and single-point forces of constraint ( $\emptyset QBG1$ ) for output and translation components of the displacement vector ( $PUBGV1$ ) for the differential stiffness solution.
115.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
116. DPD extracts Eigenvalue Extraction Data from Dynamics data block.
117. Go to DMAP No. 136 and print Error Message No. 3 if there is no Eigenvalue Extraction Data.
119. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa}^b - \lambda M_{aa}] \{u_a\} = 0 ,$$

calculates rigid body modes by finding a square matrix  $[\phi_{ro}]$  such that

$$[m_0] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} D\phi_{ro} \\ \phi_{ro} \end{bmatrix} ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit value of a selected component
- 2) Unit value of the largest component
- 3) Unit value of the generalized mass.

120.  $\emptyset FP$  formats the summary of eigenvalue extraction information ( $\emptyset EIGS$ ) prepared by READ and places it on the system output file for printing.
121. Go to DMAP No. 138 and print Error Message No. 4 if no eigenvalues were found.
122.  $\emptyset FP$  formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.
123. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o] \{\phi_a\} , \quad \left\{ \frac{\phi_a}{\phi_o} \right\} = \{\phi_f\} ,$$

$$\left\{ \frac{\phi_f}{\phi_s} \right\} = \{\phi_n\} , \quad \{\phi_m\} = [G_m] \{\phi_n\} ,$$

$$\left\{ \frac{\phi_n}{\phi_m} \right\} = \{\phi_g\}$$

NORMAL MODES WITH DIFFERENTIAL STIFFNESS

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}]^T \{\phi_f\}$ .

124. CASE copies the record corresponding to the third subcase from CASECC into CASEXX.
125. SDR2 calculates element forces ( $\emptyset BEF1$ ) and stresses ( $\emptyset BES1$ ) and prepares eigenvectors ( $\emptyset PHIG$ ) and single-point forces of constraint ( $\emptyset BQG1$ ) for output and translation components of the eigenvectors ( $PPHIG$ ) for the normal mode solution.
126.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
127. Go to DMAP No. 130 if no real eigenvalue solution deformed structure plots are requested.
128. PL $\emptyset T$  generates all requested real eigenvalue solution deformed structure and contour plots.
129. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
131. Go to DMAP No. 144 and make normal exit.
133. Print Error Message No. 1 and terminate execution.
135. Print Error Message No. 2 and terminate execution.
137. Print Error Message No. 3 and terminate execution.
139. Print Error Message No. 4 and terminate execution.
141. Print Error Message No. 5 and terminate execution.
143. Print Error Message No. 6 and terminate execution.

## DISPLACEMENT RIGID FORMATS

### 2.13.3 Output for Normal Modes with Differential Stiffness

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed.

The value of the determinant of the sum of the elastic stiffness and the differential stiffness is also automatically printed.

The following output may be requested:

1. Nonzero components of the applied static load for the linear solution at selected grid points.
2. Displacement and nonzero components of the single-point forces of constraint, with and without differential stiffness, at selected grid points.
3. Forces and stresses in selected elements, with and without differential stiffness.
4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Deformed and undeformed plots with and without differential stiffness.
2. Contour plots of stresses and displacements with and without differential stiffness.

The following output may be requested for the eigenvector solution subcase:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Undeformed plot of the structural model and mode shapes for selected modes.
5. Contour plots of stresses and displacements for selected modes.

### 2.13.4 Case Control Deck for Normal Modes with Differential Stiffness

The following items relate to subcase definition and data selection for Normal Modes with Differential Stiffness:

1. The Case Control Deck must contain three subcases. Output selections may be made above the subcase level and within the individual subcases.
2. The linear solution is output from the first subcase. The static differential stiffness solution is output from the second subcase. The eigenvector solution is output from the third subcase.
3. An SPC set must be selected above the subcase level unless all constraints are specified on GRID cards.

## NORMAL MODES WITH DIFFERENTIAL STIFFNESS

4. A static loading condition must be defined in the first subcase with a LØAD, TEMPERATURE(LØAD), or DEFØRM selection, unless all loading is specified by grid point displacements on SPC cards.
5. DSCØEFFICIENT must appear in the second subcase, either to select a DSFACT set from the Bulk Data Deck, or to explicitly select the DEFAULT value of unity.
6. METHØD must appear in the third subcase to select an EIGR bulk data card.

### 2.13.5 Parameters for Normal Modes with Differential Stiffness

The following parameters are used in Normal Modes with Differential Stiffness:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.
3. CØUPMASS - CPBAR, CPRØD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
6. VØLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
7. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

#### 2.13.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

#### 2.13.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Normal Modes with Differential Stiffness. See Section 2.3.7 for details.

#### 2.13.8 Rigid Format Error Messages from Normal Modes with Differential Stiffness

The following fatal errors are detected by the DMAP statements in the Normal Modes with Differential Stiffness rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

##### NORMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

##### NORMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 2 - FREE BØDY SUPPORTS NØT ALLØWED.

Free bodies are not allowed in Normal Modes with Differential Stiffness. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

##### NORMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 3 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

##### NORMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 4 - NØ EIGENVALUE FØUND.

No eigenvalues were found in the frequency range specified by the user.

##### NORMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 5 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

##### NORMAL MØDES WITH DIFFERENTIAL STIFFNESS ERRØR MESSAGE NØ. 6 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

## DISPLACEMENT RIGID FORMATS

### 2.14 STATIC ANALYSIS USING CYCLIC SYMMETRY

#### 2.14.1 DMAP Sequence for Static Analysis Using Cyclic Symmetry

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 14

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 14 - STATIC ANALYSIS WITH CYCLIC SYMMETRY - APR. 1986 $  
2 PRECHK ALL $  
3 FILE KKK=SAVE/PK=SAVE $  
4 FILE UXV=APPEND $  
5 PARAM //*MPY*/CARDNO/O/O $  
6 PARAM //*NOP*/V,Y,CYC10=1 $  
7 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/MINUS1=-1 $  
8 PLTTRAN BGPDT,SIL/BGPD, SIP/LUSET/S,N,LUSEP $  
9 GP2 GEOM2,EQEXIN/ECT $  
10 PARAML PCDB//*PRES*///JUMPPLOT $  
11 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
12 COND P1,JUMPPLOT $  
13 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPPLOT $  
14 PRTMSG PLTSETX// $  
15 PARAM //*MPY*/PLTFLG/1/1 $  
16 PARAM //*MPY*/PFILE/O/O $  
17 COND P1,JUMPPLOT $  
18 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
19 PRTMSG PLOTX1// $  
20 LABEL P1 $  
21 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PARAM ///*AND*//NOMGG/NOGRAV/V,Y,GRDPNT=-1 $  
23 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
24 PARAM ///*AND*//NOELMT/NOGENL/NOSIMP $  
25 COND ERROR4,NOELMT $  
26 PURGE GPST/NOSIMP/OGPST/GENEL $  
27 COND LBL1,NOSIMP $  
28 PARAM ///*ADD*//NOKGGX/1/O $  
29 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/  
C,Y,CPROD/C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  
C,Y,CPTUBE/C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
30 PURGE KGGX,GPST/NOKGGX/MGG/NOMGG $  
31 COND JMPKGG,NOKGGX $  
32 EMA GPECT,KDICT,KELM/KGGX,GPST $  
33 LABEL JMPKGG $  
34 COND JMPMGG,NOMGG $  
35 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
36 LABEL JMPMGG $  
37 COND LBL1,GRDPNT $  
38 COND ERROR2,NOMGG $  
39 GPWG BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $  
40 OFP OGPWG,,,,,/S,N,CARDNO $  
41 LABEL LBL1 $  
42 EQUIV KGGX,KGG/NOGENL $  
43 COND LBL11A,NOGENL $  
44 SMA3 GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
45 LABEL LBL11A $
```

STATIC ANALYSIS USING CYCLIC SYMMETRY

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
46 PARAM ///*MPY*//NSKIP/0/0 $  
47 GP4 CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,YS,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
48 COND ERROR3,NOL $  
49 PARAM ///*NOT*//REACDATA/REACT $  
50 COND ERROR6,REACDATA $  
51 PURGE GM/MPCF1/G0,K00,L00,P0,U00V,RUOV/OMIT/PS,KFS,KSS,QG/SINGLE $  
52 GPCYC GEOM4,EQEXIN,USET/CYCD/V,Y,CTYPE/S,N,NOGO $  
53 COND ERROR7,NOGO $  
54 COND LBL4,GENEL $  
55 PARAM ///*EQ*//GPSPFLG/AUTOSPC/0 $  
56 COND LBL4,GPSPFLG $  
57 GPSP GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
58 OFP OGPST,,,,//S,N,CARDNO $  
59 LABEL LBL4 $  
60 EQUIV KGG,KNN/MPCF1 $  
61 COND LBL2,MPCF1 $  
62 MCE1 USET,RG/GM $  
63 MCE2 USET,GM,KGG,,,/KNN,,, $  
64 LABEL LBL2 $  
65 EQUIV KNN,KFF/SINGLE $  
66 COND LBL3,SINGLE $  
67 SCE1 USET,KNN,,,/KFF,KFS,KSS,,, $  
68 LABEL LBL3 $  
69 EQUIV KFF,KAA/OMIT $  
70 COND LBL5,OMIT $
```

DISPLACEMENT RIGID FORMATS

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
71 SMP1      USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $  
72 LABEL     LBL5 $  
73 SSG1      SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PG,,,/LUSSET/NSKIP $  
74 EQUIV    PG,PL/NOSET $  
75 COND     LBL9,NOSET $  
76 SSG2      USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $  
77 COND     LBL9,OMIT $  
78 SSG3      LOO,KOO,PO,,,/UOOV,,RUOV,/-1/V,Y,IRES=-1 $  
79 COND     LBL9,IRES $  
80 MATGPR   GPL,USET,SIL,RUOV//*0* $  
81 LABEL     LBL9 $  
82 EQUIV    PL,PX/CYCIO $  
83 COND     LBL10,CYCIO $  
84 CYCT1    PL/PX,GCYCF/V,Y,CTYPE/*FORE*/V,Y,NSEGS=-1/S,Y,KMAX=-1/V,Y,NLOAD=1/S,N,NOGO $  
85 LABEL     LBL10 $  
86 COND     ERROR7,NOGO $  
87 PARAM    //**ADD*/KINDEX/O/O $  
88 LABEL     LBL11 $  
89 CYCT2    CYCD,KAA,,PX,,/KKK,,PK,,/*FORE*/V,Y,NSEGS/KINDEX/V,Y,CYCSEQ=-1/V,Y,NLOAD/S,N,NOGO $  
90 COND     ERROR7,NOGO $  
91 RBMG2    KKK/LKK $  
92 SSG3      LKK,KKK,PK,,,/UKV,,RUKV,/-1/V,Y,IRES $  
93 CYCT2    CYCD,,,UKV,RUKV,/,UXV,RUXV,/*BACK*/V,Y,NSEGS/KINDEX/V,Y,CYCSEQ/V,Y,NLOAD/S,N,NOGO $  
94 COND     ERROR7,NOGO $
```

STATIC ANALYSIS USING CYCLIC SYMMETRY

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 14

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
95  COND      LBL14,IRES $  
96  MATGPR    GPL,USET,SIL,RUXV//*A* $  
97  LABEL     LBL14 $  
98  PARAM     //*ADD*/KINDEX/KINDEX/1 $  
99  PARAM     //*SUB*/DONE/V,Y,KMAX/KINDEX $  
100 COND     LBL15,DONE $  
101 REPT     LBL11,360 $  
102 JUMP     ERROR1 $  
103 LABEL     LBL15 $  
104 EQUIV    UXV,ULV/CYC10 $  
105 COND     LBL16,CYC10 $  
106 CYCT1    UXV/ULV,GCYCB/V,Y,CTYPE/*BACK*/V,Y,NSEGS/V,Y,KMAX/V,Y,NLOAD/  
S,N,NOGO $  
107 COND     ERROR7,NOGO $  
108 LABEL     LBL16 $  
109 SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PGG,QG/NSKIP/  
*STATICS* $  
110 COND     NOMPCF,GRDEQ $  
111 EQMCK    CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,UGV,PGG,QG,CSTM/  
OQM1/V,Y,OPT=0/V,Y,GRDEQ/NSKIP $  
112 OFFP     OQM1,,,,,/S,N,CARDNO $  
113 LABEL     NOMPCF $  
114 SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PGG/  
OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*STATICS* $  
115 OFFP     OUGV1,OPG1,OQG1,OEF1,OES1,/S,N,CARDNO $  
116 SCAN     CASECC,OES1,OEF1/OESF1/*RF* $  
117 OFFP     OESF1,,,,,/S,N,CARDNO $  
118 COND     P2,JUMPPLOT $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 14

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
119 PLOT    PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/  
          PLOTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $  
120 PRTMSG  PLOTX2// $  
121 LABEL   P2 $  
122 JUMP    FINIS $  
123 LABEL   ERROR1 $  
124 PRTPARM // -1/*CYCSTATIC* $  
125 LABEL   ERROR2 $  
126 PRTPARM // -2/*CYCSTATIC* $  
127 LABEL   ERROR3 $  
128 PRTPARM // -3/*CYCSTATIC* $  
129 LABEL   ERROR4 $  
130 PRTPARM // -4/*CYCSTATIC* $  
131 LABEL   ERROR6 $  
132 PRTPARM // -6/*CYCSTATIC* $  
133 LABEL   ERROR7 $  
134 PRTPARM // -7/*CYCSTATIC* $  
135 LABEL   FINIS $  
136 PURGE   DUMMY/MINUS1 $  
137 END     $
```

## STATIC ANALYSIS USING CYCLIC SYMMETRY

### 2.14.2 Description of Important DMAP Operations for Static Analysis Using Cyclic Symmetry

7. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
8. PLTRAN modifies special scalar grid points in the BGPDT and SIL tables.
9. GP2 generates Element Connection Table with internal indices.
12. Go to DMAP No. 20 if there are no structure plot requests.
13. PLTSET transforms user input into a form used to drive the structure plotter.
14. PRTMSG prints error messages associated with the structure plotter.
17. Go to DMAP No. 20 if no undeformed structure plots are requested.
18. PL $\emptyset$ T generates all requested undeformed structure plots.
19. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
21. GP3 generates Static Loads Table and Grid Point Temperature Table.
23. TA1 generates element tables for use in matrix assembly and stress recovery.
25. Go to DMAP No. 129 and print Error Message No. 4 if no elements have been defined.
27. Go to DMAP No. 41 if there are no structural elements.
29. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
31. Go to DMAP No. 33 if no stiffness matrix is to be assembled.
32. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
34. Go to DMAP No. 36 if no mass matrix is to be assembled.
35. EMA assembles mass matrix  $[M_{gg}]$ .
37. Go to DMAP No. 41 if no weight and balance information is requested.
38. Go to DMAP No. 125 and print Error Message No. 2 if no mass matrix exists.
39. GPWG generates weight and balance information.
40. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
42. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
43. Go to DMAP No. 45 if there are no general elements.
44. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
47. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g] \{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
48. Go to DMAP No. 127 and print Error Message No. 3 if no independent degrees of freedom are defined.
50. Go to DMAP No. 131 and print Error Message No. 6 if free-body supports are present.

52. GPCYC prepares segment boundary table (CYCD).
53. Go to DMAP No. 133 and print Error Message No. 7 if CYJ0IN data is inconsistent.
54. Go to DMAP No. 59 if general elements are present.
55. Go to DMAP No. 59 if no potential grid point singularities exist.
56. GPSP generates a table of potential grid point singularities.
57. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
58. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if no multipoint constraints exist.
59. Go to DMAP No. 64 if no multipoint constraints exist.
60. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
61. MCE2 partitions stiffness matrix

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} \mid K_{nm} \\ \hline K_{nn} + & \\ K_{mn} \mid K_{mm} & \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

62. 63. 64. 65. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  if no single-point constraints exist.
66. Go to DMAP No. 68 if no single-point constraints exist.
67. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} \mid K_{fs} \\ \hline K_{sf} + & \\ K_{ss} \mid & \end{bmatrix}.$$

68. 69. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
70. Go to DMAP No. 72 if no omitted coordinates exist.
71. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} \mid K_{ao} \\ \hline K_{aa} + & \\ K_{oa} \mid K_{oo} & \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .

72. SSG1 generates static load vectors  $\{P_g\}$ .

## STATIC ANALYSIS USING CYCLIC SYMMETRY

74. Equivalence  $\{P_g\}$  to  $\{P_\ell\}$  if no constraints are applied.
75. Go to DMAP No. 81 if no constraints are applied.
76. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{ \frac{\bar{P}_n}{P_m} \right\} , \quad \{P_n\} = \{P_n\} + [G_m^T] \{P_m\} ,$$

$$\{P_n\} = \left\{ \frac{\bar{P}_f}{P_s} \right\} , \quad \{P_f\} = \{P_f\} - [K_{fs}] \{Y_s\} ,$$

$$\{P_f\} = \left\{ \frac{\bar{P}_a}{P_o} \right\} , \quad \{P_a\} = \{P_a\} + [G_o^T] \{P_o\} ,$$

$$\{P_a\} = \left\{ \frac{P_\ell}{P_r} \right\}$$

and calculates determinate forces of reaction  $\{q_r\} = -\{P_r\} - [D^T] \{P_\ell\}$ .

77. Go to DMAP No. 81 if no omitted coordinates exist.
78. SSG3 solves for displacements of omitted coordinates (these are not transformed)

$$\{u_o^0\} = [K_{oo}]^{-1} \{P_o\}$$

and calculates residual vector ( $RU\emptyset V$ ) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}] \{u_o^0\} ,$$

$$\epsilon_o = \frac{\{u_o^T\} \{\delta P_o\}}{\{P_o^T\} \{u_o^0\}} .$$

79. Go to DMAP No. 81 if residual vectors are not to be printed.
80. MATGPR prints the residual vector for omitted coordinates ( $RU\emptyset V$ ).
82. Equivalence  $\{P_\ell\}$  to  $\{P_x\}$  if symmetric components of loads have been input.
83. Go to DMAP No. 85 if symmetric components of loads have been input.
84. CYCT1 transforms loads on analysis points to symmetric components by the equation

$$\{P_x\} = [G] \{P_\ell\} .$$

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86. Go to DMAP No. 133 and print Error Message No. 7 if a CYCT1 error was found.
88. Beginning of loop for cyclic index (KINDEX) values.
89. CYCT2 transforms matrices and loads from symmetric components to solution set by the equations

$$[K_{kk}] = [G_1^T][K_{aa}][G_1] + [G_2^T][K_{aa}][G_2],$$

where  $G_1 = G_C$  (cosine) and  $G_2 = G_S$  (sine) for rotational symmetry,

and  $G_1 = G_S$  (Symmetric) and  $G_2 = G_A$  (Antisymmetric) for dihedral symmetry,

$$\{P_k\} = [G_C^T]\{P_c\} + [G_S^T]\{P_s\} \text{ for rotational symmetry,}$$

$$\{P_k^1\} = [G_S^T]\{P_{cS}\} + [G_A^T]\{P_{sA}\},$$

$$\text{and } \{P_k^2\} = [G_A^T]\{P_{cA}\} + [G_S^T]\{P_{sS}\} \text{ for dihedral symmetry.}$$

90. Go to DMAP No. 133 and print Error Message No. 7 if a CYCT2 error was found.
91. RBMG2 decomposes constrained stiffness matrix for solution set

$$[K_{kk}] = [L_{kk}][U_{kk}]$$

92. SSG3 solves for displacements of solution set coordinates

$$\{u_k\} = [K_{kk}]^{-1}\{P_k\}$$

and calculates residual vector (RUKV) and residual vector error ratio for solution set coordinates

$$\{\delta P_k\} = \{P_k\} - [K_{kk}]\{u_k\},$$

$$\epsilon_k = \frac{\{u_k^T\}\{\delta P_k\}}{\{P_k^T\}\{u_k\}}.$$

93. CYCT2 finds symmetric components of displacement from solution set data and appends to output for each KINDEX.
94. Go to DMAP No. 133 and print Error Message No. 7 if a CYCT2 error was found.
95. Go to DMAP No. 97 if residual vectors are not to be printed.
96. MATGPR prints the residual vector for solution set coordinates (RUXV).
100. Go to DMAP No. 103 if all cyclic index (KINDEX) values are complete.
101. Go to DMAP No. 88 if additional cyclic index values are needed.
102. Go to DMAP No. 123 and print Error Message No. 1 if number of loops exceeds 360.
104. Equivalence  $\{u_x\}$  to  $\{u_y\}$  if output of symmetric components was requested.
105. Go to DMAP No. 108 if output of symmetric components was requested.

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106. CYCT1 transforms displacements from symmetric components to physical components.
107. Go to DMAP No. 131 and print Error Message No. 7 if a CYCT1 error was found.
109. SDR1 recovers dependent displacements

$$\{u_0\} = [G_0] \{u_a\} + \{u_0^0\} ,$$

$$\left\{ \frac{u_a}{u_0} \right\} = \{u_f\} , \quad \left\{ \frac{u_f}{Y_s} \right\} = \{u_n\} ,$$

$$\{u_m\} = [G_m] \{u_n\} , \quad \left\{ \frac{u_n}{u_m} \right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T] \{u_f\} + [K_{ss}] \{Y_s\} .$$

110. Go to DMAP No. 113 if no multipoint constraint force balance is requested.
111. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance ( $\emptyset QM1$ ) for output.
112.  $\emptyset FP$  formats the table prepared by EQMCK and places it on the system output file for printing.
114. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PG1$ ), displacement vectors ( $\emptyset UGV1$ ) and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the displacement vector ( $PUGV1$ ).
115.  $\emptyset FP$  formats the tables prepared by SDR2 and places them on the system output file for printing.
116. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
117.  $\emptyset FP$  formats the scanned output table prepared by SCAN and places it on the system output file for printing.
118. Go to DMAP No. 121 if no deformed structure plots are requested.
119. PL $\emptyset T$  generates all requested deformed structure and contour plots.
120. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
122. Go to DMAP No. 135 and make normal exit.
124. Print Error Message No. 1 and terminate execution.
126. Print Error Message No. 2 and terminate execution.
128. Print Error Message No. 3 and terminate execution.
130. Print Error Message No. 4 and terminate execution.
132. Print Error Message No. 6 and terminate execution.
134. Print Error Message No. 7 and terminate execution.

#### 2.14.3 Output for Static Analysis Using Cyclic Symmetry

The following printed output, for each loading condition and each symmetric segment or index, may be requested for Static Analysis Using Cyclic Symmetry:

1. Displacements and components of static loads and single-point forces of constraint at selected grid points or scalar points.
2. Forces and stresses in selected elements.
3. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed and deformed plots of the structural model (1 segment).
2. Contour plots of stresses and displacements (1 segment).
3. X-Y plot of any component of displacement, static load, or single-point force of constraint for a grid point or scalar point.
4. X-Y plot of any stress or force component for an element.

#### 2.14.4 Case Control Deck for Static Analysis Using Cyclic Symmetry

The following items relate to subcase definition and data selection for Static Analysis Using Cyclic Symmetry:

1. A separate group of subcases must be defined for each symmetric segment. For dihedral symmetry, a separate group of subcases must be defined for each half. There may be up to 360 subcases corresponding to 1° segments.
2. The different loading conditions are defined within each group of subcases. The loads on each symmetric segment and the selected output requests may be independent. The number of loading cases is specified on the PARAM card NLLOAD.
3. The SPC and MPC request must appear above the subcase level and may not be changed.
4. An alternate loading method is to define a separate group of subcases for each harmonic index, k. The parameter CYCL0 is included and the load components for each index are defined directly within each group for the various loading conditions.

#### 2.14.5 Parameters for Static Analysis Using Cyclic Symmetry

The following parameters are used in Static Analysis Using Cyclic Symmetry:

1. ASET0UT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.

STATIC ANALYSIS USING CYCLIC SYMMETRY

2. AUT0SPC - reserved for future optional use. The default value is -1.
3. C0UPMASS - CPBAR, CPR0D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. CTYPE - required. The BCD value of this parameter defines the type of cyclic symmetry as follows:
  - (1) R0T - rotational symmetry
  - (2) DRL - dihedral symmetry, using right and left halves
  - (3) DSA - dihedral symmetry, using symmetric and antisymmetric components
5. CYC10 - optional. The integer value of this parameter specifies the form of the input and output data. A value of +1 is used to specify physical segment representation, and a value of -1 for cyclic transform representation. The default value is +1.
6. CYCSEQ - optional. The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 specifies alternating cosine and sine terms. The default value is -1.
7. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCF0RCE. If the integer value is zero, the basic origin is used. The default value is -1.
8. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
9. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
10. KMAX - optional. The integer value of this parameter specifies the maximum value of the harmonic index. The default value is ALL which implies NSEGS/2 for NSEGS even and (NSEGS - 1)/2 for NSEGS odd.
11. NL0AD - optional. The integer value of this parameter is the number of static loading conditions. The default value is 1.
12. NSEGS - required. The integer value of this parameter is the number of identical segments in the structural model.

## DISPLACEMENT RIGID FORMATS

13. OPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCFORCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
14. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
15. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
16. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

### 2.14.6 Rigid Format Error Messages from Static Analysis Using Cyclic Symmetry

The following fatal errors are detected by the DMAP statements in the Static Analysis Using Cyclic Symmetry rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

STATICS WITH CYCLIC SYMMETRY ERROR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 360 LØOPS.

An attempt has been made to use more than 360 cyclic index (KINDEX) values. This number may be increased by ALTERing the REPT instruction in the DMAP.

STATICS WITH CYCLIC SYMMETRY ERROR MESSAGE NØ. 2 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

STATICS WITH CYCLIC SYMMETRY ERROR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

## STATIC ANALYSIS USING CYCLIC SYMMETRY

STATICS WITH CYCLIC SYMMETRY ERROR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

STATICS WITH CYCLIC SYMMETRY ERROR MESSAGE NØ. 6 - FREE BODY SUPPORTS NOT ALLOWED.

Free bodies are not allowed in Static Analysis Using Cyclic Symmetry. The SUPPORT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

STATICS WITH CYCLIC SYMMETRY ERROR MESSAGE NØ. 7 - CYCLIC TRANSFORMATION DATA ERROR.

See Section 1.12 for proper modeling techniques and corresponding PARAM card requirements.

DISPLACEMENT RIGID FORMATS

2.14-16 (05/30/86)

## DISPLACEMENT RIGID FORMATS

### 2.15 NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

#### 2.15.1 DMAP Sequence for Normal Modes Analysis Using Cyclic Symmetry

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN DISP 15 NORMAL MODES ANALYSIS WITH CYCLIC SYMMETRY-APR. 1986 $  
2 PRECHK ALL $  
3 PARAM //*MPY*/CARDNO/0/0 $  
4 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
NOGPDT/MINUS1=-1 $  
5 PLTTRAN BGPD,PLTTRAN,SIL/BGPD,PLTTRAN,S,N,LUSEP $  
6 GP2 GEOM2,EQEXIN/ECT $  
7 PARAML PCDB//*PRES*///JUMPLOT $  
8 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPLOT $  
9 COND P1,JUMPLOT $  
10 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/  
S,N,JUMPLOT $  
11 PRTMSG PLTSETX// $  
12 PARAM //*MPY*/PLTFLG/1/1 $  
13 PARAM //*MPY*/PFILE/0/0 $  
14 COND P1,JUMPLOT $  
15 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,ECT,,/PLOTX1/  
NSIL/LUSET/S,N,JUMPLOT/S,N,PLTFLG/S,N,PFILE $  
16 PRTMSG PLOTX1// $  
17 LABEL P1 $  
18 GP3 GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $  
19 TA1 ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
20 COND ERROR6,NOSIMP $  
21 PURGE OGPST/GENEL $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PARAM //ADD*/NOKGGX/1/0 $  
23 PARAM //ADD*/NOMGG/1/0 $  
24 EMG EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/  
C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/  
C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
25 PURGE KGGX,GPST/NOKGGX $  
26 COND JMPKGG,NOKGGX $  
27 EMA GPECT,KDICT,KELM/KGGX,GPST $  
28 LABEL JMPKGG $  
29 COND ERROR1,NOMGG $  
30 EMA GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
31 COND LGPWG,GRDPNT $  
32 GPWG BGPDP,CSTM,EQEXIN,MGG/0GPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
33 OFP OGPWG,/,/S,N,CARDNO $  
34 LABEL LGPWG $  
35 EQUIV KGGX,KGG/NOGENL $  
36 COND LBL11,NOGENL $  
37 SMA3 GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
38 LABEL LBL11 $  
39 PARAM //MPY*/NSKIP/0/0 $  
40 GP4 CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/  
LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
41 COND ERROR3,NOL $  
42 PARAM //NOT*/REACDATA/REACT $  
43 COND ERROR4,REACDATA $  
44 PURGE GM/MPCF1/GO/OMIT/KFS,QG/SINGLE $
```

NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45 GPCYC GEOM4,EQEXIN,USET/CYCD/V,Y,CTYPE/S,N,NOGO $
46 COND ERROR5,NOGO $
47 COND LBL4,GENEL $
48 PARAM //EQ*/GPSPFLG/AUTOSPC/O $
49 COND LBL4,GPSPFLG $
50 GPSP GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
51 OFP OGPST,,,./S,N,CARDNO $
52 LABEL LBL4 $
53 EQUIV KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
54 COND LBL2,MPCF1 $
55 MCE1 USET,RG/GM $
56 MCE2 USET,GM,KGG,MGG,,/KNN,MNN,, $
57 LABEL LBL2 $
58 EQUIV KNN,KFF/SINGLE/MNN,MFF/SINGLE $
59 COND LBL3,SINGLE $
60 SCE1 USET,KNN,MNN,,/KFF,KFS,,MFF,, $
61 LABEL LBL3 $
62 EQUIV KFF,KAA/OMIT $
63 EQUIV MFF,MAA/OMIT $
64 COND LBL5,OMIT $
65 SMP1 USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
66 SMP2 USET,GO,MFF/MAA $
67 LABEL LBL5 $
68 DPD DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,EED,EQDYN/
LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFR/
NONLFT/NOTRL/S,N,NOEED//NOUE $
69 COND ERROR2,NOEED $
```

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
70 CYCT2    CYCD,KAA,MAA,,,/KKK,MKK,,,/*FORE*/V,Y,NSEGS=-1/V,Y,KINDEX=-1/
      V,Y,CYCSEQ=-1/1/S,N,NOGO $

71 COND    ERROR5,NOGO $

72 READ    KKK,MKK,,,EED,,CASECC/LAMK,PHIK,MI,OEIGS/*MODES*/S,N,NEIGV $

73 OFP     OEIGS,,,,,/S,N,CARDNO $

74 COND    FINIS,NEIGV $

75 OFP     LAMK,,,,,/S,N,CARDNO $

76 CYCT2    CYCD,,,PHIK,LAMK,,,PHIA,LAMA/*BACK*/V,Y,NSEGS/V,Y,KINDEX/
      V,Y,CYCSEQ/1/S,N,NOGO $

77 COND    ERROR5,NOGO $

78 SDR1    USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,QG/1/*REIG* $

79 COND    NOMPCF,GRDEQ $

80 EQMCK   CASECC,EQEXIN,GPL,BGPDT,SIL,USET,KGG,GM,PHIG,LAMA,QG,CSTM/
      OQM1/V,Y,OPT=0/V,Y,GRDEQ/-1 $

81 OFP     OQM1,,,,,/S,N,CARDNO $

82 LABEL   NOMPCF $

83 SDR2    CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,QG,PHIG,EST,,/
      OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG* $

84 OFP     OPHIG,OQG1,OEF1,OES1,,/S,N,CARDNO $

85 SCAN    CASECC,OES1,OEF1/OESF1/*RF* $

86 OFP     OESF1,,,,,/S,N,CARDNO $

87 COND    P2,JUMPPLOT $

88 PLOT    PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,,PPHIG,GPECT,OES1/
      PLTX2/NSIL/LUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $

89 PRTMSG  PLTX2// $

90 LABEL   P2 $

91 JUMP    FINIS $

92 LABEL   ERROR1 $

93 PRTPARM ///*CYCMODES* $
```

NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 15

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
94  LABEL    ERROR2 $  
95  PRTPARM //-/CYCMODES* $  
96  LABEL    ERROR3 $  
97  PRTPARM //-/CYCMODES* $  
98  LABEL    ERROR4 $  
99  PRTPARM //-/CYCMODES* $  
100  LABEL   ERROR5 $  
101  PRTPARM //-/CYCMODES* $  
102  LABEL   ERROR6 $  
103  PRTPARM //-/CYCMODES* $  
104  LABEL   FINIS $  
105  PURGE   DUMMY/MINUS1 $  
106  END     $
```

## DISPLACEMENT RIGID FORMATS

### 2.15.2 Description of Important DMAP Operations for Normal Modes Analysis Using Cyclic Symmetry

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
5. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
6. GP2 generates Element Connection Table with internal indices.
9. Go to DMAP No. 17 if there are no structure plot requests.
10. PLTSET transforms user input into a form used to drive the structure plotter.
11. PRTMSG prints error messages associated with the structure plotter.
14. Go to DMAP No. 17 if no undeformed structure plots are requested.
15. PL0T generates all requested undeformed structure plots.
16. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
18. GP3 generates Static Loads Table and Grid Point Temperature Table.
19. TA1 generates element tables for use in matrix assembly and stress recovery.
20. Go to DMAP No. 102 and print Error Message No. 6 if no structural elements have been defined.
24. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
26. Go to DMAP No. 28 if no stiffness matrix is to be assembled.
27. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
29. Go to DMAP No. 92 and print Error Message No. 1 if no mass matrix is to be assembled.
30. EMA assembles mass matrix  $[M_{gg}]$ .
31. Go to DMAP No. 34 if no weight and balance information is requested.
32. GPWG generates weight and balance information.
33. OFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
35. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
36. Go to DMAP No. 38 if there are no general elements.
37. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
40. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g] \{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
41. Go to DMAP No. 96 and print Error Message No. 3 if no independent degrees of freedom are defined.
43. Go to DMAP No. 98 and print Error Message No. 4 if free-body supports are present.
45. GPCYC prepares segment boundary table (CYCD).
46. Go to DMAP No. 100 and print Error Message No. 5 if CYJ0IN data is inconsistent.

NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

47. Go to DMAP No. 52 if general elements are present.
49. Go to DMAP No. 52 if no potential grid point singularities exist.
50. GPSP generates a table of potential grid point singularities.
51. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
53. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
54. Go to DMAP No. 57 if no multipoint constraints exist.
55. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
56. MCE2 partitions stiffness matrix

$$[K_{gg}] = \begin{bmatrix} - \\ K_{nn} \mid K_{nm} \\ \hline K_{mn} \mid K_{mm} \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] .$$

58. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.
59. Go to DMAP No. 61 if no single-point constraints exist.
60. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} \mid K_{fs} \\ \hline K_{sf} \mid K_{ss} \end{bmatrix} \quad \text{and} \quad [M_{nn}] = \begin{bmatrix} M_{ff} \mid M_{fs} \\ \hline M_{sf} \mid M_{ss} \end{bmatrix} .$$

62. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
63. Equivalence  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.
64. Go to DMAP No. 67 if no omitted coordinates exist.
65. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - \\ K_{aa} \mid K_{ao} \\ \hline K_{oa} \mid K_{oo} \end{bmatrix} ,$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$  .

## DISPLACEMENT RIGID FORMATS

66. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} - & M_{aa} & M_{ao} \\ M_{aa} & + & M_{ao} \\ M_{ao} & M_{oo} & \end{bmatrix},$$

and performs matrix reduction

$$[M_{aa}] = [M_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oa}] + [G_o^T][M_{oo}][G_o].$$

68. DPD extracts Eigenvalue Extraction Data from Dynamics data block.

69. Go to DMAP No. 94 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

70. CYCT2 transforms matrices from symmetric components to solution set by the equations

$$[K_{kk}] = [G_1^T][K_{aa}][G_1] + [G_2^T][K_{aa}][G_2],$$

and  $[M_{kk}] = [G_1^T][M_{aa}][G_1] + [G_2^T][M_{aa}][G_2],$

where  $G_1 = G_c$  (cosine) and  $G_2 = G_s$  (sine) for rotational symmetry,

and  $G_1 = G_S$  (Symmetric) and  $G_2 = G_A$  (Antisymmetric) for dihedral symmetry.

71. Go to DMAP No. 100 and print Error Message No. 5 if a CYCT2 error was found.

72. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{kk} - \lambda M_{kk}]\{u_k\} = 0,$$

calculates modal mass matrix

$$[m] = [\phi_k^T][M_{kk}][\phi_k]$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit value of a selected component
- 2) Unit value of the largest component
- 3) Unit value of the generalized mass.

73. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.

74. Go to DMAP No. 104 and make normal exit if no eigenvalues were found.

75. ØFP formats the eigenvalues (LAMK) prepared by READ and places them on the system output file for printing.

76. CYCT2 finds symmetric components of eigenvectors from solution set eigenvectors.

77. Go to DMAP No. 100 and print Error Message No. 5 if a CYCT2 error was found.

## NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

78. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_0\} = [G_0] \{\phi_a\}, \quad \left\{ \frac{\phi_a}{\phi_0} \right\} = \{\phi_f\},$$

$$\left\{ \frac{\phi_f}{\phi_s} \right\} = \{\phi_n\}, \quad \{\phi_m\} = [G_m] \{\phi_n\},$$

$$\left\{ \frac{\phi_n}{\phi_m} \right\} = \{\phi_g\}$$

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}]^T \{\phi_f\}$ .

- 79. Go to DMAP No. 82 if no multipoint constraint force balance is requested.
- 80. EQMCK calculates the force and moment equilibrium check and prepares the multipoint constraint force balance ( $\emptyset QM1$ ) for output.
- 81. ØFP formats the table prepared by EQMCK and places it on the system output file for printing.
- 83. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares eigenvectors ( $\emptyset PHIG$ ) and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the eigenvectors (PPHIG).
- 84. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.
- 85. SCAN examines the element stresses and forces calculated by SDR2 and generates scanned output that meets the specifications set by the user.
- 86. ØFP formats the scanned output table prepared by SCAN and places it on the system output file for printing.
- 87. Go to DMAP No. 90 if no deformed structure plots are requested.
- 88. PLØT generates all requested deformed structure and contour plots.
- 89. PRTMSG prints plotter data, engineering data, and contour data for each deformed plot generated.
- 91. Go to DMAP No. 104 and make normal exit.
- 93. Print Error Message No. 1 and terminate execution.
- 95. Print Error Message No. 2 and terminate execution.
- 97. Print Error Message No. 3 and terminate execution.
- 99. Print Error Message No. 4 and terminate execution.
- 101. Print Error Message No. 5 and terminate execution.
- 103. Print Error Message No. 6 and terminate execution.

## DISPLACEMENT RIGID FORMATS

### 2.15.3 Output for Normal Modes Analysis Using Cyclic Symmetry

The Eigenvalue Summary Table and the Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed.

Each NASTRAN run calculates modes for only one symmetry index, k. The following output may be requested:

1. Eigenvectors along with the associated eigenvalue for each mode.
2. Nonzero components of the single-point forces of constraint for selected modes at selected grid points.
3. Forces and stresses in selected elements for selected modes.
4. Scanned output of forces and elements in selected elements.

The following plotter output may be requested:

1. Undeformed plot of the structural model and mode shapes for selected modes.
2. Contour plots of stresses and displacements for selected modes.

### 2.15.4 Case Control Deck for Normal Modes Analysis Using Cyclic Symmetry

The following items relate to subcase definition and data selection for Normal Modes Analysis Using Cyclic Symmetry:

1. METH0D must be used to select an EIGR card that exists in the Bulk Data Deck.
2. An SPC set must be selected unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection cards or with General Elements.
3. Multiple subcases are used only to control output requests. A single subcase is sufficient if the same output is desired for all modes. If multiple subcases are present, the output requests will be honored in succession for increasing mode numbers. MODES may be used to repeat subcases in order to make the same output request for several consecutive modes.

### 2.15.5 Parameters for Normal Modes Analysis Using Cyclic Symmetry

The following parameters are used in Normal Modes Analysis Using Cyclic Symmetry:

1. ASET0UT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT0SPC - reserved for future optional use. The default value is -1.

## NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

3. C0UPMASS - CPBAR, CPR0D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. CTYPE - required. The BCD value of this parameter defines the type of cyclic symmetry as follows:
  - (1) R0T - rotational symmetry
  - (2) DRL - dihedral symmetry, using right and left halves
  - (3) DSA - dihedral symmetry, using symmetric and antisymmetric components
5. CYCSEQ - optional. The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 specifies alternating cosine and sine terms. The default value is -1.
6. GRDEQ - optional. A positive integer value of this parameter selects the grid point about which equilibrium will be checked for the Case Control output request, MPCF0RCE. If the integer value is zero, the basic origin is used. The default value is -1.
7. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
8. KINDEX - required. The integer value of this parameter specifies a single value of the harmonic index.
9. NSEGS - required. The integer value of this parameter is the number of identical segments in the structural model.
10. OPT - optional. A positive integer value of this parameter causes both equilibrium and multipoint constraint forces to be calculated for the Case Control output request, MPCF0RCE. A negative integer value of this parameter causes only the equilibrium force balance to be calculated for the output request. The default value is 0 which causes only the multipoint constraint forces to be calculated for the output request.
11. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.

## DISPLACEMENT RIGID FORMATS

12. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
13. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

### 2.15.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

### 2.15.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Normal Modes Analysis Using Cyclic Symmetry. See Section 2.3.7 for details.

### 2.15.8 Rigid Format Error Messages from Normal Modes Analysis Using Cyclic Symmetry

The following fatal errors are detected by the DMAP statements in the Normal Modes Analysis Using Cyclic Symmetry rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR REAL EIGENVALUE ANALYSIS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTIONØ DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHOD in the Case Control Deck must select an EIGR set.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT, or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

## NORMAL MODES ANALYSIS USING CYCLIC SYMMETRY

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 4 - FREE BØDY SUPPØRTS NØT ALLØWED.

Free bodies are not allowed in Normal Modes Analysis Using Cyclic Symmetry. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 5 - CYCLIC TRANSFØRMATIØN DATA ERRØR.

See Section 1.12 for proper modeling techniques and corresponding PARAM card requirements.

NØRMAL MØDES WITH CYCLIC SYMMETRY ERRØR MESSAGE NØ. 6 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

DISPLACEMENT RIGID FORMATS

2.15-14 (05/30/86)

DISPLACEMENT RIGID FORMATS

2.16 STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESSORS

2.16.1 DMAP Sequence for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

-----  
1 BEGIN DISP 16 - STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS-APR. 1986 \$  
2 PRECHK ALL \$  
3 PARAM //\*MPY\*/CARDNO/0/0 \$  
4 GP1 GEOM1,GEOM2,/GPL,EQEXIN,GPDTCSTM,BGPDT,SIL/S,N,LUSET/S,N,  
NOGPDT/MINUS1=-1 \$  
5 COND ERROR3,NOGPDT \$  
6 PLTTRAN BGPDT,SIL/BGPDP,SIP/LUSET/S,N,LUSEP \$  
7 GP2 GEOM2,EQEXIN/ECT \$  
8 PARAML PCDB//\*PRES\*///JUMPPLOT \$  
9 PARAMR //\*COMPLEX\*//V,Y,SIGN/0.0/CSIGN \$  
10 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT \$  
11 COND P1,JUMPPLOT \$  
12 PLTSET PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL/S,N,  
JUMPPLOT \$  
13 PRMSG PLTSETX// \$  
14 PARAM //\*MPY\*/PLTFLG/1/1 \$  
15 PARAM //\*MPY\*/PFILE/0/0 \$  
16 COND P1,JUMPPLOT \$  
17 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,,./PLOTX1/  
NSIL/LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE \$  
18 PRMSG PLOTX1// \$  
19 LABEL P1 \$  
20 GP3 GEOM3,EQEXIN,GEOM2/SLT,GPTT/S,N,NOGRAV \$  
21 PARAM //\*AND\*/NOMGG/NOGRAV/V,Y,GRDPNT=-1 \$

## DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 TAI      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/LUSET/S,N,  
           NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
  
23 COND    ERROR1,NOSIMP $  
  
24 PURGE   OGPST/GENEL $  
  
25 PARAM   ///*ADD*/NOKGGX/1/0 $  
  
26 EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
           S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,  
           CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,  
           CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $  
  
27 COND    JMPKGG,NOKGGX $  
  
28 EMA     GPECT,KDICT,KELM/KGGX,GPST $  
  
29 LABEL   JMPKGG $  
  
30 COND    JMPMGG,NOMGG $  
  
31 EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
  
32 LABEL   JMPMGG $  
  
33 COND    LBL1,GRDPNT $  
  
34 COND    ERROR4,NOMGG $  
  
35 GPWG   BGPDP,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $  
  
36 OFP    OGPWG, , , , /S,N,CARDNO $  
  
37 LABEL   LBL1 $  
  
38 EQUIV  KGGX,KGG/NOGENL $  
  
39 COND    LBL11,NOGENL $  
  
40 SMA3   GEI,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
  
41 LABEL   LBL11 $  
  
42 PARAM   ///*MPY*/NSKIP/0/0 $  
  
43 GP4    CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,/RG,YS,USET,ASET/  
           LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/S,N,  
           NSKIP/S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,  
           AUTOSPC $  
  
44 COND    ERROR5,NOL $
```

STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESSORS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45 PURGE GM/MPCF1/G0,K00,L00,P0,U00V,RUOV/OMIT/PS,KFS,KSS,QG/SINGLE/  
PBS,KBFS,KBSS,KDFS,KDSS/SINGLE $  
46 COND LBL4D,REACT $  
47 JUMP ERROR2 $  
48 LABEL LBL4D $  
49 COND LBL4,GENEL $  
50 PARAM //EQ*/GPSPFLG/AUTOSPC/O $  
51 COND LBL4,GPSPFLG $  
52 GPSP GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $  
53 OFP OGPST,,,./S,N,CARDNO $  
54 LABEL LBL4 $  
55 EQUIV KGG,KNN/MPCF1 $  
56 COND LBL2,MPCF2 $  
57 MCE1 USET,RG/GM $  
58 MCE2 USET,GM,KGG,,,/KNN,,, $  
59 LABEL LBL2 $  
60 EQUIV KNN,KFF/SINGLE $  
61 COND LBL3,SINGLE $  
62 SCE1 USET,KNN,,,/KFF,KFS,KSS,,, $  
63 LABEL LBL3 $  
64 EQUIV KFF,KAA/OMIT $  
65 COND LBL5,OMIT $  
66 SMP1 USET,KFF,,,/GO,KAA,K00,L00,,,, $  
67 LABEL LBL5 $  
68 RBMG2 KAA/LLL $  
69 SSG1 SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT,/PGNA,,,/  
LUSET/1 $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
70 PARAM ///*AND*/ALOAD/V,Y,APRESS/V,Y,ATEMP $
71 COND NOAL,ALOAD $
72 ALG CASECC,,EQEXIN,,ALGDB,,CASECCA1,GEOM3A1/S,Y,APRESS/S,Y,
      ATEMP/-1/-1/V,Y,IPRTC1/S,N,IFAIL $
73 COND FINIS,IFAIL $
74 PARAM ///*AND*/ALOAD/V,Y,APRESS/V,Y,ATEMP $
75 COND NOAL,ALOAD $
76 GP3 GEOM3A1,EQEXIN,GEOM2/SLTA1,GPTTA1/NOGRAV $
77 SSG1 SLTA1,BGPDT,CSTM,SIL,EST,MPT,GPTTA1,EDT,MGG,CASECCA1,DIT,/
      PGA1,,,/LUSET/1 $
78 ADD PGNA,PGA1/PG $
79 LABEL NOAL $
80 EQUIV PGNA,PG/ALOAD $
81 EQUIV PG,PL/NOSET $
82 COND LBL10,NOSET $
83 SSG2 USET,GM,YS,KFS,GO,,PG/,PO,PS,PL $
84 LABEL LBL10 $
85 SSG3 LLL,KAA,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/OMIT/V,Y,IRES=-1/
      1/S,N,EPsi $
86 COND LBL9,IRES $
87 MATGPR GPL,USET,SIL,RULV//*L* $
88 MATGPR GPL,USET,SIL,RUOV//*0* $
89 LABEL LBL9 $
90 SDR1 USET,,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,/UGV,PG1,QG/1/*DS0* $
91 SDR2 CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QG,UGV,EST,,PG/
      OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/*DS0* $
92 OFP OUGV1,OPG1,OQG1,OEF1,OES1,,/S,N,CARDNO $
93 COND P2,JUMPPLLOT $
```

STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESSORS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
94 PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUGV1,,GPECT,OES1/
          PLOTX2/NSIL/LUSET/JUMPPLOT/PLTFLG/S,N,PFILE $

95 PRTMSG    PLOTX2// $

96 LABEL     P2 $

97 TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/X1,X2,X3,ECPT,GPCT/LUSET/
          NOSIMP/O/NOGENL/GENEL $

98 DSMG1     CASECC,GPTT,SIL,EDT,UGV,CSTM,MPT,ECPT,GPCT,DIT/KDGG/
          DSCOSET$

99 COND      NOALO,ALOAD $

100 EQUIV    PGNA,PG $

101 LABEL     NOALO $

102 PARAM    ///*ADD*/SHIFT/-1/0 $

103 PARAM    ///*ADD*/COUNT/ALWAYS=-1/NEVER=1 $

104 PARAMR   ///*ADD*/DSEPSI/0.0/0.0 $

105 PARAML   YS///*NULL*///NOYS $

106 LABEL     OUTLPTOP $

107 EQUIV    PG,PG1/NOYS $

108 PARAM    ///*KLOCK*/TO $

109 EQUIV    KDGG,KDNN/MPCF2 $

110 COND     LBL2D,MPCF2 $

111 MCE2     USET,GM,KDGG,,,/KDNN,,, $

112 LABEL     LBL2D $

113 EQUIV    KDNN,KDFF/SINGLE $

114 COND     LBL3D,SINGLE $

115 SCE1     USET,KDNN,,,/KDFF,KDFS,KDSS,,, $

116 LABEL     LBL3D $

117 EQUIV    KDFF,KDAA/OMIT $

118 COND     LBL5D,OMIT $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
119 SMP2    USET,GO,KDFF/KDAA $  
120 LABEL   LBL5D $  
121 ADD     KAA,KDAA/KBLL/(1.0,0.0)/CSIGN $  
122 ADD     KFS,KDFS/KBFS/(1.0,0.0)/CSIGN $  
123 ADD     KSS,KDSS/KBSS/(1.0,0.0)/CSIGN $  
124 COND    PGOK,NOYS $  
125 MPYAD   KBSS,YS,/PSS/O $  
126 MPYAD   KBFS,YS,/PFS/O $  
127 UMERGE  USET,PFS,PSS/PN/*N*/*F*/*S* $  
128 EQUIV   PN,PGX/MPCF2 $  
129 COND    LBL6D,MPCF2 $  
130 UMERGE  USET,PN,/PGX/*G*/*N*/*M* $  
131 LABEL   LBL6D $  
132 ADD     PGX,PG/PGG/(-1.0,0.0) $  
133 EQUIV   PGG,PG1/ALWAYS $  
134 LABEL   PGOK $  
135 ADD     PG1,/PGO/ $  
136 COPY    UGV/AUGV $  
137 RBMG2   KBLL/LBLL/S,N,POWER/S,N,DET $  
138 PRTPARM //O/*DET* $  
139 PRTPARM //O/*POWER* $  
140 LABEL   INLPTOP $  
141 PARAM   ///*KLOCK*/TI $  
142 COND    NOAL1,ALOAD $  
143 ALG     CASECC,EDT,EQEXIN,AUGV,ALGDB,CSTM,BGPDT/CASECCA,GEOM3A/S,Y,  
APRESS/S,Y,ATEMP/-1/-1/V,Y,IPRTCL/S,N,IFAIL/V,Y,SIGN/V,  
Y,ZORIGN/V,Y,FXCOOR/V,Y,FYCOOR/V,Y,FZCOOR $
```

STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESSORS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
144  COND      DONE,IFAIL $  
145  PARAM     //*MPY*/V,Y,IPRTCL/O $  
146  PARAM     //*AND*/ALOAD/V,Y,APRESS/V,Y,ATEMP $  
147  COND      NOAL1,ALOAD $  
148  GP3       GEOM3A,EQEXIN,GEOM2/SLTA,GPTTA/NOASL/NOGRAV/NOATL $  
149  SSG1      SLTA,BGPDT,CSTM,SIL,EST,MPT,GPTTA,EDT,MGG,CASECCA,DIT,/PGA,,,/  
             LUSET/1 $  
150  ADD       PG1,PGA/PG2 $  
151  LABEL     NOAL1 $  
152  EQUIV    PG1,PG2/ALOAD $  
153  SSG2      USET,GM,YS,KDFS,GO,,PG2/,PBO,PBS,PBL $  
154  SSG3      LBLL,KBLL,PBL,,,/UBLV,,RUBLV,/-1/V,Y,IRES/NDSKIP/S,N,  
             EPSI $  
155  COND      LBL9D,IRES $  
156  MATGPR   GPL,USET,SIL,RUBLV//*L* $  
157  LABEL     LBL9D $  
158  SDR1      USET,,UBLV,,YS,GO,GM,PBS,KBFS,KBSS,/UBGV,,QBG/1/*DS1* $  
159  COND      NOAL2,ALOAD $  
160  EQUIV    UBGV,AUGV $  
161  LABEL     NOAL2 $  
162  ADD       UBGV,UGV/DUGV/(-1.0,0.0) $  
163  DSMG1    CASECC,GPTT,SIL,EDT,DUGV,CSTM,MPT,ECPT,GPCT,DIT/DKDGG/V,N,  
             DSCOSET $  
164  MPYAD    DKDGG,UBGV,PG0/PG11/O $  
165  ADD       PG11,PGA/PG12 $  
166  DSCHK    PG2,PG12,UBGV//C,Y,EPS10=1.E-5/S,N,DSEPSI/C,Y,NT=10/  
             TO/TI/S,N,DONE/S,N,SHIFT/S,N,COUNT/C,Y,BET,D=4 $  
167  COND      DONE,DONE $
```

DISPLACEMENT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
168  COND      SHIFT,SHIFT $  
169  EQUIV     PG,PG1/NEVER $  
170  EQUIV     PG11,PG1/ALWAYS $  
171  EQUIV     PG1,PG11/NEVER $  
172  REPT      INLPTOP,1000 $  
173  TABPT     PG11,PG1,PG,,// $  
174  LABEL      SHIFT $  
175  ADD       DKDGG,KDGG/KDGG1/(-1.0,0.0) $  
176  EQUIV     UBGV,UGV/ALWAYS/KDGG1,KDGG/ALWAYS $  
177  EQUIV     KDGG,KDGG1/NEVER/UGV,UBGV/NEVER $  
178  REPT      OUTLPTOP,1000 $  
179  TABPT     KDGG1,KDGG,UGV,,// $  
180  LABEL      DONE $  
181  PARAM     ///*NOP*/V,Y,KTOUT=-1 $  
182  COND      JMPKTOUT,KTOUT $  
183  ADD       KGG,KDGG/KTOTAL/(1.0,0.0)/CSIGN $  
184  OUTPUT1   KTOTAL,,,//C,Y,LOCATION=-1/C,Y,INPTUNIT=0 $  
185  OUTPUT1, ,,,,-/3/0 $  
186  LABEL      JMPKTOUT $  
187  ALG       CASECC,EDT,EQEXIN,UBGV,ALGDB,CSTM,BGPDT/CASECCB,GEOM3B/  
-1/-1/V,Y,STREAML/V,Y,PGEOM/V,Y,IPRTCF/S,N,IFAIL/V,Y,SIGN/  
V,Y,ZORIGN/V,Y,FXCOOR/V,Y,FYCOOR/V,Y,FZCOOR $  
188  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDP,,QBG,UBGV,EST,,/  
OQBG1,OUBGV1,OESB1,OEFB1,PUBGV1/*DS1* $  
189  OFP       OUBGV1,OQBG1,OEFB1,OESB1,,//S,N,CARDNO $  
190  SDR1      USET,PG2,UBLV,,YS,GO,GM,PBS,KBFS,KBSS,/AUBGV,APGG,AQBG/  
1/*DS1* $  
191  GPFDR    CASECC,AUBGV,KELM,KDICT,ECT,EQEXIN,GPECT,APGG,AQBG/ONRGY1,  
OGPFB1/*STATICS* $
```

STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESSORS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

DISPLACEMENT APPROACH, RIGID FORMAT 16

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
192 OFF      ONRGY1,OGPFB1,,,//S,N,CARDNO $  
193 COND     P3,JUMPPLT $  
194 PLOT     PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIP,PUBGV1,,GPECT,  
             OESB1/PLOTX3/NSIL/LUSET/JUMPPLT/PLTFLG/S,N,PFILE $  
195 PRTMSG   PLOTX3// $  
196 LABEL    P3 $  
197 JUMP     FINIS $  
198 LABEL    ERROR1 $  
199 PRTPARM  // -1/*ASTA* $  
200 LABEL    ERROR2 $  
201 PRTPARM  // -2/*ASTA* $  
202 LABEL    ERROR3 $  
203 PRTPARM  // -3/*ASTA* $  
204 LABEL    ERROR4 $  
205 PRTPARM  // -4/*ASTA* $  
206 LABEL    ERROR5 $  
207 PRTPARM  // -5/*ASTA* $  
208 LABEL    FINIS $  
209 PURGE   DUMMY/MINUS1 $  
210 END     $
```

2.16.2 Description of Important DMAP Operations for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
5. Go to DMAP No. 202 and print Error Message No. 3 if there is no Grid Point Definition Table.
6. PLTTRAN modifies special scalar grid points in the BGPDT and SIL tables.
7. GP2 generates Element Connection Table with internal indices.
9. PARAMR sets CSIGN=(SIGN, 0.0), where SIGN = +1.0 for analysis type run and SIGN = -1.0 for design type run.
11. Go to DMAP No. 19 if there are no structure plot requests.
12. PLTSET transforms user input into a form used to drive the structure plotter.
13. PRTMSG prints error messages associated with the structure plotter.
16. Go to DMAP No. 19 if no undeformed structure plots are requested.
17. PL0T generates all requested undeformed structure plots.
18. PRTMSG prints plotter data and engineering data for each undeformed plot generated.
20. GP3 generates Static Loads Table and Grid Point Temperature Table.
22. TA1 generates element tables for use in matrix assembly and stress recovery.
23. Go to DMAP No. 198 and print Error Message No. 1 if there are no structural elements.
26. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no stiffness matrix is to be assembled.
28. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
30. Go to DMAP No. 32 if no mass matrix is to be assembled.
31. EMA assembles mass matrix  $[M_{gg}]$ .
33. Go to DMAP No. 37 if no weight and balance information is requested.
34. Go to DMAP No. 204 and print Error Message No. 4 if no mass matrix exists.
35. GPWG generates weight and balance information.
36. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
38. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if no general elements exist.
39. Go to DMAP No. 41 if no general elements exist.
40. SMA3 adds general elements to  $[K_{gg}^X]$  to obtain stiffness matrix  $[K_{gg}]$ .
43. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g] \{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
44. Go to DMAP No. 206 and print Error Message No. 5 if no independent degrees of freedom are defined.

STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESSORS

46. Go to DMAP No. 48 if no free-body supports are supplied.
47. Go to DMAP No. 200 and print Error Message No. 2.
49. Go to DMAP No. 54 if general elements are present.
51. Go to DMAP No. 54 if no potential grid point singularities exist.
52. GPSP generates a table of potential grid point singularities.
53. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
55. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if no multipoint constraints exist.
56. Go to DMAP No. 59 if no multipoint constraints exist.
57. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \mid R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
58. MCE2 partitions stiffness matrix

$$[K_{gg}] = \begin{bmatrix} \cdots & | & K_{nn} \\ \hline K_{nn} & + & K_{nm} \\ \cdots & | & K_{mm} \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

60. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  if no single-point constraints exist.
61. Go to DMAP No. 63 if no single-point constraints exist.
62. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} \cdots & | & K_{ff} \\ \hline K_{ff} & + & K_{fs} \\ \cdots & | & K_{sf} \end{bmatrix}.$$

64. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
65. Go to DMAP No. 67 if no omitted coordinates exist.
66. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} \cdots & | & K_{aa} \\ \hline K_{aa} & + & K_{ao} \\ \cdots & | & K_{oa} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

- and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .
68. RMBG2 decomposes constrained stiffness matrix  $[K_{aa}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

DISPLACEMENT RIGID FORMATS

69. SSG1 generates non-aerodynamic static load vectors  $\{P_g^N\}$ .

71. Go to DMAP No. 79 if no aerodynamic loads exist.

72. ALG generates aerodynamic load data.

77. SSG1 generates aerodynamic load vector  $\{P_g^A\}$ .

78. Add  $\{P_g^N\}$  and  $\{P_g^A\}$  to form total load vector  $\{P_g\}$ .

80. Equivalence  $\{P_g\}$  to  $\{P_g^N\}$  if no aerodynamic loads exist.

81. Equivalence  $\{P_g\}$  to  $\{P_\ell\}$  if no constraints are applied.

82. Go to DMAP No. 84 if no constraints are applied.

83. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{ \begin{array}{c} \bar{P}_n \\ \bar{P}_m \end{array} \right\}, \quad \{P_n\} = \bar{P}_n + [G_m^T] \{P_m\},$$

$$\{P_f\} = \left\{ \begin{array}{c} \bar{P}_f \\ \bar{P}_s \end{array} \right\}, \quad \{P_f\} = \bar{P}_f - [K_{fs}] \{Y_s\},$$

$$\{P_a\} = \left\{ \begin{array}{c} P_a \\ P_0 \end{array} \right\}, \text{ and } \{P_\ell\} = \{P_a\} + [G_0^T] \{P_0\}.$$

85. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{aa}]^{-1} \{P_\ell\},$$

solves for displacements of omitted coordinates

$$\{u_0^0\} = [K_{oo}]^{-1} \{P_0\},$$

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{aa}] \{u_\ell\},$$

$$\epsilon_\ell = \frac{\{u_\ell^T\} \{\delta P_\ell\}}{\{P_\ell^T\} \{u_\ell\}}$$

and calculates residual vector (RUOV) and residual vector error ratio for omitted coordinates

$$\{\delta P_0\} = \{P_0\} - [K_{oo}] \{u_0^0\},$$

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$$\epsilon_0 = \frac{\{u_0^T\}\{\delta P_0\}}{\{P_0^T\}\{u_0^0\}} .$$

86. Go to DMAP No. 89 if residual vectors are not to be printed.
87. MATGPR prints the residual vector for independent coordinates (RULV).
88. MATGPR prints the residual vector for omitted coordinates (RUØV).
90. SDR1 recovers dependent displacements

$$\{u_0\} = [G_0]\{u_\ell\} + \{u_0^0\} ,$$

$$\left\{ \frac{u_a}{u_0} \right\} = \{u_f\} , \quad \left\{ \frac{u_f}{Y_s} \right\} = \{u_n\} ,$$

$$\{u_m\} = [G_m]\{u_n\} , \quad \left\{ \frac{u_n}{u_m} \right\} = \{u_g\}$$

and recovers single-point forces of constraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\}.$$

91. SDR2 calculates element forces ( $\emptyset EF1$ ) and stresses ( $\emptyset ES1$ ) and prepares load vectors ( $\emptyset PG1$ ), displacement vectors ( $\emptyset UGV1$ ) and single-point forces of constraint ( $\emptyset QG1$ ) for output and translation components of the displacement vector ( $PUGV1$ ) for the static solution.
92. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.
93. Go to DMAP No. 96 if no deformed static solution structure plots are requested.
94. PLØT generates all requested static solution deformed structure and contour plots.
95. PRTMSG prints plotter data, engineering data, and contour data for each deformed static solution plot generated.
97. TA1 generates element tables for use in differential stiffness matrix assembly.
98. DSMG1 generates differential stiffness matrix  $[K_{gg}^d]$ .
99. Go to DMAP No. 101 if no aerodynamic loads exist.
100. Equivalence  $\{P_g^{NA}\}$  to  $\{P_g\}$  to remove aerodynamic loads from total load vector before entering the differential stiffness loop. New aerodynamic loads will be generated in the loop.
106. Beginning of outer (stiffness adjustment) loop for differential stiffness iteration.
107. Equivalence  $\{P_g\}$  to  $\{P_{g1}\}$  if no enforced displacements are specified.

DISPLACEMENT RIGID FORMATS

109. Equivalence  $[K_{gg}^d]$  to  $[K_{nn}^d]$  if no multipoint constraints exist.

110. Go to DMAP No. 112 if no multipoint constraints exist.

111. MCE2 partitions differential stiffness matrix

$$[K_{gg}^d] = \left[ \begin{array}{c|c} K_{nn}^d & K_{nm}^d \\ \hline K_{mn}^d & K_{mm}^d \end{array} \right]$$

and performs matrix reduction

$$[K_{nn}^d] = [K_{nn}^d] + [G_m^T][K_{mn}^d][G_m] + [K_{mn}^d][G_m] + [G_m^T][K_{mm}^d][G_m].$$

113. Equivalence  $[K_{nn}^d]$  to  $[K_{ff}^d]$  if no single-point constraints exist.

114. Go to DMAP No. 116 if no single-point constraints exist.

115. SCE1 partitions out single-point constraints

$$[K_{nn}^d] = \left[ \begin{array}{c|c} K_{ff}^d & K_{fs}^d \\ \hline K_{sf}^d & K_{ss}^d \end{array} \right].$$

117. Equivalence  $[K_{ff}^d]$  to  $[K_{aa}^d]$  if no omitted coordinates exist.

118. Go to DMAP No. 120 if no omitted coordinates exist.

119. SMP2 partitions constrained differential stiffness matrix

$$[K_{ff}^d] = \left[ \begin{array}{c|c} K_{aa}^d & K_{ao}^d \\ \hline K_{oa}^d & K_{oo}^d \end{array} \right].$$

and performs matrix reduction

$$[K_{aa}^d] = [K_{aa}^d] + [K_{oa}^d]^T[G_o] + [G_o]^T[K_{oa}^d] + [G_o]^T[K_{oo}^d][G_o].$$

121. ADD  $[K_{aa}]$  and  $[K_{aa}^d]$  to form  $[K_{\ell\ell}^b]$ .

122. ADD  $[K_{fs}]$  and  $[K_{fs}^d]$  to form  $[K_{fs}^b]$ .

123. ADD  $[K_{ss}]$  and  $[K_{ss}^d]$  to form  $[K_{ss}^b]$ .

124. Go to DMAP No. 134 if no enforced displacements are specified.

125. MPYAD multiplies  $[K_{ss}^b]$  and  $\{Y_s\}$  to form  $\{P_{ss}\}$ .

126. MYPAD multiplies  $[K_{fs}^b]$  and  $\{Y_s\}$  to form  $\{P_{fs}\}$ .

127. UMERGE combines  $\{P_{fs}\}$  and  $\{P_{ss}\}$  to form  $\{P_n\}$ .

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128. Equivalence  $\{P_n\}$  to  $\{P_g^X\}$  if no multipoint constraints exist.
  129. Go to DMAP No. 131 if no multipoint constraints exist.
  130. UMERGE expands  $\{P_n\}$  to form  $\{P_g^X\}$ .
  132. ADD  $\{-P_g^X\}$  and  $\{P_g\}$  to form  $\{P_{gg}\}$ .
  133. Equivalence  $\{P_{gg}\}$  to  $\{P_{g1}\}$ .
  135. ADD  $\{P_{g1}\}$  and nothing to create  $\{P_{go}\}$ .
  136. Copy  $\{u_g\}$  to  $\{u_g^A\}$  to initialize aerodynamic displacements.
  137. RBMG2 decomposes the combined differential stiffness matrix and elastic stiffness matrix
- $$[K_{\ell\ell}^b] = [L_{\ell\ell}^b][U_{\ell\ell}^b].$$
138. PRTPARM prints the scaled value of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.
  139. PRTPARM prints the scale factor (power of ten) of the determinant of the combined differential stiffness matrix and elastic stiffness matrix.
  140. Beginning of inner (load correction) loop for differential stiffness iteration.
  142. Go to DMAP No. 151 if no aerodynamic loads exist.
  143. ALG generates aerodynamic load data.
  144. Go to DMAP No. 180 if ALG fails to converge while generating aerodynamic load data.
  149. SSG1 generates aerodynamic load vector  $\{P_g^A\}$ .
  150. ADD  $\{P_{g1}\}$  to  $\{P_g^A\}$  to form total load vector  $\{P_{g2}\}$ .
  153. SSG2 applies constraints to static load vectors

$$\begin{aligned} \{P_{g1}\} &= \left\{ \begin{array}{c} \bar{P}_n^b \\ \bar{P}_m^b \end{array} \right\}, & \{P_n^b\} &= \bar{P}_n^b + [G_m^T] \{P_m^b\}, \\ \{P_n^b\} &= \left\{ \begin{array}{c} \bar{P}_f^b \\ \bar{P}_s^b \end{array} \right\}, & \{P_f^b\} &= \bar{P}_f^b - [K_{fs}^d] \{Y_s\}, \\ \{P_f^b\} &= \left\{ \begin{array}{c} \bar{P}_a^b \\ \bar{P}_o^b \end{array} \right\} \quad \text{and} \quad \{P_\ell^b\} &= \bar{P}_a^b + [G_o^T] \{P_o^b\}. \end{aligned}$$

## DISPLACEMENT RIGID FORMATS

154. SSG3 solves for displacements of independent coordinates for current differential stiffness load vector

$$\{u_\ell^b\} = [K_{\ell\ell}^b]^{-1} \{P_\ell^b\} ,$$

and calculates residual vector (RBULV) and residual vector error ratio for current differential stiffness load vector

$$\{\delta P_\ell^b\} = \{P_\ell^b\} - [K_{\ell\ell}^b] \{u_\ell^b\} ,$$

$$\epsilon_\ell^b = \frac{\{u_\ell^b\}^T \{\delta P_\ell^b\}}{\{P_\ell^b\}^T \{u_\ell^b\}}$$

155. Go to DMAP No. 157 if the residual vector for current differential stiffness solution is not to be printed.

156. MATGPR prints the residual vector for current differential stiffness solution.

158. SDR1 recovers dependent displacements for the current differential stiffness solution

$$\{u_0^b\} = [G_0] \{u_\ell^b\} + \{u_0^{ob}\} , \quad \left\{ \begin{array}{c} u_\ell^b \\ u_0^b \end{array} \right\} = \{u_f\} ,$$

$$\left\{ \begin{array}{c} u_f^b \\ \gamma_s^b \end{array} \right\} = \{u_n^b\} , \quad \{u_m^b\} = [G_m] \{u_n^b\} ,$$

$$\left\{ \begin{array}{c} u_n^b \\ u_m^b \end{array} \right\} = \{u_g^b\}$$

and recovers single-point forces of constraint for the current differential stiffness solution

$$\{q_s^b\} = -\{P_s^b\} + [K_{sf}^b] \{u_f^b\} + [K_{ff}^b] \{\gamma_s^b\} .$$

159. Go to DMAP No. 161 if no aerodynamic loads exist.

160. Equivalence  $\{u_g^B\}$  and  $\{u_g^A\}$ .

162. ADD  $-\{u_g^B\}$  and  $\{U_g\}$  to form  $\{U_g^d\}$ .

163. DSMG1 generates differential stiffness matrix  $[\delta K_{gg}^d]$ .

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164. MYPAD forms the load vector for inner loop iteration

$$\{P_{gI1}\} = [\delta K_{gg}^d] \{U_g^b\} + \{P_{go}\}.$$

165. ADD  $\{P_{gI1}\}$  and  $\{P_g^A\}$  to form  $\{P_{gI2}\}$ .

166. DSCHK performs differential stiffness convergence checks.

167. Go to DMAP No. 180 if differential stiffness iteration is complete.

168. Go to DMAP No. 174 if additional differential stiffness matrix changes are necessary for further iteration.

169. Break the previous equivalence of  $\{P_g\}$  and  $\{P_{g1}\}$ .

170. Equivalence  $\{P_{gI1}\}$  to  $\{P_{g1}\}$ .

171. Break the previous equivalence of  $\{P_{g1}\}$  to  $\{P_{gI1}\}$ .

172. Go to DMAP No. 140 for an additional inner loop differential stiffness iteration.

173. TABPT table prints vectors  $\{P_{gI1}\}$ ,  $\{P_{g1}\}$ , and  $\{P_g\}$ .

175. ADD  $-[\delta K_{gg}^d]$  and  $[K_{gg}^d]$  to form  $[K_{gg1}^d]$ .

176. Equivalence  $\{U_g^b\}$  to  $\{U_g\}$  and  $[K_{gg1}^d]$  to  $[K_{gg}^d]$ .

177. Break the previous equivalence of  $[K_{gg}^d]$  to  $[K_{gg1}^d]$  and  $\{U_g\}$  to  $\{U_g^b\}$ .

178. Go to DMAP No. 106 for an additional outer loop differential stiffness iteration.

179. TABPT table prints  $[K_{gg1}^d]$ ,  $[K_{gg}^d]$ , and  $\{U_g\}$ .

182. Go to DMAP No. 186 if the total stiffness matrix [KTOTAL] is not to be saved on an external file.

183. ADD  $[K_{gg}^d]$  and  $[K_{gg}^d]$  to form  $[KTOTAL]$ .

184. OUTPUT1 outputs  $[KTOTAL]$  to an external file.

185. OUTPUT1 prints the names of the data blocks on the external file.

187. ALG generates final aerodynamic results and generates GRID and STREAML2 bulk data cards on the system punch file, if requested.

188. SDR2 calculates element forces ( $\{\delta EFB1\}$ ) and stresses ( $\{\delta ESB1\}$ ) and prepares displacement vectors ( $\{\delta UBGV1\}$ ) and single-point forces of constraint ( $\{\delta QBG1\}$ ) for output and translation components of the displacement vector ( $\{\delta PUBGV1\}$ ) for the differential stiffness solution.

189. OFP formats the tables prepared by SDR2 and places them on the system output file for printing.

190. SDR1 recovers dependent displacements after differential stiffness loop for grid point force balance.

191. GPFDR calculates for requested sets the grid point force balance and element strain energy for output.

DISPLACEMENT RIGID FORMATS

192.  $\emptyset$ FP formats the tables prepared by GPFDR and places them on the system output file for printing.
193. Go to DMAP No. 196 if no differential stiffness solution deformed plots are requested.
194. PL $\emptyset$ T generates all requested differential stiffness solution deformed structure and contour plots.
195. PRTMSG prints plotter data, engineering data, and contour data for each differential stiffness solution deformed plot generated.
197. Go to DMAP No. 208 and make normal exit.
199. Print Error Message No. 1 and terminate execution.
201. Print Error Message No. 2 and terminate execution.
203. Print Error Message No. 3 and terminate execution.
205. Print Error Message No. 4 and terminate execution.
207. Print Error Message No. 5 and terminate execution.

## STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESSORS

### 2.16.3 Output for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The value of the determinant of the sum of the elastic stiffness and the differential stiffness is automatically printed for each differential stiffness loading condition.

Iterative differential stiffness computations are terminated for one of five reasons. Iteration termination reasons are automatically printed in an information message. These reasons have the following meanings:

1. REASON 0 means the iteration procedure was incomplete at the time of exit. This is caused by either an unexpected interruption of the iteration procedure (i.e., system abort) or termination is not scheduled (for the other four reasons) at the completion of the current iteration.
2. REASON 1 means the iteration procedure converged to the EPSI $\emptyset$  value supplied by the user on a PARAM bulk data card. (The default value of EPSI $\emptyset$  is 1.0E-5.)
3. REASON 2 means the iteration procedure is diverging from the EPSI $\emptyset$  value supplied by the user on a PARAM bulk data card. (The default value of EPSI $\emptyset$  is 1.0E-5.)
4. REASON 3 means insufficient time remaining to achieve convergence to the EPSI $\emptyset$  value supplied by the user on a PARAM bulk data card. (The default value of EPSI $\emptyset$  is 1.0E-5.)
5. REASON 4 means the number of iterations supplied by the user on a PARAM bulk data card has been met. (The default number of iterations is 10.)

Parameter values at the time of exit are automatically output as follows:

1. Parameter D $\emptyset$ NE: -1 is normal; + N is the estimate of the number of iterations required to achieve convergence.
2. Parameter SHIFT: +1 indicates a return to the top of the inner loop was scheduled; -1 indicates a return to top of the outer loop was scheduled following the current iteration.
3. Parameter DSEPSI: the value of the ratio of energy error to total energy at the time of exit.

The following output may be requested:

1. Nonzero Components of the applied static load for the linear solution at selected grid points.
2. Displacements and nonzero components of the single-point forces of constraint, with and without differential stiffness, at selected grid points.
3. Forces and stresses in selected elements, with and without differential stiffness.

## DISPLACEMENT RIGID FORMATS

4. Undeformed and deformed plots of the structural model.
5. Contour plots of stresss and displacements.

### 2.16.4 Case Control Deck for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The following items relate to subcase definition and data selection for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors:

1. The Case Control Deck must contain two subcases.
2. A static loading condition must be defined above the subcase level with a LOAD, TEMPERATURE (LOAD), or DEFORM selection, unless all loading is specified by grid point displacements on SPC cards.
3. An SPC set must be selected above the subcase level unless all constraints are specified on GRID cards.
4. Output requests that apply only to the linear solution must appear in the first subcase.
5. Output requests that apply only to the solution with differential stiffness must be placed in the second subcase.
6. Output requests that apply to both solutions, with and without differential stiffness, may be placed above the subcase level.

### 2.16.5 Parameters for Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The following parameters are used in Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors:

1. APRESS - optional. A positive integer value causes the generation of aerodynamic pressure loads. A negative integer value suppresses the generation of these loads. The default value is -1.
2. ASETOUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
3. ATEMP - optional. A positive integer value causes the generation of aerodynamic temperature loads. A negative integer value suppresses the generation of these loads. The default value is -1.
4. AUTOSPC - reserved for future optional use. The default value is -1.

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5. BETAD - optional. The integer value of this parameter is the number of iterations allowed for computing the load correction in the inner (load) loop before shifting to the outer (stiffness) loop, which adjusts the differential stiffness. The default value is 4 iterations.
6. C0UPMASS - CPBAR, CPR0D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
7. EPSI0 - optional. The real value of this parameter is used to test the convergence of the iterated differential stiffness. The default value is  $10^{-5}$ .
8. FXC00R, FYC00R and FZC00R - optional. The real values of these parameters are the fractions of the displacements used to redefine the blade geometry. The default values are: FXC00R = 1.0, FYC00R = 1.0 and FZC00R = 1.0.
9. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed.
10. IPRTCI, IPRTCL and IPRTCF - optional. If IPRTi is a positive integer, then intermediate print will be generated in the ALG module based on the print option in the ALGDB data table. If IPRTi = 0 (the default), no intermediate print will be generated.
11. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSG3 module.
12. KT0UT - optional. A positive integer value of this parameter indicates that the user wants to save the total stiffness matrix on an external file (GIN0 file INPT) via the OUTPUT1 module in the rigid format. The default value is -1 when not needed.
13. L0CATI0N and INPTUNIT - required when using the KT0UT parameter. See Section 5.5 for a description of these parameters which are required by the OUTPUT1 module. The default values for L0CATI0N and INPTUNIT are -1 and 0, respectively.
14. NI - optional. The integer value of this parameter limits the cumulative number of iterations in both loops. The default value is 10 iterations.
15. PGE0M - optional. The integer value of this parameter specifies the punching of various bulk data cards. PGE0M = 1 causes the punching of GRID bulk data cards. PGE0M = 2 causes the punching of CTRIA2 and PTRIA2 bulk data cards. PGE0M = 3 causes the

## DISPLACEMENT RIGID FORMATS

- punching of GRID cards and the modified ALGDB table on DTI cards. The default value of -1 suppresses the punching of any of these cards.
16. SIGN - optional. The real value of this parameter controls the type of run being performed. SIGN = 1.0 specifies a standard analysis type run. SIGN = -1.0 specifies a design type run. The default value is 1.0.
  17. STREAML - optional. The integer value of this parameter specifies the punching of various bulk data cards. STREAML = 1 causes the punching of STREAML1 bulk data cards. STREAML = 2 causes the punching of STREAML2 bulk data cards. STREAML = 3 causes both STREAML1 and STREAML2 cards to be punched. The default value of -1 suppresses the punching of any of these cards.
  18. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
  19. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
  20. WTMASS - optional. The terms of the mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module.

### 2.16.6 Rigid Format Error Messages from Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors

The following fatal errors are detected by the DMAP statements in the Static Aerothermoelastic Design/Analysis of Axial-Flow Compressors. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

AERØTHERMØELASTIC ERRØR NØ. 1 - NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No structural elements have been defined with Connection cards.

AERØTHERMØELASTIC ERRØR NØ. 2 - FREE BØDY SUPPORTS NØT ALLØWED.

Free bodies are not allowed in Static Analysis with Differential Stiffness. The SUPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

STATIC AEROTHERMOELASTIC DESIGN/ANALYSIS OF AXIAL-FLOW COMPRESSORS

AERØTHERMØELASTIC ERRØR NØ. 3 - NØ GRID PØINT DATA IS SPECIFIED.

No points have been defined with GRID or SPØINT cards.

AERØTHERMØELASTIC ERRØR NØ. 4 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATØNS.

The mass matrix is null because either no elements were defined with Connection cards, nonstructural mass was not defined on a Property card, or the density was not defined on a Material card.

AERØTHERMØELASTIC ERRØR NØ. 5 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

DISPLACEMENT RIGID FORMATS

2.16-24 (05/30/86)

### 3. HEAT RIGID FORMATS

#### 3.1 STATIC HEAT TRANSFER ANALYSIS

##### 3.1.1 DMAP Sequence for Static Heat Transfer Analysis

RIGID FORMAT DMAP LISTING  
APRIL 1985 RELEASE

HEAT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN HEAT 01 - STATIC HEAT TRANSFER ANALYSIS - APR. 1985 $  
2 PRECHK ALL $  
3 FILE HQG=APPEND/HPGG=APPEND/HUGV=APPEND/HGM=SAVE/HKNN=SAVE $  
4 PARAM //MPY*/CARDNO/O/O $  
5 GP1 GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/  
NOGPDT/MINUS1=-1 $  
6 PLTTRAN BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $  
7 GP2 GEOM2,HEQEXIN/ECT $  
8 PARAML PCDB//PRES///JUMPPLOT $  
9 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
10 COND HP1,JUMPPLOT $  
11 PLTSET PCDB,HEQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,HNSIL/  
S,N,JUMPPLOT $  
12 PRTMSG PLTSETX// $  
13 PARAM //MPY*/PLTFLG/1/1 $  
14 PARAM //MPY*/PFILE/O/O $  
15 COND HP1,JUMPPLOT $  
16 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIL,,ECT,,/PLOTX1/  
HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
17 PRTMSG PLOTX1// $  
18 LABEL HP1 $  
19 GP3 GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/NOGRAV $  
20 TA1 ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/  
HLUSET/S,N,NOSIMP/1/NOGENL/GENEL $  
21 COND ERROR4,NOSIMP $
```

HEAT RIGID FORMATS

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HEAT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
22 PURGE HKGG,GPST/NOSIMP $  
23 COND HLBL1,NOSIMP $  
24 PARAM //*ADD*/HNOKGG/1/O $  
25 EMG HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,,,,,/S,N,HNOKGG $  
26 PURGE HKGG,GPST/HNOKGG $  
27 COND HLBL1,HNOKGG $  
28 EMA HGPECT,HKDICT,HKELM/HKGG,GPST $  
29 LABEL HLBL1 $  
30 PARAM //*MPY*/NSKIP/O/O $  
31 LABEL HLBL11 $  
32 GP4 CASECC,GEOM4,HEQEXIN,GPDT,BGPDT,CSYM,GPST/RG,YS,HUSET,HASET/  
HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,HREPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
33 COND ERROR3,NOL $  
34 PARAM //*AND*/NOSR/SINGLE/REACT $  
35 PURGE HKRR,HKLR,HQR,HDM/REACT/GM/MPCF1/HGO,HKOO,HL00,HPO,HUOOV,  
HRUOV/OMIT/HPS,HKFS,HKSS/SINGLE/HQG/NOSR $  
36 PARAM //*EQ*/GPSPFLG/AUTOSPC/O $  
37 COND HLBL4,GPSPFLG $  
38 GPSP GPL,GPST,HUSET,HSIL/OGPST/S,N,NOGPST $  
39 OFF OGPST,,,,,/S,N,CARDNO $  
40 LABEL HLBL4 $  
41 EQUIV HKGG,HKNN/MPCF1 $  
42 COND HLBL2,MPCF1 $  
43 MCE1 HUSET,RG/GM $  
44 MCE2 HUSET,GM,HKGG,,,/HKNN,,, $  
45 LABEL HLBL2 $
```

STATIC HEAT TRANSFER ANALYSIS

RIGID FORMAT DMAP LISTING  
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HEAT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
46 EQUIV HKNN,HKFF/SINGLE $
47 COND HLBL3,SINGLE $
48 SCE1 HUSET,HKNN,,,/HKFF,HKFS,HKSS,,, $
49 LABEL HLBL3 $
50 EQUIV HKFF,HKAA/OMIT $
51 COND HLBL5,OMIT $
52 SMP1 HUSET,HKFF,,,/HGO,HKAA,HKOO,HLOO,,,,, $
53 LABEL HLBL5 $
54 EQUIV HKAA,HKLL/REACT $
55 COND HLBL6,REACT $
56 RBMG1 HUSET,HKAA,/HKLL,HKLR,HKRR,,, $
57 LABEL HLBL6 $
58 RBMG2 HKLL/HLLL $
59 COND HLBL7,REACT $
60 RBMG3 HLLL,HKLR,HKRR/HDM $
61 LABEL HLBL7 $
62 SSG1 HSLT,BGPDT,CSTM,HSIL,HEST,MPT,GPTT,EDT,,CASECC,DIT,/
      HPG,,,SCR/HLUSET/NSKIP $
63 EQUIV HPG,HPL/NOSET $
64 COND HLBL10,NOSET $
65 SSG2 HUSET,GM,YS,HKFS,HGO,HDM,HPG/HQR,HPO,HPS,HPL $
66 LABEL HLBL10 $
67 SSG3 HLLL,HKLL,HPL,HLOO,HKOO,HPO/HULV,HUOOV,HRULV,HRUOV/OMIT/
      V,Y,IRES=-1/NSKIP/S,N,EPSI $
68 COND HLBL9,IRES $
69 MATGPR GPL,HUSET,HSIL,HRULV//*L* $
70 MATGPR GPL,HUSET,HSIL,HRUOV//*0* $
```

HEAT RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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HEAT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
71 LABEL HLBL9 $  
72 SDR1 HUSER,HPG,HULV,HUOOV,YS,HGO,GM,HPS,HKFS,HKSS,HQR/HUGV,HPGG,  
HQG/NSKIP/*HSTATICS* $  
73 COND HLBL8,HREPEAT $  
74 REPT HLBL11,100 $  
75 JUMP ERROR1 $  
76 PARAM ///*NOT*/HTEST/HREPEAT $  
77 COND ERROR5,HTEST $  
78 LABEL HLBL8 $  
79 SDR2 CASECC,CSTM,MPT,DIT,HEQEXIN,HSIL,GPTT,EDT,BGPDP,,HQG,HUGV,  
HEST,,HPGG/HOPG1,HOQG1,HOUGV1,,HOEF1,HPUGV1/*STATICS* $  
80 OFP HOUGV1,HOPG1,HOQG1,HOEF1,,//S,N,CARDNO $  
81 COND HP2,JUMPPLOT $  
82 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIP,HPUGV1,,HGPECT,  
/PLOTX2/HNSIL/HLUSEP/JUMPPLOT/PLTFLG/  
S,N,PFILE $  
83 PRTPARM PLOTX2// $  
84 LABEL HP2 $  
85 JUMP FINIS $  
86 LABEL ERROR1 $  
87 PRTPARM //1/*HSTA* $  
88 LABEL ERROR3 $  
89 PRTPARM //3/*HSTA* $  
90 LABEL ERROR4 $  
91 PRTPARM //4/*HSTA* $  
92 LABEL ERROR5 $  
93 PRTPARM //5/*HSTA* $  
94 LABEL FINIS $
```

STATIC HEAT TRANSFER ANALYSIS

RIGID FORMAT DMAP LISTING  
APRIL 1985 RELEASE

HEAT APPROACH, RIGID FORMAT 1

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

95 PURGE DUMMY/MINUS1 \$

96 END \$

### 3.1.2 Description of Important DMAP Operations for Static Heat Transfer Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.
6. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.
7. GP2 generates Element Connection Table with internal indices.
10. Go To DMAP No. 18 if there are no structure plot requests.
11. PLTSET transforms user input into a form used to drive the structure plotter.
12. PRTMSG prints error messages associated with the structure plotter.
15. Go to DMAP No. 18 if no boundary and structure (heat conduction) element plots are requested.
16. PL0T generates all requested boundary and heat conduction element plots.
17. PRTMSG prints plotter data and engineering data for each plot generated.
19. GP3 generates applied Static (Thermal) Loads Table (HSLT) and Grid Point Temperature Table.
20. TA1 generates element tables for use in matrix assembly, load generation, and data recovery.
21. Go to DMAP No. 90 and print Error Message No. 4 if no elements have been defined.
23. Go to DMAP No. 29 if there are no heat conduction elements.
25. EMG generates element heat conduction matrix tables and dictionaries for later assembly by the EMA module.
27. Go to DMAP No. 29 if no heat conduction matrix is to be assembled.
28. EMA assembles heat conduction matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
31. Beginning of loop for additional constraint sets.
32. GP4 generates flags defining members of various displacement sets (USET), forms multipoint constraint equations  $[R_g] \{u_g\} = 0$  and forms enforced displacement vector  $\{Y_s\}$ .
33. Go to DMAP No. 88 and print Error Message No. 3 if no independent degrees of freedom are defined.
37. Go to DMAP No. 40 if no potential grid point singularities exist.
38. GPSP generates a table of potential grid point singularities.
39. OFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
41. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  if no multipoint constraints exist.
42. Go to DMAP No. 45 if no multipoint constraints exist.
43. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m | R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .

STATIC HEAT TRANSFER ANALYSIS

44. MCE2 partitions heat conduction matrix

$$[K_{gg}] = \begin{bmatrix} - & \\ K_{nn} & | & K_{nm} \\ \hline K_{mn} & + & K_{mm} \end{bmatrix}$$

and performs matrix reduction

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m].$$

46. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  if no single-point constraints exist.

47. Go to DMAP No. 49 if no single-point constraints exist.

48. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & | & K_{fs} \\ \hline K_{sf} & + & K_{ss} \end{bmatrix}.$$

50. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.

51. Go to DMAP No. 53 if no omitted coordinates exist.

52. SMP1 partitions constrained heat conduction matrix

$$[K_{ff}] = \begin{bmatrix} - & \\ K_{aa} & | & K_{ao} \\ \hline K_{oa} & + & K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [K_{aa}] + [K_{oa}^T][G_o]$ .

54. Equivalence  $[K_{aa}]$  to  $[K_{\ell\ell}]$  if no free-body supports exist.

55. Go to DMAP No. 57 if no free-body supports exist.

56. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & | & K_{\ell r} \\ \hline K_{r\ell} & + & K_{rr} \end{bmatrix}.$$

58. RBMG2 decomposes constrained heat conduction matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

59. Go to DMAP No. 61 if no free-body supports exist.

60. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

HEAT RIGID FORMATS

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|} .$$

- 62. SSG1 generates static thermal load vectors  $\{P_g\}$ .
- 63. Equivalence  $\{P_g\}$  to  $\{P_\ell\}$  if no constraints are applied.
- 64. Go to DMAP No. 66 if no constraints are applied.
- 65. SSG2 applies constraints to static thermal load vectors

$$\{P_g\} = \left\{ \begin{array}{c} \bar{P}_n \\ \bar{P}_m \end{array} \right\} , \quad \{P_n\} = \left\{ \begin{array}{c} \bar{P}_n \\ \bar{P}_m \end{array} \right\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{ \begin{array}{c} \bar{P}_f \\ \bar{P}_s \end{array} \right\} , \quad \{P_f\} = \left\{ \begin{array}{c} \bar{P}_f \\ \bar{P}_s \end{array} \right\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{ \begin{array}{c} \bar{P}_a \\ \bar{P}_o \end{array} \right\} , \quad \{P_a\} = \left\{ \begin{array}{c} \bar{P}_a \\ \bar{P}_o \end{array} \right\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{ \begin{array}{c} P_\ell \\ -P_r \end{array} \right\}$$

and calculates determinate thermal powers  $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$ .

- 67. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^0\} = [K_{oo}]^{-1}\{P_o\} ,$$

calculates residual vector (HRULV) and residual vector error ratio for independent coordinates

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

## STATIC HEAT TRANSFER ANALYSIS

$$\epsilon_x = \frac{\{u_x^T\}\{\delta p_x\}}{\{p_x^T\}\{u_x\}}$$

and calculates residual vector (HRU0V) and residual vector error ratio for omitted coordinates

$$\{\delta p_0\} = \{p_0\} - [K_{00}]\{u_0^0\} ,$$

$$\epsilon_0 = \frac{\{u_0^T\}\{\delta p_0\}}{\{p_0^T\}\{u_0^0\}}$$

- 68. Go to DMAP No. 71 if residual vectors are not to be printed.
- 69. MATGPR prints the residual vector for independent coordinates (HRULV).
- 70. MATGPR prints the residual vector for omitted coordinates (HRU0V).
- 72. SDR1 recovers dependent temperatures

$$\left\{ \frac{u_x}{u_r} \right\} = \{u_a\} , \quad \{u_0\} = [G_0]\{u_a\} + \{u_0^0\} ,$$

$$\left\{ \frac{u_a}{u_0} \right\} = \{u_f\} , \quad \left\{ \frac{u_f}{Y_s} \right\} = \{u_n\} ,$$

$$\{u_m\} = [G_m]\{u_n\} , \quad \left\{ \frac{u_n}{u_m} \right\} = \{u_g\}$$

and recovers single-point powers of sustained thermal constraint

$$\{q_s\} = -\{p_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\} .$$

- 73. Go to DMAP No. 78 if all constraint sets have been processed.
- 74. Go to DMAP No. 31 if additional sets of constraints need to be processed.
- 75. Go to DMAP No. 86 and print Error Message No. 1 as the number of constraint sets exceeds 100.
- 77. Go to DMAP No. 92 and print Error Message No. 5 if multiple boundary conditions are attempted with an improper subset.
- 79. SDR2 calculates conduction and boundary element heat flows and gradients (H0EF1) and prepares thermal load vectors (H0PG1), temperature vectors (H0UGV1) and single-point powers of constraint (H0QG1) for output and components of the temperature vector (HPUGV1).

## HEAT RIGID FORMATS

80. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.
81. Go to DMAP No. 84 if no temperature profile plots are requested.
82. PLØT generates all requested temperature profile and thermal contour plots.
83. PRTMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.
85. Go to DMAP No. 94 and make normal exit.
87. Print Error Message No. 1 and terminate execution.
89. Print Error Message No. 3 and terminate execution.
91. Print Error Message No. 4 and terminate execution.
93. Print Error Message No. 5 and terminate execution.

## STATIC HEAT TRANSFER ANALYSIS

### 3.1.3 Output for Static Heat Transfer Analysis

The following output may be requested for Static Heat Transfer Analysis:

1. Temperatures (THERMAL) and nonzero components of static loads ( $\emptyset$ LOAD) and constrained heat flow (SPCF $\emptyset$ RCE) at selected grid points or scalar points.
2. The punch option of a THERMAL request will produce TEMP bulk data cards.
3. Flux density (ELF $\emptyset$ RCE) in selected elements.
4. Plots of the structural model and temperature profiles.
5. Contour plots of the thermal field.

### 3.1.4 Case Control Deck for Static Heat Transfer Analysis

The following items relate to subcase definition and data selection for Static Heat Transfer Analysis:

1. A separate subcase must be defined for each unique combination of constraints and static loads.
2. A static loading condition must be defined for (not necessarily within) each subcase with a L $\emptyset$ AD selection, unless all loading is specified with grid point temperatures on SPC cards.
3. An SPC set must be selected for (not necessarily within) each subcase, unless all constraints are specified on GRID cards or Scalar Connection cards.
4. Loading conditions associated with the same sets of constraints should be in contiguous subcases, in order to avoid unnecessary looping.
5. REPCASE may be used to repeat subcases in order to allow multiple sets of the same output item.

### 3.1.5 Parameters for Static Heat Transfer Analysis

The following parameters are used in Static Heat Transfer Analysis:

1. ASET $\emptyset$ OUT - optional. A positive integer value of this parameter causes the HASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT $\emptyset$ SPC - reserved for future optional use. The default value is -1.
3. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following each execution of the SSG3 module.

## HEAT RIGID FORMATS

### 3.1.6 Rigid Format Error Messages from Static Heat Transfer Analysis

The following fatal errors are detected by the DMAP statements in the Static Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

#### STATIC HEAT TRANSFER ANALYSIS ERROR MESSAGE NO. 1 - ATTEMPT TO EXECUTE MORE THAN 100 LOOPS.

An attempt has been made to use more than 100 different sets of boundary conditions. This number may be increased by ALTERing the REPT instruction following SDR1.

#### STATIC HEAT TRANSFER ANALYSIS ERROR MESSAGE NO. 3 - NO INDEPENDENT DEGREES OF FREEDOM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPPOINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPPORT, OMIT or GRDSET cards, or grounded on Scalar Connection cards.

#### STATIC HEAT TRANSFER ANALYSIS ERROR MESSAGE NO. 4 - NO ELEMENTS HAVE BEEN DEFINED.

No elements have been defined with either Connection cards or GENEL cards.

#### STATIC HEAT TRANSFER ANALYSIS ERROR MESSAGE NO. 5 - A LOOPING PROBLEM RUN ON A NON-LOOPING SUBSET.

A problem requiring boundary condition changes was run on subset 1 or 3. The problem should be restarted on subset 0.

# HEAT RIGID FORMATS

## 3.2 NONLINEAR STATIC HEAT TRANSFER ANALYSIS

### 3.2.1 DMAP Sequence for Nonlinear Static Heat Transfer Analysis

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

HEAT APPROACH, RIGID FORMAT 3

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN HEAT 03 - NONLINEAR STATIC HEAT TRANSFER ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 PARAM //MPY*/CARDNO/0/0 $  
4 GP1 GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/  
NOGPDT/MINUS1=-1 $  
5 PLTTRAN BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $  
6 GP2 GEOM2,HEQEXIN/ECT $  
7 PARAML PCDB//PRES*///JUMPPLOT $  
8 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
9 COND HP1,JUMPPLOT $  
10 PLTHBDY GEOM2,ECT,EPT,HSIL,HEQEXIN,BGPDT/PECT,PSIL,PEQEXIN,PBGPDT/  
NHBDY/V,Y,MESH=NO $  
11 EQUIV ECT,PECT/NHBDY/HSIL,PSIL/NHBDY/HEQEXIN,PEQEXIN/NHBDY/  
BGPDT,PBGPDT/NHBDY $  
12 PLTSET PCDB,PEQEXIN,PECT/PLTSETX,HPLTPAR,HGPSETS,HELSETS/S,N,HNSIL/  
S,N,JUMPPLOT $  
13 PRTMSG PLTSETX// $  
14 PARAM //MPY*/PLTFLG/1/1 $  
15 PARAM //MPY*/PFILE/0/0 $  
16 COND HP1,JUMPPLOT $  
17 PLOT HPLTPAR,HGPSETS,HELSETS,CASECC,PBGPDT,PEQEXIN,PSIL,,,./PLOTX1/  
HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
18 PRTMSG PLOTX1// $  
19 LABEL HP1 $  
20 GP3 GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/NOGRAV $
```

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RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
21 SETVAL //S,N,REPEATH/-1 $  
22 LABEL LOOPTOP $  
23 CASE CASEXX,/CASEXX/*TRANRESP*/S,N,REPEATH/S,N,NOLOOP $  
24 PARAML CASEXX//*DTI*/1/8//S,N,TEMPMATE $  
25 PARAM ///*STSR*/V,N,TEMPMATE/-10 $  
26 TA1 ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/  
HLUSET/S,N,NOSIMP/1/NOGENL/HXYZ $  
27 COND ERROR2,NOSIMP $  
28 PARAM ///*ADD*/HNOKGG/1/0 $  
29 EMG HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,,,,,/S,N,HNOKGG $  
30 PURGE HKGG,GPST/HNOKGG $  
31 COND JMPKGGX,HNOKGG $  
32 EMA HGPECT,HKDICT,HKELM/HKGGX,GPST $  
33 LABEL JMPKGGX $  
34 RMG HEST,MATPOOL,GPTT,HKGGX/HRGG,HQGE,HKGG/C,Y,TABS/C,Y,SIGMA=0.0/  
S,N,HNLR/HLUSET $  
35 EQUIV HKGGX,HNOKGG/HNLR $  
36 PURGE HQGE,HRGG/HNLR $  
37 GP4 CASEXX,GEOM4,HEQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,HUSET,HASET/  
HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/  
S,N,NSKIP/S,N,REPEATH/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
S,Y,AUTOSPC $  
38 COND ERROR1,NOL $  
39 PURGE GM/MPCF1/HPS, HKFS, HKSF, HRSN, HQG/SINGLE $  
40 PARAM ///*EQ*/GPSPFLG/AUTOSPC/O $  
41 COND HLBL5,GPSPFLG $  
42 GPSP GPL,GPST,HUSET,HSIL/OGPST/S,N,NOGPST $  
43 OFP OGPST,,,//S,N,CARDNO $  
44 LABEL HLBL5 $
```

NONLINEAR STATIC HEAT TRANSFER ANALYSIS

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```
45 EQUIV HKGG,HKNN/MPCF1/HRGG,HRNN/MPCF1 $  
46 COND HLBL1,MPCF1 $  
47 MCE1 HUSET,RG/GM $  
48 MCE2 HUSET,GM,HKGG,HRGG,,/HKNN,HRNN,, $  
49 LABEL HLBL1 $  
50 EQUIV HKNN,HKFF/SINGLE/HRNN,HRFN/SINGLE $  
51 COND HLBL2,SINGLE $  
52 VEC HUSET/VFS/*N*/*F*/*S* $  
53 PARTN HKNN,VFS,/HKFF,HKSF,HKFS,HKSS $  
54 PARTN HRNN,,VFS/HRFN,HRSN,,/1 $  
55 LABEL HLBL2 $  
56 DECOMP HKFF/HLLL,HULL/O/O/MDIAG/DET/PWR/S,N,KSING $  
57 COND ERROR3,KSING $  
58 SSG1 HSLT,BGPDT,CSTM,HSIL,HEST,MPT,GPTT,EDT,,CASEXX,DIT,/HPG,,,SCR/HLUSET/NSKIP $  
59 EQUIV HPG,HPF/NOSET $  
60 COND HLBL3,NOSET $  
61 SSG2 HUSET,GM,,HKFS,,,HPG/,HPS,HPF $  
62 LABEL HLBL3 $  
63 SSGHT HUSET,HSIL,GPTT,GM,HEST,MPT,DIT,HPF,HPS,HPF,HPF,HKFS,HKSF,  
HKSS,HRFN,HRSN,HLLL,HULL/HUGV,HQG,HRULV/HNNLK=1/HNLR/  
C,Y,EPSHT=.001/C,Y,TABS=0.0/C,Y,MAXIT=4/V,Y,IRES/  
MPCF1/SINGLE $  
64 COND HLBL4,IRES $  
65 MATGPR GPL,HUSET,HSIL,HRULV//*F* $  
66 LABEL HLBL4 $  
67 SDR2 CASEXX,CSTM,MPT,DIT,HEQEXIN,HSIL,GPTT,EDT,BGPDP,,HQG,HUGV,HEST,,  
HPG/HOPG1,HQG1,HUGV1,HOES1,HOEF1,HPUGV1/*STATICS* $  
68 OFF HUGV1,HOPG1,HQG1,,/S,N,CARDNO $
```

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```
69 SDRHT HSIL,HUSET,HUGV,HOEF1,HSLT,HEST,DIT,HQGE,,,/HOEF1X/C,Y,TABS/  
HNLR $  
70 OFP HOEF1X,,,,,/S,N,CARDNO $  
71 COND HP2,JUMPPLOT $  
72 PLTSET PCDB,HEQEXIN,ECT/PSMES,DPLTPAR,DGPSETS,DELSETS/S,N,DSIL/DJ $  
73 PLOT DPLTPAR,DGPSETS,DELSETS,CASEXX,BGPDT,HEQEXIN,HSIP,HPUUGV1,,  
HGPECT,HOES1/PLOTX2/DSIL/HLUSEP/JUMPPLOT/PLTFLG/S,N,PFILE $  
74 PRTMSG PLOTX2// $  
75 LABEL HP2 $  
76 COND FINIS,REPEATH $  
77 REPT LOOPTOP,100 $  
78 JUMP FINIS$  
79 LABEL ERROR1 $  
80 PRTPARM //1/*HNLI* $  
81 LABEL ERROR2 $  
82 PRTPARM //2/*HNLI* $  
83 LABEL ERROR3 $  
84 PRTPARM //3/*HNLI* $  
85 LABEL FINIS$  
86 PURGE DUMMY/MINUS1 $  
87 END $
```

## NONLINEAR STATIC HEAT TRANSFER ANALYSIS

### 3.2.2 Description of Important DMAP Operations for Nonlinear Static Heat Transfer Analysis

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.
5. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.
6. GP2 generates the Element Connection Table with internal indices.
9. Go to DMAP No. 19 if there are no structure plot requests.
10. PLTHBDY modifies the data in the ECT, HSIL, HEQEXIN and BGPDT tables to permit the plotting of HBDY (thermal boundary) elements.
11. Equivalence PECT to ECT, PSIL to HSIL, PEQEXIN to HEQEXIN and PBGPDT to BGPDT if there are no HBDY elements.
12. PLTSET transforms user input into a form used to drive the structure plotter.
13. PRTMSG prints error messages associated with the structure plotter.
16. Go to DMAP No. 19 if no boundary and structure (heat conduction) element plots are requested.
17. PL0T generates all requested boundary and heat conduction element plots.
18. PRTMSG prints plotter and engineering data for each generated plot.
20. GP3 generates applied Static (Heat Flux) Loads Table (HSLT) and the Grid Point Temperature Table.
23. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it to CASEXX.
24. PARAML extracts the 8<sup>th</sup> word in the data record of CASEXX (representing the thermal material set ID) and stores its value in the parameter TEMPIMATE.
25. PARAM stores the value of the parameter TEMPIMATE in the 10<sup>th</sup> word of COMMON /SYSTEM/.
26. TA1 generates element tables for use in matrix assembly, load generation, and heat flux data recovery.
27. Go to DMAP No. 81 and print Error Message No. 2 if no elements have been defined.
29. EMG generates element heat conduction matrix tables and dictionaries for later assembly by the EMA module.
31. Go to DMAP No. 33 if no heat conduction matrix is to be assembled.
32. EMA assembles heat conduction matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
34. RMG generates the radiation matrix,  $[R_{gg}]$ , and adds the estimated linear component of radiation to the heat conduction matrix. The element radiation flux matrix,  $[Q_{ge}]$ , is also generated for use in recovery data for the HBDY elements.
35. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there is no linear component of radiation.
37. GP4 generates flags defining members of various displacement sets (HUSET) and forms multipoint constraint equations  $[R_g] \{u_g\} = \{0\}$ .
38. Go to DMAP No. 79 and print Error Message No. 1 if no independent degrees of freedom are defined.

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41. Go to DMAP No. 44 if no potential grid point singularities exist.
42. GPSP generates a table of potential grid point singularities. These singularities may be extraneous in a radiation problem, since some points may transfer heat through radiation only.
43. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
45. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[R_{gg}]$  to  $[R_{nn}]$  if no multipoint constraints exist.
46. Go to DMAP No. 49 if no multipoint constraints exist.
47. MCE1 partitions the multipoint constraint equation matrix  $[R_g] = [R_m | R_n]$  and solves for the multipoint constraint transformation matrix

$$[G_m] = -[R_m]^{-1} [R_n].$$

48. MCE2 partitions heat conduction and radiation matrices

$$[K_{gg}] = \begin{bmatrix} K_{nn} & K_{nm} \\ K_{mn} & K_{mm} \end{bmatrix} \quad \text{and} \quad [R_{gg}] = \begin{bmatrix} R_{nn} & R_{nm} \\ R_{mn} & R_{mm} \end{bmatrix}$$

and performs matrix reductions

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \text{ and}$$

$$[R_{nn}] = [R_{nn}] + [G_m^T][R_{mn}] + [R_{mn}^T][G_m] + [G_m^T][R_{mm}][G_m].$$

50. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[R_{nn}]$  to  $[R_{fn}]$  if no single-point constraints exist.
51. Go to DMAP No. 55 if no single-point constraints exist.
52. VEC generates a partitioning vector  $\{u_n\} \rightarrow \{u_f\} + \{u_s\}$ .
53. PARTN partitions the heat conduction matrix

$$[K_{nn}] = \begin{bmatrix} K_{ff} & K_{fs} \\ K_{fs} & K_{ss} \end{bmatrix}.$$

54. PARTN partitions the radiation matrix

$$[R_{nn}] = \begin{bmatrix} R_{fn} \\ R_{sn} \end{bmatrix}.$$

56. DECOMP decomposes the potentially unsymmetric matrix  $[K_{ff}]$  into upper and lower triangular factors  $[U_{ff}]$  and  $[L_{ff}]$ .
57. Go to DMAP No. 83 and print Error Message No. 3 if the matrix is singular.
58. SSG1 generates the input heat flux vector  $\{P_g\}$ .

## NONLINEAR STATIC HEAT TRANSFER ANALYSIS

59. Equivalence  $\{P_g\}$  to  $\{P_f\}$  if no constraints are applied.
60. Go to DMAP No. 62 if no constraints of any kind exist.
61. SSG2 reduces the heat flux vector

$$\{P_g\} = \left\{ \frac{\bar{P}_n}{P_m} \right\},$$

$$\{P_n\} = \{\bar{P}_n\} + [G_m^T] \{P_m\}$$

and  $\{P_n\} = \left\{ \frac{P_f}{P_s} \right\}.$

63. SSGHT solves the nonlinear heat transfer problem by an iteration technique which is limited by parameters EPSHT and MAXIT. The output data blocks are:  $\{u_g\}$ , the solution temperature vector,  $\{q_g\}$ , the heat flux due to single-point constraints, and  $\{\delta P_g\}$ , the matrix of residual heat fluxes at each iteration step.
64. Go to DMAP No. 66 if residual vectors are not to be printed.
65. MATGPR prints the residual vectors for independent coordinates (HRULV).
67. SDR2 calculates the heat flux due to conduction and convection in the elements (H0EF1) and prepares the temperature vector (H0UGV1), the load vector (H0PG1), and the power of constraint (H0QG1) for output and components of the temperature vector (HPUGV1).
68. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.
69. SDRHT processes the HBDY elements to produce heat flux into the elements (H0EF1X) due to convection, radiation, and applied flux.
70. ØFP formats the element flux table prepared by SDRHT and places it on the system output file for printing.
71. Go to DMAP No. 75 if no temperature profile plots are requested.
72. PLTSET transforms user input into a form used to drive the structure plotter.
73. PLØT generates all requested temperature profile and thermal contour plots.
74. PRIMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.
76. Go to DMAP No. 85 and make normal exit if all constraint sets have been processed.
77. Go to DMAP No. 22 if additional constraint sets need to be processed.
78. Go to DMAP No. 85 and make normal exit.
80. Print Error Message No. 1 and terminate execution.
82. Print Error Message No. 2 and terminate execution.
74. Print Error Message No. 3 and terminate execution.

### 3.2.3 Output for Nonlinear Static Heat Transfer Analysis

The following output may be requested for the last iteration in Nonlinear Static Heat Transfer Analysis:

1. Temperature (THERMAL) and nonzero components of static loads ( $\emptyset$ L $\emptyset$ AD) and constrained heat flow (SPCF $\emptyset$ RCE) at selected grid points or scalar points.
2. The punch option of a THERMAL request will produce TEMP bulk data cards.
3. Flux density (ELF $\emptyset$ RCE) in selected elements. In the case of CHBDY elements, a flux density summary is produced that includes applied flux, radiation flux, and convective flux.
4. Plots of the structural model and temperature profiles.
5. Contour plots of the thermal field.

### 3.2.4 Case Control Deck for Nonlinear Static Heat Transfer Analysis

The following items relate to subcase definition and data selection for Nonlinear Static Heat Transfer Analysis:

1. A separate subcase must be defined for each unique combination of constraints and loading conditions.
2. An estimated temperature distribution vector must be defined on TEMP cards and selected with a TEMP(MATERIAL) request for each subcase. Temperatures for constrained components are taken from these TEMP cards and entries on SPC cards are ignored.

### 3.2.5 Parameters for Nonlinear Static Heat Transfer Analysis

The following parameters are used in Nonlinear Static Heat Transfer Analysis:

1. ASET $\emptyset$ OUT - optional. A positive integer value of this parameter causes the HASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUT $\emptyset$ SPC - reserved for future optional use. The default value is -1.
3. EPSHT - optional. The real value of this parameter is used to test the convergence of the nonlinear heat transfer solution (see Section 8.4.1 of the Theoretical Manual). The default value is 0.001.
4. IRES - optional. A positive integer value of this parameter causes the printing of the residual vectors following the execution of the SSGHT module for each iteration.

5. MAXIT - optional. The integer value of this parameter limits the maximum number of iterations. The default value is 4 iterations.
6. SIGMA - optional. The real value of this parameter is the Stefan-Boltzmann constant. The default value is 0.0.
7. TABS - optional. The real value of this parameter is the absolute reference temperature. The default value is 0.0.

### 3.2.6 Rigid Format Error Messages from Nonlinear Static Heat Transfer Analysis

The following fatal errors are detected by the DMAP statements in the Nonlinear Static Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

NØNLINÆR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 1 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

Either no degrees of freedom have been defined on GRID, SPØINT or Scalar Connection cards, or all defined degrees of freedom have been constrained by SPC, MPC, SUPØRT, ØMIT or GRDSET cards, or grounded on Scalar Connection cards.

NØNLINÆR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 2 - NØ SIMPLE STRUCTURAL ELEMENTS.

No structural elements have been defined with Connection Cards.

NØNLINÆR STATIC HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 3 - STIFFNESS MATRIX SINGULAR.

The heat conduction matrix is singular due to unspecified grid point temperatures.

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3.2-10 (05/30/86)

## HEAT RIGID FORMATS

### 3.3 TRANSIENT HEAT TRANSFER ANALYSIS

#### 3.3.1 DMAP Sequence for Transient Heat Transfer Analysis

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OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN HEAT 09 - TRANSIENT HEAT TRANSFER ANALYSIS - APR. 1986 $  
2 PRECHK ALL $  
3 PARAM //*MPY*/CARDNO/0/0 $  
4 GP1 GEOM1,GEOM2,/GPL,HEQEXIN,GPDT,CSTM,BGPDT,HSIL/S,N,HLUSET/  
S,N,NOGPDT/MINUS1=-1 $  
5 PLTTRAN BGPDT,HSIL/BGPDP,HSIP/HLUSET/S,N,HLUSEP $  
6 PURGE HUSET,GM,HGO,HKAA,HBA,HPSO,HKFS,HQP,HEST/NOGPDT $  
7 COND HLBL5,NOGPDT $  
8 GP2 GEOM2,HEQEXIN/ECT $  
9 PARAML PCDB//*PRES*///JUMPPLOT $  
10 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
11 COND HP1,JUMPPLOT $  
12 PLTSET PCDB,HEQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,HNSIL/  
S,N,JUMPPLOT $  
13 PRTMSG PLTSETX// $  
14 PARAM //*MPY*/PLTFLG/1/1 $  
15 PARAM //*MPY*/PFILE/0/0 $  
16 COND HP1,JUMPPLOT$  
17 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,HEQEXIN,HSIL,,ECT,,/PLOTX1/  
HNSIL/HLUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
18 PRTMSG PLOTX1// $  
19 LABEL HP1 $  
20 GP3 GEOM3,HEQEXIN,GEOM2/HSLT,GPTT/1 $  
21 TA1 ECT,EPT,BGPDT,HSIL,GPTT,CSTM/HEST,,HGPECT,,/  
HLUSET/S,N,NOSIMP=-1/1/123/123 $
```

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```
22 PURGE    HKGG,GPST,HBGG/NOSIMP $  
23 COND     HLBL1,NOSIMP $  
24 PARAM    ///*ADD*/NOKGGX/I/O $  
25 PARAM    ///*ADD*/NOBGG/I/O $  
26 EMG      HEST,CSTM,MPT,DIT,GEOM2,/HKELM,HKDICT,,,HBELM,HBDICT,/S,N,  
           NOKGGX//S,N,NOBGG $  
27 PURGE    HKGGX,GPST/NOKGGX $  
28 COND     JMPKGGX,NOKGGX $  
29 EMA      HGPECT,HKDICT,HKELM/HKGGX,GPST $  
30 LABEL    JMPKGGX $  
31 COND     JMPHBGG,NOBGG $  
32 EMA      HGPECT,HBDICT,HBELM/HBGG, $  
33 LABEL    JMPHBGG $  
34 PURGE    HBNN,HBFF,HBAA,HBGG/NOBGG $  
35 LABEL    HLBL1 $  
36 RMG      HEST,MATPOOL,GPTT,HKGGX/HRGG,HQGE,HKG/C,Y,TABS/C,Y,SIGMA=0.0/  
           S,N,HNLR/HLUSET $  
37 EQUIV   HKGGX,HKG/HNLR $  
38 PURGE    HRGG,HRNN,HRFF,HRAA,HRDD/HNLR $  
39 GP4      CASECC,GEOM4,HEQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,HUSSET,ASET/  
           HLUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/  
           S,N,REACT/0/123/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/  
           S,Y,AUTOSPC $  
40 PURGE    GM,GMD/MPCF1/HGO,HGOD/OMIT/HKFS,HPSO,HQP/SINGLE $  
41 COND     HLBL2,NOSIMP $  
42 PARAM    ///*EQ*/GPSPFLG/AUTOSPC/O $  
43 COND     HLBL2,GPSPFLG $  
44 GPSP    GPL,GPST,HUSSET,HSIL/0GPST/S,N,NOGPST $  
45 OFP     OGPST,/,//S,N,CARDNO $
```

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```
46 LABEL HLBL2 $  
47 EQUIV HKGG,HKNN/MPCF1/HRGG,HRNN/MPCF1/HBGG,HBNN/MPCF1 $  
48 COND HLBL3,MPCF1 $  
49 MCE1 HUSET,RG/GM $  
50 MCE2 HUSET,GM,HKGG,HRGG,HBGG,/HKNN,HRNN,HBNN, $  
51 LABEL HLBL3 $  
52 EQUIV HKNN,HKFF/SINGLE/HRNN,HRFF/SINGLE/HBNN,HBFF/SINGLE $  
53 COND HLBL4,SINGLE $  
54 SCE1 HUSET,HKNN,HRNN,HBNN,/HKFF,HKFS,,HRFF,HBFF, $  
55 LABEL HLBL4 $  
56 EQUIV HKFF,HKAA/OMIT $  
57 EQUIV HRFF,HRAA/OMIT $  
58 EQUIV HBFF,HBAA/OMIT $  
59 COND HLBL5,OMIT $  
60 SMP1 HUSET,HKFF,,,/HGO,HKAA,HKOO,HL00,,,,, $  
61 COND HLBLR,HNLR $  
62 SMP2 HUSET,HGO,HRFF/HRAA $  
63 LABEL HLBLR $  
64 COND HLBL5,NOBGG $  
65 SMP2 HUSET,HGO,HBFF/HBAA $  
66 LABEL HLBL5 $  
67 DPD DYNAMICS,GPL,HSIL,HUSET/GPLD,HSILD,HUSETD,TFPOOL,HDLT,,,  
HNLFT,HTRL,,HEQDYN/HLUSET/S,N,HLUSETD/123 /S,N,NODLT/  
123/123/S,N,NONLFT/S,N,NOTRL/123//S,N,NOUE $  
68 COND ERROR1,NOTRL $  
69 EQUIV HGO,HGOD/NOUE/GM,GMD/NOUE $  
70 PURGE HPPO,HPSO,HPDO,HPDT/NODLT $
```

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```
71 MTRXIN CASECC,MATPOOL,HEQDYN,,TFPOOL/HK2PP,,HB2PP/HLUSETD/  
S,N,NOK2PP/123/S,N,NOB2PP $  
  
72 PARAM ///*AND*/KDEKA/NOUE/NOK2PP $  
  
73 PURGE HK2DD/NOK2PP/HB2DD/NOB2PP $  
  
74 EQUIV HKAA,HKDD/KDEKA/HB2PP,HB2DD/NOA/HK2PP,HK2DD/NOA/HRAA,HRDD/  
NOUE $  
  
75 COND HLBL6,NOGPDT $  
  
76 GKAD HUSETD,GM,HGO,HKAA,HBAAS,HRAA,,HK2PP,,HB2PP/HKDD,HBDD,  
HRDD,GMD,HGOD,HK2DD,,HB2DD/*TRANRESP*/*DISP*/  
*DIRECT*/C,Y,G=0.0/C,Y,W3=0.0/C,Y,W4=0.0/NOK2PP/-1/  
NOB2PP/MPCF1/SINGLE/OMIT/NOUE/  
-1/NOBGG/NOSIMP/-1 $  
  
77 LABEL HLBL6 $  
  
78 EQUIV HK2DD,HKDD/NOSIMP/HB2DD,HBDD/NOGPDT $  
  
79 PARAM ///*MPY*/REPEATT/1/-1 $  
  
80 LABEL HLBL10 $  
  
81 CASE CASECC,/CASEXX/*TRAN*/S,N,REPEATT/S,N,NOLOOP $  
  
82 TRLG CASEXX,HUSETD,HDLT,HSLT,BGPDT,HSIL,CSTM,HTRL,DIT,GMD,HGOD,,  
HEST,,/HPPO,HPSO,HPDO,HPDT,,HTOL/S,N,NOSET $  
  
83 EQUIV HPPO,HPDO/NOSET $  
  
84 TRHT CASEXX,HUSETD,HNLFT,DIT,GPTT,HKDD,HBDD,HRDD,HPDT,HTRL/  
HUDVT,HPNLD/C,Y,BETA=.55/C,Y,TABS=0.0/HNLR/C,Y,RADLIN=-1/  
C,Y,SIGMA=0.0 $  
  
85 VDR CASEXX,HEQDYN,HUSETD,HUDVT,HTOL,XYCDB,HPNLD/HOUDV1,HOPNL1/  
*TRANRESP*/*DIRECT*/O/S,N,NOD/S,N,NOP/O $  
  
86 COND HLBL7,NOD $  
  
87 SDR3 HOUDV1,HOPNL1,,,./HOUDV2,HOPNL2,,, $  
  
88 OFF HOUDV2,HOPNL2,,,./S,N,CARDNO $  
  
89 XYTRAN XYCDB,HOUDV2,HOPNL2,,,./HXYPLTTA/*TRAN*//*DSET*/S,N,HPFILE/  
S,N,HCARDNO $  
  
90 XYPLOT HXYPLTTA// $  
  
91 LABEL HLBL7 $
```

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```
92 PARAM ///*AND*/PJUMP/NOP/JUMPPLOT $  
93 COND HLBL9,PJUMP $  
94 EQUIV HUDVT,HUPV/NOA $  
95 COND HLBL8,NOA $  
96 SDR1 HUSERD,,HUDVT,,,HGOD,GMD,HPSO,HKFS,,/HUPV,,HQP/1/  
*DYNAMICS* $  
97 LABEL HLBL8 $  
98 SDR2 CASEXX,CSTM,MPT,DIT,HEQDYN,HSILD,,,BGPDP,HTOL,HQP,HUPV,HEST,  
XYCDB,HPO/HOPP1,HQQP1,HOUVP1,HOES1,HOEF1,HPUGV/*TRANRESP* $  
99 SDRHT HSILD,HUSERD,HUPV,HOEF1,HSLT,HEST,DIT,HQGE,HDLT,/HOEF1X/C,Y,  
TABS/HNLR $  
100 EQUIV HOEF1X,HOEF1/MINUS1 $  
101 SDR3 HOPP1,HQQP1,HOUVP1,HOES1,HOEF1,/HOPP2,HQQP2,HOUVP2,HOES2,  
HOEF2, $  
102 OFP HOPP2,HQQP2,HOUVP2,HOEF2,HOES2,//S,N,CARDNO $  
103 COND HP2,JUMPPLOT $  
104 PLOT PLTPAR,GPSETS,ELSETS,CASEXX,BGPDT,HEQEXIN,HSIP,,HPUGV,  
HGPECT,/PLOTX2/HNSIL/HLUSEP/JUMPPLOT/PLTFLG/  
S,N,PFIE $  
105 PRTPMSG PLOTX2// $  
106 LABEL HP2 $  
107 XYTRAN XYCDB,HOPP2,HQQP2,HOUVP2,HOES2,HOEF2/HXYPLTT/*TRAN*//*PSET*/S,N,  
PFIE/S,N,CARDNO $  
108 XYPLOT HXYPLTT// $  
109 LABEL HLBL9 $  
110 COND FINIS,REPEATT $  
111 REPT HLBL10,100 $  
112 PRTPARM //-/HTRD* $  
113 JUMP FINIS $  
114 LABEL ERROR1 $
```

HEAT RIGID FORMATS

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```
115 PRTPARM //1/*HTRD* $  
116 LABEL FINIS$  
117 PURGE DUMMY/MINUS1 $  
118 END $
```

## TRANSIENT HEAT TRANSFER ANALYSIS

### 3.3.2 Description of Important DMAP Operations for Transient Heat Transfer Analysis

4. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external degree of freedom indices.
5. PLTTRAN modifies special scalar grid points in the BGPDT and HSIL tables.
7. Go to DMAP No. 66 if there is no Grid Point Definition Table.
8. GP2 generates the Element Connection Table with internal indices.
11. Go to DMAP No. 19 if there are no structure plot requests.
12. PLTSET transforms user input into a form used to drive the structure plotter.
13. PRTMSG prints error messages associated with the structure plotter.
16. Go to DMAP No. 19 if no boundary and structure (heat conduction) element plots are requested.
17. PLØT generates all requested boundary and heat conduction element plots.
18. PRTMSG prints plotter data and engineering data for each generated plot.
20. GP3 generates applied Static (Heat Flux) Load Tables (HSLT) and the Grid Point Temperature Table.
21. TA1 generates element tables for use in matrix assembly, load generation, and data recovery.
23. Go to DMAP No. 35 if no heat conduction or boundary elements exist.
26. EMG generates element heat conduction and capacitance matrix tables and dictionaries for later assembly by the EMA module.
28. Go to DMAP No. 30 if no heat conduction matrix is to be assembled.
29. EMA assembles heat conduction matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
31. Go to DMAP No. 33 if no heat capacitance matrix is to be assembled.
32. EMA assembles heat capacitance matrix  $[B_{gg}]$ .
36. RMG generates the radiation matrix,  $[R_{gg}]$ , and adds the estimated linear component of radiation to the conductivity matrix. The element-radiation flux matrix,  $[Q_{ge}]$ , is also generated for use in data recovery.
37. Equivalence the linear heat transfer matrix,  $[K_{gg}]$ , to the heat conduction matrix if no radiation exists.
39. GP4 generates flags defining members of various displacement sets (HUSET) and forms the multipoint constraint equations,  $[R_g] \{u_g\} = 0$ .
41. Go to DMAP No. 46 if no simple elements exist.
43. Go to DMAP No. 46 if no potential grid point singularities exist.
44. GPSP generates a table of potential grid point singularities. These singularities may be extraneous in a radiation problem, since some points may transfer heat through radiation only.
45. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.

HEAT RIGID FORMATS

47. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$ ,  $[R_{gg}]$  to  $[R_{nn}]$ , and  $[B_{gg}]$  to  $[B_{nn}]$  if no multipoint constraints exist.
48. Go to DMAP No. 51 if no multipoint constraints exist.
49. MCE1 partitions the multipoint constraint equation matrix,  $[R_g] = [R_m | R_n]$ , and solves for the multipoint constraint transformation matrix,

$$[G_m] = -[R_m]^{-1} [R_n].$$

50. MCE2 partitions heat conduction and radiation matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} \\ K_{nn} & + \\ \hline K_{mn} & K_{mm} \end{bmatrix},$$

$$[R_{gg}] = \begin{bmatrix} - & R_{nn} \\ R_{nn} & + \\ \hline R_{mn} & R_{mm} \end{bmatrix},$$

$$[B_{gg}] = \begin{bmatrix} - & B_{nn} \\ B_{nn} & + \\ \hline B_{mn} & B_{mm} \end{bmatrix},$$

and performs matrix reductions

$$[K_{nn}] = [K_{nn}] + [G_m^T][K_{mn}] + [K_{mn}][G_m] + [G_m^T][K_{mm}][G_m].$$

The same equation is applied to  $[R_{nn}]$  and  $[B_{nn}]$ .

52. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$ ,  $[B_{nn}]$  to  $[B_{ff}]$ , and  $[R_{nn}]$  to  $[R_{ff}]$  if no single-point constraints exist.
53. Go to DMAP No. 55 if no single-point constraints exist.
54. SCE1 partitions the matrices as follows:

$$[K_{nn}] = \begin{bmatrix} - & K_{ff} \\ K_{ff} & + \\ \hline K_{sf} & K_{ss} \end{bmatrix}.$$

$[R_{nn}]$  and  $[B_{nn}]$  are partitioned in the same manner, except that only the ff partitions are saved.

56. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  if no omitted coordinates exist.
57. Equivalence  $[R_{ff}]$  to  $[R_{aa}]$  if no omitted coordinates exist.

## TRANSIENT HEAT TRANSFER ANALYSIS

58. Equivalence  $[B_{ff}]$  to  $[B_{aa}]$  if no omitted coordinates exist.
59. Go to DMAP No. 66 if no omitted coordinates exist.
60. SMP1 partitions the heat conduction matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} & | & K_{ao} \\ \hline K_{aa} & + & | & \\ K_{oa} & | & K_{oo} \end{bmatrix},$$

solves for the transformation matrix  $[G_0]$ :

$$[K_{oo}] [G_0] = -[K_{oa}],$$

and solves for the reduced heat conduction matrix  $[K_{aa}]$ :

$$[K_{aa}] = [K_{aa}] + [K_{ao}] [G_0].$$

61. Go to DMAP No. 63 if no radiation matrix exists.
62. SMP2 partitions constrained radiation matrix

$$[R_{ff}] = \begin{bmatrix} - & R_{aa} & | & R_{ao} \\ \hline R_{aa} & + & | & \\ R_{oa} & | & R_{oo} \end{bmatrix},$$

and performs matrix reduction

$$[R_{aa}] = [R_{aa}] + [R_{oa}^T] [G_0] + [G_0^T] [R_{oa}] + [G_0^T] [R_{oo}] [G_0].$$

64. Go to DMAP No. 66 if no heat capacitance matrix,  $[B_{ff}]$ , exists.
65. SMP2 calculates a reduced heat capacitance matrix,  $[B_{aa}]$ , with the same equation as DMAP No. 62.
67. DPD generates the table defining the displacement sets each degree of freedom belongs to (HUSETD), including extra points. It prepares the Transfer Function Pool, the Dynamics Load Table, the Nonlinear Function Table, and the Transient Response List.
68. Go to DMAP No. 114 and print Error Message No. 1 if there is no Transient Response List.
69. Equivalence  $[G_0]$  to  $[G_0^d]$  and  $[G_m]$  to  $[G_m^d]$  if no extra points were defined.
71. MTRXIN selects the direct input matrices  $[K_{pp}^2]$  and  $[B_{pp}^2]$ .
74. Equivalence  $[K_{aa}]$  to  $[K_{dd}^1]$  if there are no direct input stiffness matrices and no extra points;  $[B_{pp}]$  to  $[B_{dd}^2]$  and  $[K_{pp}]$  to  $[K_{dd}^2]$  if only extra points are used; and  $[R_{aa}]$  to  $[R_{dd}]$  if no extra points are used.
75. Go to DMAP No. 77 if there is no Grid Point Definition Table.
76. GKAD expands the matrices to include extra points and assembles heat conduction, capacitance, and radiation matrices for use in the transient analysis:

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$$[K_{dd}^1] = \begin{bmatrix} K_{aa} & 0 \\ 0 & 0 \end{bmatrix},$$

$$[B_{dd}^1] = \begin{bmatrix} B_{aa} & 0 \\ 0 & 0 \end{bmatrix},$$

$$[R_{dd}] = \begin{bmatrix} R_{aa} & 0 \\ 0 & 0 \end{bmatrix},$$

and  $[K_{dd}] = [K_{dd}^1] + [K_{dd}^2]$ ,

$$[B_{dd}] = [B_{dd}^1] + [B_{dd}^2].$$

(Nonzero values of the parameters W4, G, and W3 (see the PARAM bulk data card) are not recommended for use in heat transfer analysis and therefore do not appear in the above equations.)

- 78. Equivalence  $[K_{dd}^2]$  to  $[K_{dd}]$  and  $[B_{dd}^2]$  to  $[B_{dd}]$  if no matrices were generated from the element heat conduction and capacitance assemblers.
- 80. Beginning of loop for additional dynamic load sets.
- 81. CASE extracts the appropriate record from CASECC corresponding to the current loop and copies it into CASEXX.
- 82. TRLG generates matrices of heat flux loads versus time.  $\{P_p^0\}$ ,  $\{P_s^0\}$ , and  $\{P_d^0\}$  are generated with one column per output time step.  $\{P_d^t\}$  is generated with one column per solution time step, and the Transient Output List is a list of output time steps.
- 83. Equivalence  $\{P_p^0\}$  to  $\{P_d^0\}$  if the d and p sets are the same.
- 84. TRHT integrates the equation of motion:

$$[B_{dd}] \{\dot{u}\} + [K_{dd}] \{u\} = \{P_d\} + \{N_d\},$$

where  $\{u\}$  is a vector of temperatures at any time,

$\{\dot{u}\}$  is the time derivative of  $\{u\}$  ("velocity"),

$\{P_d\}$  is the applied heat flux at any time step, and

$\{N_d\}$  is the total nonlinear heat flux from radiation and/or NOLINI data, extrapolated from the previous solution vector.

The output consists of the  $[u_d^t]$  matrix containing temperature vectors and temperature "velocity" vectors for the output time steps.

- 85. VDR prepares the solution set temperatures, temperature "velocities", and nonlinear loads, sorted by time step, for output.
- 86. Go to DMAP No. 91 if there is no output request for the solution set.

TRANSIENT HEAT TRANSFER ANALYSIS

87. SDR3 prepares the requested output of the solution set temperatures, temperature "velocities", and nonlinear loads sorted by point number or element number.
88. ØFP formats the tables prepared by SDR3 for output sorted by point number or element number and places them on the system output file for printing.
89. XYTRAN prepares the input for requested X-Y plots of the solution set quantities.
90. XYPLØT prepares the requested X-Y plots of the solution set temperatures, "velocities" and nonlinear loads versus time.
93. Go to DMAP No. 109 if no further output is requested.
94. Equivalence  $\{u_d\}$  to  $\{u_p\}$  if no structure points were input.
95. Go to DMAP No. 97 if no structure points were input.
96. SDR1 recovers the dependent temperatures:

$$\{u_o\} = [G_o^d] \{u_d\} ,$$

$$\left\{ \frac{u_d}{u_o} \right\} = \{u_f\} ,$$

$$\left\{ \frac{u_f + u_e}{u_s} \right\} = \{u_n\} ,$$

$$\{u_m\} = [G_m^d] \{u_f + u_e\}$$

$$\text{and } \left\{ \frac{u_n + u_e}{u_m} \right\} = \{u_p\} .$$

The module also recovers the heat flux into the points having single-point constraints:

$$\{q_s\} = -\{P_s\} + [K_{fs}^T] \{u_f\} .$$

98. SDR2 calculates requested heat flux transfer in the elements and prepares temperatures, "velocities", and heat flux loads for output sorted by time step.
99. SDRHT modifies the HØEF1 data block by combining the heat flow data from different sources for the HBDY elements and writes the results on the HØEF1X output data block.
100. Equivalence HØEF1 data block to the HØEF1X data block.
101. SDR3 prepares requested output sorted by point number or element number.
102. ØFP formats the tables prepared by SDR3 for output and places them on the system output file for printing.
103. Go to DMAP No. 106 if no temperature profile plots are requested.
104. PLØT generates all requested temperature profile plots and thermal contours for specified times.

## HEAT RIGID FORMATS

105. PRTMSG prints plotter data, engineering data, and contour data for each temperature profile and thermal contour plot generated.
107. XYTRAN prepares the input for requested X-Y plots.
108. XYPL0T prepares the requested X-Y plots of temperatures, "velocities", element flux, and applied heat loads versus time.
110. Go to DMAP No. 116 if no additional dynamic load sets need to be processed.
111. Go to DMAP No. 80 if additional dynamic load sets need to be processed.
112. Print Error Message No. 2 and terminate execution.
113. Go to DMAP No. 116 and make normal exit.
115. Print Error Message No. 1 and terminate execution.

## TRANSIENT HEAT TRANSFER ANALYSIS

### 3.3.3 Output for Transient Heat Transfer Analysis

The following printed output, sorted by point number or element number (SØRT2), is available at selected multiples of the integration time step:

1. Temperatures (THERMAL) and derivatives of temperatures (VELØCITY) for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SDISPLACEMENT and SVELØCITY for SØLUTIØN points (points used in the formulation of the dynamic equation).
2. Nonzero components of the applied load vector (ØLØAD) and constrained heat flow (SPCFØRCE) for a list of PHYSICAL points.
3. Nonlinear load vector for a list of SØLUTIØN points.
4. Flux density (ELFØRCE) in selected elements.

The following plotter output is available:

1. Plot of the Structural model.
2. Temperature profiles and thermal contours for selected time intervals.
3. X-Y plot of temperature or derivative of temperature for a PHYSICAL point or a SØLUTIØN point.
4. X-Y plot of the applied load vector, nonlinear load vector, or constrained heat flow.
5. X-Y plot of flux density for an element.

The data used for preparing the X-Y plots may be punched or printed in tabular form (see Volume I, Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

### 3.3.4 Case Control Deck for Transient Heat Transfer Analysis

The following items relate to subcase definition and data selection for Transient Heat Transfer Analysis:

1. One subcase must be defined for each dynamic loading condition.
2. DLØAD and/or NØNLINÆR must be used to define a time-dependent loading condition for each subcase. The static load cards (QVECT, QVØL, QHBDY, QBDY1, and QBDY2) can also be used to define a dynamic load by using these cards with, or instead of, the DAREA cards. The set identification number on the static load cards (field 2) is used in the same manner as the set identification number on the DAREA cards (field 2).
3. All constraints must be defined above the subcase level.

## HEAT RIGID FORMATS

4. TSTEP must be used to select the time-step intervals to be used for integration and output in each subcase.
5. If nonzero initial conditions are desired, IC must be used to select a TEMP set in the Bulk Data Deck.
6. An estimated temperature distribution vector must be defined on TEMP cards and selected with a TEMP (MATERIAL) request if radiation effects are included.
7. On restart following an unscheduled exit due to insufficient time, the subcase structure should be changed to reflect any completed loading conditions.

### 3.3.5 Parameters for Transient Heat Transfer Analysis

The following parameters are used in Transient Heat Transfer Analysis:

1. ASETOUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTOSPC - reserved for future optional use. The default value is -1.
3. BETA - optional. The real value of this parameter is used as a factor in the integration algorithm (see Section 8.4.2 of the Theoretical Manual). The default value is 0.55.
4. RADLIN - optional. A positive integer value of this parameter causes some of the radiation effects to be linearized (see Equation 2, Section 8.4.2 of the Theoretical Manual). The default value is -1.
5. SIGMA - optional. The real value of this parameter is the Stefan-Boltzmann constant. The default value is 0.0.
6. TABS - optional. The real value of this parameter is the absolute reference temperature. The default value is 0.0.

### 3.3.6 Rigid Format Error Messages from Transient Heat Transfer Analysis

The following fatal errors are detected by the DMAP instructions in the Transient Heat Transfer Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional material, including suggestions for remedial action.

TRANSIENT HEAT TRANSFER ANALYSIS ERROR MESSAGE NO. 1 - TRANSIENT RESPONSE LIST REQUIRED FOR TRANSIENT RESPONSE CALCULATIONS.

TRANSIENT HEAT TRANSFER ANALYSIS

Time step intervals to be used must be specified on a TSTEP card in the Bulk Data Deck and a TSTEP selection must be made in the Case Control Deck.

TRANSIENT HEAT TRANSFER ANALYSIS ERRØR MESSAGE NØ. 2 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØOPS.

An attempt has been made to use more than 100 dynamic load sets. This number may be increased by ALTERing the REPT instruction following the last XYPLØT instruction.

HEAT RIGID FORMATS

3.3-16 (05/30/86)

#### 4. AERO RIGID FORMATS

##### 4.1 BLADE CYCLIC MODAL FLUTTER ANALYSIS

###### 4.1.1 DMAP Sequence for Blade Cyclic Modal Flutter Analysis

RIGID FORMAT DMAP LISTING  
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AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN     AERO 09 - COMPRESSOR BLADE MODAL FLUTTER ANALYSIS - APR. 1986 $  
2 PRECHK    ALL $  
3 FILE      PHIHL=APPEND/AJL=APPEND/FSAVE=APPEND/CASEYY=APPEND/CLAMAL=  
APPEND/OVG=APPEND/QHHL=APPEND $  
4 PARAM     //*MPY*/CARDNO/0/0 $  
5 GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPD,CSM,BGPDT,SIL/S,N,LUSET/S,N,  
NOGPDT/MINUSI=-1 $  
6 COND      ERROR5,NOGPDT $  
7 GP2       GEOM2,EQEXIN/ECT $  
8 GP3       GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $  
9 TA1       ECT,EPT,BGPDT,SIL,GPTT,CSM/EST,GEI,GPECT,,/LUSET/S,N,  
NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
10 COND     ERROR5,NOSIMP $  
11 PURGE    OGPST/GENEL $  
12 PARAM    //*ADD*/NOKGGX/1/0 $  
13 PARAM    //*ADD*/NOMGG/1/0 $  
14 PARAM    //*NOP*/V,Y,KGGIN=-1 $  
15 COND      JMPKGGIN,KGGIN $  
16 PARAM    //*ADD*/NOKGGX/-1/0 $  
17 INPUTT1  /KTOTAL,,,./C,Y,LOCATION=-1/C,Y,INPTUNIT=0 $  
18 EQUIV    KTOTAL,KGGX $  
19 LABEL    JMPKGGIN $  
20 EMG      EST,CSM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/S,  
N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,  
CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/C,Y,  
CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $
```

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RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
21  COND    JMPKGGX,NOKGGX $  
22  EMA     GPECT,KDICT,KELM/KGGX,GPST $  
23  LABEL   JMPKGGX $  
24  COND    ERROR1,NOMGG $  
25  EMA     GPECT,MDICT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $  
26  COND    LGPWG,GRDPNT $  
27  GPWG   BGPDT,CSTM,EQEXIN,MGG/0GPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $  
28  OFP    OGPWG,,,,,/S,N,CARDNO $  
29  LABEL   LGPWG $  
30  EQUIV  KGGX,KGG/NOGENL $  
31  COND    LBL11,NOGENL $  
32  SMA3   GE1,KGGX/KGG/LUSET/NOGENL/NOSIMP $  
33  LABEL   LBL11 $  
34  GP4    CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM./RG.,USET,ASET/  
          LUSET/S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/O/  
          S,N,REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,  
          AUTOSPC $  
35  PARAM   ///*NOT*/REACDATA/REACT $  
36  COND    ERROR6,REACDATA $  
37  PURGE  GM,GMD/MPCF1/G0,GOD/OMIT/KFS,QPC/SINGLE $  
38  GPCYC  GEOM4,EQEXIN,USET/CYCD/V,Y,CTYPE/S,N,NOGO $  
39  COND    ERROR7,NOGO $  
40  COND    LBL4,GENEL $  
41  PARAM   ///*EQ*/GPSPFLG/AUTOSPC $  
42  COND    LBL4,GPSPFLG $  
43  GPSP   GPL,GPST,USET,SIL/0GPST/S,N,NOGPST $  
44  OFP    OGPST,,,,,/S,N,CARDNO $  
45  LABEL   LBL4 $
```

## BLADE CYCLIC MODAL FLUTTER ANALYSIS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER ~ SOURCE LISTING

```
46 EQUIV KGG,KNN/MPCF1/MGG,MNN/MPCF1 $  
47 COND LBL2,MPCF1 $  
48 MCE1 USET,RG/GM $  
49 MCE2 USET,GM,KGG,MGG,,/KNN,MNN,, $  
50 LABEL LBL2 $  
51 EQUIV KNN,KFF/SINGLE/MNN,MFF/SINGLE $  
52 COND LBL3,SINGLE $  
53 SCE1 USET,KNN,MNN,,/KFF,KFS,,MFF,, $  
54 LABEL LBL3 $  
55 EQUIV KFF,KAA/OMIT/MFF,MAA/OMIT $  
56 COND LBL5, OMIT $  
57 SMP1 USET,KFF,,,/GO,KAA,KOO,L00,,,,, $  
58 SMP2 USET,GO,MFF/MAA $  
59 LABEL LBL5 $  
60 DPD DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,EED,EQDYN/  
LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  
NONLFT/NOTRL/S,N,NOEED//S,N,NOUE $  
61 COND ERROR2,NOEED $  
62 EQUIV GO,GOD/NOUE/GM,GMD/NOUE $  
63 CYCT2 CYCD,KAA,MAA,,,/KKK,MKK,,,/*FORE*/V,Y,NSEGS=-1/V,Y,  
KINDEX=-1/V,Y,CYCSEQ=-1/1/S,N,NOGO $  
64 COND ERROR7,NOGO $  
65 READ KKK,MKK,,,EED,,,CASECC/LAMK,PHIK, ,OEIGS/*MODES*/S,N,  
NEIGV $  
66 OFP OEIGS,LAMK,,,//S,N,CARDNO $  
67 COND ERROR4,NEIGV $  
68 CYCT2 CYCD,,,PHIK,LAMK,,,PHIA,LAMA/*BACK*/V,Y,NSEGS/V,Y,  
KINDEX/V,Y,CYCSEQ/1/S,N,NOGO $  
69 COND ERROR7,NOGO $
```

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RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
70 SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,/1/*REIG* $  
71 SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,LAMA,,PHIG,EST,,/,  
              OPHIG,,,PPHIG/*REIG* $  
72 OFP       OPHIG,,,,,/S,N,CARDNO $  
73 PARAML    PCDB//*PRES*///JUMPLOT $  
74 PURGE     PLTSETZ,PLTPARZ,GPSETSZ,ELSETSZ/JUMPLOT $  
75 COND      PZZ,JUMPLOT $  
76 PLTSET   PCDB,EQEXIN,ECT/PLTSETZ,PLTPARZ,GPSETSZ,ELSETSZ/  
              S,N,NSILZ/S,N,JUMPZ=-1 $  
77 PRTMSG    PLTSETZ// $  
78 COND      PZZ,JUMPZ $  
79 PLOT      PLTPARZ,GPSETSZ,ELSETSZ,CASECC,BGPDT,EQEXIN,SIL,,PPHIG,,/  
              PLOTZ/NSILZ/LUSET/JUMPZ/PLTFLGZ=-1/S,N,PFILEZ=0 $  
80 PRTMSG    PLOTZ// $  
81 LABEL     PZZ $  
82 APDB      EDT,USET,BGPDT,CSTM,EQEXIN,GM,GO/AERO,ACPT,FLIST,GTKA,PVECT/  
              S,N,NK/S,N,NJ/V,Y,MINMACH/V,Y,MAXMACH/V,Y,IREF/V,Y,MTYPE/  
              NEIGV/V,Y,KINDEX=-1 $  
83 PARTN    PHIA,PVECT,/PHIAX,,,/1 $  
84 SMPYAD    PHIAX,MAA,PHIAX,,,/MI/3/1/1/0/1 $  
85 MTRXIN    CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,  
              NOK2PP/S,N,NOM2PP/S,N,NOB2PP $  
86 PURGE     K2DD/NOK2PP/M2DD/NOM2PP/B2DD/NOB2PP $  
87 EQUIV     M2PP,M2DD/NOSET/B2PP,B2DD/NOSET/K2PP,K2DD/NOSET $  
88 GKAD      USETD,GM,GO,,,,,K2PP,M2PP,B2PP,,,GMD,GOD,K2DD,M2DD,B2DD/  
              *CMPLEV/*DISP/*MODAL*/0.0/0.0/0.0/NOK2PP/  
              NOM2PP/NOB2PP/MPCF1/SINGLE/OMIT/NOUE/  
              -1/-1/-1/-1 $  
89 GKAM      USETD,PHIAX,MI,LAMK,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,  
              PHIDH/NOUE/C,Y,LMODES=999999/C,Y,LFREQ=0.0/C,Y,HFREQ=0.0/  
              NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE/C,Y,  
              KDAMP=-1 $
```

## BLADE CYCLIC MODAL FLUTTER ANALYSIS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
90 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/JUMPPLOT $  
91 COND P2,JUMPPLOT $  
92 PLTSET PCDB,EQDYN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/S,N,NSIL1/S,N,  
JUMPPLOT $  
93 PRTMSG PLTSETX//$/  
94 PARAM ///*MPY*/PLTFLG/1/1 $  
95 PARAM ///*MPY*/PFILE/0/0 $  
96 COND P2,JUMPPLOT $  
97 PLOT PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQDYN,,,./PLOTX1/NSIL1/  
LUSET/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $  
98 PRTMSG PLOTX1//$/  
99 LABEL P2 $  
100 PARAM ///*ADD*/DESTRY/0/1 $  
101 AMG AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/S,N,DESTRY $  
102 PURGE D1JE,D2JE/NODJE $  
103 COND NODJE,NODJE $  
104 INPUTT2 /D1JE,D2JE,,,/C,Y,POSITION=-1/C,Y,UNITNUM=11/C,Y,USRLABEL=  
TAPEID $  
105 LABEL NODJE $  
106 PARAM ///*ADD*/XQHHL/1/0 $  
107 AMP AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,,/  
NOUE/S,N,XQHHL $  
108 PARAM ///*MPY*/NOP/1/1 $  
109 PARAM ///*MPY*/NOH/0/1 $  
110 PARAM ///*MPY*/FLOOP/V,Y,NODJE=-1/0 $  
111 LABEL LOOPTOP $  
112 FA1 KHH,BHH,MHH,QHHL,CASECC,FLIST/FSAVE,KXHH,BXHH,MXHH/S,N,FLOOP/  
S,N,TSTART/S,N,NOCEAD $
```

AERO RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
113 EQUIV KXHH,PHIH/NOCEAD/BXHH,CLAMA/NOCEAD/
KXHH,PHIHL/NOCEAD/BXHH,CLAMAL/NOCEAD/
CASECC,CASEYY/NOCEAD $

114 COND VDR,NOCEAD $

115 CEAD KXHH,BXHH,MXHH,EED,CASECC/PHIH,CLAMA,OCEIGS,/S,N,EIGVS $

116 COND LBLZAP,EIGVS $

117 LABEL VDR $

118 VDR CASECC,EQDYN,USETD,PHIH,CLAMA,,/OPHIH,/CEIGEN/*MODAL*/
123/S,N,NOH/S,N,NOP/FMODE $

119 COND LBL16,NOH $

120 OFP OPHIH,,,./S,N,CARDNO $

121 LABEL LBL16 $

122 FA2 PHIH,CLAMA,FSAVE/PHIHL,CLAMAL,CASEYY,OVG/S,N,TSTART/C,Y,VREF=
1.0/C,Y,PRINT=YESB $

123 COND CONTINUE,TSTART $

124 LABEL LBLZAP $

125 COND CONTINUE,FLOOP $

126 REPT LOOPTOP,100 $

127 JUMP ERROR3 $

128 LABEL CONTINUE $

129 PARAML XYCDB//PRES///NOXYCDB $

130 COND NOXYOUT,NOXYCDB $

131 XYTRAN XYCDB,OVG,,,./XYPLTCE/*VG*/PSET*/S,N,PFILE/S,N,CARDNO $

132 XYPLOT XYPLTCE//$

133 LABEL NOXYOUT $

134 PARAM //AND*/PJUMP/NOP=-1/JUMPPLOT $

135 COND FINIS,PJUMP $

136 MODACC CASEYY,CLAMAL,PHIHL,CASECC,,/CLAMAL1,CPHIH1,CASEZZ,,/
*CEIGN* $
```

## BLADE CYCLIC MODAL FLUTTER ANALYSIS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
137 DDR1      CPHIH1,PHIDH/CPHID $  
138 EQUIV     CPHID,CPHIP/NOA $  
139 COND      LBL14,NOA $  
140 SDR1      USETD,,CPHID,,,GOD,GMD,,KFS,,CPHIP,,QPC/1/*DYNAMICS* $  
141 LABEL     LBL14 $  
142 EQUIV     CPHID,CPHIA/NOUE $  
143 COND      LBLNOE,NOUE $  
144 VEC       USETD/RP/*D*/*A*/*E* $  
145 PARTN     CPHID,,RP/CPHIA,,,/1/3 $  
146 LABEL     LBLNOE $  
147 SDR2      CASEZZ,CSTM,MPT,DIT,EQDYN,SILD,,,BGPDT,CLAMAL1,QPC,CPHIP,EST,,,/  
               ,OQPC1,OCPHIP,OESC1,OEFC1,PCPHIP/*CEIGN* $  
148 OFP       OCPHIP,OQPC1,OESC1,OEFC1,,/S,N,CARDNO $  
149 COND      P3,JUMPLOT $  
150 PLOT      PLTPAR,GPSETS,ELSETS,CASEZZ,BGPDT,EQDYN,SILD,,PCPHIP,,/PLOTX3/  
               NSIL1/LUSET/JUMPLOT/PLTFLG/PFILE $  
151 PRTPARM   PLOTX3//$  
152 LABEL     P3 $  
153 JUMP      FINIS $  
154 LABEL     ERROR1 $  
155 PRTPARM   //1/*BLADEMDS* $  
156 LABEL     ERROR2 $  
157 PRTPARM   //2/*BLADEMDS* $  
158 LABEL     ERROR3 $  
159 PRTPARM   //3/*BLADEMDS* $  
160 LABEL     ERROR4 $  
161 PRTPARM   //4/*BLADEMDS* $
```

AERO RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 9

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
162 LABEL    ERROR5 $  
163 PRTPARM //-*BLADEMDS* $  
164 LABEL    ERROR6 $  
165 PRTPARM //-*BLADEMDS* $  
166 LABEL    ERROR7 $  
167 PRTPARM //-*BLADEMDS* $  
168 LABEL    FINIS $  
169 PURGE   DUMMY/MINUS1 $  
170 END      $
```

4.1.2 Description of Important DMAP Operations for Blade Cyclic Modal Flutter Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. Go to DMAP No. 162 and print Error Message No. 5 if no grid points are defined.
7. GP2 generates Element Connection Table with internal indices.
8. GP3 generates Static Loads Table and Grid Point Temperature Table.
9. TA1 generates element tables for use in matrix assembly and stress recovery.
10. Go to DMAP No. 162 and print Error Message No. 5 if no structural elements have been defined.
15. Go to DMAP No. 19 if no stiffness matrix is supplied by the user on an external file.
16. Set parameter NOKGGX = -1 so that the stiffness matrix will not be generated in DMAP No. 20.
17. INPUTT1 reads the user-supplied stiffness matrix [KTOTAL] from an external file (GINØ file INPT).
18. Equivalence  $[K_{gg}^x]$  to [KTOTAL].
20. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
21. Go to DMAP No. 23 if no stiffness matrix is to be assembled.
22. EMA assembles stiffness matrix  $[K_{gg}^x]$  and Grid Point Singularity Table.
24. Go to DMAP No. 154 and print Error Message No. 1 if no mass matrix is to be assembled.
25. EMA assembles mass matrix  $[M_{gg}]$ .
26. Go to DMAP No. 29 if no weight and balance information is requested.
27. GPWG generates weight and balance information.
28. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
30. Equivalence  $[K_{gg}^x]$  to  $[K_{gg}]$  if there are no general elements.
31. Go to DMAP No. 33 if there are no general elements.
32. SMA3 adds general elements to  $[K_{gg}^x]$  to obtain stiffness matrix  $[K_{gg}]$ .
34. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
36. Go to DMAP No. 164 and print Error Message No. 6 if free-body supports are present.
38. GPCYC prepares segment boundary table.
39. Go to DMAP No. 166 and print Error Message No. 7 if the CYJØIN data is inconsistent.
40. Go to DMAP No. 45 if general elements are present.
42. Go to DMAP No. 45 if no potential grid point singularities exist.
43. GPSP generates a table of potential grid point singularities.

AERO RIGID FORMATS

44. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
46. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
47. Go to DMAP No. 50 if no multipoint constraints exist.
48. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m \ ; R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .
49. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \begin{bmatrix} \bar{K}_{nn} & K_{nm} \\ K_{mn} & K_{mm} \end{bmatrix} \text{ and } [M_{gg}] = \begin{bmatrix} \bar{M}_{nn} & M_{nm} \\ M_{mn} & M_{mm} \end{bmatrix}$$

and performs matrix reductions

$$\begin{aligned} [K_{nn}] &= [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \text{ and} \\ [M_{nn}] &= [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m]. \end{aligned}$$

51. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.
52. Go to DMAP No. 54 if no single-point constraints exist.
53. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & K_{fs} \\ K_{sf} & K_{ss} \end{bmatrix} \text{ and } [M_{nn}] = \begin{bmatrix} M_{ff} & M_{fs} \\ M_{sf} & M_{ss} \end{bmatrix}.$$

55. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  and  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.
56. Go to DMAP No. 59 if no omitted coordinates exist.
57. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} \bar{K}_{aa} & K_{ao} \\ K_{oa} & K_{oo} \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$ .

58. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} \bar{M}_{aa} & M_{ao} \\ M_{oa} & M_{oo} \end{bmatrix}$$

and performs matrix reduction

$$[M_{aa}] = [M_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oo}][G_o] + [G_o^T][M_{oa}] .$$

60. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFPØØL), and Eigenvalue Extraction Data (EED).
61. Go to DMAP No. 156 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.
62. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for dynamic analysis.
63. CYCT2 transforms matrices from symmetric components to solution set.
64. Go to DMAP No. 166 and print Error Message No. 7 if a CYCT2 error was found.
65. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{kk} - \lambda M_{kk}]\{\phi_k\} = 0 ,$$

and normalizes eigenvectors according to one of the following user requests:

- 1) Unit value of a selected component
- 2) Unit value of the largest component
- 3) Unit value of the generalized mass.

66. ØFP formats the summary of eigenvalue extraction information (ØEIGS) and the eigenvalues (LAMK) prepared by READ and places them on the system output file for printing.
67. Go to DMAP No. 160 and print Error Message No. 4 if no eigenvalues were found.
68. CYCT2 finds symmetric components of eigenvectors from solution set eigenvectors.
69. Go to DMAP No. 166 and print Error Message No. 7 if a CYCT2 error was found.
70. SDR1 recovers dependent components of the eigenvectors

$$\{\phi_o\} = [G_o] \{\phi_a\} , \quad \left\{ \frac{\phi_a}{\phi_o} \right\} = \{\phi_f\} ,$$

$$\left\{ \frac{\phi_f}{\phi_s} \right\} = \{\phi_n\} , \quad \{\phi_m\} = [G_m] \{\phi_n\} ,$$

$$\left\{ \frac{\phi_n}{\phi_m} \right\} = \{\phi_g\} .$$

71. SDR2 prepares eigenvectors (ØPHIG) for output and PPHIG for deformed plotting.
72. ØFP formats the table prepared by SDR2 and places it on the system output file for printing.
75. Go to DMAP No. 81 if there are no structure plot requests.

76. PLTSET transforms user input into a form used to drive the structure plotter.
77. PRTMSG prints error messages associated with the structure plotter.
78. Go to DMAP No. 81 if no deformed (modal) structure plots are requested.
79. PL0T generates all requested deformed (modal) structure plots.
80. PRTMSG prints plotter data and engineering data for each deformed (modal) structure plot generated.
82. APDB processes the aerodynamic data cards from EDT. AER0 and ACPT reflect the aerodynamic parameters. PVECT is a partitioning vector and GTKA is a transformation matrix between aerodynamic (K) and structural (a) degrees of freedom.
83. PARTN partitions the eigenvector into all sine or all cosine components.
84. SMPYAD calculates the modal mass matrix

$$[M] = \begin{bmatrix} x \\ \phi_a \end{bmatrix}^T [M_{aa}] \begin{bmatrix} x \\ \phi_a \end{bmatrix} .$$

85. MXTRIN selects the direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ .
87. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^2]$  if no constraints are applied.
88. GKAD applies constraints to direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ , forming  $[K_{dd}^2]$ ,  $[M_{dd}^2]$  and  $[B_{dd}^2]$  and forms  $[G_{md}]$  and  $[G_{od}]$ .
89. GKAM selects eigenvectors to form  $[\phi_{dh}]$  and assembles stiffness, mass and damping matrices in modal coordinates:

$$\begin{aligned} [K_{hh}] &= \begin{bmatrix} k_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}] , \\ [M_{hh}] &= \begin{bmatrix} m_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}] , \\ [B_{hh}] &= \begin{bmatrix} b_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}] , \end{aligned}$$

where

KDAMP = -1 (default)

$m_i$  = modal masses

$b_i = m_i 2\pi f_i g(f_i)$

$k_i = m_i 4\pi^2 f_i$

KDAMP = 1

$m_i$  = modal masses

$b_i = 0$

$k_i = (1+ig(f_i)) 4\pi^2 f_i^2 m_i$

91. Go to DMAP No. 99 if no plot output is requested.

## BLADE CYCLIC MODAL FLUTTER ANALYSIS

92. PLTSET transforms user input into a form used to drive the structure plotter.
93. PRTMSG prints error messages associated with the structure plotter.
96. Go to DMAP No. 99 if no undeformed aerodynamic or structural element plots are requested.
97. PLØT generates all requested undeformed aerodynamic and structural element plots.
98. PRTMSG prints plotter data and engineering data for each undeformed aerodynamic and structural element plot generated.
101. AMG forms the aerodynamic matrix list  $[A_{jj}]$ , the area matrix  $[S_{kj}]$ , and the downwash coefficients  $[D_{jk}^1]$  and  $[D_{jk}^2]$ .
103. Go to DMAP No. 105 if there are no user-supplied downwash coefficients.
104. INPUTT2 provides the user-supplied downwash factors due to extra points ( $[D_{je}^1]$ ,  $[D_{je}^2]$ ). PARAM NØDJE must be set to enter these matrices. The downwash  $w_j$  on box j due to the motion of an extra point,  $u_e$ , is given by

$$\{w_j\} = [D_{je}^1 + ikD_{je}^2]\{u_e\} .$$

107. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$\begin{aligned} [\phi_{dh}] &= \begin{bmatrix} \phi_{ai} & \phi_{ae} \\ \phi_{ei} & \phi_{ee} \end{bmatrix} , & [G_{ki}] &= [G_{ka}^T]^T [\phi_{ai}] , \\ [D_{jh}^1] &\Leftarrow [D_{ji}^1 | D_{je}^1] , & [D_{ji}^1] &= [D_{jk}^1]^T [G_{ki}] , \\ [D_{jh}^2] &\Leftarrow [D_{ji}^2 | D_{je}^2] \text{ and} & [D_{ji}^2] &= [D_{jk}^2]^T [G_{ki}] . \end{aligned}$$

For each (m,k) pair:

$$[D_{jh}] = [D_{jh}^1] + ik[D_{jh}^2] .$$

For each group:

$$\begin{aligned} [Q_{jh}] &= [A_{jj}^T]^{-1} [D_{jh}]_{group} , \\ [Q_{kh}] &= [S_{kj}] [Q_{jh}] , \\ [Q_{ih}] &= [G_{ki}]^T [Q_{kh}] \\ \text{and} \quad [Q_{hh}] &\Leftarrow \left[ \frac{Q_{ih}}{Q_{eh}} \right] . \end{aligned}$$

110. PARAM initializes the flutter loop counter (FLØØP) to zero.
111. Beginning of loop for flutter.

## AERO RIGID FORMATS

112. FA1 computes the total aerodynamic mass matrix [ $M_{hh}^X$ ], the total aerodynamic stiffness matrix [ $K_{hh}^X$ ] and the total aerodynamic damping matrix [ $B_{hh}^X$ ] as well as a looping table FSAVE. For the K-method

$$M_{hh}^X = (k^2/b^2)M_{hh} + (\rho/2)Q_{hh},$$

$$K_{hh}^X = K_{hh}$$

and       $B_{hh}^X = 0$ .

113. Set up equivalences for the KE- and PK-methods.  
 114. Go to DMAP No. 117 for the KE- and PK-methods.  
 115. CEAD extracts complex eigenvalues and eigenvectors from the equation

$$[M_{hh}^X p^2 + B_{hh}^X p + K_{hh}^X] \{ \phi_h \} = 0$$

and normalizes eigenvectors to unit magnitude of the largest component.

116. Go to DMAP No. 124 if no complex eigenvalues were found.  
 118. VDR prepares eigenvectors ( $\emptyset\phi_{PHI}$ ) for output, using only the extra points introduced for dynamic analysis and modal coordinates.  
 119. Go to DMAP No. 121 if there is no output request for the extra points introduced for dynamic analysis or modal coordinates.  
 120. ØFP formats the table of eigenvectors for extra points introduced for dynamic analysis and modal coordinates prepared by VDR and places it on the system output file for printing.  
 122. FA2 appends eigenvectors to PHIHL, eigenvalues to CLAMAL, Case Control to CASEYY, and V-g plot data to ØVG.  
 123. Go to DMAP No. 128 if there is insufficient time for another flutter loop.  
 125. Go to DMAP No. 128 if the flutter loop is complete.  
 126. Go to DMAP No. 111 for additional aerodynamic configuration triplet values.  
 127. Go to DMAP No. 158 and print Error Message No. 3 if the number of flutter loops exceeds 100.  
 130. Go to DMAP No. 133 if there are no X-Y plot requests.  
 131. XYTRAN prepares the input for requested X-Y plots.  
 132. XYPLÖT prepares the requested X-Y plots of displacements, velocities, accelerations, forces, stresses, loads and single-point forces of constraint versus time.  
 135. Go to DMAP No. 168 and make normal exit if there are no output requests involving dependent degrees of freedom or forces and stresses.  
 136. MØDACC selects a list of eigenvalues and eigenvectors whose imaginary parts (velocity in input units) are close to a user input list.

# BLADE CYCLIC MODAL FLUTTER ANALYSIS

137. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$\{\phi_d^c\} = \{\phi_{dh}\}\{\phi_h\} .$$

138. Equivalence  $\{\phi_d^c\}$  to  $\{\phi_p^c\}$  if no constraints are applied.

139. Go to DMAP No. 141 if no constraints are applied.

140. SDR1 recovers dependent components of eigenvectors

$$\{\phi_0^c\} = [G_o^d] \{\phi_d^c\} , \quad \left\{ \frac{\phi_d^c}{\phi_0^c} \right\} = \{\phi_f^c + \phi_e^c\} ,$$

$$\left\{ \frac{\phi_f^c + \phi_e^c}{\phi_s^c} \right\} = \{\phi_n^c + \phi_e^c\} , \quad \{\phi_m^c\} = [G_m^d] \{\phi_n^c + \phi_e^c\} ,$$

$$\left\{ \frac{\phi_f^c + \phi_e^c}{\phi_m^c} \right\} = \{Q_p^c\}$$

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}^T]\{\phi_f\}$ ,  $\frac{0}{q_s} = \{Q_p^c\}$ .

142. Equivalence  $\{\phi_d^c\}$  to  $\{\phi_a^c\}$  if there are no extra points introduced for dynamic analysis.

143. Go to DMAP No. 146 if there are no extra points.

144. VEC generates a d-size partitioning vector (RP) for the a- and e-sets

$$\{u_d\} + \{u_a\} + \{u_e\} .$$

145. PARTN performs partition of  $\{\phi_d^c\}$  using RP

$$\{\phi_d^c\} \quad \left\{ \frac{\phi_a^c}{\phi_e^c} \right\} .$$

147. SDR2 calculates element forces ( $\emptyset EFC1$ ) and stresses ( $\emptyset ESC1$ ) and prepares eigenvectors ( $\emptyset CPHIP$ ) and single-point forces of constraint ( $\emptyset QPC1$ ) for output and PCPHIP for deformed plotting.

148. OFP formats the tables prepared by SDR2 and places them on the system output file for printing.

149. Go to DMAP No. 152 if no deformed aerodynamic or structural element plots are requested.

150. PL0T prepares all deformed aerodynamic and structural element plots.

151. PRTMSG prints plotter data and engineering data for each deformed plot generated.

153. Go to DMAP No. 168 and make normal exit.

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155. Print Error Message No. 1 and terminate execution.
157. Print Error Message No. 2 and terminate execution.
159. Print Error Message No. 3 and terminate execution.
161. Print Error Message No. 4 and terminate execution.
163. Print Error Message No. 5 and terminate execution.
165. Print Error Message No. 6 and terminate execution.
167. Print Error Message No. 7 and terminate execution.

## BLADE CYCLIC MODAL FLUTTER ANALYSIS

### 4.1.3 Output for Blade Cyclic Modal Flutter Analysis

The real Eigenvalue Summary Table and the real Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues are included even though all may not be used in the modal formulation.

The complex eigenvalues are included in the Flutter Summary and are printed for each aerodynamic loop.

The grid point singularities from the structural model are also output.

A Flutter Summary for each value of the configuration parameters is printed out unless PRINT=N0. This shows Mach number, density, reduced frequency, velocity, damping, and frequency for each complex eigenvalue.

V-g and V-f plots may be requested by the XYOUT control cards by specifying the curve type as VG. The "points" are loop numbers and the "components" are G or F.

Printed output of the following types, sorted by complex eigenvalue root number (SORT1) and (m, k, p), may be requested for all complex eigenvalues kept, either as real and imaginary parts or as magnitude and phase angle (0° - 360° lead). (Eigenvectors are not available for the KE-method.)

1. The eigenvector for a list of PHYSICAL and AERODYNAMIC points (grid points, extra points, and aerodynamic points) or SOLUTION points (modal coordinates and extra points).
2. Nonzero components of the single-point forces of constraint for a list of PHYSICAL points.
3. Complex stresses and forces in selected elements.

The OFREQUENCY Case Control card can select a subset of the complex eigenvectors for data recovery. In addition, undeformed and deformed shapes may be requested. Undeformed shapes may include only structural or structural and aerodynamic elements.

### 4.1.4 Case Control Deck for Blade Cyclic Modal Flutter Analysis

The following items relate to subcase definition and data selection for Blade Cyclic Modal Flutter Analysis:

1. Only one subcase is allowed.
2. Desired direct input matrices for stiffness [ $K_{pp}^2$ ], mass [ $M_{pp}^2$ ], and damping [ $B_{pp}^2$ ] must be selected via the keywords K2PP, M2PP, or B2PP.
3. CMETHOD must be used to select an EIGC card from the Bulk Data Deck. (K method only.)
4. FMETHOD must be used to select a FLUTTER card from the Bulk Data Deck.

5. METHOD must be used to select an EIGR card that exists in the Bulk Data Deck.
6. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.
7. An SPC set must be selected unless the model is a free body or all constraints are specified on GRID cards, Scalar Connection Cards or with General Elements.
8. Each NASTRAN run calculates modes for only one symmetry index, K.

#### 4.1.5 Parameters for Blade Cyclic Modal Flutter Analysis

The following parameters are used in Blade Cyclic Modal Flutter Analysis:

1. ASETOUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTOSPC - reserved for future optional use. The default value is -1.
3. COPUMASS - CPBAR, CPRD, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. CTYPE - required. The BCD value of this parameter defines the type of cyclic symmetry as follows:
  - (1) ROT - rotational symmetry
  - (2) DRL - dihedral symmetry, using right and left halves
  - (3) DSA - dihedral symmetry, using symmetric and antisymmetric components
5. CYCSEQ - optional. The integer value of this parameter specifies the procedure for sequencing the equations in the solution set. A value of +1 specifies that all cosine terms should be sequenced before all sine terms, and a value of -1 specifies alternating cosine and sine terms. The default value is -1.
6. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
7. IREF - optional. A positive integer value of this parameter defines the reference streamline number. IREF must be equal to an SLN on a STREAML2 bulk data card. The default value of -1 represents the streamsurface at the blade tip. If IREF does not correspond to an SLN, then the default will be taken.

BLADE CYCLIC MODAL FLUTTER ANALYSIS

8. KDAMP - optional. An integer value of +1 causes modal damping terms to be put into the complex stiffness matrix for structural damping (+1 recommended for K and KE methods). The default value is -1.
9. KGGIN - optional. A positive integer of this parameter indicates that the user-supplied stiffness matrix is to be read from an external file (GIN $\emptyset$  file INPT) via the INPUTT1 module in the rigid format. The default value is -1 when not needed.
10. KINDEX - required. The integer value of this parameter specifies a single value of the harmonic index.
11. LFREQ and HFREQ - required unless parameter LM $\emptyset$ DES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LM $\emptyset$ DES must be set to 0.
12. LM $\emptyset$ DES - used unless set to 0. The integer value of this parameter is the number of lowest modes to be used in the modal formulation. The default value of 999999 will result in all modes being used.
13. L $\emptyset$ CATION and INPTUNIT - required when using the KGGIN parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT1 module. The default values for L $\emptyset$ CATION and INPTUNIT are -1 and 0, respectively.
14. MAXMACH - optional. The real value of this parameter is the maximum Mach number below which the subsonic unsteady cascade theory is valid. The default value is 0.80.
15. MINMACH - optional. The real value of this parameter is the minimum Mach number above which the supersonic unsteady cascade theory is valid. The default value is 1.01.
16. MTYPE - optional. The BCD value of this parameter controls which components of the cyclic modes are to be used in the modal formulation. MTYPE = SINE uses only sine components and MTYPE = C $\emptyset$ SINE uses only cosine components. The default value is C $\emptyset$ SINE.
17. N $\emptyset$ DJE - optional. A positive integer of this parameter indicates that user-supplied downwash matrices due to extra points are to be read in from an external file via the INPUTT2 module in the rigid format. The default value is -1 when not needed.
18. NSEG - required. The integer value of this parameter is the number of identical segments in the structural model.
19. P $\emptyset$ POSITION, UNITNUM and USRLABEL - required when using the N $\emptyset$ DJE parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT2 module. The defaults for P $\emptyset$ POSITION, UNITNUM and USRLABEL are -1, 11 and TAPEID, respectively.

20. PRINT - optional. The BCD value, NØ, of this parameter suppresses the automatic printing of the flutter summary for the K method. The default value is YESB.
21. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
22. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
23. VREF - optional. Velocities are divided by the real value of this parameter to convert units or to compute flutter indices. The default value is 1.0.
24. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

#### 4.1.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

#### 4.1.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Blade Cyclic Modal Flutter Analysis. See Section 2.3.7 for details.

#### 4.1.8 Rigid Format Error Messages from Blade Cyclic Modal Flutter Analysis

The following fatal errors are detected by the DMAP statements in the Blade Cyclic Modal Flutter Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

BLADE FLUTTER ANALYSIS ERRØR NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

## BLADE CYCLIC MODAL FLUTTER ANALYSIS

BLADE FLUTTER ANALYSIS ERRØR NØ. 2 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

BLADE FLUTTER ANALYSIS ERRØR NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØOPS.

An attempt has been made to use more than 100 flutter loops. This number can be increased by ALTERing the REPT instruction following the FA2 module.

BLADE FLUTTER ANALYSIS ERRØR NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATØRN.

No real eigenvalues were found in the frequency range specified by the user.

BLADE FLUTTER ANALYSIS ERRØR NØ. 5 - NØ GRID PØINT DATA IS SPECIFIED ØR NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No points have been defined with GRID or SPØINT cards or no structural elements have been defined with Connection cards.

BLADE FLUTTER ANALYSIS ERRØR NØ. 6 - FREE BØDY SUPPORTS NOT ALLOWED.

Free bodies are not allowed in Blade Cyclic Modal Flutter Analysis. The SØPØRT cards must be removed from the Bulk Data Deck and other constraints applied if required for stability.

BLADE FLUTTER ANALYSIS ERRØR NØ. 7 - CYCLIC TRANSFØRMATØRN DATA ERRØR.

See Section 1.12 for proper modeling techniques and corresponding PARAM card requirements.

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4.2 MODAL FLUTTER ANALYSIS

4.2.1 DMAP Sequence for Modal Flutter Analysis

RIGID FORMAT DMAP LISTING  
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AERO APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN     AERO 10 - MODAL FLUTTER ANALYSIS - APR. 1986 $  
2 PRECHK    ALL $  
3 FILE      PHHL=APPEND/AJL=APPEND/FSAVE=APPEND/CASEYY=APPEND/  
            CLAMAL=APPEND/OVG=APPEND/QHHL=APPEND/SKJ=APPEND/QHJL=APPEND/  
            QKHL=APPEND/ $  
4 PARAM     //*MPY*/CARDNO/0/0 $  
5 GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
            S,N,NOGPDT/MINUS1=-1 $  
6 COND      ERROR5,NOGPDT $  
7 GP2       GEOM2,EQEXIN/ECT $  
8 PARAML    PCDB//*PRES*///JUMPPLOT $  
9 GP3       GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $  
10 TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,,/  
            LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
11 COND      ERROR1,NOSIMP $  
12 PARAM    //*ADD*/NOKGGX/1/0 $  
13 PARAM    //*ADD*/NOMGG /1/0 $  
14 EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
            S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/  
            C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/  
            C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
            V,Y,VOLUME/V,Y,SURFACE $  
15 PURGE    KGGX,GPST/NOKGGX $  
16 COND      JMPKGGX,NOKGGX $  
17 EMA      GPECT,KDICT,KELM/KGGX,GPST $  
18 LABEL    JMPKGGX $  
19 COND      ERROR1,NOMGG $
```

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RIGID FORMAT DMAP LISTING  
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AERO APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
20 EMA      GPECT,MIDCT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
21 COND     LGPWG,GRDPNT $
22 GPWG     BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
23 OFP      OGPWG,,,,//S,N,CARDNO $
24 LABEL    LGPWG $
25 EQUIV   KGGX,KGG/NOGENL $
26 COND     LBL11,NOGENL $
27 SMA3    GEI,/KGGY/LUSET/NOGENL/-1 $
28 ADD     KGGX,KGGY/KGG $
29 LABEL    LBL11 $
30 GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/LUSET/
          S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N,OMIT/S,N,REACT/O/
          REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
31 PARAM   //EQ*/GPSPFLG/AUTOSPC/O $
32 COND     LBL4,GPSPFLG $
33 GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
34 OFP     OGPST,,,,//S,N,CARDNO $
35 LABEL    LBL4 $
36 EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
37 PURGE   GM/MPCF1/DM,MR/REACT $
38 COND     LBL2,MPCF1 $
39 MCE1    USET,RG/GM $
40 MCE2    USET,GM,KGG,MGG,,/KNN,MNN,, $
41 LABEL    LBL2 $
42 EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE $
43 COND     LBL3,SINGLE $
44 SCE1    USET,KNN,MNN,,/KFF,KFS,,MFF,,
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
45  LABEL    LBL3 $  
46  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $  
47  PURGE    GO/OMIT $  
48  COND     LBL5, OMIT $  
49  PARAM    ///*PREC*/PREC $  
50  SMP1     USET,KFF,,,/GO,KAA,KOO,L00,,,,, $  
51  SMP2     USET,GO,MFF/MAA $  
52  LABEL    LBL5 $  
53  COND     LBL6,REACT $  
54  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $  
55  RBMG2    KLL/LLL/ $  
56  RBMG3    LLL,KLR,KRR/DM $  
57  RBMG4    DM,MLL,MLR,MRR/MR $  
58  LABEL    LBL6 $  
59  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,,,,,,EED,EQDYN/  
LUSET/S,N,LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/  
NONLFT/NOTRL/S,N,NOEED/123/S,N,NOUE $  
60  COND     ERROR2,NOEED $  
61  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $  
62  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,  
NEIGV $  
63  OFP      OEIGS,,,,,/S,N,CARDNO $  
64  COND     ERROR4,NEIGV $  
65  OFP      LAMA,,,,,/S,N,CARDNO $  
66  MTRXIN   CASECC,MATPOOL,EQDYN,,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,  
NOK2PP/S,N,NOM2PP/S,N,NOB2PP $  
67  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA $
```

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RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
68 GKAD USETD,GM,GO,,,K2PP,M2PP,B2PP/,,,GMD,GOD,K2DD,M2DD,B2DD/  
*CMPLEV*/DISP/*MODAL*/0.0/0.0/0.0/NOK2PP/  
NOM2PP/NOB2PP/MPCF1/SINGLE/OMIT/NOUE/  
-1/-1/ -1/-1 $  
  
69 GKAM USETD,PHIA,,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,  
PHIDH/NOUE/C,Y,LMODES=0/C,Y,LFREQ=0./C,Y,HFREQ=-1.0/  
NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE/C,Y,KDAMP $  
  
70 APD EDT,EQDYN,ECT,BGPDT,SILD,USETD,CSTM,GPLD/EQAERO,ECTA,BGPA,SILA,  
USETA,SPLINE,AERO,ACPT,FLIST,CSTMA,GPLA,SILGA/S,N,NK/S,N,NJ/  
S,N,LUSETA/S,N,BOV $  
  
71 PARAM //*MPY*/PFILE/0/1 $  
  
72 PURGE PLTSETA,PLTPARA,GPSETS,A,ELSETSA/JUMPLOT $  
  
73 COND SKPPLT,JUMPLOT $  
  
74 PARAM //*MPY*/PLTFLG/0/1 $  
  
75 PLTSET PCDB,EQAERO,ECTA/PLTSETA,PLTPARA,GPSETS,A,ELSETSA/S,N,NSIL1/S,  
N,JUMPLOT $  
  
76 PRTMSG PLTSETA // $  
  
77 COND SKPPLT,JUMPLOT $  
  
78 PLOT PLTPARA,GPSETS,A,ELSETSA,CASECC,BGPA,EQAERO, ,,,/PLOTX2/  
NSIL1/LUSETA/S,N,JUMPLOT/S,N,PLTFLG/S,N,PFILE $  
  
79 PRTMSG PLOTX2 // $  
  
80 LABEL SKPPLT $  
  
81 COND ERROR2,NOEED $  
  
82 GI SPLINE,USET ,CSTMA,BGPA,SIL , ,GM,GO/GTKA/NK/LUSET $  
  
83 PARAM //*ADD*/DESTRY/0/1/ $  
  
84 AMG AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/S,N,DESTRY $  
  
85 COND NODJE, NODJE $  
  
86 INPUTT2 /D1JE,D2JE,,,/C,Y,P1=0/C,Y,P2=11/C,Y,P3=XXXXXXXX $  
  
87 LABEL NODJE $  
  
88 PARAM //*ADD*/XQHHL/1/0 $
```

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AERO APPROACH, RIGID FORMAT 10

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
89 AMP      AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,QKHL,  
          QHJL/NOUE/S,N,XQHHL/V,Y,GUSTAERO=-1 $  
90 PARAM    ///*MPY*/FLOOP/V,Y,NODJE=-1/O $  
91 LABEL    LOOPTOP $  
92 FA1      KHH,BHH,MHH,QHHL,CASECC,FLIST/FSAVE,KXHH,BXHH,MXHH/  
          S,N,FLOOP/S,N,TSTART/S,N,NOCEAD $  
93 EQUIV   KXHH,PHIH/NOCEAD/BXHH,CLAMA/NOCEAD/KXHH,PHIHL/NOCEAD/BXHH,  
          CLAMAL/NOCEAD/CASECC,CASEYY/NOCEAD $  
94 COND     VDR,NOCEAD $  
95 CEAD     KXHH,BXHH,MXHH,EED,CASECC/PHIH,CLAMA,OCEIGS,/S,N,EIGVS $  
96 COND     LBLZAP,EIGVS $  
97 LABEL    VDR $  
98 VDR      CASECC,EQDYN ,USETD,PHIH,CLAMA,,/OPHIH,//*CEIGEN*/*MODAL*/  
          123/S,N,NOH/S,N,NOP/FMODE $  
99 COND     LBL16,NOH $  
100 OFP     OPHIH,,,,,/S,N,CARDNO $  
101 LABEL    LBL16 $  
102 FA2      PHIHL,CLAMAL,CASEYY,OVG/S,N,TSTART/  
          C,Y,VREF=1.0/C,Y,PRINT=YES $  
103 COND     CONTINUE,TSTART $  
104 LABEL    LBLZAP $  
105 COND     CONTINUE,FLOOP $  
106 REPT    LOOPTOP,100 $  
107 JUMP    ERROR3 $  
108 LABEL    CONTINUE $  
109 PARAML  XYCDB///*PRES*///NOXYCDB $  
110 COND     NOXYOUT,NOXYCDB $  
111 XYTRAN XYCDB,OVG,,,/,XYPLTCE/*VG*/*PSET*/S,N,PFILE/S,N,CARDNO/  
          S,N,NOXYPL $
```

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
112  COND      NOXYOUT,NOXYPL $  
113  XYPLOT    XYPLTCE// $  
114  LABEL      NOXYOUT $  
115  PARAM      ///*AND*/PJUMP/NOP=-1/JUMPPLOT $  
116  COND      FINIS,PJUMP $  
117  MODACC    CASEYY,CLAMAL,PHIHL,,,/CLAMAL1,CPHIH1,CASEZZ,,/*CEIGN* $  
118  ADR       CPHIH1,CASEZZ,QKHL,CLAMAL1,SPLINE,SILA,USETA/PKF/BOV/  
C,Y,MACH = 0.0/*FLUTTER* $  
119  DDR1      CPHIH1,PHIDH/CPHID $  
120  EQUIV     CPHID ,CPHIP/NOA $  
121  PURGE     QPC/NOA $  
122  COND      LBL14,NOA $  
123  SDR1      USETD,,CPHID ,,,GOD,GMD,,KFS,,CPHIP,,QPC/1 /*DYNAMICS* $  
124  LABEL     LBL14 $  
125  EQUIV     CPHID ,CPHIA/NOUE $  
126  COND      LBLNOE,NOUE $  
127  VEC       USETA/RP/*D*/*A*/*E* $  
128  PARTN    CPHID ,RP/CPHIA,,,/1/3 $  
129  LABEL     LBLNOE $  
130  MPYAD     GTKA,CPHIA,/CPHIK/1/1/0/PREC $  
131  UMERGE    USETA,CPHIP,/CPHIPS/*PS*/*P*/*SA* $  
132  UMERGE    USETA,CPHIPS,CPHIK/CPHIPA/*PA*/*PS*/*K* $  
133  UMERGE    USETA,QPC,/QPAC/*PA*/*P*/*K* $  
134  SDR2      CASEZZ,CSTMA,MPT,DIT,EQAERO,SILA,,,BGPA,CLAMAL1,QPAC,CPHIPA,  
EST,,,OQPAC1,OCPHIPA,OESC1,OEF1,PCPHIPA/*CEIGN* $  
135  OFFP     OCPHIPA,OQPAC1,OESC1,OEF1,,/S,N,CARDNO $  
136  COND      FINIS,JUMPPLOT $
```

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```
137 PLOT      PLTPARA,GPSETSA,ELSETSA,CASEZZ,BGPA,EQAERO,SILGA,,PCPHIPA,,  
          /PLOTX3/NSIL1/LUSETA/JUMPPLOT/PLTFLG/S,N,  
          PFILE $  
  
138 PRTMSG    PLOTX3// $  
  
139 JUMP      FINIS $  
  
140 LABEL     ERROR3 $  
  
141 PRTPARM   //-*FLUTTER* $  
  
142 LABEL     ERROR2 $  
  
143 PRTPARM   //-*FLUTTER* $  
  
144 LABEL     ERROR1 $  
  
145 PRTPARM   //-*FLUTTER* $  
  
146 LABEL     ERROR4 $  
  
147 PRTPARM   //-*FLUTTER* $  
  
148 LABEL     ERROR5 $  
  
149 PRTPARM   //-*FLUTTER* $  
  
150 LABEL     FINIS $  
  
151 PURGE    DUMMY/MINUS1 $  
  
152 END      $
```

4.2.2 Description of Important DMAP Operations for Modal Flutter Analysis

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. Go to DMAP No. 148 and print Error Message No. 5 if no grid points are defined.
7. GP2 generates Element Connection Table with internal indices.
9. GP3 generates Static Loads Table and Grid Point Temperature Table.
10. TA1 generates element tables for use in matrix assembly and stress recovery.
11. Go to DMAP No. 148 and print Error Message No. 5 if no structural elements have been defined.
14. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
16. Go to DMAP No. 18 if no stiffness matrix is to be assembled.
17. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
19. Go to DMAP No. 144 and print Error Message No. 1 if no mass matrix is to be assembled.
20. EMA assembles mass matrix  $[M_{gg}]$ .
21. Go to DMAP No. 24 if no weight and balance information is requested.
22. GPWG generates weight and balance information.
23. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
25. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
26. Go to DMAP No. 29 if there are no general elements.
27. SMA3 forms the general element stiffness matrix  $[K_{gg}^Y]$ .
28. ADD combines the structural stiffness matrix  $[K_{gg}^X]$  with the general element stiffness matrix  $[K_{gg}^Y]$  to obtain the stiffness matrix  $[K_{gg}]$ .
30. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
32. Go to DMAP No. 35 if no potential grid point singularities exist.
33. GPSP generates a table of potential grid point singularities.
34. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
36. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
38. Go to DMAP No. 41 if no multipoint constraints exist.
39. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m | R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .

## MODAL FLUTTER ANALYSIS

40. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} \\ \frac{K_{nn} + K_{nm}}{K_{mn} + K_{mm}} & - \end{bmatrix} \quad \text{and} \quad [M_{gg}] = \begin{bmatrix} - & M_{nn} \\ \frac{M_{nn} + M_{nm}}{M_{mn} + M_{mm}} & - \end{bmatrix}$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] .$$

42. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.

43. Go to DMAP No. 45 if no single-point constraints exist.

44. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} - & K_{ff} \\ \frac{K_{ff} + K_{fs}}{K_{sf} + K_{ss}} & - \end{bmatrix} \quad \text{and} \quad [M_{nn}] = \begin{bmatrix} - & M_{ff} \\ \frac{M_{ff} + M_{fs}}{M_{sf} + M_{ss}} & - \end{bmatrix} .$$

46. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  and  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.

48. Go to DMAP No. 52 if no omitted coordinates exist.

50. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} \\ \frac{K_{aa} + K_{ao}}{K_{oa} + K_{oo}} & - \end{bmatrix} ,$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$  .

51. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} - & M_{aa} \\ \frac{M_{aa} + M_{ao}}{M_{oa} + M_{oo}} & - \end{bmatrix}$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oo}][G_o] + [G_o^T][M_{ao}] .$$

53. Go to DMAP No. 58 if there are no free-body supports.

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54. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix} \quad \text{and} \quad [M_{aa}] = \begin{bmatrix} M_{\ell\ell} & M_{\ell r} \\ M_{r\ell} & M_{rr} \end{bmatrix}$$

55. RBMG2 decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

56. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\epsilon = \frac{\|X\|}{\|K_{rr}\|}.$$

57. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

59. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFP00L), and Eigenvalue Extraction Data (EED).

60. Go to DMAP No. 142 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.

61. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for dynamic analysis.

62. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{\phi_a\} = 0,$$

calculates rigid body modes by finding a matrix  $[\phi_{ro}]$  such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} D\phi_{ro} \\ \phi_{ro} \end{bmatrix},$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

MODAL FLUTTER ANALYSIS

- 1) Unit value of a selected component
  - 2) Unit value of the largest component
  - 3) Unit value of the generalized mass.
63. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.
64. Go to DMAP No. 146 and print Error Message No. 4 if no eigenvalues were found.
65. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.
66. MXTRIN selects the direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ .
67. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^2]$  if no constraints are applied.
68. GKAD applies constraints to direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ , forming  $[K_{dd}^2]$ ,  $[M_{dd}^2]$  and  $[B_{dd}^2]$  and forms  $[G_{md}]$  and  $[G_{od}]$ .
69. GKAM selects eigenvectors to form  $[\phi_{dh}]$  and assembles stiffness, mass and damping matrices in modal coordinates:

$$[K_{hh}] = \begin{bmatrix} k_i & 0 \\ 0 & 1 & 0 \end{bmatrix} + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}] ,$$

$$[M_{hh}] = \begin{bmatrix} m_i & 0 \\ 0 & 1 & 0 \end{bmatrix} + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}] ,$$

$$[B_{hh}] = \begin{bmatrix} b_i & 0 \\ 0 & 1 & 0 \end{bmatrix} + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}] ,$$

where

KDAMP = -1 (default)

$m_i$  = modal masses

$b_i = m_i 2\pi f_i g(f_i)$

$k_i = m_i 4\pi^2 f_i$

KDAMP = 1

$m_i$  = modal masses

$b_i = 0$

$k_i = (1+ig(f_i)) 4\pi^2 f_i^2 m_i$

70. APD processes the aerodynamic data cards from EDT. It adds the k points and the SA points to USETD making USETA. EQAERØ, ECTA, BGPA, CSTMA, GPLA and SILA are updated to reflect the new elements. AERØ and ACPT reflect the aerodynamic parameters. SILGA is a special SIL for plotting.
73. Go to DMAP No. 80 if no plot output is requested.
75. PLTSET transforms user input into a form used to drive the structure plotter.
76. PRTMSG prints error messages associated with the structure plotter.
77. Go to DMAP No. 80 if no undeformed aerodynamic or structural element plots are requested.

AERO RIGID FORMATS

78. PL0T generates all requested undeformed aerodynamic and structural element plots.
79. PRTMSG prints plotter data and engineering data for each undeformed aerodynamic and structural element plot generated.
81. Go to DMAP No. 142 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.
82. GI forms a transformation matrix  $[G_{ka}^T]$  which interpolates between aerodynamic (k) and structural (a) degrees of freedom.
84. AMG forms the aerodynamic matrix list  $[A_{jj}]$ , the area matrix  $[S_{kj}]$ , and the downwash coefficients  $[D_{jk}^1]$  and  $[D_{jk}^2]$ .
85. Go to DMAP No. 87 if there are no user-supplied downwash coefficients.
86. INPUTT2 provides the user-supplied downwash factors due to extra points ( $[D_{je}^1]$ ,  $[D_{je}^2]$ ). PARAM N0DJE must be set to enter these matrices. The downwash  $w_j$  on box j due to the motion of an extra point,  $u_e$ , is given by

$$\{w_j\} = [D_{je}^1 + ikD_{je}^2]\{u_e\} .$$

89. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$\begin{aligned} [\phi_{dh}] &= \begin{bmatrix} \phi_{ai} & \phi_{ae} \\ \phi_{ei} & \phi_{ee} \end{bmatrix} , & [G_{ki}] &= [G_{ka}^T]^T [\phi_{ai}] , \\ [D_{jh}^1] &\Leftarrow [D_{ji}^1 | D_{je}^1] , & [D_{ji}^1] &= [D_{jk}^1]^T [G_{ki}] , \\ [D_{jh}^2] &\Leftarrow [D_{ji}^2 | D_{je}^2] \text{ and} & [D_{ji}^2] &= [D_{jk}^2]^T [G_{ki}] . \end{aligned}$$

For each (m,k) pair:

$$[D_{jh}] = [D_{jh}^1] + ik[D_{jh}^2] .$$

For each group:

$$\begin{aligned} [Q_{jh}] &= [A_{jj}^T]^{-1}_{group} [D_{jh}]_{group} , \\ [Q_{kh}] &= [S_{kj}] [Q_{jh}] , \\ [Q_{ih}] &= [G_{ki}]^T [Q_{kh}] \\ \text{and } [Q_{hh}] &\Leftarrow \begin{bmatrix} Q_{ih} \\ Q_{eh} \end{bmatrix} . \end{aligned}$$

90. PARAM initializes the flutter loop counter (FL00P) to zero.

91. Beginning of loop for flutter.

92. FA1 computes the total aerodynamic mass matrix  $[M_{hh}^X]$ , the total aerodynamic stiffness matrix  $[K_{hh}^X]$  and the total aerodynamic damping matrix  $[B_{hh}^X]$  as well as a looping table

## MODAL FLUTTER ANALYSIS

FSAVE. For the K-method

$$M_{hh}^X = (k^2/b^2)M_{hh} + (p/2)Q_{hh},$$

$$K_{hh}^X = K_{hh}$$

$$\text{and } B_{hh}^X = 0.$$

93. Set up equivalences for the KE- and PK-methods.
94. Go to DMAP No. 97 for the KE- and PK-methods.
95. CEAD extracts complex eigenvalues and eigenvectors from the equation
 
$$[M_{hh}^X p^2 + B_{hh}^X p + K_{hh}^X] \{\phi_h\} = 0$$
 and normalizes eigenvectors to unit magnitude of the largest component.
96. Go to DMAP No. 104 if no complex eigenvalues were found.
98. VDR prepares eigenvectors ( $\emptyset\text{PHIH}$ ) for output, using only the extra points introduced for dynamic analysis and modal coordinates.
99. Go to DMAP No. 101 if there is no output request for the extra points introduced for dynamic analysis or modal coordinates.
100.  $\emptyset\text{FP}$  formats the table of eigenvectors for extra points introduced for dynamic analysis and modal coordinates prepared by VDR and places it on the system output file for printing.
102. FA2 appends eigenvectors to PHIHL, eigenvalues to CLAMAL, Case Control to CASEYY, and V-g plot data to  $\emptyset\text{VG}$ .
103. Go to DMAP No. 108 if there is insufficient time for another flutter loop.
105. Go to DMAP No. 108 if the flutter loop is complete.
106. Go to DMAP No. 91 for additional aerodynamic configuration triplet values.
107. Go to DMAP No. 140 and print Error Message No. 3 if the number of flutter loops exceeds 100.
110. Go to DMAP No. 114 if there are no X-Y plot requests.
111. XYTRAN prepares the input for requested V-g plotting.
112. Go to DMAP No. 114 if no plots are possible as requested.
113. XYPL $\emptyset$ T prepares the requested V-g plots.
116. Go to DMAP No. 150 and make normal exit if there are no output requests involving dependent degrees of freedom or forces and stresses.
117. M $\emptyset$ DACC selects a list of eigenvalues and eigenvectors whose imaginary parts (velocity in input units) are close to a user input list.
118. ADR builds a matrix of aerodynamic forces for each aerodynamic point and prints requested aerodynamic forces for selected elements.

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119. DDR1 transforms the complex eigenvectors from modal to physical coordinates

$$\{\phi_d^C\} = \{\phi_{dh}\}\{\phi_h\} .$$

120. Equivalence  $\{\phi_d^C\}$  to  $\{\phi_p^C\}$  if no constraints are applied.

122. Go to DMAP No. 124 if no constraints are applied.

123. SDR1 recovers dependent components of eigenvectors

$$\{\phi_0^C\} = [G_0^d] \{\phi_d^C\} , \quad \left\{ \frac{\phi_d}{\phi_0} \right\} = \{\phi_f^C + \phi_e^C\} ,$$

$$\left\{ \frac{\phi_f^C + \phi_e^C}{\phi_s^C} \right\} = \{\phi_n^C + \phi_e^C\} , \quad \{\phi_m^C\} = [G_m^d] \{\phi_n^C + \phi_e^C\} ,$$

$$\left\{ \frac{\phi_f^C + \phi_e^C}{\phi_m^C} \right\} = \{\phi_p^C\}$$

and recovers single-point forces of constraint  $\{q_s\} = [K_{fs}^T]\{\phi_f\}$ ,  $\left\{ \frac{0}{-q_s} \right\} = \{Q_p^C\}$ .

125. Equivalence  $\{\phi_d^C\}$  to  $\{\phi_a^C\}$  if there are no extra points introduced for dynamic analysis.

126. Go to DMAP No. 129 if there are no extra points.

127. VEC generates a d-size partitioning vector (RP) for the a- and e-sets

$$\{u_d\} + \{u_a\} + \{u_e\} .$$

128. PARTN performs partition of  $\{\phi_d^C\}$  using RP

$$\{\phi_d^C\} \Rightarrow \left\{ \frac{\phi_a^C}{\phi_e^C} \right\} .$$

130. MPYAD recovers the displacements at the aerodynamic points (k)

$$\{\phi_k^C\} = [G_{ka}^T]^T \{\phi_a^C\} .$$

131. UMERGE is used to expand  $\{\phi_p^C\}$  to the ps-set.

MODAL FLUTTER ANALYSIS

132. UMERGE places  $\{\phi_k^c\}$  in its proper place in the displacement vector

$$\{\phi_{pa}^c\} \Leftarrow \left\{ \frac{\phi_{ps}^c}{\frac{c}{\phi_k^c}} \right\} .$$

133. UMERGE is used to expand  $\{Q_p^c\}$  to the pa-set.

134. SDR2 calculates element forces ( $\emptyset EFC1$ ) and stresses ( $\emptyset ESC1$ ) and prepares eigenvectors ( $\emptyset CPHIPA$ ) and single-point forces of constraint ( $\emptyset QPAC1$ ) for output and PCPHIPA for deformed plotting.

135. ØFP formats the tables prepared by SDR2 and places them on the system output file for printing.

136. Go to DMAP No. 150 and make normal exit if no deformed aerodynamic or structural element plots are requested.

137. PLØT prepares all deformed aerodynamic and structural element plots.

138. PRTMSG prints plotter data and engineering data for each deformed plot generated.

139. Go to DMAP No. 150 and make normal exit.

141. Print Error Message No. 3 and terminate execution.

143. Print Error Message No. 2 and terminate execution.

145. Print Error Message No. 1 and terminate execution.

147. Print Error Message No. 4 and terminate execution.

149. Print Error Message No. 5 and terminate execution.

#### 4.2.3 Output for Modal Flutter Analysis

The real Eigenvalue Summary Table and the real Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed. All real eigenvalues are included even though all may not be used in the modal formulation.

The complex eigenvalues are included in the Flutter Summary and are printed for each aerodynamic loop.

The grid point singularities from the structural model are also output.

A Flutter Summary for each value of the configuration parameters is printed out unless PRINT=N0. This shows Mach number, density, reduced frequency, velocity, damping, and frequency for each complex eigenvalue.

V-g and V-f plots may be requested by the XYOUT control cards by specifying the curve type as VG. The "points" are loop numbers and the "components" are G or F.

Printed output of the following types, sorted by complex eigenvalue root number (S0RT1) and ( $m$ ,  $k$ ,  $\rho$ ), may be requested for all complex eigenvalues kept, either as real and imaginary parts or as magnitude and phase angle ( $0^\circ$  -  $360^\circ$  lead). (Eigenvectors are not available for the KE-method.)

1. The eigenvector for a list of PHYSICAL and AERODYNAMIC points (grid points, extra points, and aerodynamic points) or SOLUTION points (modal coordinates and extra points).
2. Nonzero components of the single-point forces of constraint for a list of PHYSICAL points.
3. Complex stresses and forces in selected elements.

The FREQUENCY Case Control card can select a subset of the complex eigenvectors for data recovery. In addition, undeformed and deformed shapes may be requested. Undeformed shapes may include only structural or structural and aerodynamic elements.

The eigenvectors used in the modal formulation may be obtained for the analysis points by using the ALTER feature to print the matrix of eigenvectors following the execution of READ. The eigenvectors for all points in the model may be obtained by running the problem initially on the Normal Modes Analysis Rigid Format or by making a modified restart using the Normal Modes Analysis Rigid Format.

## MODAL FLUTTER ANALYSIS

### 4.2.4 Case Control Deck for Modal Flutter Analysis

The following items relate to subcase definition and data selection for Modal Flutter Analysis:

1. Only one subcase is allowed.
2. Desired direct input matrices for stiffness [ $K_{pp}^2$ ], mass [ $M_{pp}^2$ ], and damping [ $B_{pp}^2$ ] must be selected via the keywords K2PP, M2PP, or B2PP.
3. CMETHOD must be used to select an EIGC card from the Bulk Data Deck. (K method only.)
4. FMETHOD must be used to select a FLUTTER card from the Bulk Data Deck.
5. METHOD must be used to select an EIGR card that exists in the Bulk Data Deck.
6. SDAMPING must be used to select a TABDMP1 table if structural damping is desired.

### 4.2.5 Parameters for Modal Flutter Analysis

The following parameters are used in Modal Flutter Analysis:

1. ASETOUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTSPC - reserved for future optional use. The default value is -1.
3. C0UPMASS - CPBAR, CPR0D, CPQUAD1, CPQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. GUSTAER0 - optional. An integer value of +1 causes gust loads to be computed. The default value is -1 for no gust loads.
6. KDAMP - optional. An integer value of +1 causes modal damping terms to be put into the complex stiffness matrix for structural damping (+1 recommended for K and KE methods). The default value is -1.
7. LFREQ and HFREQ - required, unless LM0DES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LM0DES must be set to 0.

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8. LMODES - required, unless LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
9. MACH - optional. The real value of this parameter selects the closest Mach numbers to be used to compute aerodynamic matrices. The default value is 0.0.
10. NODJE - optional. A positive integer of this parameter indicates that user-supplied downwash matrices due to extra points are to be read from an external file via the INPUTT2 module in the rigid format. The default value is -1 when not needed.
11. P1, P2 and P3 - required when using the NODJE parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT2 module. The default values for P1, P2 and P3 are 0, 11 and XXXXXXXX, respectively.
12. PRINT - optional. The BCD value, NØ, of this parameter suppresses the automatic printing of the flutter summary for the K method. The default value is YES.
13. VREF - optional. Velocities are divided by the real value of this parameter to convert units or to compute flutter indices. The default value is 1.0.
14. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

### 4.2.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

### 4.2.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Flutter Analysis. See Section 2.3.7 for details.

### 4.2.8 Rigid Format Error Messages from Modal Flutter Analysis

The following fatal errors are detected by the DMAP statements in the Modal Flutter Analysis rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

## MODAL FLUTTER ANALYSIS

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FØRMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 2 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 3 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØOPS.

An attempt has been made to use more than 100 flutter loops. This number can be increased by ALTERing the REPT instruction following the FA2 module.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATIØN.

No real eigenvalues were found in the frequency range specified by the user.

MØDAL FLUTTER ANALYSIS ERRØR MESSAGE NØ. 5 - NØ GRID PØINT DATA IS SPECIFIED ØR NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No points have been defined with GRID or SPØINT cards or no structural elements have been defined with Connection cards.

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4.2-20 (05/30/86)

AERO RIGID FORMATS

4.3 MODAL AEROELASTIC RESPONSE

4.3.1 DMAP Sequence for Modal Aeroelastic Response

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

AERC APPROACH, RIGID FORMAT 11

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

OPTIONS IN EFFECT GO ERR=2 LIST NODECK NOREF NOOSCAR

```
-----  
1 BEGIN     AERO 11 - MODAL AEROELASTIC RESPONSE - APR. 1986 $  
2 PRECHK    ALL $  
3 FILE      AJJL=APPEND/QHHL=APPEND/QKHL=APPEND/QHJL=APPEND/SKJ=APPEND $  
4 PARAM     //*MPY*/CARDNO/O/O $  
5 GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/S,N,LUSET/  
S,N,NOGPDT/MINUSI=-1 $  
6 COND      ERROR1,NOGPDT $  
7 GP2       GEOM2,EQEXIN/ECT $  
8 PARAML    PCDB//*PRES*/V,Y,NODJE=-1//JUMPPLOT $  
9 PARAML    XYCDB//*PRES*///NOXYCDB $  
10 GP3      GEOM3,EQEXIN,GEOM2/,GPTT/NOGRAV $  
11 TA1       ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,,/  
LUSET/S,N,NOSIMP/1/S,N,NOGENL/S,N,GENEL $  
12 COND      ERROR3,NOSIMP $  
13 PARAM    //*ADD*/NOKGGX/1/O $  
14 PARAM    //*ADD*/NOMGG /1/O $  
15 EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,,/S,N,NOKGGX/  
S,N,NOMGG///C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/  
C,Y,CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/C,Y,CPTUBE/  
C,Y,CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC/  
V,Y,VOLUME/V,Y,SURFACE $  
16 PURGE    KGGX,GPST/NOKGGX $  
17 COND      JMPKGGX,NOKGGX $  
18 EMA      GPECT,KDICT,KELM/KGGX,GPST $  
19 LABEL    JMPKGGX $  
20 COND      ERROR1,NOMGG $
```

AERO RIGID FORMATS

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 11

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
21 EMA      GPECT,MDUCT,MELM/MGG,/-1/C,Y,WTMASS=1.0 $
22 COND     LGPWG,GRDPNT $
23 GPWG     BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT=-1/C,Y,WTMASS $
24 OFP      OGPWG,,,,,/S,N,CARDNO $
25 LABEL    LGPWG $
26 EQUIV   KGGX,KGG/NOGENL $
27 COND     LBL11,NOGENL $
28 SMA3    GEI,/KGGY/LUSET/NOGENL/-1 $
29 ADD     KGGX,KGGY/KGG $
30 LABEL    LBL11 $
31 GP4     CASECC,GEOM4,EQEXIN,GPDT,BGPDT,CSTM,GPST/RG,,USET,ASET/LUSET/
          S,N,MPCF1/S,N,MPCF2/S,N,SINGLE/S,N, OMIT/S,N,REACT/O/S,N,
          REPEAT/S,N,NOSET/S,N,NOL/S,N,NOA/C,Y,ASETOUT/S,Y,AUTOSPC $
32 PARAM   //EQ*/GPSPFLG/AUTOSPC/O $
33 PURGE   GM/MPCF1/DM,MR/REACT $
34 COND     LBL4,GPSPFLG $
35 GPSP    GPL,GPST,USET,SIL/OGPST/S,N,NOGPST $
36 OFP     OGPST,,,,,/S,N,CARDNO $
37 LABEL    LBL4 $
38 EQUIV   KGG,KNN/MPCF1/MGG,MNN/MPCF1 $
39 COND     LBL2,MPCF1 $
40 MCE1    USET,RG/GM $
41 MCE2    USET,GM,KGG,MGG,,/KNN,MNN,, $
42 LABEL    LBL2 $
43 EQUIV   KNN,KFF/SINGLE/MNN,MFF/SINGLE $
44 COND     LBL3,SINGLE $
45 SCE1    USET,KNN,MNN,,/KFF,KFS,,MFF,,
```

## MODAL AEROELASTIC RESPONSE

RIGID FORMAT DMAP LISTING  
APRIL 1986 RELEASE

AERO APPROACH, RIGID FORMAT 11

LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
46  LABEL    LBL3 $  
47  EQUIV    KFF,KAA/OMIT/ MFF,MAA/OMIT $  
48  PURGE    GO/OMIT $  
49  COND     LBL5, OMIT $  
50  PARAM    ///*PREC*/PREC $  
51  SMP1     USET,KFF,,,GO,KAA,KOO,LOO,,,,$  
52  SMP2     USET,GO,MFF/MAA $  
53  LABEL    LBL5 $  
54  COND     LBL6,REACT $  
55  RBMG1    USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $  
56  RBMG2    KLL/LLL/ $  
57  RBMG3    LLL,KLR,KRR/DM $  
58  RBMG4    DM,MLL,MLR,MRR/MR $  
59  LABEL    LBL6 $  
60  DPD      DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,TFPOOL,DLT,PSDL,FRL,,TRL,  
             EED,EQDYN/LUSET/S,N,LUSETD/NOTFL/NODLT/S,N,NOPSDL/  
             NOFRL/NONLFT/NOTRL/S,N,NOEED/123/S,N,NOUE $  
61  COND     ERROR2,NOEED $  
62  EQUIV    GO,GOD/NOUE/GM,GMD/NOUE $  
63  READ     KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/*MODES*/S,N,  
             NEIGV $  
64  OFP      OEIGS,,,,//S,N,CARDNO $  
65  COND     ERROR4,NEIGV $  
66  OFP      LAMA,,,,//S,N,CARDNO $  
67  MTRXIN   CASECC,MATPOOL,EQDYN.,TFPOOL/K2PP,M2PP,B2PP/LUSETD/S,N,  
             NOK2PP/S,N,NOM2PP/S,N,NOB2PP $  
68  EQUIV    M2PP,M2DD/NOA/B2PP,B2DD/NOA/K2PP,K2DD/NOA $
```

AERO RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
69 GKAD USETD,GM,GO,,,,,K2PP,M2PP,B2PP///,GMD,GOD,K2DD,M2DD,B2DD/
*CMPEV*/DISP/*MODAL*/0.0/0.0/0.0/NOK2PP/
NOM2PP/NOB2PP/MPCF1/SINGLE/OMIT/NOUE/
-1/-1/-1 $
```

```
70 GKAM USETD,PHIA,,LAMA,DIT,M2DD,B2DD,K2DD,CASECC/MHH,BHH,KHH,
PHIDH/NOUE/C,Y,LMODES=0/C,Y,LFREQ=0./C,Y,HFREQ=-1.0/
NOM2PP/NOB2PP/NOK2PP/S,N,NONCUP/S,N,FMODE/C,Y,KDAMP $
```

```
71 APD EDT,EQDYN,ECT,BGPDT,SILD,USETD,CSTM,GPLD/EQAERO,ECTA,BGPA,SILA,
USETA,SPLINE,AERO,ACPT,FLIST,CSTMA,GPLA,SILGA/S,N,NK/S,N,NJ/
S,N,LUSETA/S,N,BOV $
```

```
72 PARAM //*MPY*/PFILE/0/1 $
```

```
73 PURGE PLTSETA,PLTPARA,GPSETSA,ELSETSA/JUMPPLOT $
```

```
74 COND SKPPLT,JUMPPLOT $
```

```
75 PARAM //*MPY*/PLTFLG/0/1 $
```

```
76 PLTSET PCDB,EQAERO,ECTA/PLTSETA,PLTPARA,GPSETSA,ELSETSA/S,N,NSIL1/S,N,
JUMPPLOT $
```

```
77 PRTMSG PLTSETA // $
```

```
78 COND SKPPLT,JUMPPLOT $
```

```
79 PLOT PLTPARA,GPSETSA,ELSETSA,CASECC,BGPA,EQAERO, ,,/PLOTX2/
NSIL1/LUSETA/S,N,JUMPPLOT/S,N,PLTFLG/S,N,PFILE $
```

```
80 PRTMSG PLOTX2 // $
```

```
81 LABEL SKPPLT $
```

```
82 GI SPLINE,USET ,CSTMA,BGPA,SIL , ,GM,GO/GTKA/NK/
LUSET $
```

```
83 PARAM //*ADD*/DESTRY/0/1/ $
```

```
84 AMG AERO,ACPT/AJJL,SKJ,D1JK,D2JK/NK/NJ/S,N,DESTRY $
```

```
85 COND NODJE,NODJE $
```

```
86 INPUTT2 /D1JE,D2JE,,,/C,Y,P1=0/C,Y,P2=11/C,Y,P3=XXXXXXXX $
```

```
87 LABEL NODJE $
```

```
88 PARAM //*ADD*/XQHHL/1/0 $
```

```
89 AMP AJJL,SKJ,D1JK,D2JK,GTKA,PHIDH,D1JE,D2JE,USETD,AERO/QHHL,QKHL,
QHJL/NOUE/S,N,XQHHL/V,Y,GUSTAERO=-1 $
```

## MODAL AEROELASTIC RESPONSE

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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
90 FRLG      CASECC,USETD,DLT,FRL,GMD,GOD,DIT,PHIDH/PPF,PSF,PDF,FOL,PHF1/  
*MODAL*/S,N,FREQY/S,N,APP $  
  
91 PARAM     ///*NOT*/NOFRY/FREQY $  
  
92 PURGE    PPF/NOFRY $  
  
93 GUST      CASECC,DLT,FRL,DIT,QHJL,,,ACPT,CSTMA,PHF1/PHF/  
S,N,NOGUST/BOV/C,Y,MACH/C,Y,Q $  
  
94 EQUIV    PHF1,PHF/NOGUST $  
  
95 FRRD2    KHH,BHH,MHH,QHHL,PHF,FOL/UHVF/BOV/C,Y,Q/C,Y,MACH $  
  
96 EQUIV    UHVF,UHVT/FREQY/FOL,TOL/FREQY $  
  
97 COND      IFTSKP,FREQY $  
  
98 IFT       UHVF,CASECC,TRL,FOL/UHVT,TOL/C,Y,IFTM=0 $  
  
99 LABEL    IFTSKP $  
  
100 MODACC   CASECC,TOL,UHVT,,,/TOL1,UHVT1,,,/APP $  
  
101 ADR      UHVT1,CASECC,QKHL,TOL1,SPLINE,SILA,USETA/PKF/BOV/  
C,Y,MACH/APP $  
  
102 VDR      CASECC,EQDYN,USETD,UHVT1,TOL1,XYCDB,/OUHV1,/APP/*MODAL*/  
O/S,N,NOH/S,N,NOP/FMODE $  
  
103 COND      NOH, NOH $  
  
104 SDR3     OUHV1,,,,,/OUHV2,,,,, $  
  
105 OFP      OUHV2,,,,,/S,N,CARDNO $  
  
106 COND      NOH,NOXYCDB $  
  
107 XYTRAN   XYCDB,OUHV2,,,./XYPTTA/APP/*HSET*/S,N,PFILE/S,N,CARDNO/  
S,N,NOXYPL $  
  
108 COND      NOH,NOXYPL $  
  
109 XYPLOT   XYPTTA $  
  
110 LABEL    NOH $  
  
111 PARAM     ///*AND*/PJUMP/NOP/JUMPPLOT $  
  
112 COND      FINIS,PJUMP $  
  
113 SDR1     USETD,,PHIDH,,,GOD,GMD,,KFS,,/PHIP,,QP/1/*DYNAMICS* $
```

AERO RIGID FORMATS

RIGID FORMAT DMAP LISTING  
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LEVEL 2.0 NASTRAN DMAP COMPILER - SOURCE LISTING

```
114 EQUIV PHIDH,PHIAH/NOUE $  
115 COND NOUE1,NOUE $  
116 VEC USETD/EVEC/*D*/*A*/*E* $  
117 PARTN PHIDH,,EVEC/PHIAH,,,/1 $  
118 LABEL NOUE1 $  
119 MPYAD GTKA,PHIAH,/PHIK/1/1/0/PREC $  
120 UMERGE USETA,PHIP,,/PHIPS/*PS*/*P*/*SA* $  
121 UMERGE USETA,PHIPS,PHIK/PHIPA/*PA*/*PS*/*K* $  
122 UMERGE USETA,QP,/QPA/*PA*/*P*/*PS* $  
123 SDR2 CASECC,CSTMA,MPT,DIT,EQAERO,SILA,,,BGPA,LAMA,QPA,PHIPA,  
EST,XYCDB,/,MQP1,MPHIPA1,MES1,MEF1,/*MMREIG* $  
124 COND NOPF,NOFRY $  
125 SDR2 CASECC,,,EQDYN,,,,PPF,,,XYCDB,/OPP1,,,,/*FREQ* $  
126 SDR3 OPP1,,,/QPP2,,,/$  
127 LABEL NOPF $  
128 SDR3 MPHIPA1,MES1,MEF1,MQP1,,/MPHIPA2,MES2,MEF2,MQP2,, $  
129 DDRMM CASECC,UHVT1,TOL1,MPHIPA2,MQP2,MES2,MEF2,XYCDB,EST,MPT,DIT/  
OUPV2,OQP2,OES2,OEF2, $  
130 OFP OUPV2,,OES2,OEF2,OQP2,./S,N,CARDNO $  
131 SCAN CASECC,OES2,OEF2/OESF2/C,N,*RF* $  
132 OFP OESF2,,,./S,N,CARDNO $  
133 COND P2,JUMPPLOT $  
134 MPYAD PHIPA,UHVT1,/UVT1/0 $  
135 SDR2 CASECC,CSTMA,,,EQAERO,,,BGPA,TOL,,UVT1,,,/,PUVPAT/APP $  
136 PLOT PLTPARA,GPSETSA,ELSETSA,CASECC,BGPA,EQAERO,SILGA,,PUVPAT,,/  
PLOTX3/NSIL1/LUSETA/JUMPPLOT/PLTFLG/PFILE $  
137 PRTMSG PLOTX3// $
```

MODAL AEROELASTIC RESPONSE

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```
138 LABEL    P2 $  
139 COND     FINIS,NOXYCDB $  
140 XYTRAN   XYCDB,,OQP2,OUPV2,OES2,OEF2/XYPLTT/APP/*PSET*/  
              S,N,PFILE/S,N,CARDNO/S,N,NOXYPL $  
141 COND     NOXYPLTT,NOXYPL $  
142 XYPLOT   XYPLTT $  
143 LABEL    NOXYPLTT $  
144 COND     FINIS,NOFRY $  
145 COND     FINIS,NOPSDL $  
146 RANDOM   XYCDB,DIT,PSDL,OUPV2,,OQP2,OES2,OEF2,CASECC/PSDF,AUTO/  
              S,N,NORN $  
147 COND     FINIS,NORN $  
148 XYTRAN   XYCDB,PSDF,AUTO,,,/XYPLTR/*RAND/*PSET*/S,N,PFILE/  
              S,N,CARDNO/S,N,NOXYPL $  
149 COND     FINIS,NOXYPL $  
150 XYPLOT   XYPLTR $  
151 JUMP     FINIS $  
152 LABEL    ERROR2 $  
153 PRTPARM  // -2/*AERORESP* $  
154 LABEL    ERROR1 $  
155 PRTPARM  // -1/*AERORESP* $  
156 LABEL    ERROR4 $  
157 PRTPARM  // -4/*AERORESP* $  
158 LABEL    ERROR3 $  
159 PRTPARM  // -3/*AERORESP* $  
160 LABEL    FINIS $  
161 PURGE    DUMMY/MINUS1 $  
162 END      $
```

4.3.2 Description of Important DMAP Operations for Modal Aeroelastic Response

5. GP1 generates coordinate system transformation matrices, tables of grid point locations, and tables relating the internal and external grid point numbers.
6. Go to DMAP No. 158 and print Error Message No. 3 if no grid points are defined.
7. GP2 generates Element Connection Table with internal indices.
10. GP3 generates Grid Point Temperature Table (element temperature).
11. TA1 generates element tables for use in matrix assembly and stress recovery.
12. Go to DMAP No. 158 and print Error Message No. 3 if no structural elements have been defined.
15. EMG generates structural element stiffness and mass matrix tables and dictionaries for later assembly by the EMA module.
17. Go to DMAP No. 19 if no stiffness matrix is to be assembled.
18. EMA assembles stiffness matrix  $[K_{gg}^X]$  and Grid Point Singularity Table.
20. Go to DMAP No. 154 and print Error Message No. 1 if no mass matrix is to be assembled.
21. EMA assembles mass matrix  $[M_{gg}]$ .
22. Go to DMAP No. 25 if no weight and balance information is requested.
23. GPWG generates weight and balance information.
24. ØFP formats the weight and balance information prepared by GPWG and places it on the system output file for printing.
26. Equivalence  $[K_{gg}^X]$  to  $[K_{gg}]$  if there are no general elements.
27. Go to DMAP No. 30 if there are no general elements.
28. SMA3 forms the general element stiffness matrix  $[K_{gg}^Y]$ .
29. ADD combines the structural stiffness matrix  $[K_{gg}^X]$  with the general element stiffness matrix  $[K_{gg}^Y]$  to obtain the stiffness matrix  $[K_{gg}]$ .
31. GP4 generates flags defining members of various displacement sets (USET) and forms multipoint constraint equations  $[R_g] \{u_g\} = 0$ .
34. Go to DMAP No. 37 if no potential grid point singularities exist.
35. GPSP generates a table of potential grid point singularities.
36. ØFP formats the table of potential grid point singularities prepared by GPSP and places it on the system output file for printing.
38. Equivalence  $[K_{gg}]$  to  $[K_{nn}]$  and  $[M_{gg}]$  to  $[M_{nn}]$  if no multipoint constraints exist.
39. Go to DMAP No. 42 if no multipoint constraints exist.
40. MCE1 partitions multipoint constraint equations  $[R_g] = [R_m | R_n]$  and solves for multipoint constraint transformation matrix  $[G_m] = -[R_m]^{-1}[R_n]$ .

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41. MCE2 partitions stiffness and mass matrices

$$[K_{gg}] = \begin{bmatrix} - & K_{nn} & K_{nm} \\ K_{mn} & - & K_{mm} \end{bmatrix} \quad \text{and} \quad [M_{gg}] = \begin{bmatrix} - & M_{nn} & M_{nm} \\ M_{mn} & - & M_{mm} \end{bmatrix}$$

and performs matrix reductions

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] \quad \text{and}$$

$$[M_{nn}] = [\bar{M}_{nn}] + [G_m^T][M_{mn}] + [M_{mn}^T][G_m] + [G_m^T][M_{mm}][G_m] .$$

43. Equivalence  $[K_{nn}]$  to  $[K_{ff}]$  and  $[M_{nn}]$  to  $[M_{ff}]$  if no single-point constraints exist.

44. Go to DMAP No. 46 if no single-point constraints exist.

45. SCE1 partitions out single-point constraints

$$[K_{nn}] = \begin{bmatrix} K_{ff} & K_{fs} \\ K_{sf} & K_{ss} \end{bmatrix} \quad \text{and} \quad [M_{nn}] = \begin{bmatrix} M_{ff} & M_{fs} \\ M_{sf} & M_{ss} \end{bmatrix} .$$

47. Equivalence  $[K_{ff}]$  to  $[K_{aa}]$  and  $[M_{ff}]$  to  $[M_{aa}]$  if no omitted coordinates exist.

49. Go to DMAP No. 53 if no omitted coordinates exist.

51. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} - & K_{aa} & K_{ao} \\ K_{aa} & - & K_{oo} \\ K_{oa} & K_{oo} & - \end{bmatrix},$$

solves for transformation matrix  $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction  $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$  .

52. SMP2 partitions constrained mass matrix

$$[M_{ff}] = \begin{bmatrix} - & M_{aa} & M_{ao} \\ M_{aa} & - & M_{oo} \\ M_{oa} & M_{oo} & - \end{bmatrix}$$

and performs matrix reduction

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}^T][G_o] + [G_o^T][M_{oo}][G_o] + [G_o^T][M_{oa}] .$$

54. Go to DMAP No. 59 if no free-body supports exist.

55. RBMG1 partitions out free-body supports

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix} \quad \text{and} \quad [M_{aa}] = \begin{bmatrix} M_{\ell\ell} & M_{\ell r} \\ M_{r\ell} & M_{rr} \end{bmatrix} .$$

56. RBMG2 decomposes constrained stiffness matrix  $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$ .

57. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}],$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D]$$

and calculates rigid body error ratio

$$\varepsilon = \frac{\|X\|}{\|K_{rr}\|} .$$

58. RBMG4 forms rigid body mass matrix

$$[m_r] = [M_{rr}] + [M_{\ell r}^T][D] + [D^T][M_{\ell r}] + [D^T][M_{\ell\ell}][D].$$

- 60. DPD generates flags defining members of various displacement sets used in dynamic analysis (USETD), tables relating the internal and external grid point numbers (GPLD), including extra points introduced for dynamic analysis (SILD), and prepares Transfer Function Pool (TFP00L), and Eigenvalue Extraction Data (EED).
- 61. Go to DMAP No. 152 and print Error Message No. 2 if there is no Eigenvalue Extraction Data.
- 62. Equivalence  $[G_o]$  to  $[G_o^d]$  and  $[G_m]$  to  $[G_m^d]$  if there are no extra points introduced for dynamic analysis.
- 63. READ extracts real eigenvalues and eigenvectors from the equation

$$[K_{aa} - \lambda M_{aa}]\{\phi_a\} = 0 ,$$

calculates rigid body modes by finding a matrix  $[\phi_{ro}]$  such that

$$[m_o] = [\phi_{ro}^T][m_r][\phi_{ro}]$$

is diagonal and normalized, computes rigid body eigenvectors

$$[\phi_{ao}] = \begin{bmatrix} D \\ \phi_{ro} \end{bmatrix} ,$$

calculates modal mass matrix

$$[m] = [\phi_a^T][M_{aa}][\phi_a]$$

and normalizes eigenvectors according to one of the following user requests:

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- 1) Unit value of a selected component
  - 2) Unit value of the largest component
  - 3) Unit value of the generalized mass.
64. ØFP formats the summary of eigenvalue extraction information (ØEIGS) prepared by READ and places it on the system output file for printing.
65. Go to DMAP No. 156 and print Error Message No. 4 if no eigenvalues were found.
66. ØFP formats the eigenvalues (LAMA) prepared by READ and places them on the system output file for printing.
67. MXTRIN selects the direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ .
68. Equivalence  $[M_{pp}^2]$  to  $[M_{dd}^2]$ ,  $[B_{pp}^2]$  to  $[B_{dd}^2]$  and  $[K_{pp}^2]$  to  $[K_{dd}^{2d}]$  if no constraints are applied.
69. GKAD applies constraints to direct input matrices  $[K_{pp}^2]$ ,  $[M_{pp}^2]$  and  $[B_{pp}^2]$ , forming  $[K_{dd}^2]$ ,  $[M_{dd}^2]$  and  $[B_{dd}^2]$  and forms  $[G_{md}]$  and  $[G_{od}]$ .
70. GKAM selects eigenvectors to form  $[\phi_{dh}]$  and assembles stiffness, mass and damping matrices in modal coordinates:

$$[K_{hh}] = \begin{bmatrix} k_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][K_{dd}^2][\phi_{dh}] ,$$

$$[M_{hh}] = \begin{bmatrix} m_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][M_{dd}^2][\phi_{dh}] ,$$

$$[B_{hh}] = \begin{bmatrix} b_i & 0 \\ 0 & 0 \end{bmatrix} + [\phi_{dh}^T][B_{dd}^2][\phi_{dh}] ,$$

where

KDAMP = -1 (default)

$m_i$  = modal masses

$b_i = m_i 2\pi f_i g(f_i)$

$k_i = m_i 4\pi^2 f_i^2$

KDAMP = 1

$m_i$  = modal masses

$b_i = 0$

$k_i = (1+ig(f_i)) 4\pi^2 f_i^2 m_i$

71. APD processes the aerodynamic data cards from EDT. It adds the k points and the SA points to USETD making USETA. EQAERØ, ECTA, BGPA, CSTMA, GPLA and SILA are updated to reflect the new elements. AERØ and ACPT reflect the aerodynamic parameters. SILGA is a special SIL for plotting.
74. Go to DMAP No. 81 if no plot output is requested.
76. PLTSET transforms user input into a form used to drive the structure plotter.
77. PRTMSG prints error messages associated with the structure plotter.

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78. Go to DMAP No. 81 if no undeformed aerodynamic or structural element plots are requested.
79. PL0T generates all requested undeformed aerodynamic and structural element plots.
80. PRTMSG prints plotter data and engineering data for each undeformed aerodynamic and structural element plot generated.
82. GI forms a transformation matrix  $[G_{ka}^T]$  which interpolates between aerodynamic (k) and structural (a) degrees of freedom.
84. AMG forms the aerodynamic matrix list  $[A_{jj}]$ , the area matrix  $[S_{kj}]$ , and the downwash coefficients  $[D_{jk}^1]$  and  $[D_{jk}^2]$ .
85. Go to DMAP No. 87 if there are no user-supplied downwash coefficients.
86. INPUTT2 provides the user-supplied downwash factors due to extra points ( $[D_{je}^1]$ ,  $[D_{je}^2]$ ). PARAM N0DJE must be set to enter these matrices. The downwash  $w_j$  on box j due to the motion of an extra point,  $u_e$ , is given by

$$\{w_j\} = [D_{je}^1 + ikD_{je}^2]\{u_e\} .$$

89. AMP computes the aerodynamic matrix list related to the modal coordinates as follows:

$$[\phi_{dh}] = \begin{bmatrix} \phi_{ai} & \phi_{ae} \\ \phi_{ei} & \phi_{ee} \end{bmatrix} , \quad [G_{ki}] = [G_{ka}^T]^T [\phi_{ai}] ,$$

$$[D_{jh}^1] \Leftarrow [D_{ji}^1 | D_{je}^1] ,$$

$$[D_{ji}^1] = [D_{jk}^1]^T [G_{ki}] ,$$

$$[D_{jh}^2] \Leftarrow [D_{ji}^2 | D_{je}^2] \text{ and}$$

$$[D_{ji}^2] = [D_{jk}^2]^T [G_{ki}] .$$

For each (m,k) pair:

$$[D_{jh}] = [D_{jh}^1] + ik[D_{jh}^2] .$$

For each group:

$$[Q_{jh}] = [A_{jj}^T]^{-1} [D_{jh}]_{group} ,$$

$$[Q_{kh}] = [S_{kj}] [Q_{jh}] ,$$

$$[Q_{ih}] = [G_{ki}]^T [Q_{kh}]$$

and  $[Q_{hh}] \Leftarrow \begin{bmatrix} Q_{ih} \\ Q_{eh} \end{bmatrix} .$

90. FRLG forms the dynamic load vector  $\{P_h\}$  from the frequency response data or transient data using a Fourier Transform.
93. GUST forms the loading due to gusts and adds to the direct loads.
94. Equivalence {PHF1} to {PHF} if there are no gust loads.

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95. FRRD2 solves for the modal displacements using

$$[-M_{hh}\omega^2 + iB_{hh}\omega + K + qQ_{hh}(k)]U_h = P_h(\omega) .$$

96. Equivalence  $\{\text{UHVF}\}$  to  $\{\text{UHVT}\}$  and  $\text{FOL}$  to  $\text{TOL}$  if it is a frequency response formulation.
97. Go to DMAP No. 99 if it is a frequency response formulation.
98. IFT performs Inverse Fourier Transform of the displacements for transient formulation.
100. MODACC uses data from  $\text{DFREQ}$  or  $\text{DTIME}$  data cards to select solutions for data recovery.
101. ADR produces aerodynamic load output (PKF) for selected points in frequency response only.
102. VDR prepares solution set displacements ( $\{\text{UHVI}\}$ ), sorted by frequency or time, for output. The solution set includes mode amplitudes and extra points.
103. Go to DMAP No. 110 if the request is for output sorted by frequency or time step.
104. SDR3 prepares requested output sorted by solution set points.
105. DFP formats the table prepared by SDR3 for output sorted by solution set point and places it on the system output file for printing.
106. Go to DMAP No. 110 if no X-Y plots are requested.
107. XYTRAN prepares the input for X-Y plotting of solution set points versus time or frequency.
108. Go to DMAP No. 110 if no plots are possible as requested.
109. XYPLDT prepares the requested X-Y plots of solution set points versus time or frequency.
112. Go to DMAP No. 160 if no output for physical points is requested.
113. SDR1 recovers physical displacements (PHIP) and forces of constraint (QP) for the real eigenvectors associated with the modes.
114. Equivalence  $\{\phi_{dh}\}$  to  $\{\phi_{ah}\}$  if there are no extra points introduced for dynamic analysis.
115. Go to DMAP No. 118 if no extra points are present.
116. VEC generates a d-size partitioning vector (EVEC) for the a- and e-sets

$$\{u_d\} + \{u_a\} + \{u_e\} .$$

117. PARTN performs partition of  $\{\phi_{dh}\}$  using EVEC

$$\{\phi_{dh}\} \Rightarrow \left\{ \begin{array}{c} \phi_{ah} \\ 0 \end{array} \right\} .$$

119. MPYAD recovers the displacements at the aerodynamic points (k)

$$\{\phi_k\} = [G_{ka}^T]^T \{\phi_{ah}\} .$$

120. UMERGE is used to expand  $\{Q_p\}$  to the ps-set.

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121. UMERGE places  $\{\phi_k\}$  in its proper place in the displacement vector

$$\{\phi_{pa}\} \Leftarrow \left\{ \frac{\phi_{ps}}{\phi_k} \right\} .$$

122. UMERGE is used to expand  $\{Q_p\}$  to the pa-set.

123. SDR2 calculates element forces (MEF1) and stresses (MES1) and prepares eigenvectors (MPHIPA1) and single-point forces of constraint (MQP1) for output sorted by frequency or time.

124. Go to DMAP No. 127 if it is not a frequency response formulation.

125. SDR2 prepares load vectors for output ( $\emptyset_{PP1}$ ) sorted by frequency.

126. SDR3 prepares requested load output sorted by point number.

128. SDR3 prepares requested modal quantities output sorted by point number.

129. DDRMM prepares a subset of the element forces ( $\emptyset_{EF2}$ ) and stresses ( $\emptyset_{ES2}$ ), displacement vectors ( $\emptyset_{UPV2}$ ), and single-point forces of constraint ( $\emptyset_{QP2}$ ) for output sorted by point number or element number.

130.  $\emptyset_{FP}$  formats the requested physical output prepared by DDRMM and places it on the system output file for printing.

131. SCAN examines the element stresses and forces calculated by DDRMM and generates scanned output that meets the specifications set by the user.

132.  $\emptyset_{FP}$  formats the scanned output table prepared by SCAN and places it on the system output file for printing.

133. Go to DMAP No. 138 if no deformed aerodynamic or structural element plots are requested.

134. MPYAD generates vectors for use by the SDR2 module.

135. SDR2 prepares vectors for deformed plotting.

136. PL $\emptyset$ T prepares all requested deformed aerodynamic and structural element plots.

137. PRTMSG prints plotter data and engineering data for each deformed plot generated.

139. Go to DMAP No. 160 and make normal exit if no X-Y plots are requested.

140. XYTRAN prepares the input for physical point X-Y plots.

141. Go to DMAP No. 143 if no plots are possible as requested.

142. XYPL $\emptyset$ T prepares the requested X-Y plots of displacements, forces, stresses, loads and single-point forces of the constraint versus frequency or time.

144. Go to DMAP No. 160 and make normal exit if it is a transient response formulation.

145. Go to DMAP No. 160 and make normal exit if no power spectral density functions or autocorrelation functions are requested.

146. RAND $\emptyset$ M calculates power spectral density functions (PSDF) and autocorrelation functions (AUT $\emptyset$ ) using the previously calculated frequency response.

147. Go to DMAP No. 160 and make normal exit if no X-Y plots of RAND $\emptyset$ M calculations are requested.

148. XYTRAN prepares the input for requested X-Y plots of the RAND $\emptyset$ M output.

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149. Go to DMAP No. 160 and make normal exit if no plots are possible as requested.
150. XYPL0T prepares the requested X-Y plots of autocorrelation functions and power spectral density functions.
151. Go to DMAP No. 160 and make normal exit.
153. Print Error Message No. 2 and terminate execution.
155. Print Error Message No. 1 and terminate execution.
157. Print Error Message No. 4 and terminate execution.
159. Print Error Message No. 3 and terminate execution.

#### 4.3.3 Output for Modal Aeroelastic Response

The real Eigenvalue Summary Table and real Eigenvalue Analysis Summary, as described under Normal Modes Analysis (see Section 2.3.3), are automatically printed.

The following printed output, sorted by point number or element number (SORT2), is available, either as real and imaginary parts or as magnitude and phase angle ( $0^\circ$  -  $360^\circ$  lead), for the list of frequencies or times specified by ØFREQUENCY or ØTIME (in transient formulations, these are real):

1. Displacements, velocities and accelerations for a list of PHYSICAL points (grid points and extra scalar points introduced for dynamic analysis) or SOLUTION points (points used in the formulation of the dynamic equation). Velocities and accelerations are not available for transient analysis.
2. Nonzero components of the applied load vector and single-point forces of constraint for a list of PHYSICAL points. Aerodynamic forces on selected aerodynamic elements.
3. Stresses and forces in selected elements (ALL available only for SORT1).

The following printed output is available for Random Response calculations:

1. Power spectral density function and mean deviation for the response of selected components for points or elements. The expected frequency of zero crossings.
2. Autocorrelation function for the response of selected components for points or elements.

The following plotter output is available:

1. Undeformed plot of the structural model.
2. Deformed shapes of the aerodynamic and structural model for selected intervals.
3. X-Y plot of any component of displacement, velocity or acceleration of a PHYSICAL point or a SOLUTION point.
4. X-Y plot of any component of the applied load vector or single-point force of constraint.
5. X-Y plot of any stress or force component for an element.

The following plotter output is available for Random Response calculations:

1. X-Y plot of the power spectral density versus frequency for the response of selected components for points or elements.
2. X-Y plot of the autocorrelation versus time lag for the response of selected components for points or elements.

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The data used for preparing the X-Y plots may be punched or printed in tabular form (see Volume I, Section 4.3). Also, a printed summary is prepared for each X-Y plot which includes the maximum and minimum values of the plotted function.

### 4.3.4 Case Control Deck for Modal Aeroelastic Response

The following items relate to subcase definition and data selection for Modal Aeroelastic Response:

1. METHOD must appear above the subcase level to select an eigenvalue extraction method.
2. At least one subcase must be defined for each unique set of direct input matrices (K2PP, M2PP, B2PP) or frequencies.
3. Consecutive subcases for each set of direct input matrices or frequencies are used to define the loading condition - one subcase for each dynamic loading condition.
4. Constraints must be defined above the subcase level.
5. DLLOAD must be used to define a frequency-dependent loading condition for each subcase. If transient loads are selected, a Fourier Transform is used to compute frequency-dependent loads. All loads in one run must be of the same type.
6. FREQUENCY must be used to select one, and only one, FREQ, FREQ1, or FREQ2 card from the Bulk Data Deck. If TLLOADs are selected, a TSTEP must be selected.
7. ØFREQUENCY (ØTIME) may be used above the subcase level or within each subcase to select a subset of the solution frequencies (times) for output requests. The default is to use all solution frequencies (times).
8. If Random Response calculations are desired, RANDOM must be used to select RANDPS and RANDTi cards from the Bulk Data Deck. Only one ØFREQUENCY and FREQUENCY card can be used for each set of direct input matrices.

### 4.3.5 Parameters for Modal Aeroelastic Response

The following parameters are used in Modal Aeroelastic Response:

1. ASETØUT - optional. A positive integer value of this parameter causes the ASET output data block to be generated by the GP4 module. A negative integer value or 0 suppresses the generation of this output data block. The default value is 0.
2. AUTØSPC - reserved for future optional use. The default value is -1.

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3. C0UPMASS - CPBAR, CPRØD, CQUAD1, CQUAD2, CPTRIA1, CPTRIA2, CPTUBE, CPQDPLT, CPTRPLT, CPTRBSC - optional. These parameters cause the generation of coupled mass matrices rather than lumped mass matrices for all bar elements, rod elements, and plate elements that include bending stiffness.
4. GRDPNT - optional. A positive integer value of this parameter causes the Grid Point Weight Generator to be executed and the resulting weight and balance information to be printed. All fluid related masses are ignored.
5. GUSTAERØ - optional. An integer value of +1 causes gust loads to be computed. The default value is -1 for no gust loads.
6. IFTM - optional. The integer value of this parameter selects the method for the integration of the Inverse Fourier Transform. An integer value of 0 specifies a rectangular fit; 1 specifies a trapezoidal fit; and 2 specifies a cubic spline fit to obtain solutions versus time for which aerodynamic forces are functions of frequency. The default value is 0.
7. KDAMP - optional. An integer value of +1 causes modal damping terms to be put into the complex stiffness matrix for structural damping (+1 recommended for K and KE methods). The default value is -1.
8. LFREQ and HFREQ - required, unless parameter LMØDES is used. The real values of these parameters give the cyclic frequency range (LFREQ is the lower limit and HFREQ is the upper limit) of the modes to be used in the modal formulation. To use this option, parameter LMØDES must be set to 0.
9. LMØDES - required, unless parameters LFREQ and HFREQ are used. The integer value of this parameter is the number of lowest modes to be used in the modal formulation.
10. MACH - optional. The real value of this parameter selects the closest Mach numbers to be used to compute aerodynamic matrices. The default value is 0.0.
11. NØDJE - optional. A positive integer for this parameter indicates that user-supplied downwash matrices due to extra points are to be read from an external file via the INPUTT2 module in the rigid format. The default value is -1 when not needed.
12. P1, P2, and P3 - required when using the NØDJE parameter. See Section 5.5 for a description of these parameters which are required by the INPUTT2 module. The default values for P1, P2 and P3 are 0, 11 and XXXXXXXX, respectively.
13. Q - required. The real value of this parameter defines the dynamic pressure.

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14. SURFACE - optional. The computations of the external surface areas for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
15. VOLUME - optional. The volume computations for the two-dimensional and three-dimensional elements are activated by this parameter when they are generated in the EMG module. The results are multiplied by the real value of this parameter. See the description under the PARAM bulk data card for details.
16. WTMASS - optional. The terms of the structural mass matrix are multiplied by the real value of this parameter when they are generated in the EMA module. Not recommended for use in hydroelastic problems.

### 4.3.6 Optional Diagnostic Output for FEER

Special detailed information obtained by requesting DIAG 16 in the Executive Control Deck is the same as that described under Normal Modes Analysis (see Section 2.3.6).

### 4.3.7 The APPEND Feature

The APPEND feature can be used for real eigenvalue extraction in Modal Aeroelastic Response. See Section 2.3.7 for details.

### 4.3.8 Rigid Format Error Messages from Modal Aeroelastic Response

The following fatal errors are detected by the DMAP statements in the Modal Aeroelastic Response rigid format. The text for each error message is given below in capital letters and is followed by additional explanatory material, including suggestions for remedial action.

#### MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 1 - MASS MATRIX REQUIRED FØR MØDAL FORMULATION.

The mass matrix is null because either no structural elements were defined with Connection cards, nonstructural mass was not defined on a Property card or the density was not defined on a Material card.

#### MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 2 - EIGENVALUE EXTRACTION DATA REQUIRED FØR REAL EIGENVALUE ANALYSIS.

Eigenvalue extraction data must be supplied on an EIGR card in the Bulk Data Deck and METHØD in the Case Control Deck must select an EIGR set.

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MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 3 - NØ GRID PØINT DATA IS SPECIFIED ØR NØ STRUCTURAL ELEMENTS HAVE BEEN DEFINED.

No points have been defined with GRID or SPØINT cards or no structural elements have been defined with Connection cards.

MØDAL AERØELASTIC RESPØNSE ERRØR NØ. 4 - REAL EIGENVALUES REQUIRED FØR MØDAL FØRMULATØRN.

No real eigenvalues were found in the frequency range specified by the user.