# OPTIMIZATION AND ANALYSIS OF UNSTIFFENED AND STIFFENED ALUMINUM PLATE AND A CURVED STIFFENED ALUMINUM PANEL WITH PANDA2, BIGBOSOR4, AND STAGS

by

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flat.abstract

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ABSTRACT

The main purpose of this report is to provide new PANDA2 users with a guide-by-example on the details of using PANDA2.

Unstiffened and axially stiffened flat aluminum plates and a curved stiffened aluminum panel are optimized and analyzed with PANDA2. Comparisons between PANDA2, BIGBOSOR4, and STAGS predictions are given for the optimum designs obtained by PANDA2. (BIGBOSOR4 is used only for the analysis of the optimized STIFFENED panels) The plates and curved panel are designed to carry loads well above those corresponding to local buckling of the skin. Two loadings are considered:

SECTION 1: Load Case 1. pure axial compression Nx and

SECTION 2: Load Case 2. combined axial compression Nx and in-plane shear Nxy in which the in-plane shear Nxy is the dominant loading component: Nxy = 10Nx.

For the case with pure axial compression (SECTION 1) four examples are considered:

Sub-section 1.1: Example 1. an unstiffened aluminum plate 10 inches wide and 50 inches long,

Sub-section 1.2: Example 2. an unstiffened aluminum plate 50 inches wide and 50 inches long with "fake" axial stiffeners spaced 10 inches apart,

Sub-section 1.3: Example 3. a 50 x 50 inch blade-stiffened aluminum plate with real axial stiffeners spaced at 10-inch intervals. Two sub-cases are processed, the first in which the local buckling load cannot be less than 0.2 times the design load and the second in which the local buckling load cannot be less than 0.5 times the design load.

Sub-section 1.4: Example 4. a 50 x 50 inch blade-stiffened aluminum CYLINDRICAL panel with real axial stiffeners the spacing of which is one of the decision variables in the optimization.

SECTION 2: For the case with combined axial compression and in-plane shear loading only Example 1 is considered.

PANDA2 is used to find optimum designs of Examples 1, 3, and 4. In Example 2 the same plate thickness is used as that found by optimization for Example 1. The "fake" stiffeners are introduced into the STAGS model. The "fake" stiffeners are represented in the STAGS model by constraint conditions that force the normal deflection of the plate to be zero over the entire length of the panel at a width-wise spacing of 10 inches.

SECTION 1:
Tables 1.1 - 1.80 and Figures 1.1 - 1.96 pertain to Load Case 1, pure axial compression, Nx = -1000 lb/in applied in Examples 1 - 4.

Sub-section 1.1:
Tables 1.1 - 1.21 and Figures 1.1 - 1.29 pertain to pure axial compression, Nx = -1000 lb/in applied to Example 1.

Sub-section 1.2:
Tables 1.22 - 1.26 and Figures 1.30 - 1.40 pertain to pure axial compression, Nx = -1000 lb/in applied to Example 2.

Sub-section 1.3:
Tables 1.27 - 1.63 and Figures 1.41 - 1.71 pertain to pure axial compression, Nx = -1000 lb/in applied to Example 3.

Sub-section 1.4:
Tables 1.64 - 1.80 and Figures 1.72 - 1.96 pertain to pure axial compression, Nx = -1000 lb/in applied to Example 4.

SECTION 2:
Tables 2.1 - 2.13 and Figures 2.1 - 2.27 pertain to Load Case 2, combined axial compression, Nx = -30 lb/in and in-plane shear, Nxy = +300 lb/in applied to Example 1 only.

During optimizations of the unstiffened plate the only decision variable is the thickness of the plate. Figure 0.1 shows the geometry of Example 1. During optimization of the stiffened plate (Example 3) the decision variables are: 1. the thickness of the panel skin, 2. the thickness of the blade stiffeners, and 3. the height of the blade stiffeners. During optimization of the stiffened cylindrical panel (Example 4) the decision variables are the same as those in Example 3 plus the spacing of the axial stiffeners.

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panda2.news.item753

ITEM 753 added to the file, ...panda2/doc/panda2.news

753 June, 2008
I may have written this before and forgotten. Since it is an important point I repeat it here. PLEASE DON'T TRY TO EVALUATE PANDA2 BY RUNNING WHAT I CALL "ACADEMIC" PROBLEMS, SUCH AS THE POSTBUCKLING BEHAVIOR OF AN UNSTIFFENED SQUARE FLAT PLATE. PANDA2 was created for designing STIFFENED panels and shells. Usually the optimum design of a stiffened panel has a spacing between the stiffeners that is small compared to the overall length of the panel, or, if there exist "rings" (transverse stiffeners) the stiffener spacing is small compared to the length of the panel between adjacent rings.

The post-local-buckling theory used in PANDA2 is based on the assumption that the portion of the panel that buckles locally, that is, the skin between adjacent stringers and rings, is much longer in the axial direction than it is in the "hoop" (transverse or "y") direction. You can run a PANDA2 case involving a square unstiffened plate loaded into the postbuckling regime, but the results may not agree very well with those obtained from a general-purpose nonlinear finite element analysis of the same plate. This does not mean that since PANDA2 may not predict very well details of the behavior of a postbuckled square plate that it is no good for optimizing stiffened panels or shells.

The way to evaluate PANDA2 is first to optimize a practical stiffened panel with it, then evaluate PANDA2's prediction for the optimized design by application of a general-purpose computer program (such as STAGS) to that optimum design. Stay away from the "academic" problems because they may well fall outside of the area for which PANDA2 was intended and therefore mislead you in your decision whether or not to use PANDA2 to design practical stiffened shell and plate structures.

[redacted] REFERENCES

PANDA2, BOSOR4, BIGBOSOR4, STAGS REFERENCES

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ABOUT PANDA2:


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"PANDA2 - Program for minimum weight design of stiffened, composite, locally buckled panels", COMPUTERS AND STRUCTURES, Vol. 25, No. 4, pp 469-605, 1987

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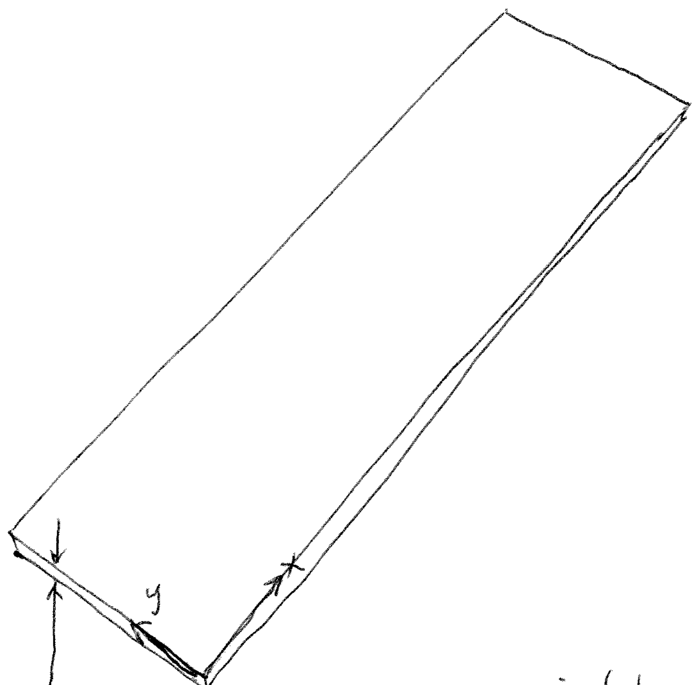
*************** END PANDA2 LITERATURE *********************

Geometry for Sub-sections 1.1
& Section 2




thickness, $t$ = decision variable

Sub-section 1.1 : $\begin{cases} N_x = -1000 \text{ lb/in} \\ N_{xy} = 0 \end{cases}$

SECTION 2 : $\begin{cases} N_x = -30 \text{ lb/in} \\ N_{xy} = +300 \text{ lb/in} \end{cases}$



Fig. 0.1

flat.discussion

SECTION 0: HOW TO USE THIS MANUAL

At intervals throughout this manual the runstreams used to generate results are listed in tables. These runstreams "point" to tables and figures that represent the input data and results generated. Please attempt to reproduce the results given here by using the same runstreams and the same input data.

This manual has two aspects:

1. How to use PANDA2 to get certain results, and

2. Discussions of the physics of the particular cases introduced here.

I hope that therefore this manual will help you to learn to use PANDA2 and also to understand better the physics of buckling and postbuckling for the particular cases introduced here.

Immediately Following the ABSTRACT is a list of references pertaining to PANDA2, BOSOR4, BIGBOSOR4, and STAGS.

For information about STAGS, please see the following references:


B. O. Almroth, F. A. Brogan, "The STAGS Computer Code", NASA CR-2950, NASA Langley Research Center, Hampton, Va.(1978)

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Please contact Charles Rankin for how to obtain a copy of STAGS.
*****************************************************************

SECTION 1: PANELS UNDER PURE AXIAL COMPRESSION, Nx = -1000 lb/in

EXAMPLES 1, 2, 3, 4 UNDER PURE AXIAL COMPRESSION, Nx = -1000 LB/IN

Tables 1.1 - 1.80 and Figures 1.1 - 1.96 pertain to this section

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SUBSECTION 1.1: EXAMPLE 1
UNSTIFFENED PLATE 50 INCHES LONG BY 10 INCHES WIDE

Tables 1.1 - 1.21 and Figures 1.1 - 1.29 pertain to this subsection.

This example is included as one of the example cases for PANDA2. The case is called "flat" and is located in the directory, ...panda2/case/flat.

Table 1.1 is a modified form of the file, flat.readme, located in that directory. This table contains the runstream used to generate the PANDA2 results contained in Tables 1.5 and 1.8 and in Figs. 1.1 - 1.3. The input data for the various PANDA2 processors (BEGIN, DECIDE, MAINSETUP, CHOOSEPLOT) are listed in Tables 1.2, 1.3. 1.4, 1.6, and 1.7.

During optimization the only decision variable is the plate thickness (Table 1.3). The input to MAINSETUP is listed in Table 1.4. Notice that the factors of safety for general instability and local buckling are both set equal to 0.2.

In this case local and general buckling are the same thing because there are no stiffeners.

*** NOTE ***: Local postbuckling is permitted at the design load (the applied load combination listed in Table 1.4, for example) whenever the factor of safety for local buckling is set by the user to be LESS THAN UNITY. In this case the factor of safety of 0.2 for local buckling means that local buckling shall not occur at less than 0.2 times the design load, which is Nx = -1000 lb/in.

Whenever the user chooses to do optimization (ITYPE = 1 in Table 1.4, the "PANDAOPT" process (see Table 1.1) produces an output file called *.OPP, in which "*" stands for the name of the case assigned by the user. In this case "*" = "flat" . Table 1.5 lists the flat.OPP file for this example. The fact that the PANDA2 user has to execute PANDAOPT more than once for a typical optimization is explained in Section 21.4 on pp. 579 - 582 of the long 1987 original paper on PANDA2: PANDA2 - Program for minimum weight design...", Computers & Structures, Vol. 25, No. 4, pp. 469 - 605, 1987.

NOTE: Optimization leads to a thickness, t = 0.08581 in. However, in the example case in the panda2 directory, ...panda2/case/flat, the optimum thickness is slightly different, t = 0.087041 inch. The difference arises from the use of an initial imperfection, 0.01 inch, corresponding to the result in Table 1.5. However, the results shown subsequently for this example correspond to the old thickness, t = 0.087041 inch. I obtained all those results before I re-did the optimization for presentation here, and I was too lazy to do the whole thing over again with the slightly different thickness, 0.08581 inch. The difference for the purpose of this demonstration is not significant.

The PANDA2 user can obtain plots of various quantities vs. design iterations through the use of CHOOSEPLOT and DIPLOT. (See Table 1.1). Input for CHOOSEPLOT in this case is listed in Table 1.6, and the three postscript files generated by DIPLOT, flat.3.ps, flat.4.ps, and flat.5.ps, are presented as Figs. 1.1 - 1.3.

After determining an optimum design, the PANDA2 user should always do a "fixed" design analysis of the optimized structure. The appropriate input data for MAINSETUP are listed in Table 1.7. Note that now NPRINT = 2 and ITYPE = 2. (ITYPE = 2 means analyze the given design at the given load. In this case the "given" design is the optimum design.)

Note: Some of the input for MAINSETUP will be unclear to most PANDA2 users. When in doubt, simply hit "enter" rather than provide a value. (This strategem works only in connection with interactive input to MAINSETUP). PANDA2 will then provide a default value. (This applies to certain sophisticated strategy or model indices, not to things such as applied loads, which must have some value that the PANDA2 user knows about.)

Table 1.8 lists part of the *.OPM file (flat.OPM), which is output from PANDAOPT from the analysis of a fixed design. Here the flat.OPM file has been severely abridged in order to save space. When you run the case at your facility you can look through the entire flat.OPM file for this case if you are interested. A more extended presentation of the *.OPM file is listed for Example 3 in Tables 1.33 - 1.45 (the stiffened panel). The *.OPM file is divided into chapters. In the heading for each chapter there is an explanation of what is going on. Please see the beginning of Table 1.33 for a summary and some references.

The margins corresponding to the previously optimized design are listed at the end of Table 1.8. Note that the most critical margins are Margins 3 and 4. Margin 4 may seem to be a mystery. Please read the PANDA2 paper about mode jumping ("Optimization of stiffened panels in which mode jumping is accounted for", AIAA Paper 97-1141, 38th AIAA Structures meeting, 1997) to learn more. In this particular case (no stiffeners) the four margins, 1, 2, 6, and 8 represent the same phenomenon: buckling of the unstiffened plate. They have slightly different values because different models are used in their determination. Remember, in this particular case of an unstiffened panel general and local buckling are the same phenomenon.

Next we want to use PANDA2 to determine results for a simulation of a test on the optimized panel. In a test of such a panel, we would subject the panel to increasing load and measure displacements and strains. The "test simulation" mode of analysis in PANDA2 is invoked with use of ITYPE = 3 as input for MAINSETUP and PANDAOPT.

Table 1.9 lists a runstream by means of which we determine the behavior of the optimized panel under increasing axial compression. In this example we are starting from scratch, although this is not necessary. We could just as well have started from a new execution of MAINSETUP rather than going back to BEGIN and then using CHANGE. I do this here in order to demonstrate the use of the PANDA2 processor called CHANGE, which over the years I have found very useful for storing previously obtained optimum designs.

Table 1.10 lists input data for CHANGE for this particular case. When CHANGE is executed interactively the *.CHG file is generated and is saved for possible future use. In this way one can very easily re-generate optimum designs obtained earlier. I always use CHANGE after having obtained an optimum design in order to save that optimum design in a compact file, *.CHG, that can be used in the future easily to re-generate the optimum design.

Table 1.11 lists the input for MAINSETUP for the "test simulation" analysis type, that is, for ITYPE = 3 .

Next, we wish to plot selected quantities vs applied load. This is done as before via CHOOSEPLOT/DIPLOT, except this time, rather than plotting quantities vs. design iterations, we will obtain plots of quantities vs. applied load. Table 1.12 lists the input to CHOOSEPLOT by means of which Figs. 1.4, 1.5, 1.6, 1.8, 1.10, 1.11, and 1.12 are generated from the execution of DIPLOT.

In this particular example, execution of DIPLOT (immediately following execution of CHOOSEPLOT) leads to generation of the following postscript files: flat.3.ps (design margins vs load), flat.4.ps (panel behavior(s) vs. load), flat.5.ps (panel module cross section deformation vs. load), flat.7.ps (3-dimensional view of one full axial wavelength at the design load), flat.8.ps (axial strain at selected locations in the panel module cross section vs. load), flat.9.ps (hoop strain at selected locations in the panel module cross section vs. load), and flat.10.ps (in-plane shear strain at selected locations in the panel module cross section vs. load). PANDA2 cannot plot stress quantities.

Note that the deformed panel cross section plotted in Fig. 1.6 appears to be somewhat strange. That is because the unstiffened panel is treated in a manner analogous to a stiffened panel, an example of which is shown in Fig. 1.7, which is taken from the PANDA2 example case, ..panda2/case/riks. In PANDA2 local behavior, that is behavior of the skin and one stiffener for a single discretized module of a multi-stiffener panel, is obtained from a model in which symmetry conditions are applied midway between stringers.

The deformations vary in the axial direction (normal to the plane of the paper) trigonometrically. The "panel module" concept is described in detail in the original long PANDA2 paper published in Computers & Structures in 1987. PANDA2 users should read that paper.

Figure 1.8 is a "3-dimensional" view of the deformation of part of the unstiffened panel corresponding to one full axial wavelength of the post-local buckling deformation. Figure 1.9, taken from the PANDA2 example case, ..panda2/case/riks, shows how the analogous plot looks when there exists a stringer (axial stiffener).

Figures 1.10 - 1.12 are plots of extreme fiber axial, hoop, and in-plane shear strain at two locations in the panel module, as indicated in Fig. 1.6: Nodal Point 1 and Nodal Point 11 in Segment 1 of the discretized cross-section module model.

Table 1.13 lists another set of input data for CHOOSEPLOT that, after execution of DIPLOT, generates a new postscript file, flat.4.ps, that is plotted in Fig. 1.13.

Tables 1.14 - 1.16 and Figures 1.14 and 1.15 demonstrate the effect of a bigger initial imperfection on the behavior of the optimized panel under increasing load (ITYPE = 3 type of analysis). Note that the presence of the imperfection smooths the results especially in the neighborhood of the bifurcation point (Nx between -200 and -250 lb/in). When optimizing shells for cases in which post-local buckling is permitted (factor of safety for local buckling less than unity), it is a good idea always to provide a small local imperfection so that design iterations will not "jump around" too much: the behavior of the imperfect panel is "smoother" than that of the perfect panel, especially in the neighborhood of the bifurcation point corresponding to local buckling of the perfect panel.

Tables 1.17 - 1.21 and Figs. 1.16 - 1.29 pertain to generation of a STAGS finite element model and results from STAGS for that model of the unstiffened 50 x 10 inch plate. Table 1.19 lists input data for the PANDA2 processor called STAGSUNIT. The runstream listed in Table 1.17 re-establishes the optimum design obtained by PANDA2, and execution of the PANDA2 processor called STAGSUNIT produces two valid input files for STAGS: flat.bin and flat.inp. These files represent the optimum design and loading for the PANDA2 case.

Details on the running of STAGS are not given here. Briefly, the procedure is first to run a linear bifurcation buckling analysis (or analyses if more than one analysis is required to obtain the proper buckling mode or modes), followed by one or more nonlinear equilibrium analyses in which one or more linear buckling modes are used as initial imperfection shapes with user-specified amplitudes. Please see several PANDA2 papers for more details on this, especially the two most recent papers on PANDA2 published at the AIAA Structures meetings in 2006 and 2007.

Table 1.20 lists the most critical output from STAGS for the linear bifurcation buckling analysis of the perfect panel. The STAGS and PANDA2 predictions of linear buckling are in almost perfect agreement. Figures 1.16 - 1.29 are plots generated via the STAGS processors called STAPL and XYTRANS.

Note that in the relatively far post-local-buckling regime the STAGS model leads to the prediction of certain local stress and strain concentrations that cannot be predicted with the approximate PANDA2 post-buckling model. For example, the very high effective stress at the four corners of the plate shown in Figs. 1.20 and 1.21 cannot be predicted by the PANDA2 model.

******** IMPORTANT NOTE ************** IMPORTANT NOTE **********************
NOTE: PANDA2's model is based on the assumption that a post-local-buckling deformation pattern, such as that shown in Figs. 1.8 and 1.9, is repeated over the length of the panel. There is no consideration of the boundary conditions at the axially loaded ends of the panel in the approximate PANDA2 model. This model is an extension of a theory formulated by Koiter in the 1940's. (Please see the PANDA2 paper on post-buckling in the CNAME journal for details on this model). One can see from Fig. 1.23, for example, that the post-local buckling pattern does not, according to the STAGS model, vary in the axial direction as sin(n*pi/L), as is the case with the PANDA2 model, results from which are displayed in Figs. 1.8 and 1.9.
*********** END OF IMPORTANT NOTE ******************************************

Table 1.21 lists input data valid for use with a plot routine, plotps.linux, that is included as part of the PANDA2 package. This plot routine, written more than 10 years ago by my son, Bill Bushnell, is located in the directory, ../bin . The first seven lines of Table 1.21 describe how to generate the data from the STAGS processor called "XYTRANS" and how to obtain a plot via ../bin/plotps.linux.

Figure 1.19 shows results from STAGS for the unstiffened 50 x 10 inch plate. Compare this plot with the prediction from PANDA2 given in Fig. 1.5.

Figures 1.20 - 129 give results from the STAGS model. Compare the STAGS predictions in Fig. 1.24 with the PANDA2 predictions given as traces 1 and 2 in Fig. 1.10. Compare the STAGS predictions in Fig. 1.25 with the PANDA2 results plotted as traces 3 and 4 in Fig. 1.10. The sketch inserted in Fig. 1.25 shows the locations of the 9 integration points in a finite element that includes the right-most longitudinal edge of the panel in the STAGS model. PANDA2 and STAGS are in fair agreement for the highest extreme fiber axial strains in the postbuckled panel.

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SUBSECTION 1.2: EXAMPLE 2
50 x 50 INCH PLATE WITH "FAKE" STRINGERS SPACED AT 10-INCH intervals

Tables 1.22 - 1.26 and Figures 1.30 - 1.40 pertain to this subsection.

The purpose of this sub-section is to demonstrate that the behavior of a 50 x 10 inch flat plate by itself does not represent very well the behavior of a flat plate with the same dimensions that forms an interior part of the panel skin in a stiffened panel that consists of several identical skin-stiffener modules or bays. In other words, if you try to approximate the behavior of the skin of a stiffened panel that is located between two adjacent stringers located in the interior of a stiffened panel by a model of a simply-supported piece of skin with appropriate length and width, you may be misled by the predictions of the simplified model, such as that which is the subject of the previous sub-section.

In this example the panel skin has a thickness equal to that used in most of the previous subsection: t = 0.087041 inch. There is no optimization.

Table 1.22 lists the runstream used for production of this sub-section. Tables 1.23 - 1.26 list input for the PANDA2 processors, BEGIN, DECIDE, MAINSETUP/PANDAOPT, and STAGSUNIT. Figures 1.30 - 1.40 present results from STAGS.

Table 1.23 lists the input for BEGIN. In the PANDA2 model the panel is stiffened by huge but very soft stringers (axial stiffeners) spaced at 10-inch intervals. The purpose of these "fake" stiffeners is to prevent early general buckling while not absorbing a significant amount of prebuckling load from the panel skin. Also, in the PANDA2 model a very small axial load, Nx = 1.0 lb/in, is used so that the panel will not buckle either locally or generally.

NOTE: The sole purpose of this rather artificial problem is to use STAGS to ascertain the effect on post-local buckling behavior of multiple bays as compared to the post-buckling behavior of a single bay 10 inches in width, that is, the behavior of a 50 x 10 inch unstiffened plate.

Table 1.24 lists input for the PANDA2 processor called STAGSUNIT. Note that for Stringer model the index "5" is used. When this option is used (infrequently) the stringers are replaced in the STAGS model by constraints that force the normal displacement w to be constant along the axial lines where the "fake" stringers would be located. Since the STAGS model is set up in a way that no rigid-body motions are permitted, "w = constant" actually means "w = 0". By this device general buckling of the "stiffened" plate is prevented.

Figures 1.30 shows the linear buckling mode shape, which is used as an initial imperfection shape in the nonlinear STAGS run to follow. Note that the predicted linear buckling eigenvalue (buckling load factor) agrees very well with that from PANDA2 (Table 1.8) and with the 1-bay (50 x 10 inch unstiffened panel) STAGS model shown in Fig. 1.16.

Figure 1.31 shows the load-normal displacement curve for the first approximately 70 load steps in the STAGS nonlinear equilibrium analysis (INDIC = 3).

The plot in Fig. 1.32 represents the load-normal-displacement plot for 268 "riks" steps in the nonlinear STAGS analysis. During the last approximately 200 "riks" steps STAGS is simply cycling repeatedly over the same equilibrium states, shown in Fig. 1.32 as the points plotted approximately between Nx = -595 lb/in and Nx = -705 lb/in in the approximate range 1.3 < w < 1.505 inch. The usual way for the user to get out of this "sand-trap" is to perform a nonlinear transient analysis at a load level slightly in excess of the highest load level reached in the STAGS static analysis. This was not done in this rather artificial case. For examples in which this has been done, please see the two most recent PANDA2 papers (2006 and 2007).

Results from the nonlinear STAGS runs are displayed in Figs. 1.31 - 1.40. Figures 1.31, 1.32, and 1.40 show the normal displacement at the center of the panel vs axial load. In Fig. 1.40 the STAGS prediction for the multi-bay "stiffened" panel is compared with that for the 50 x 10 inch one-bay model in Fig. 1.19. Note that the maximum normal displacement in the center of the "multi-bay" 50 x 50 inch panel is significantly less than that of the 50 x 10 inch "one bay" panel because the middle bay of the "multi-bay" panel is stiffened by the neighboring bays. In the "multi-bay" panel there is "mode jumping" in the interior bays which is not present in the "one-bay" (50 x 10 inch) panel.

Figures 1.33 - 1.39 give "fringe" plots of the normal displacement w over the entire panel at several "riks" steps. One can see that the post-local buckling pattern changes rather dramatically in the interior bays of the "stiffened" panel. The distribution of normal displacement w in the two bays nearest the two longitudinal edges (edges that run along x) does not change that much and more-or-less resemble the distribution of w displayed in Fig. 1.18 (one-bay STAGS model).

Needless to say, PANDA2 cannot predict this complex type of post-local-buckling behavior, which represents a type of mode jumping.

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SUBSECTION 1.3: EXAMPLE 3
50 x 50 INCH PLATE WITH REAL STRINGERS SPACED AT 10-INCH INTERVALS

************* IMPORTANT NOTE **************** IMPORTANT NOTE ********************
There is an error in the input data for BEGIN: The maximum allowable effective stress in material type 1 was set equal to 1000000. It should have been 60000. Fortunately, this error did not affect the optimum design because the stress constraints are not critical even with use of the correct maximum allowable stress of 60000 psi. (However, the error DOES dramatically affect the value of Margin No. 3 on p.1 of Table 1.45. With the correct value of 60000 psi Margin No. 3 becomes something like 1.49 rather than 40.5. Margin No. 8 is similarly affected. This means that the highest effective stress, according to the margins, is in the panel skin rather than in the stringer, as is implied by the margins listed on p.1 of Table 1.45, which are based on the incorrect value of maximum allowable stress of 1000000 psi used for Material Type 1.
************ END OF IMPORANT NOTE **********************************************

There are two subsets of results given here. Call them "Example 3.1" and "Example 3.2". In Example 3.1 the factor of safety for local buckling is 0.2. That is, local buckling shall not occur at less than 0.2 times the design load, Nx = -1000 lb/in. In Example 3.2 the factor of safety for local buckling is 0.5. That is, local buckling shall not occur at less than 0.5 times the design load, Nx = -1000 lb/in.

Example 3.1

Tables 1.27 - 1.53 and Figures 1.41 - 1.60 pertain to this subsection.

The purpose of this sub-section is to demonstrate that the behavior of a 50 x 10 inch unstiffened flat plate or a 50 x 50 inch flat plate with "fake" stiffeners does not represent very well the behavior of a 50 x 50 panel with real stiffeners that has been optimized (with the stiffener spacing held constant at 10 inches).

Table 1.27 lists the runstream used to generate the results presented in this sub-section. Tables 1.28 - 1.30 list the input data for the PANDA2 processors, BEGIN, DECIDE, and MAINSETUP/PANDAOPT. The decision variables for optimization are the stringer height, the panel skin thickness, and the stiffener thickness. The name of the case is now "riks" instead of "flat". The name, "riks" was chosen because this case is similar to the PANDA2 example case, ...panda2/case/riks. In that case the axial load, Nx = -5000 lb/in, and a one-module STAGS model was used for the STAGS analysis. Also, in the PANDA2 model corresponding to the sample case, ...panda2/case/riks, the panel was 100 inches wide instead of 50 inches as in the case explored here. Also, the boundary condition on the two axially loaded edges was CLAMPED rather than SIMPLY-SUPPORTED in the ..panda2/case/riks example. Also, the PANDA2 processor called STAGSMODEL was used to generate the STAGS models in the original "riks" case; STAGSUNIT did not exist at that time. The ...panda2/case/riks example is described in detail in the paper, "Optimization of stiffened panels in which mode jumping is accounted for", AIAA Paper 97-1141, 38th AIAA Structures meeting, 1997. That paper includes comparisons of results from PANDA2 and STAGS for extreme fiber stress and strain. NOTE: As presently written the PANDA2 processor called STAGSUNIT cannot generate STAGS models of panels clamped at the axially loaded ends.

Table 1.31 lists output from the optimization analysis (ITYPE= 1 in the *.OPT file). This is the riks.OPP file generated during the seven executions of PANDAOPT listed near the beginning of the runstream in Table 1.27.

Figures 1.41 and 1.42 show the design margins and objective vs. design iterations. These plots are generated by the execution of chooseplot (input in Table 1.31(b)) followed immediately by execution of diplot.

Table 1.32 lists input appropriate for the analysis of a "fixed" design, that is, analysis type ITYPE = 2 . Here the index for amount of output is set equal to 2, that is NPRINT = 2 in the riks.OPT file.

The PANDA2 "fixed" design run produces a large riks.OPM file, parts of which are listed in Tables 1.33 - 1.45. The output from PANDA2 contained in the *.OPM file is divided into chapters which identify what is going on during the computations in the PANDA2 mainprocessor, PANDAOPT. The first three pages of Table 1.33 list some PANDA2 references and lists what computations occur in each "chapter" of the PANDAOPT run. The remainder of Table 1.33 lists what happens in Chapter 1. Tables 1.34 - 1.45 list what happens in selected other chapters. The new user of PANDA2 is urged to inspect the entire *.OPM file produced with NPRINT = 2 and ITYPE = 2 in the *.OPT file.

Here are some highlights of the riks.OPM file in this case:

1. The distributions of resultants, Nx, Ny, Nxy, over a single panel module (local post-buckling not yet accounted for) are listed in Table 1.34. The panel module segment numbering, nodal point numbering, and layer numbering conventions are also displayed in Table 1.34. These sketches show what is called in PANDA2 jargon a single module of the multi-module panel. The local buckling and post-local buckling behavior of a stiffened panel is determined from the behavior of a single panel module. This is an approximation, of course. It is one of the reasons the PANDA2 user is urged always to use a general-purpose computer program to evaluate panels designed with PANDA2. The advantage of using a single module model to determine local behavior is the reduction in computer resources and time required to find optimum designs in the presence of very complex and extremely nonlinear behavior.

2. PANDA2's prediction of local buckling is listed in Table 1.35. This is the prediction of local buckling from what is called "the discretized single-module model", described in detail in the long 1987 PANDA2 paper identified near the beginning of Table 1.33.

3. Table 1.37 lists output from the Koiter post-local buckling analysis described in detail in the paper, "Optimization of composite, stiffened, imperfect panels under

combined loads for service in the postbuckling regime", Computer Methods in Applied Mechanics and Enginering, Vol. 103 (1993), pp 43-114. On the last three pages of Table 1.37 are listed the distributions of normal displacement w, reference surface strains Ex, Ey, Exy, stress resultants Nx, Ny, Nxy, and in-plane tangent stiffnesses, C11TAN, C12TAN, C22TAN, and C33TAN, over the single skin-stringer panel module cross section. The panel module is depicted on p. 4 of Table 1.37.

4. Table 1.38 lists the stresses in each layer through the thickness and at selected nodal points over the panel module cross section corresponding to the locally post-buckled state. Again, the single panel module is displayed on p. 1 of Table 1.38.

5. Table 1.39 lists the effective stiffnesses of the post-locally buckled panel module segments. Note especially that the effective axial, hoop, and shear stiffnesses of the locally postbuckled panel skin are considerably less than those of the unbuckled panel. These reduced quantities are used in the computation of general buckling of the locally postbuckled panel.

6. Table 1.43 lists buckling load factors for stiffener segments.

7. Table 1.44 lists buckling load factors from "PANDA-type" models for local buckling and general buckling. "PANDA-type" models are described in the paper, "Theoretical basis of the PANDA computer program for preliminary design of stiffened panels under combined in-plane loads", Computers & Structures, Vol. 27, No. 4, pp. 541-563 (1987).

8. Table 1.45 lists the optimum design, the design margins, and the objective.

Table 1.46 lists the input for STAGSUNIT, the PANDA2 processor that, given the input listed in Table 1.46, produces the two valid input files for STAGS: riks.bin and riks.inp. This version of the file, riks.STG, produces STAGS input files valid for linear bifurcation buckling of a perfect shell. (For an example of a version of riks.STG for producing STAGS input files valid for nonlinear analysis of an imperfect shell see Table 1.48).

Figures 1.43 and 1.44 show the linear buckling mode and load factor, 0.25038, predicted by STAGS for the optimum design obtained by PANDA2. For linear buckling PANDA2 predicts a load factor, 0.262633, corresponding to a critical number of axial halfwaves of seven, which agrees with STAGS. Figure 1.44 presents the same linear buckling mode in a "fringe" plot.

The buckling mode shape with amplitude 0.01 inch is used as an initial imperfection in a STAGS nonlinear equilibrium analysis that is next conducted.

Figures 1.45 - 1.47 show the state of the panel at a load slightly less than the design load, that is, at load factor PA = 0.968825. (Load factor PA = 1.0 corresponds to the design load, Nx = -1000 lb/in). In this case STAGS was unable to determina a static equilibrium solution for load factor PA higher than 0.968825. The difficulty is caused by the presence of nonlinear bifurcation points on the nonlinear equilibrium "riks" path. The most common way to get around this difficulty is to run a STAGS nonlinear transient analysis (INDIC = 6) at a constant load level about two per cent higher than 0.968825. Details concerning this procedure are given in the two most recent PANDA2 papers (2006 and 2007). No transient run was attempted here.

Several points with regard to Figs. 1.45 - 1.47 are emphasized:

1. There is considerable overall axial bowing of the panel, as can be seen by the deformed shapes of the four interior stringers. This bowing is caused by a shift in the neutral axis that occurs because the skin of the panel is in its locally postbuckled state. At loads near the general buckling load (load factor PA near 1.0) the axial bowing is greatly amplified because the axial bending stiffness of the panel decreases with increasing axial compression, approaching zero as the axial load approaches the general buckling load.

******** IMPORTANT NOTE ********* IMPORTANT NOTE ***************
The PANDA2 model does NOT predict this overall axial bowing due to a shift in the neutral axis. The PANDA2 model of overall behavior of a panel in which the skin is in its locally postbuckled state is based on the assumption that the loading is in the plane of the neutral axis of the locally post-buckled panel, wherever that axis happens to be, or if local buckling does not occur, the loading is in the plane of the neutral axis of the unbuckled panel. No account is taken in the PANDA2 model of the fact that the axial load Nx at the ends of the panel may be at a location that gives rise to overall bending of the locally postbuckled panel. The effective axial bending moment Mx applied at the ends of the panel would be something like Nx x delta, in which delta is the shift in the neutral axis from that of the undeformed panel to that of the locally postbuckled panel. This effective Mx is NOT included in the PANDA2 model. In other words, the PANDA2 model is based on the assumption that the plane at which the axial load Nx is applied shifts as the neutral axis shifts. The behavior

of an actual fabricated panel will depend on the details of construction in the neighborhoods of the ends of the panel, where panel thickness and stiffener dimensions may vary locally in order to minimize local stress concentrations there. Consideration of these details lie well outside PANDA2's universe. In the paper, "Optimization of stiffened panels in which mode jumping is accounted for", AIAA Paper 97-1141, 38th AIAA Structures meeting, 1997, the axially loaded ends of the panel are clamped. There is reasonably good agreement of exteme fiber axial, hoop, and in-plane shear strains predicted from PANDA2 and STAGS in that case, as seen from Figs. 26, 27, and 28, respectively in the paper just cited..
**************** END OF IMPORTANT NOTE ***************************

2. From Fig. 1.45 it can be seen that the local postbuckling deformations vary along the x-axis of the panel in a way that is significantly different from the simple sinusoidal variation depicted in Figs. 1.8 and 1.9, for example. In the middle bay of the panel shown in Fig. 1.45 the axial halfwavelengths of the two outward local buckles in the middle bay are significantly longer than that of the inward buckle at the very center of the panel. The PANDA2 model is based on the assumption that the axial variation of the local postbuckled state is simple sinusoidal.

3. There is a significant difference in the locally postbuckled state near the two ends of the panel than in its interior. This can be seen in all three figures, 1.45 - 1.47. The dramatically shortened buckles in the skin at the two ends of the panel (where Nx is applied) give rise to large bending stress concentrations. These bending stress concentrations would be greatly diminished in an actual fabricated panel. This would be accomplished by increasing the thickness of the panel skin and of the stiffeners locally near the ends in a manner to minimize these stress concentrations.

4. The maximum extreme fiber effective stress in the panel skin far from the edges of the panel lies adjacent to the stringers and is far greater than that predicted by PANDA2. (See Table 1.38).
Presumably the significant difference from the PANDA2 prediction is related to the large amount of axial bowing that is predicted for the STAGS model and that is absent in the PANDA2 model.

In the STAGS model just described in-plane warping of the two longitudinal edges of the panel (x-axis oriented edges) is permitted. (See the last line of Table 1.46).

Tables 1.47 - 1.49(b) and Figs. 1.48 - 1.51(b) pertain to the same panel design but with in-plane warping of the two longitudinal edges prevented in the STAGS model. For the flat panel there is almost no difference in the nonlinear behavior of the panel; restraint of in-plane warping of the two longitudinal edges has virtually no effect on the predicted behavior.

Table 1.47 lists the input to STAGSUNIT for linear buckling; Fig. 1.48 shows the linear buckling mode; Table 1.48 lists the input to STAGSUNIT for nonlinear equilibrium; Figs. 1.49(a)-(c) show the nonlinear state of the panel at load factor PA = 0.971414; Fig. 149(d) shows the extreme fiber effective stress in finite element 721, which is adjacent to Stiffener No. 3 (Fig. 149(b)); Fig. 1.50 shows the axial bowing of Stiffener No. 3; Table 1.49(a) lists input for ..bin/plotps.linux; Fig. 1.51(a) shows the growth in bowing at the midlength of Stiffener No. 3 with increasing axial compression Nx; Table 1.49(b) lists input data for ../bin/plotps.linux; and Fig. 1.51(b) shows the difference in displacement between the bowing displacement and the normal displacement in the panel skin at the peak of an outward buckle. This difference is in reasonably good agreement with the maximum normal displacement predicted from the PANDA2 model displayed in Fig. 1.53. As with the previous STAGS model the maximum effective stress predicted by the STAGS model far exceeds that predicted by PANDA2, presumably because of the large amount of overall axial bowing predicted by the STAGS model and absent in the PANDA2 model.

Next, we go back to more PANDA2 executions.

The optimum design is saved in the riks.CHG file, which is listed in Table 1.50(a).

Table 1.50(b) lists the riks.OPT file suitable for a test simulation of the optimized panel with PANDA2, that is, analysis of the optimized panel under increasing applied load, in this case, increasing axial load Nx.

Table 1.51 lists input to CHOOSEPLOT, and with subsequent execution of DIPLOT we obtain Figs. 1.52 - 1.55. We obtain more data by executing CHOOSEPLOT and DIPLOT again, leading to Table 1.52 and Figs. 1.56 - 1.58.

We obtain predictions for the optimized panel from BIGBOSOR4 through execution of the PANDA2 processor called PANEL, input for which is listed in Table 1.53. Results from BIGBOSOR4 appear in Figs. 1.59 and 1.60. The predictions of BIGBOSOR4 for linear buckling agree well with those from PANDA2 (Table 1.35) and STAGS (Fig. 1.43). For a description of this type of BIGBOSOR4 model of a panel previously optimized by PANDA2, see the 2007 PANDA2 paper, in particular Figs. 20b and 23b and the discussion associated with those figures in that paper.

Example 3.2

Tables 1.54 - 1.68 and Figures 1.61 - 1.71 pertain to this subsection.

The results listed and plotted here are analogous to those given in the previous sub-sub-section, Example 3.1. The differences here are as follows:

1. The factor of safety for local buckling is 0.5 instead of 0.2. That is, local buckling must occur at greater than or equal to 0.5 times the design load, which in this case is axial load Nx  = -1000 lb/in. The panel is optimized under the condition that it is not allowed to go as deeply into the post-locally-buckled state as for Example 3.1.

2. This time the panel is optimized with the use of SUPEROPT rather than a small sequence of PANDAOPT executions. SUPEROPT is described in several PANDA2 papers. In particular, see the paper, "Recent enhancements to PANDA2", AIAA 37th Structures meeting, AIAA paper AIAAA-96-1337-CP, 1996, especially pp. 127 - 130.

Table 1.54 lists the runstream. Figure 1.61 shows the result from a single execution of SUPEROPT. Each "spike" corresponds to a new starting design, which is obtained randomly (but consistent with bounds on the decision variables and any linking expressions among decision variables). In the latest version of PANDA2 optimization cycles continue until there are more than 470 and less than 500 cycles. The purpose of SUPEROPT is to search for a global optimum design. While there is no assurance of finding a unique global optimum design, the aim is to use enough different starting designs during the SUPEROPT run to come close in objective to a global optimum design.

The major conclusion from this Example 3.2 study is that, since the optimized panel is not as far into its locally postbuckled state as was the case for Example 3.1, there is less axial bowing and therefore less discrepancy between the prediction of maximum effective stress from STAGS and from PANDA2. As can be seen from Fig. 1.70, axial bowing starts to occur just before the local buckling load. Axial bowing grows approximately hyperbolically as the applied axial load approaches the general buckling load.

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SUBSECTION 1.4: EXAMPLE 4
50 x 50 INCH CYLINDRICAL PANEL WITH REAL STRINGERS

Tables 1.64 - 1.80 and Figs. 1.72 - 1.96 pertain to this sub-section.

The runstream used to generate the results in this section is listed in Table 1.64. In this case the stringer spacing is one of the decision variables of the optimization problem. The other decision variables are the same as those used in Example 3: the stringer height, the skin wall thickness, and the stringer wall thickness. The stringer spacing is now included as a decision variable for two reasons:

1. The 10-inch starting value for the stringer spacing is far from optimum, and

2. In the local bifurcation buckling analysis and in the local post-buckling analysis the assumption is made by PANDA2 with regard to the discretized single module model (Fig. 1.83) that the skin is flat. This assumption is a very poor one for non-optimized CURVED stiffened panels in which the stringer spacing is much greater than the optimum one, that is, for stringer spacing that is not very small compared to the radius of the cylindrical panel.

The sequence of computer runs made for this case and the input data and output data are analogous to those described in Sub-section 3. Therefore comments here will be confined to descriptions of the physical behavior, not about "how to use PANDA2".

The following points are emphasized:

1. As with Example 3 there is an error in the input data for BEGIN: The maximum allowable effective stress in material type 1 was set equal to 1000000. It should have been 60000. Fortunately, this error did not affect the optimum design because

the stress constraints are not critical even with use of the correct maximum allowable stress of 60000 psi. (However, the error DOES dramatically affect the value of Margin No. 4 on p.14 of Table 1.70. With the correct value of 60000 psi Margin No. 4 becomes something like 0.734 rather than 27.9. Margin No. 9 is similarly affected. This means that the highest effective stress, according to the margins, is in the panel skin rather than in the stringer, as is implied by the margins listed on p.14 of Table 1.70, which are based on the incorrect value of maximum allowable stress of 1000000 psi used for Material Type 1.

2. The optimum design obtained via a sequence of 8 executions of PANDAOPT (Table 1.64, see p.14 of Table 1.70 for details) is fairly close to that obtained by a single execution of SUPEROPT, as listed in Table 1.80. While this happens in this simple case, there are many more complex cases for which SUPEROPT yields an optimum design that is significantly better (smaller weight) than that obtained from a number of sequential executions of PANDAOPT. The PANDA2 user is urged always to use SUPEROPT to obtain optimum designs of actual practical structures.

3.The BIGBOSOR4 model for local buckling (Figs. 1.74 and 1.75) may seem rather strange to the new PANDA2 user. (Note especially the numbers given for "Radius" Figs. 1.74 and 1.75). In this BIGBOSOR4 model the panel is modeled as a segment of a huge toroidal shell. Please see Figs. 20b and 23b in the paper, "Optimization of an axially compressed ring and stringer stiffened cylindrical shell with a general buckling modal imperfection", AIAA Paper 2007-2216, AIAA 48th Structures meeting, Honolulu, Hawaii, April 2007, and the discussion associated with those figures for details about this BIGBOSOR4 model.

4. For the curved panel the difference in behavior of the STAGS models corresponding to the two options: a. "in-plane deformable" straight edges, and b. "in-plane rigid" straight edges is significant. Figures 1.76 - 1.80 pertain to the "in-plane deformable" option. Figures 1.85 - 1.89 and Figs. 1.91 - 1.95 pertain to the "in-plane rigid" option. The proper boundary conditions to be used in connection with finite element models of panels optimized by PANDA2 depend on what the actual structure to be fabricated looks like. One should not blindly apply "simple support" conditions and think that the finite element model will predict what would actually happen during a test.

************** IMPORTANT NOTE *************** IMPORTANT NOTE ******************
5. When the curved panel is loaded in axial compression beyond that load which causes local buckling of the panel skin, there is axial bending near the curved ends of the panel caused by a shift in the location of the neutral axis. This shift arises because the average axial stiffness of a locally post-buckled skin is less than that of an unbuckled skin. PANDA2 does not account for the shift in the neutral axis but simply assumes that the axial load is applied at the neutral axis wherever that neutral axis happens to be. Hence, PANDA2 is designed to predict the behavior that occurs far from the curved ends, such as in the central region of the stiffened panel shown in Fig. 1.88. At the time the user employs PANDA2 to find optimum designs (the preliminary phase of the design process) the actual boundary conditions are probably not known. The behavior near the curved ends of an actual fabricated panel depend on details of how the skin thickness and stiffener height and thickness will be made to vary in the neighborhoods of these curved ends and on the presence of end rings and other neighboring structure.
********************** END OF IMPORTANT NOTE ********************************

6. Figure 1.94 shows a deformed curved panel (side view) in which there exists an initial local buckling modal imperfection of amplitude 0.01 inch. Figure 1.95 shows the same panel with a very, very small (essentially zero) initial local buckling modal imperfection of amplitude 0.000001 inch. The difference in these two figures prooves that the axial curvature evident in Fig. 1.94 and absent in Fig. 1.95, develops because the skin gets loaded into its locally post-buckled state, resulting in an outward shift of the neutral axis and therefore giving rise to axial bending in the sense indicated in Fig. 1.94. In the STAGS models generated via the PANDA2 processor, STAGSUNIT, the curved panel is free to expand radially (Poisson ratio expansion) under the uniform axial compression, Nx. Hence, the essentially perfect curved panel depicted in Fig. 1.94 appears to be undeformed. It has simple contracted in the axial direction and expanded uniformly in the radial direction. This type of Poisson ratio expansion is permitted in order that "sub-domain" STAGS models generated by STAGSUNIT will reasonably accurately represent what happens in the interior of a stiffened curved panel. (See Fig. 41 in the paper cited in Item 3 above for an example of a subdomain STAGS model produced by STAGSUNIT.)

7. Some of the STAGS nonlinear results presented in this section correspond to rotation component "rv" being free (Figures 1.88 - 1.90) and others to rotation component "rv" in the panel skin along the two curved edges being constrained, in the nonlinear (INDIC=3) phase of the STAGS analysis only, to remain zero (Figs. 1.91 - 1.94). This difference in model in this case

has a dramatic influence on the ability of STAGS easily to find nonlinear solutions up to load factor, PA = 1.0. (PA = 1.0 corresponds to the applied axial load, Nx = -1000 lb/in).

8. In the STAGS models in which "rv" remains free in both the linear and nonlinear phases of the analysis, STAGS was unable to find static equilibrium states for load factor PA higher than 0.97748. The usual way to overcome this difficulty, that is, to continue the nonlinear analysis for higher values of PA, is to perform nonlinear transient analyses at load levels about two per cent higher than the highest load level reached during the nonlinear static analysis. Please see the paper cited in Item 3 for details.

9. The STAGS model shown in Fig. 1.80, for example, is inadequate to capture the effective stress concentrations that occur in the panel skin in the regions immediately under the stringers. These stress concentrations are very local, caused by the very local bending under each stringer as the skin is loaded far into its locally post-buckled state. The BIGBOSOR4 model depicted in Fig. 1.75 demonstrates the local hoop bending concentration on either side of each stringer and very close to the line of intersection of the stringer root with the panel skin. Figure 1.83 also shows this effect. In order to capture these stress concentrations with a STAGS model, one would have to concentrate nodal points in a small region, as is done, for example in Fig. 25 in the paper cited in Item 3. This was not done here because of the extra time that would have been required. Figures 23 and 40 in the paper, "Optimization of stiffened panels in which mode jumping is accounted for", AIAA Paper 97-1141, 38th AIAA Structures meeting, 1997, show an example in which very narrow finite elements are used on either side of the stiffener in the immediate neighborhood of the line of intersection of the root of the stiffener and the panel skin.

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SECTION 2: UNSTIFFENED 50 x 10 INCH PANEL UNDER COMBINED AXIAL COMPRESSION, Nx = -30 lb/in AND IN-PLANE SHEAR, Nxy = +300 lb/in

Tables 2.1 - 2.13 and Figures 2.1 - 2.27 pertain to this section.

The runstreams used to generate the results in this section are analogous to those used in Section 1, Example 1. Therefore, there will not be much discussion in this section. The only difference is that the loading on the unstiffened plate is different. Here the main load component is in-plane shear, Nxy. In order to generate post-local-buckling results with PANDA2 it is necessary to combine the in-plane shear loading component Nxy with a small amount of axial compression, Nx. Nx should be at least 10 per cent of Nxy.

The input for BEGIN and DECIDE is the same as that for Example 1 of Section 1.

The unstiffened plate is first optimized and then the optimum design is analyzed, first with PANDA2 and then with STAGS. As with Example 1 in Section 1, there are two types of PANDA2 analysis:

1. Analysis of the fixed (previously optimized) design. Analysis type indicator ITYPE = 2 .

2. "Test simulation" of the previously optimized design. Analysis type indicator ITYPE = 3 .

As with Example 1 in Section 1, SUPEROPT is not used for this problem because there is only one decision variable: the plate thickness.

*********************** END OF THE FILE, flat.discussion ***********************

# Section 1

Buckling & Post-buckling
under uniform axial compression

$N_x = -1000$ lb/in

Sub-Section 1.1

Unstiffened Flat Plate

50 x 10 inches

$N_x = -1000$ lb/in

Table 1.1

Begin sub-section 1.1

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flat.readme

29 June, 2008

This is a monocoque aluminum flat plate under uniform
axial compression, Nx = -1000 lb/in. The plate is
allowed to go into its postbuckled state, but mode
jumping is prevented.

The case is called "flat".

The runstream is

panda2log        (activate PANDA2 commands)
begin            (establish starting design; input data = flat.BEG = Table 1.2)
setup            (PANDA2 sets up matrix templates)
decide           (choose decision variables and bounds, etc. input = flat.DEC = Table 1.3)
mainsetup        (choose loading, strategy, analysis type, etc.
                  cp flat.axial.itype1.opt flat.OPT; input=flat.OPT = Table 1.4)
pandaopt         (PANDA2 does computations)
pandaopt         (PANDA2 does computations)
pandaopt         (PANDA2 does computations)
cp flat.OPP flat.axial.opp = Table 1.5
chooseplot       (choose what to plot.
                  cp flat.axial.cpl flat.CPL; input = flat.CPL = Table 1.6)
diplot           (obtain postscript files: flat.3.ps, flat.4.ps, flat.5.ps)
cp flat.3.ps flat.margins.axialload.ps = Fig. 1.1
cp flat.4.ps flat.thickness.axialload.ps = Fig. 1.2
cp flat.5.ps flat.objective.axialload.ps = Fig. 1.3
(edit flat.OPT to get results for "fixed" (optimized)
 design, that is, change ITYPE from 1 to 2; input = flat.OPT = Table 1.7)
pandaopt
cp flat.OPM flat.opm and generate flat.axial.itype2.abridged.opm = Table 1.8
cleanpan         (clean up "flat" files)
---------------------------------------------------------
```

Note: "flat" is one of the PANDA2 sample cases, ...panda2/case/flat

Table 1.2 flat.BEG

(inches)

```
    n          $ Do you want a tutorial session and tutorial output?
      50       $ Panel length normal to the plane of the screen, L1
      10       $ Panel length in the plane of the screen, L2
    n          $ Identify type of stiffener along L1 (N,T,J,Z,R,A,C,G)
    n          $ Is the next group of layers to be a "default group" (12 layers!)?
       1       $ number of layers in the next group in Segment no.( 1)
    n          $ Can winding (layup) angles ever be decision variables?
       1       $ layer index (1,2,...), for layer no.( 1)
    y          $ Is this a new layer type?
0.1000000      $ thickness for layer index no.( 1)
       0       $ winding angle (deg.) for layer index no.( 1)
       1       $ material index (1,2,...) for layer index no.( 1)
    n          $ Any more layers or groups of layers in Segment no.( 1)
    n          $ Identify type of stiffener along L2  (N, T, J, Z, R, A)
    n          $ Is the panel curved in the plane of the screen (Y for cyls.)?
    n          $ Is panel curved normal to plane of screen? (answer N)
    y          $ Is this material isotropic (Y or N)?
0.1000000E+08  $ Young's modulus,                  E( 1)
0.3000000      $ Poisson's ratio,                 NU( 1)
 3846000.      $ transverse shear modulus,       G13( 1)
       0       $ Thermal expansion coeff.,     ALPHA( 1)
       0       $ residual stress temperature (positive),TEMPTUR( 1)
    n          $ Want to supply a stress-strain "curve" for this mat'l? (N)
    y          $ Want to specify  maximum effective stress ?
 60000.00      $ Maximum allowable effective stress in material type( 1)
    n          $ Do you want to take advantage of "bending overshoot"?
0.1000000      $ weight density (greater than 0!) of material type( 1)
    n          $ Is lamina cracking permitted along fibers (type H(elp))?
       0       $ Prebuckling phase: choose 0=simple support or 1=clamping
       0       $ Buckling: choose 0=simple support or 1=clamping
```

input for "BEGIN"

Table 1.3 flat.DEC

```
    n         $ Do you want a tutorial session and tutorial output?
    n         $ Want to use default for thickness decision variables (type H(elp)?
       1      $ Choose a decision variable (1,2,3,...)
0.1000000E-01 $ Lower bound of variable no.( 1)
 1.000000     $ Upper bound of variable no.( 1)
    n         $ Any more decision variables (Y or N) ?
    n         $ Any linked variables (Y or N) ?
    n         $ Any inequality relations among variables? (type H)
    y         $ Any escape variables (Y or N) ?
    y         $ Want to have escape variables chosen by default?
```

thickness

input for "DECIDE"

Table 1.4 flat.OPT (For optimization)

```
       n          $ Do you want a tutorial session and tutorial output?
  -1000.000       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
         0        $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
         0        $ In-plane shear in load set A,                        Nxy( 1)
       n          $ Does the axial load vary in the L2 direction?
   0.000000       $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
   0.000000       $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
       Y          $ Want to include effect of transverse shear deformation?
         0        $ IQUICK = quick analysis indicator (0 or 1)
       Y          $ Do you want to vary M for minimum local buckling load?
       N          $ Do you want to choose a starting M for local buckling?
       Y          $ Do you want to perform a "low-axial-wavenumber" search?
  0.2000000       $ Factor of safety for general instability, FSGEN( 1)
  0.2000000       $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
   1.000000       $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
   1.000000       $ Factor of safety for stress, FSSTR( 1)
       Y          $ Do you want "flat skin" discretized module for local buckling?
       N          $ Do you want wide-column buckling to constrain the design?
   0.000000       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
   0.000000       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
         0        $ Axial load applied along the (0=neutral plane), (1=panel skin)
   0.000000       $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
   0.000000       $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
   0.010000       $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
   0.010000       $ Initial local imperfection amplitude (must be positive), Wloc( 1)
       Y          $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
        50        $ Axial halfwavelength of typical general buckling mode, AXLWAV( 1)
       Y          $ Do you want PANDA2 to find the general imperfection shape?( 1)
   1.000000       $ Maximum allowable average axial strain (type H for HELP)( 1)
       N          $ Is there any thermal "loading" in this load set (Y/N)?
       Y          $ Do you want a "complete" analysis (type H for "Help")?
       N          $ Want to provide another load set ?
       N          $ Do you want to impose minimum TOTAL thickness of any segment?
       N          $ Do you want to impose maximum TOTAL thickness of any segment?
       N          $ Use reduced effective stiffness in panel skin (H(elp), Y or N)?
         0        $ NPRINT= output index (-1=min. 0=good, 1=ok, 2=more, 3=too much)
         0        $ Index for type of shell theory (0 or 1 or 2), ISAND
       Y          $ Does the postbuckling axial wavelength of local buckles change?
       Y          $ Want to suppress general buckling mode with many axial waves?
       N          $ Do you want to double-check PANDA-type eigenvalues [type (H)elp]?
         0        $ Choose (0=transverse inextensional; 1=transverse extensional)
         1        $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
optimization -> 1 $ Choose type of analysis (ITYPE = 1 or 2 or 3 or 4 or 5)
       Y          $ Do you want to prevent secondary buckling (mode jumping)?
       N          $ Do you want to use the "alternative" buckling solution?
         5        $ How many design iterations permitted in this run (5 to 25)?
   1.000000       $ MAXMAR. Plot only those margins less than MAXMAR (Type H)
       N          $ Do you want to reset total iterations to zero (Type H)?
         1        $ Index for objective (1=min. weight, 2=min. distortion)
   1.000000       $ FMARG (Skip load case with min. margin greater than FMARG)
```

flat.axial.itype1.opt

input for MAINSETUP & PANDAOPT

Note: local & general buckling are the same phenomenon because there are no stiffeners.

Table 1.5 flat.axial.opp (output from optimization)

```
flat.OPP file from optimization under axial compression (29 June, 2008)

 ************ July 2007 VERSION OF PANDA2   ************
 ***************** THIS IS THE  flat.OPP FILE ******************

 ********************** STORE PROCESSOR *********************
 The purpose of STORE is to add the latest results for
 margins, design variables, and objective to those for previous
 iterations for the specific case called flat.  Later, when
 the final design has been obtained, the entire history of the
 design evolution for the specific case flat can be plotted.
 **********************************************************

  ITRTOT,NITER,ITRPLT,ITRLST = 5 1 5 4
  IAUTOC,ITIGHT,IDESGN= 0 0 2
  IITIGH(i),i=1,3= 0 0 0
  ITRMIN(i),i=1,3= 100000 100000 100000

 ****** DESIGN VARIABLES FOR   5 ITERATIONS ******

   1     T(1 )(SKN):thickness for layer index no.(1 ): SKN seg=1 , layer=1 =
  1.0000E-01  9.0000E-02  8.5811E-02  8.5811E-02  8.5811E-02

 ********** OBJECTIVE FOR   5 ITERATIONS *********

   1    WEIGHT OF THE ENTIRE PANEL =
  5.0000E+00  4.5000E+00  4.2906E+00  4.2906E+00  4.2906E+00

   1    Absolute values of maximum constraint gradients, GRDPLT =
  5.6873E+00  4.1476E+00  3.5955E+00  3.5955E+00  3.5955E+00

 ****** DESIGN MARGINS FOR   5 ITERATIONS ******
 ****** LOAD SET NO. 1                  ******
 ****** SUB-CASE (1=MIDLENGTH, 2=PANEL END)= 1 *****

   1   Local buckling: discrete model =
  7.9800E-01  3.1102E-01  1.3645E-01  1.3645E-01  1.3645E-01

   2   Local buckling: Koiter theory. =
  8.0040E-01  3.1270E-01  1.3788E-01  1.3788E-01  1.3788E-01

   3   eff.stress:matl=1; MID. =
  4.7862E-01  1.6049E-01  5.2012E-02  5.2012E-02  5.2012E-02

   4   Hi-axial-wave post-post-buckling of module =
  2.1668E-01  6.0958E-02  2.6643E-04  2.6655E-04  2.6655E-04

   5   buck(DONL)simp-support general buck; MIDLENGTH =
  8.0558E-01  3.1655E-01  1.4125E-01  1.4125E-01  1.4125E-01

 ****** DESIGN MARGINS FOR   5 ITERATIONS ******
 ****** LOAD SET NO. 1                  ******
 ****** SUB-CASE (1=MIDLENGTH, 2=PANEL END)= 2 *****

   1   Local buckling: discrete model =
  7.9800E-01  3.1102E-01  1.3645E-01  1.3645E-01  1.3645E-01

   2   Local buckling: Koiter theory. =
  8.0040E-01  3.1270E-01  1.3788E-01  1.3788E-01  1.3788E-01

   3   eff.stress:matl=1; ENDS =
  4.7862E-01  1.6049E-01  5.2012E-02  5.2012E-02  5.2012E-02

   4   Hi-axial-wave post-post-buckling of module =
  2.1668E-01  6.0955E-02  2.7037E-04  2.6989E-04  2.6989E-04

       SUMMARY OF STATE OF THE DESIGN WITH EACH ITERATION
 ==================================================================================
 ITERA   WEIGHT                        FOR EACH LOAD SET....       ANY ABRUPT CHANGES IN MO»
DE?
 TION      OF                  (IQUICK; NO. OF CRITICAL MARGINS)    SLOPE CHANGE? (m,n) CHAN»
GE?
 NO.     PANEL     LOAD SET NO.->  1        2        3        4        5      EIG. RATIOS   EIG. RATI»
OS
                                                     LOAD SET NO.->  1   2   3     1   2   »
3
                                                      SUBCASE NO.-> 1 2 1 2 1 2   1 2 1 2 1»
 2
```

note this value is slightly different from the value 0.087041, used later. This is because the value, 0.087041 was obtained from an earlier version of panda2 and the panel was not re-optimized before the results presented were generated. I was too lazy to do all that over again with the newer optimum t=0.085811 in

Table 1.5 (concluded)

```
-----------------------------------------------------------------------------------------------
-----------------------------------------------------PANDAOPT
  1 5.0000E+00      FEASIBLE   (0; 0)  (0; 0)  (0; 0)  (0; 0)  (0; 0)   0 0 0 0 0 0 N 0 0 0 0 0»
0
  2 4.5000E+00      FEASIBLE   (0; 0)  (0; 0)  (0; 0)  (0; 0)  (0; 0)   0 0 0 0 0 0 N 0 0 0 0 0»
0
  3 4.2906E+00      FEASIBLE   (0; 2)  (0; 0)  (0; 0)  (0; 0)  (0; 0)   0 0 0 0 0 0 N 0 0 0 0 0»
0
-----------------------------------------------------PANDAOPT
  4 4.2906E+00      FEASIBLE   (0; 2)  (0; 0)  (0; 0)  (0; 0)  (0; 0)   0 0 0 0 0 0 N 0 0 0 0 0»
0
-----------------------------------------------------PANDAOPT
  5 4.2906E+00      FEASIBLE   (0; 2)  (0; 0)  (0; 0)  (0; 0)  (0; 0)   0 0 0 0 0 0 N 0 0 0 0 0»
0

IOBJAL,ITRPLT=    0    5; OBJMN0,OBJPLT(ITRPLT)=  4.2906E+00  4.2906E+00
=====================================================================================
0
  VALUES OF DESIGN VARIABLES CORRESPONDING TO BEST FEASIBLE DESIGN
 VAR. STR/ SEG. LAYER   CURRENT
 NO.  RNG  NO.   NO.     VALUE          DEFINITION
  1   SKN   1     1    8.581E-02   T(1 )(SKN):thickness for layer index no.(1 ): SKN seg=1 , lay»
er=1

 **************************************************
 ******************* DESIGN OBJECTIVE ******************
 ************                            ***********
0
  CORRESPONDING VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER   CURRENT
 NO.  RNG  NO.   NO.     VALUE          DEFINITION
            0     0    4.291E+00   WEIGHT OF THE ENTIRE PANEL

 ************                            ***********
 ******************* DESIGN OBJECTIVE ******************
 **************************************************
 ITYPE,ITRTOT,ITRMX2,IAUTOC,ITIGHT,IITIGH(1),ITRMIN(1)=
      1       5    150       0       0       0  100000
 ITYPE,ITRTOT,ITRMX2,IAUTOC,ITIGHT,IITIGH(2),ITRMIN(1)=
      1       5    300       0       0       0  100000
 ITYPE,ITRTOT,ITRMX2,IAUTOC,ITIGHT,IITIGH(3),ITRMIN(2)=
      1       5    430       0       0       0  100000
```

optimum design

objective

```
 DESCRIPTION OF FILES USED AND GENERATED IN THIS RUN:

 flat.NAM = This file contains only the name of the case.
 flat.OPP = Output data. Please list this file and inspect
            carefully before proceeding.
 flat.CBL = Labelled common blocks for PANDA2 analysis.
            (This is an unformatted sequential file.)
 flat.PL1 = Binary file containing important results for plots
            from all design iterations except those correspond-
            ing to the final PANDAOPT command.
 flat.PL2 = Binary file containing important results for plots
            from all design iterations including those corres-
            ponding to the final PANDAOPT command.
 flat.PLD = Binary file containing all design parameters that
            are decision variable candidates and the objective
            function for all design iterations.
 flat.TIT = Binary file containing definitions of margins.
 flat.Pij = Binary files containing margins for all design
            iterations. i = subcase (1 or 2);  j = load set

 For further information about files used and generated
 during operation of PANDA2, give the command HELPAN FILES.

 Menu of commands: PANDAOPT, SUPEROPT, MAINSETUP, CHANGE,
                   DECIDE, CHOOSEPLOT, PANEL, STAGSMODEL
 NOTE: IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN,
       BE SURE TO RUN  PANDAOPT  MANY TIMES DURING AN
       OPTIMIZATION.
 ***************** END OF THE  flat.OPP FILE *****************
```

Table 1.6 flat.CPL (flat.axial.cpl)

```
n         $ Do you want a tutorial session and tutorial output?
y         $ Any design variables to be plotted v. iterations (Y or N)?
   1      $ Choose a variable to be plotted v. iterations (1,2,3,..)
n         $ Any more design variables to be plotted (Y or N) ?
y         $ Any design margins to be plotted (Y or N)?
   1      $ For which load set (1 - 5) do you want behavior/margins?
   1      $ Choose a sub-case (1 or 2) within this load set
   1      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y         $ Any more margins to be plotted (Y or N) ?
   2      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y         $ Any more margins to be plotted (Y or N) ?
   3      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y         $ Any more margins to be plotted (Y or N) ?
   4      $ Choose a margin to be plotted v. iterations (1,2,3,..)
y         $ Any more margins to be plotted (Y or N) ?
   5      $ Choose a margin to be plotted v. iterations (1,2,3,..)
n         $ Any more margins to be plotted (Y or N) ?
   1      $ Give maximum value (positive) to be included in plot frame.
y         $ Do you want a plot of the objective v. iterations (Y/N)?
```

input for "CHOOSEPLOT"

flat.3.ps = flat.margins.ps (axial load.)

output from "DIPLOT"

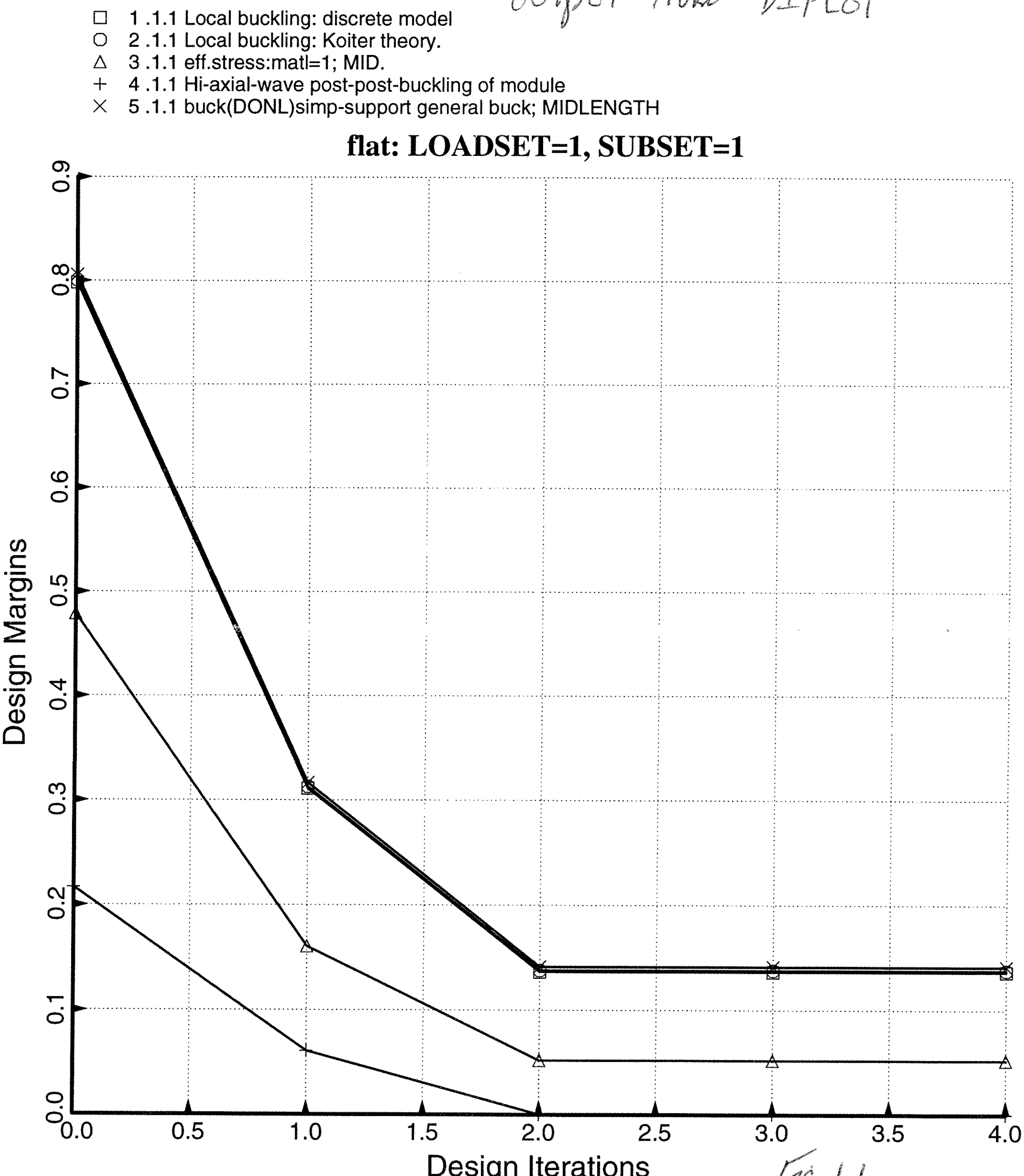



Fig. 1.1

flat.4.ps = flat.thickness.axialload.ps

output from "DIPLOT"

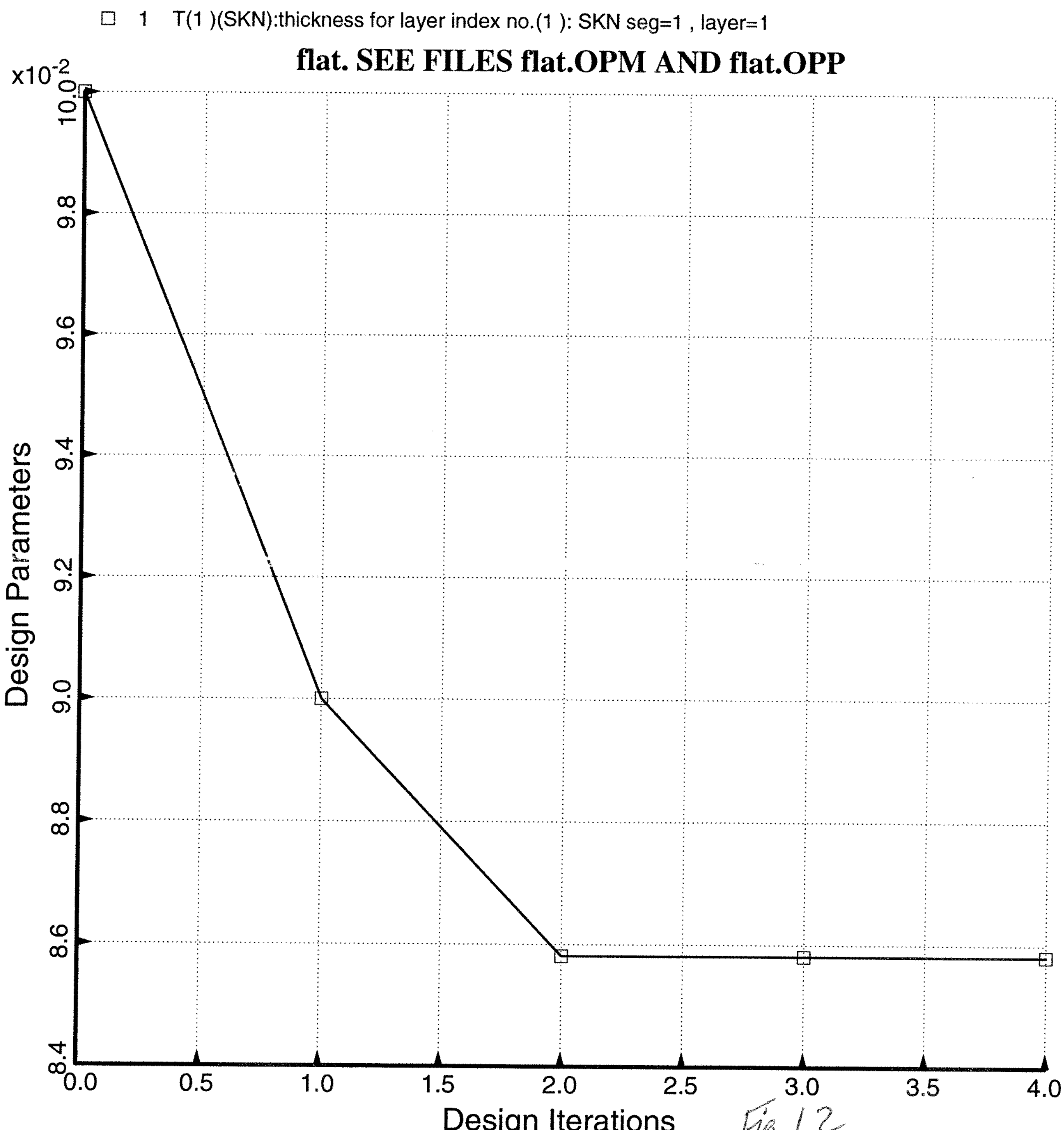



Fig. 1.2

axialload.
flat.5.ps = flat.objective.ps
output from DIPLOT

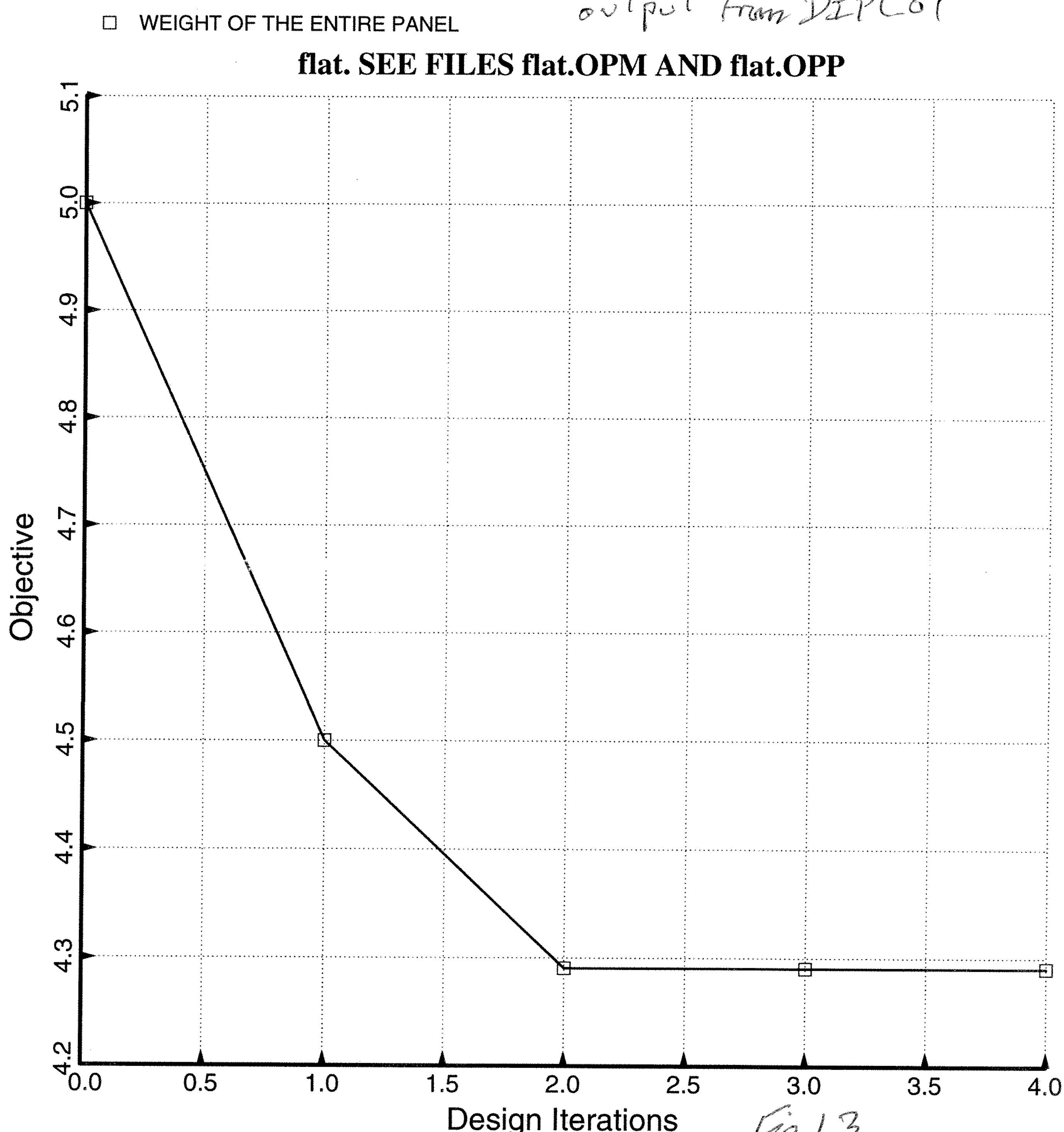



Fig. 1.3

Table 1.7 flat.OPT (fixed design)

```
      n          $ Do you want a tutorial session and tutorial output?
 -1000.000       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
        0        $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
        0        $ In-plane shear in load set A,                  Nxy( 1)
      n          $ Does the axial load vary in the L2 direction?
  0.000000       $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
  0.000000       $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
      Y          $ Want to include effect of transverse shear deformation?
        0        $ IQUICK = quick analysis indicator (0 or 1)
      Y          $ Do you want to vary M for minimum local buckling load?
      N          $ Do you want to choose a starting M for local buckling?
      Y          $ Do you want to perform a "low-axial-wavenumber" search?
 0.2000000       $ Factor of safety for general instability, FSGEN( 1)
 0.2000000       $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
  1.000000       $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
  1.000000       $ Factor of safety for stress, FSSTR( 1)
      Y          $ Do you want "flat skin" discretized module for local buckling?
      N          $ Do you want wide-column buckling to constrain the design?
  0.000000       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
  0.000000       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
        0        $ Axial load applied along the (0=neutral plane), (1=panel skin)
  0.000000       $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
  0.000000       $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
  0.010000       $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
  0.010000       $ Initial local imperfection amplitude (must be positive), Wloc( 1)
      Y          $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
       50        $ Axial halfwavelength of typical general buckling mode, AXLWAV( 1)
      Y          $ Do you want PANDA2 to find the general imperfection shape?( 1)
  1.000000       $ Maximum allowable average axial strain (type H for HELP)( 1)
      N          $ Is there any thermal "loading" in this load set (Y/N)?
      Y          $ Do you want a "complete" analysis (type H for "Help")?
      N          $ Want to provide another load set ?
      N          $ Do you want to impose minimum TOTAL thickness of any segment?
      N          $ Do you want to impose maximum TOTAL thickness of any segment?
      N          $ Use reduced effective stiffness in panel skin (H(elp), Y or N)?
note --> 2       $ NPRINT= output index (-1=min. 0=good, 1=ok, 2=more, 3=too much)
        0        $ Index for type of shell theory (0 or 1 or 2), ISAND
      Y          $ Does the postbuckling axial wavelength of local buckles change?
      Y          $ Want to suppress general buckling mode with many axial waves?
      N          $ Do you want to double-check PANDA-type eigenvalues [type (H)elp]?
        0        $ Choose (0=transverse inextensional; 1=transverse extensional)
        1        $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
note --> 2       $ Choose type of analysis (ITYPE = 1 or 2 or 3 or 4 or 5)
      Y          $ Do you want to prevent secondary buckling (mode jumping)?
      N          $ Do you want to use the "alternative" buckling solution?
        5        $ How many design iterations permitted in this run (5 to 25)?
  1.000000       $ MAXMAR. Plot only those margins less than MAXMAR (Type H)
      N          $ Do you want to reset total iterations to zero (Type H)?
        1        $ Index for objective (1=min. weight. 2=min. distortion)
  1.000000       $ FMARG (Skip load case with min. margin greater than FMARG)
```

flat.axial.itype2.opt

input to "MAINSETUP" & "PANDAOPT"

Table 1.8 flat.OPM (flat.axial.itype2.abridged.opm) (output from PANDAOPT)

abridged flat.OPM file corresponding to pure axial compression

(Note: these results are for a slightly different thickness t=0.087041 inch, from the optimum value, 0.085811, ~~printed~~ presented in the flat.OPP File listed earlier in Table 1.5)

```
 CHAPTER 26 Compute local, inter-ring, general buckling load
            factors from PANDA-type models [1B] and from
            "alternative" (double-trigonometric series
            expansion) models, Ref.[1G]. Also compute
            sandwich wall behavior [1F], if applicable.

*** BEGIN SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS) ****

 Number of constraints, NCONST=        0

  LABEL NO. IN STRUCT= 9260
 ******* ENTERING BUCPAN FROM STRUCT OR STRIMP:
 ILABEL,IPRELM,IGENRL,IGENX,    EIGMAX=
  9260     0     0     0  1.0000E+07

 general buckling: smeared stiffeners, C11=  9.5649E+05, radius, R=  5.0990E+05
 ******** ENTERING GENSTB: PANDA-type buckling model ********
 PANDA-type buckling theory is described in the journal paper:
 D. Bushnell, "Theoretical basis of the PANDA computer program"
 Computers & Structures, Vol. 27, No. 4, pp. 541-563, 1987
 Also see Items 415 and 443 in ...panda2/doc/panda2.news.
 ILABEL = unique "CALL GENSTB" within SUBROUTINE BUCPAN
 ILABLY = label number near where SUBROUTINE BUCPAN is called.
   ILABEL, ILABLY, IDESGN,  ISAND,    INDX,    ITHRU,   IROLL    IFFLAT =
    7195    9260      0       0        2        1        0        1
  Radius  R,    Axial length, A,    Width  B
  5.099020E+05  5.000000E+01  1.000000E+01
 Initial imperfections for general, panel, local buckling=
 Total out-of-roundness + modal,     W0GLOB =  1.0000E-02
 Out-of-roundness,                      WG1  =  0.0000E+00
 General buckling modal,                WG2  =  1.0000E-02
 Inter-ring buckling modal,           W0PAN =  1.0000E-02
 Local buckling modal,                W0LOC =  1.0000E-02
 ***** NOTE: Panel is modelled as if it were flat. *****
 ***** Donnell theory is used in this section (ISAND=0)
 Load Set A: Nx,  Ny,  Nxy= -1.0000E+03  0.0000E+00  5.0000E+00
 Load Set B: Nxo, Nyo, Nxyo=  0.0000E+00  0.0000E+00  0.0000E+00
 Membrane stiffnesses ((C(i,j),j=1,3),i=1,3)=
  9.5649E+05  2.8695E+05  0.0000E+00
  2.8695E+05  9.5649E+05  0.0000E+00
  0.0000E+00  0.0000E+00  3.3477E+05
      R/B,       C44MLT,       C44N,       C55N,       FFLAT=
  1.0000E+04  1.0000E+00  6.3134E-04  6.3134E-04  1.0000E+00
 Test for direction panel is long: TEST=(A/B)*SQRT(C55N/(C44N*C44MLT))=5.00E+00
 If TEST > 0.99 then d = 0;  c = SLOPE (panel is long in x-direction, Fig.(9a).
 If TEST < 0.99 then d = SLOPE; c = 0. (panel is long in y-direction, Fig.(9b).
 See Eq.(51) and Fig. 9 of "Theoretical basis..." paper (1987).
 ***(low-n)***
 (high-m) mode:ICHEK ISAND  m    n      s       EIGENVALUE  TEST
                 0     0    5    1  0.000E+00  2.384E-01  5.000E+00
 Ratio needed in ARBOCZ: EIGTST/EIGTS2= EIGRAT=  1.0000E+00

 EIGMNC=  5.01E-01  1.00E+17  2.38E-01  1.00E+17  1.00E+17  1.61E+00  1.00E+17
 SLOPEX=  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00  0.00E+00
 MWAVEX=     2         0         5         0         0         1         0
 NWAVEX=     1         0         1         0         0         1         0
 TESTX =  5.00E+00  0.00E+00  5.00E+00  0.00E+00  0.00E+00  5.00E+00  0.00E+00
 Before refinement (before CALL EIG), EIGVAL,CSLOPE=  2.3840E-01  0.0000E+00
  After refinement ( after CALL EIG), EIGVAL,CSLOPE=  2.3840E-01  0.0000E+00
```

{critical buckling load factor}

compare with value from STAGS given later in Table 1.20 & Figs. 1.16 & 1.30

(many, many lines omitted to save space)

```
 CHAPTER 28 Present design, loading, and margins for the
            current load set and subcase. See Table 6 in
 Bushnell, D.
 "Optimization of an axially compressed ring and stringer
 stiffened cylindrical shell with a general buckling modal
 imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
 Honolulu, Hawaii, April 2007
0
          SUMMARY OF INFORMATION FROM OPTIMIZATION ANALYSIS
 VAR. DEC. ESCAPE LINK. LINKED  LINKING    LOWER    CURRENT    UPPER        DEFINITION
  NO. VAR.  VAR.  VAR.    TO   CONSTANT    BOUND     VALUE     BOUND
   1   Y     Y     N      0    0.00E+00  1.00E-02  8.7041E-02  1.00E+00     T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
```

Table 1.8 (end) flat OPM (continued)

```
 Local buckling load factor from KOITER theory =  2.3750E-01 (flat skin)
 Local buckling load factor from BOSOR4 theory =  2.3720E-01 (flat skin)

*********** LOAD SET NO. 1   **************
ICASE =  1  (ICASE=1 MEANS PANEL MIDLENGTH)
            (ICASE=2 MEANS PANEL ENDS                         )

  APPLIED LOADS IN LOAD SET A ("eigenvalue" loads):
        Applied     axial       stress resultant, Nx= -1.0000E+03
        Applied circumferential stress resultant, Ny=  0.0000E+00
        Applied    in-plane     shear  resultant,Nxy=  5.0000E+00
        Applied     axial       moment resultant, Mx=  0.0000E+00
        Applied circumferential moment resultant, My=  0.0000E+00
        Applied pressure (positive for upward),    p =  0.0000E+00

  APPLIED LOADS IN LOAD SET B ( fixed uniform loads):
        Applied     axial       stress resultant,Nx0=  0.0000E+00
        Applied circumferential stress resultant,Ny0=  0.0000E+00
        Applied    in-plane    shear  resultant,Nxy0=  0.0000E+00

NOTE: "F.S." means "Factor of Safety";
"DONL" means "Donnell shell theory used.";
"SAND" means "Sanders shell theory used." panda2.news ITEM 128
"Dseg" means "Segment numbering used in discretized model"
"Iseg" means "Segment numbering used for input data." ITEM 272
0
MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
MAR. MARGIN
NO.  VALUE                DEFINITION
1   1.86E-01 Local buckling from discrete model-1.,M=5   axial halfwaves;FS=0.2
2   1.87E-01 Local buckling from Koiter theory,M=5   axial halfwaves;FS=0.2
3   8.21E-02 eff.stress:matl=1,SKN,Dseg=2,node=1,layer=1,z=0.0435; MID.;FS=1.
4   1.82E-02 Hi-axial-wave post-post-buckling of module - 1;   M=10 ;FS=1.
5   2.18E+00 eff.stress:matl=1,SKN,Iseg=1,allnode,layer=1,z=-0.0435;-MID.;FS=1.
6   1.91E-01 buck.(DONL);simp-support general buck;M=5;N=1;slope=0.;FS=0.2
7   2.52E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
8   1.91E-01 buck.(SAND);simp-support general buck;M=5;N=1;slope=0.;FS=0.2
```

Note: in this case "local" & "general" buckling are the same phenomenon because there are no stiffeners.

Table 1.9

flat.axial.itype3.runstream

25 June, 2008

RUNSTREAM FOR ITYPE=3 ANALYSIS OF FIXED (OPTIMUM DESIGN)

NAME OF CASE = "flat"

LOADING = pure axial compression:
Nx = -50, -100, -150, -200, -250, ..., -1000 lb/in

Runstream follows:

```
                                                                       Table 1.2
panda2log       (activate PANDA2 commands)
begin           (establish starting design. Input = flat.BEG)          Table 1.10
change          (change thickness to optimum.
                  cp flat.axial.chg flat.CHG; Input=flat.CHG)          Table 1.3
setup           (PANDA2 sets up matrix templates)
decide          (choose decision variables and bounds. Input=flat.DEC)
mainsetup       (choose loading, strategy, analysis type, etc.         Table 1.11
                 cp flat.axial.itype3.opt flat.OPT, Input = flat.OPT)
pandaopt        (PANDA2 performs ITYPE=3 analysis. Input=flat.OPT)
chooseplot      (choose what to plot. Input = flat.CPL = flat.cpl31)   Table 1.12
diplot          (PANDA2 gets postscript plot files, flat.3.ps, flat.4.ps,
                 flat.5.ps, flat.7.ps, flat.8.ps, flat.9.ps, flat.10.ps) Figs. 1.4, 1.5, 1.6, 1.8, 1.10, 1.11, 1.12
chooseplot      (choose what to plot. Input = flat.CPL = flat.cpl32)
diplot          (PANDA2 gets postscript plot file, flat.4.ps)          Table 1.13
mainsetup       (change imperfection amplitude from 0 to 0.1 inch)     Fig. 1.13
pandaopt        (PANDA2 performs ITYPE=3 analysis. Input=flat.OPT)     Table 1.14
chooseplot      (choose what to plot. Input = flat.CPL = flat.cpl32)   Table 1.15
diplot          (PANDA2 gets postscript plot file, flat.4.ps)
chooseplot      (choose what to plot. Input = flat.CPL = flat.cpl33)   Fig. 1.14
diplot          (PANDA2 gets postscript plot file, flat.4.ps)          Table 1.16
cleanpan        (PANDA2 cleans up files, saving only the input files)  Fig. 1.15
```

ITYPE=3 means analysis of a "fixed" design under increasing load, such as would occur during a static test of the previously optimized design

Table 1.10 flat.CHG (flat.axial.chg)

```
    n          $ Do you want a tutorial session and tutorial output?
    y          $ Do you want to change any values in Parameter Set No. 1?
       1       $ Number of parameter to change (1, 2, 3, . .)
0.8704100E-01  $ New value of the parameter
    n          $ Want to change any other parameters in this set?
    n          $ Do you want to change values of "fixed" parameters?
    n          $ Do you want to change values of allowables?
```

input for "CHANGE"

Note: The old optimum value, 0.087041, is used because I did this "fixed" design test simulation before I re-optimized the plate with the latest version of PANDA2. Also, I used a small imperfection (0.01" amplitude) in the new optimization, whereas previously I had optimized with zero imperfection amplitude.

Table 6.11 flat.OPT ~~(flat.opt3)~~ pure axial compress.

ITYPE = 3

```
            n         $ Do you want a tutorial session and tutorial output?
note ->   -50.000     $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
               0      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
               0      $ In-plane shear in load set A,                        Nxy( 1)
            n         $ Does the axial load vary in the L2 direction?
        0.000000      $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
        0.000000      $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
            Y         $ Want to include effect of transverse shear deformation?
               0      $ IQUICK = quick analysis indicator (0 or 1)
            Y         $ Do you want to vary M for minimum local buckling load?
            N         $ Do you want to choose a starting M for local buckling?
            Y         $ Do you want to perform a "low-axial-wavenumber" search?
       0.2000000      $ Factor of safety for general instability, FSGEN( 1)
       0.2000000      $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
        1.000000      $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
        1.000000      $ Factor of safety for stress, FSSTR( 1)
            Y         $ Do you want "flat skin" discretized module for local buckling?
            N         $ Do you want wide-column buckling to constrain the design?
        0.000000      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
        0.000000      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
               0      $ Axial load applied along the (0=neutral plane), (1=panel skin)
        0.000000      $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
        0.000000      $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
        0.000000      $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
    0.1000000E-06     $ Initial local imperfection amplitude (must be positive), Wloc( 1)
            Y         $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
              50      $ Axial halfwavelength of typical general buckling mode, AXLWAV( 1)
            Y         $ Do you want PANDA2 to find the general imperfection shape?( 1)
        1.000000      $ Maximum allowable average axial strain (type H for HELP)( 1)
            N         $ Is there any thermal "loading" in this load set (Y/N)?
            Y         $ Do you want a "complete" analysis (type H for "Help")?
            N         $ Want to provide another load set ?
            N         $ Do you want to impose minimum TOTAL thickness of any segment?
            N         $ Do you want to impose maximum TOTAL thickness of any segment?
            N         $ Use reduced effective stiffness in panel skin (H(elp), Y or N)?
               0      $ NPRINT= output index (-1=min. 0=good, 1=ok, 2=more, 3=too much)
               0      $ Index for type of shell theory (0 or 1 or 2), ISAND
            Y         $ Does the postbuckling axial wavelength of local buckles change?
            Y         $ Want to suppress general buckling mode with many axial waves?
            N         $ Do you want to double-check PANDA-type eigenvalues [type (H)elp]?
               0      $ Choose (0=transverse inextensional; 1=transverse extensional)
               1      $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
Note   ------> 3      $ Choose type of analysis (ITYPE = 1 or 2 or 3 or 4 or 5)
            y         $ Do you want to prevent secondary buckling (mode jumping)?
            n         $ Do you want to use the "alternative" buckling solution?
               1      $ Choose one of the load sets:  ILOAD
               1      $ Choose one of the sub cases (1  or  2):  ICASE
       -50.00000      $ Increment in axial resultant Nx:  DNX
               0      $ Increment in hoop resultant Ny:  DNY
               0      $ Increment in shear resultant Nxy:  DNXY
               0      $ Increment in axial moment resultant Mx:  DMX
               0      $ Increment in circumferential moment resultant My:  DMY
               0      $ Increment in pressure, p:  DP
               0      $ Starting multiplier for temperature distribution, TMULT
               0      $ Multiplier increment for temperature distribution, DTMULT
              20      $ Maximum number of load steps, NSTEPS
```

flat.axial.itype3.opt = input for "MAINSETUP" & "PANDAOPT"

ITYPE = 3 means fixed design with increasing load. As if you were testing the optimized panel.

Table 1.12 flat.CPL = ~~flat.cpl31~~ flat.axial.cpl31

```
n          $ Do you want a tutorial session and tutorial output?
  1        $ For which load set (1 - 5) do you want behavior/margins?
  1        $ Choose a sub-case (1 or 2) within this load set
  1        $ Indicate which load component to use in plots (1,2,...7)
y          $ Any behaviors to be plotted v. load steps (Y or N)?
  2        $ Choose a behavior to be plotted v. load steps
n          $ Any more behaviors to be plotted v. load steps (Y/N)?
y          $ Any extreme fiber strains to be plotted v. load steps?
  1        $ Choose (axial,hoop) or (+45deg,-45deg) strain plots (1 or 2)
  1        $ Choose a location (1, 2, ...) for strain plots
y          $ Any more locations for plotting v. load steps (Y/N)?
  6        $ Choose a location (1, 2, ...) for strain plots
n          $ Any more locations for plotting v. load steps (Y/N)?
y          $ Any design margins to be plotted (Y or N)?
  1        $ Choose a margin to be plotted v. iterations (1,2,3,..)
y          $ Any more margins to be plotted (Y or N) ?
  2        $ Choose a margin to be plotted v. iterations (1,2,3,..)
y          $ Any more margins to be plotted (Y or N) ?
  3        $ Choose a margin to be plotted v. iterations (1,2,3,..)
y          $ Any more margins to be plotted (Y or N) ?
  4        $ Choose a margin to be plotted v. iterations (1,2,3,..)
y          $ Any more margins to be plotted (Y or N) ?
  5        $ Choose a margin to be plotted v. iterations (1,2,3,..)
y          $ Any more margins to be plotted (Y or N) ?
  6        $ Choose a margin to be plotted v. iterations (1,2,3,..)
y          $ Any more margins to be plotted (Y or N) ?
  7        $ Choose a margin to be plotted v. iterations (1,2,3,..)
n          $ Any more margins to be plotted (Y or N) ?
  5        $ Give maximum value (positive) to be included in plot frame.
y          $ Any deformed panel module cross sections to be plotted?
  2        $ Choose a load step for which to plot the panel module
y          $ Any more load steps for which to plot panel module (Y/N)?
  5        $ Choose a load step for which to plot the panel module
y          $ Any more load steps for which to plot panel module (Y/N)?
  7        $ Choose a load step for which to plot the panel module
y          $ Any more load steps for which to plot panel module (Y/N)?
 10        $ Choose a load step for which to plot the panel module
y          $ Any more load steps for which to plot panel module (Y/N)?
 13        $ Choose a load step for which to plot the panel module
y          $ Any more load steps for which to plot panel module (Y/N)?
 17        $ Choose a load step for which to plot the panel module
y          $ Any more load steps for which to plot panel module (Y/N)?
 20        $ Choose a load step for which to plot the panel module
n          $ Any more load steps for which to plot panel module (Y/N)?
n          $ Do you want to plot layers in skin-stringer module (Y/N)?
y          $ Do you want a "3-D" plot of the buckled panel module (Y/N)?
```

input for "CHOOSEPLOT"

flat.3.ps (from flat.axial.cpl31)

output from DIPLOT
(next several figures)

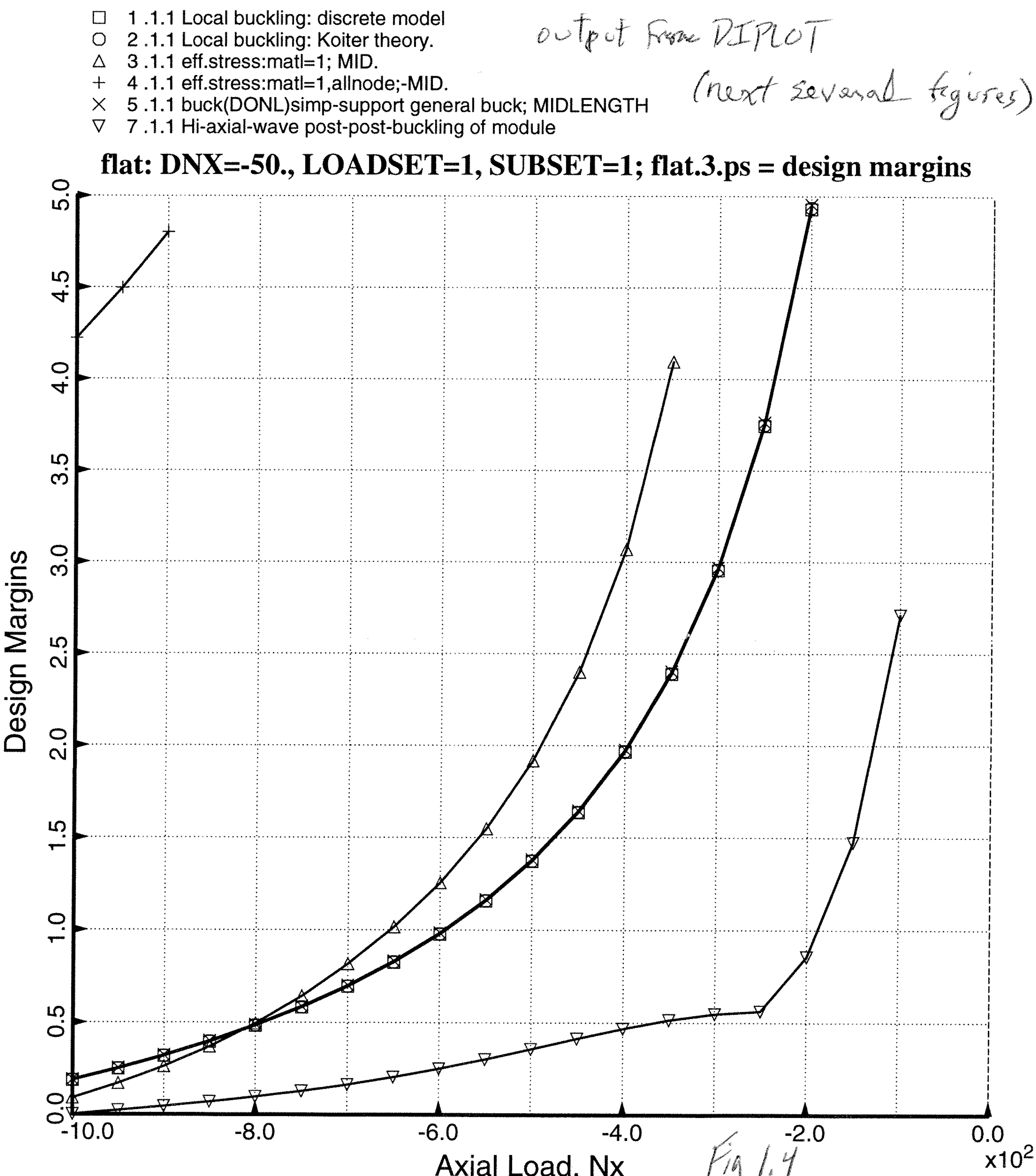
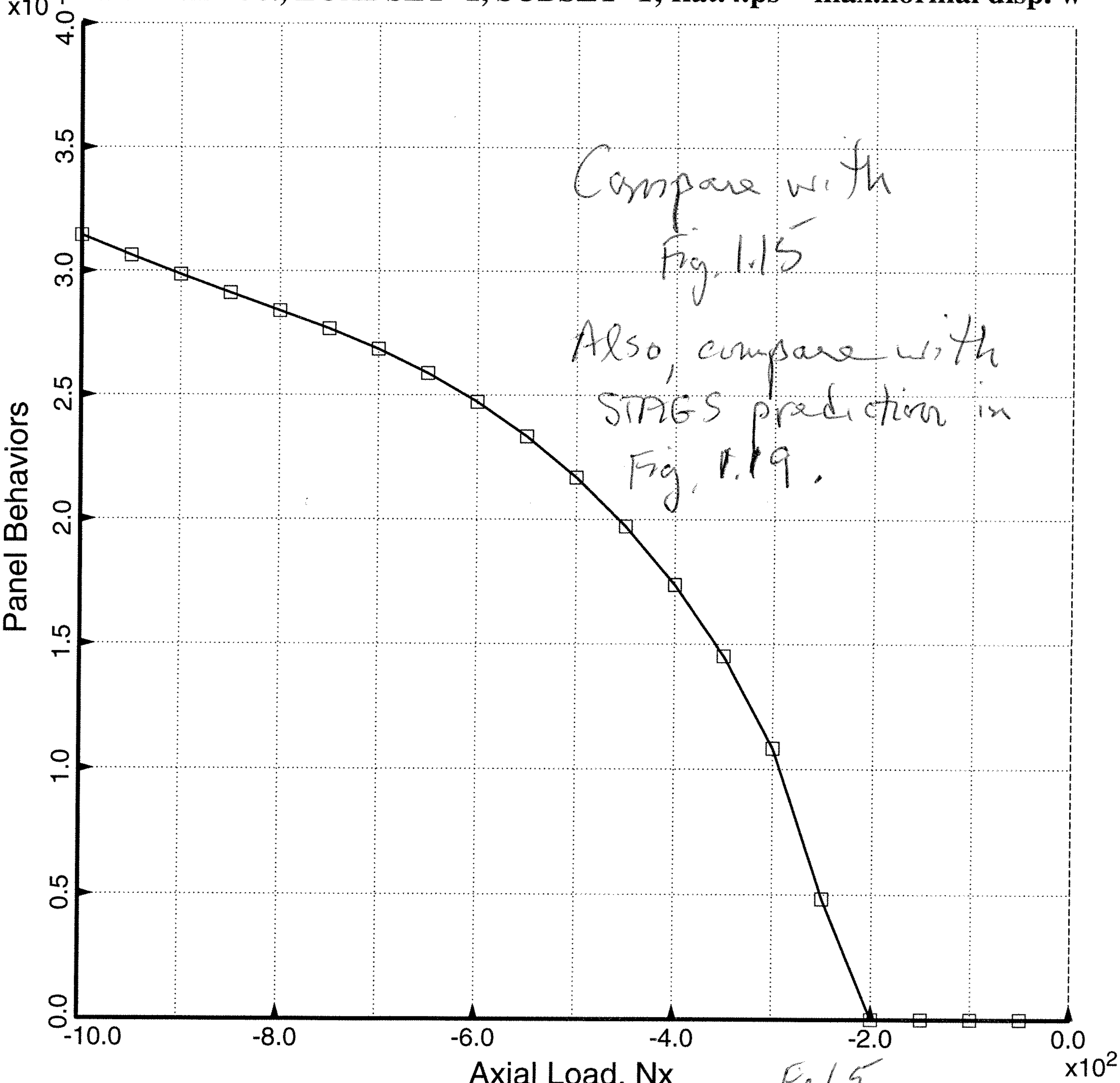



Fig. 1.4

flat.4.ps (from flat.axial.cpl31)
(imperfection amplitude = 0)

□ 2 .1.1 Max.disp.w in panel module, w(max)=Wimplocal+Wpostbuck+Wpillow

**flat: DNX=-50., LOADSET=1, SUBSET=1; flat.4.ps = max.normal disp. w**




Compare with Fig. 1.15

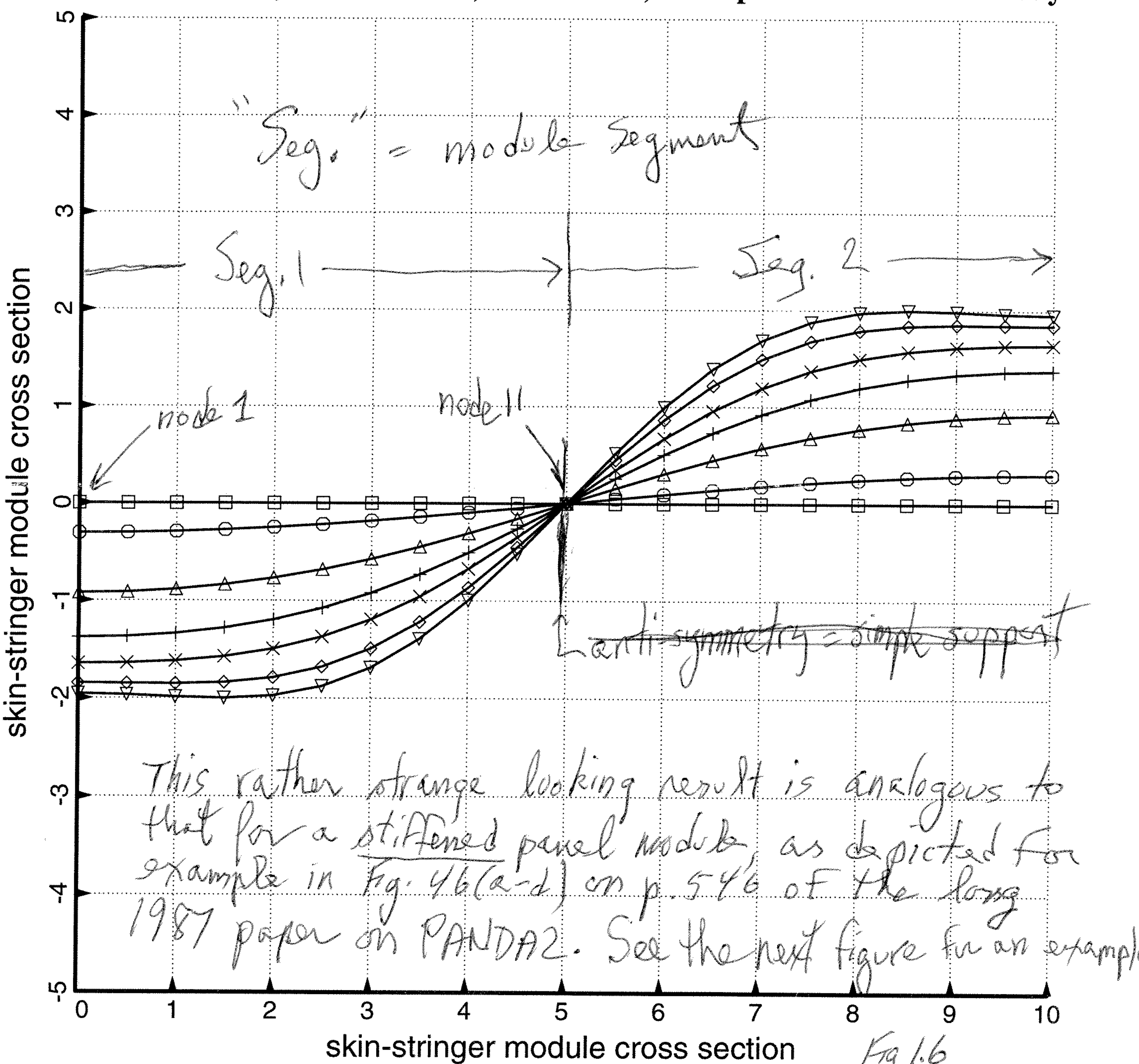
Also, compare with STAGS prediction in Fig. 1.19.

Fig 1.5

flat.5.ps (from flat.axial.cp131)

□ 2 .1.1 Panel module deformed by loads in step no. 2
○ 5 .1.1 Panel module deformed by loads in step no. 5
△ 7 .1.1 Panel module deformed by loads in step no. 7
+ 10.1.1 Panel module deformed by loads in step no. 10
× 13.1.1 Panel module deformed by loads in step no. 13
◇ 17.1.1 Panel module deformed by loads in step no. 17
▽ 20.1.1 Panel module deformed by loads in step no. 20

**flat: DNX=-50., LOADSET=1, SUBSET=1; flat.5.ps = w vs. width coord. y**




This rather strange looking result is analogous to that for a stiffened panel module, as depicted for example in Fig. 46(a-d) on p. 546 of the long 1987 paper on PANDA2. See the next figure for an example

Fig. 1.6

riks.5.ps (riks.panda2case.module.ps)

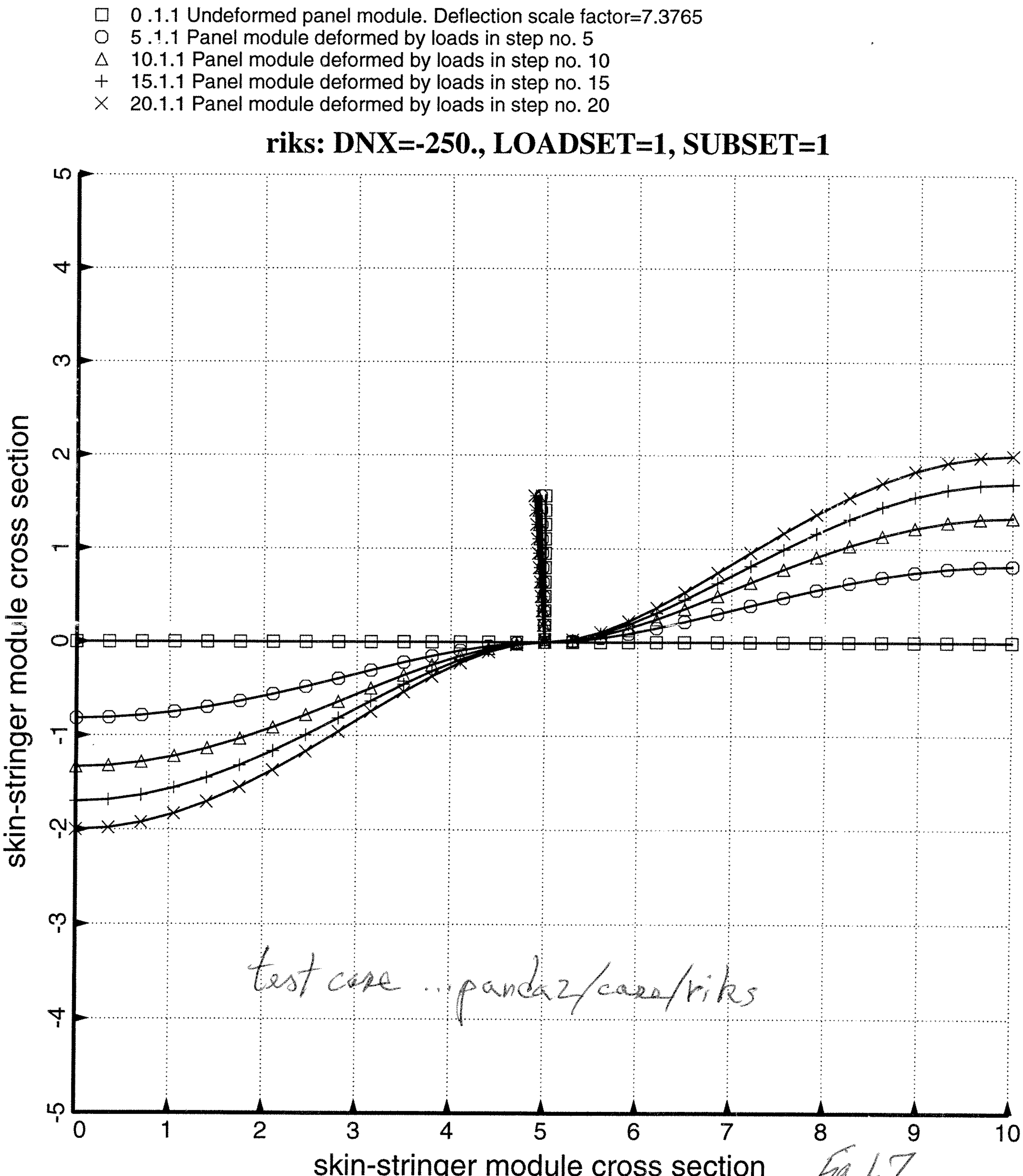
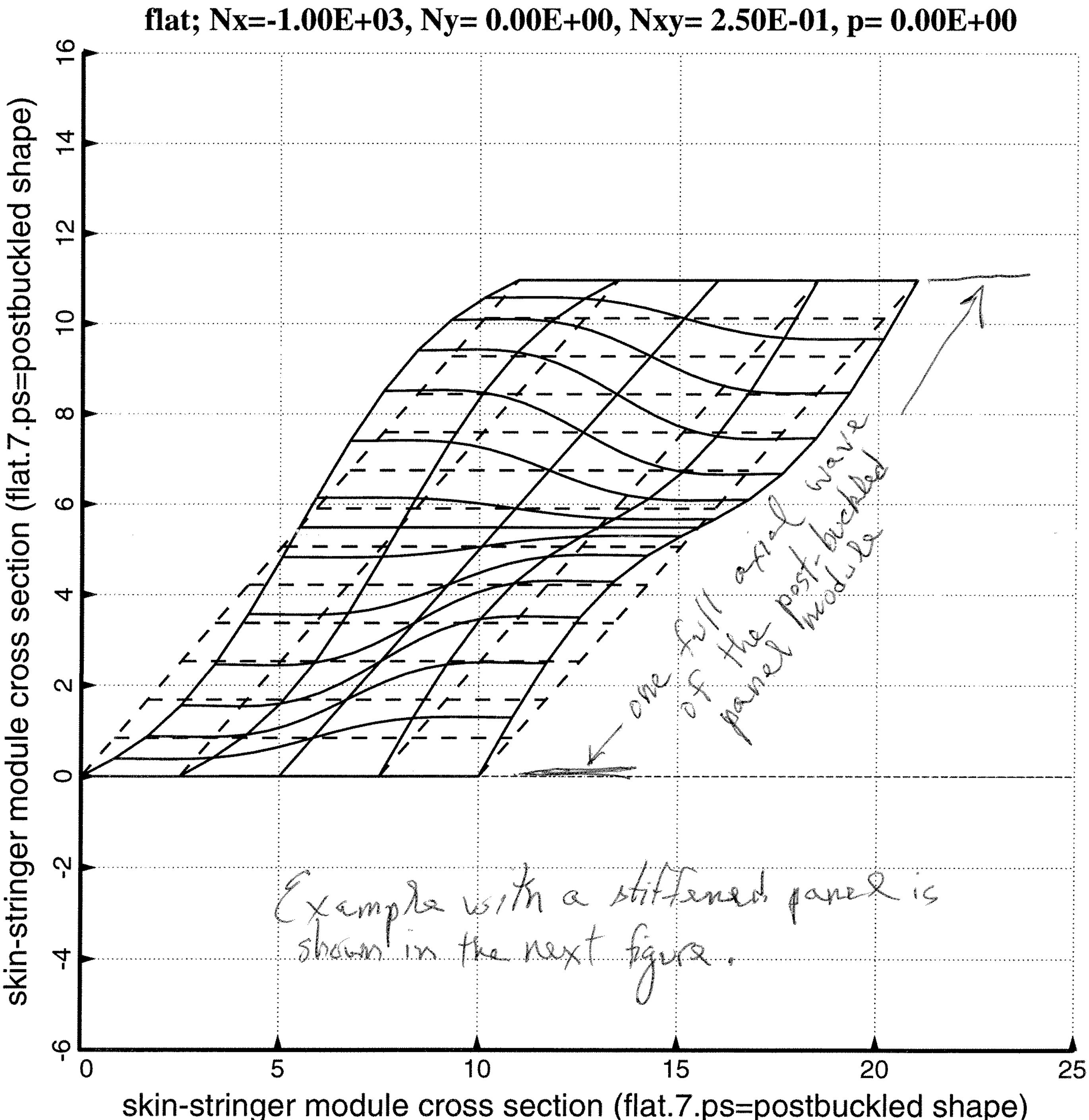



Fig. 1.7

flat.7.ps (from flat.axial.CPL31)




Example with a stiffened panel is shown in the next figure.



Fig. 1.8

riks.7.ps (riks.panda2case.3D.ps)

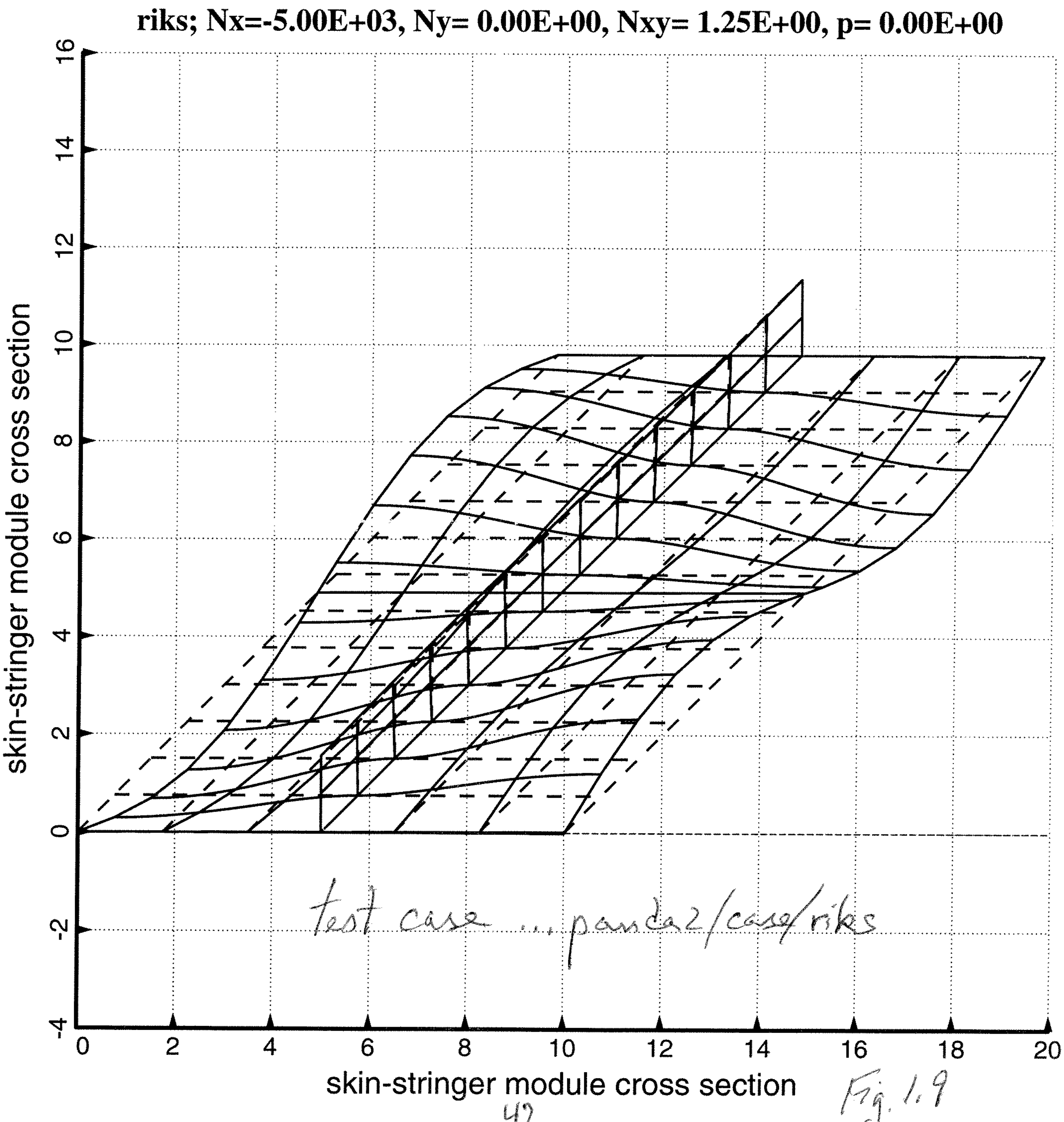



Fig. 1.9

flat.8.ps (from flat.axial.cpl31)

□ 1 .1.1 Layer 1 Extreme fiber AXIAL strains at seg. 1, node 1
○ 1 .1.1 Layer n Extreme fiber AXIAL strains at seg. 1, node 1 } traces 1 & 2
△ 6 .1.1 Layer 1 Extreme fiber AXIAL strains at seg. 1, node 11
\+ 6 .1.1 Layer n Extreme fiber AXIAL strains at seg. 1, node 11 } traces 3 & 4

**flat: DNX=-50., LOADSET=1, SUBSET=1; flat.8.ps=extreme fiber axial strain**

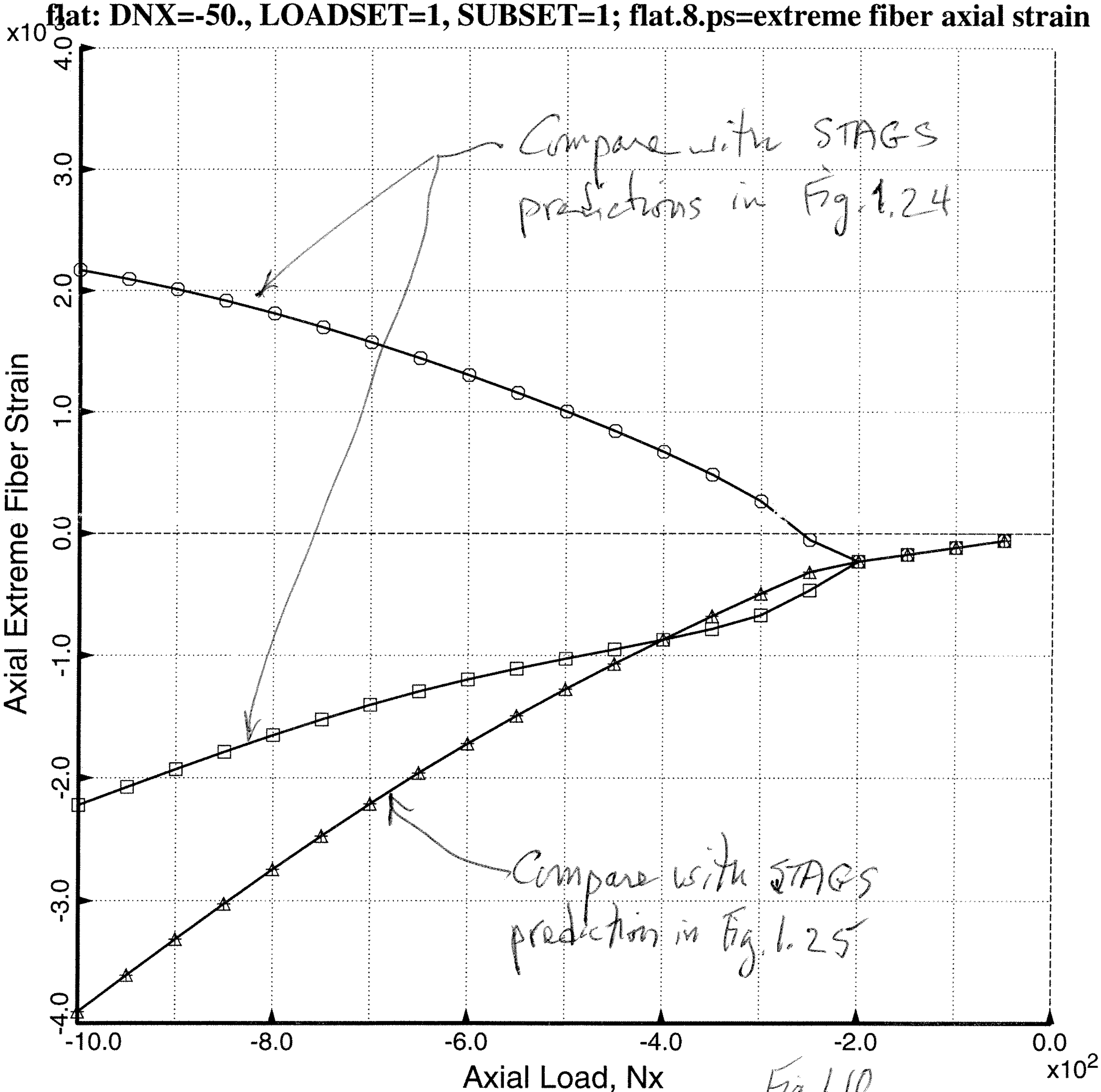



Fig. 1.10

flat.9.ps (from flat.cpl31 axial.)

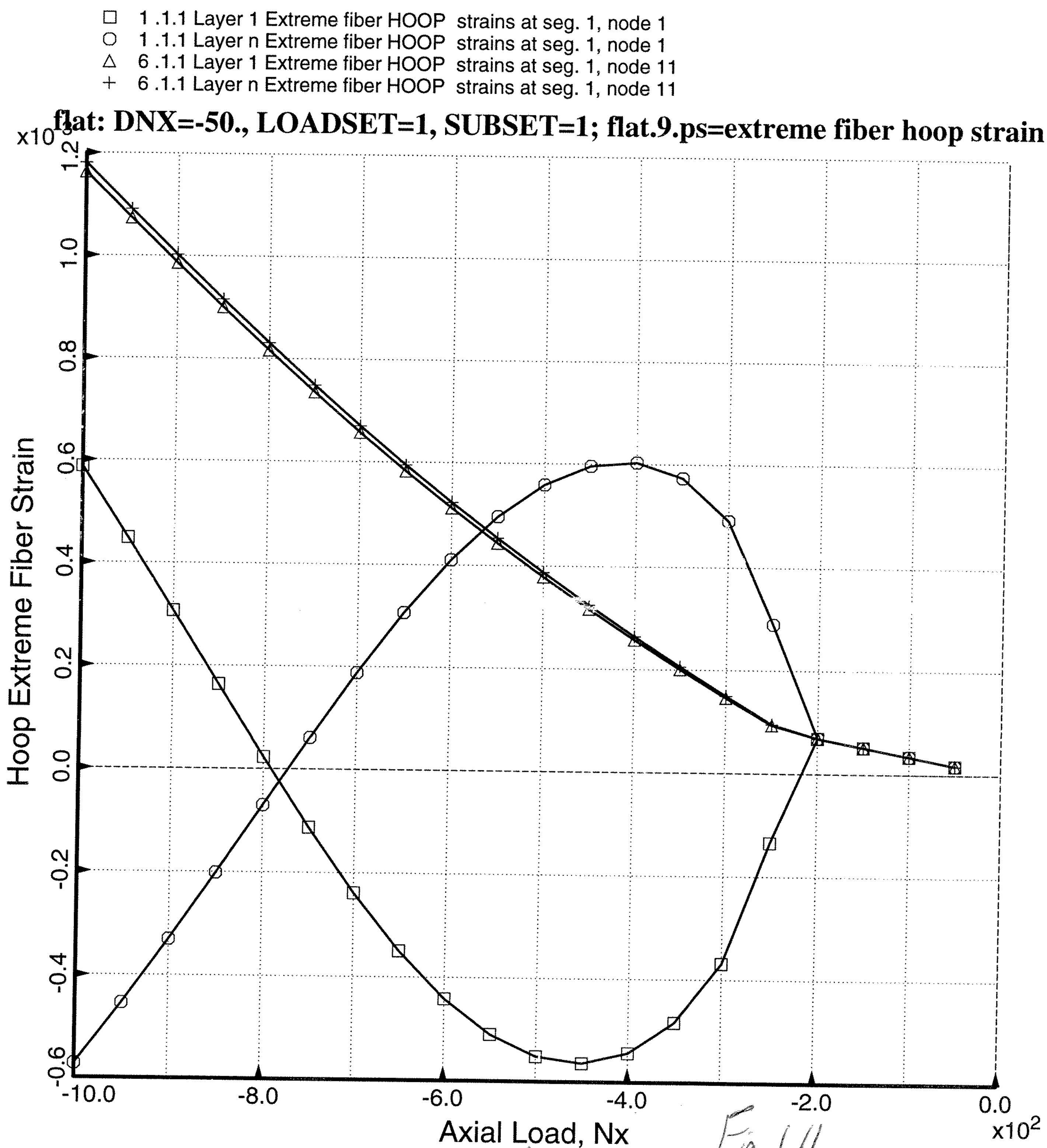



Fig. 1.11

flat.10.ps (from flat.axial.cpl31)

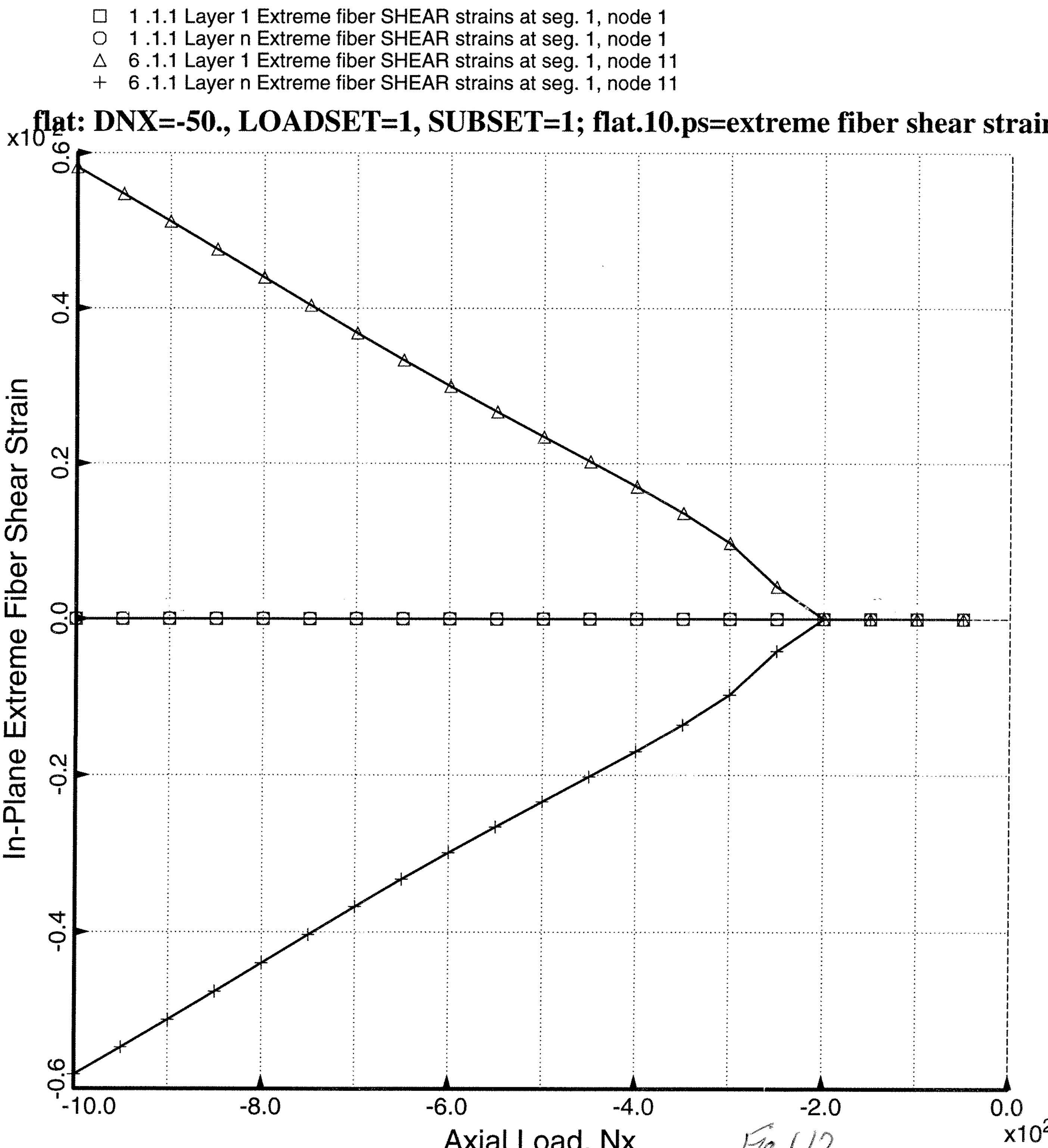



Fig. 1.12

Table 1.13 flat.CPL (flat.axial.cpl32)

```
n           $ Do you want a tutorial session and tutorial output?
    1       $ For which load set (1 - 5) do you want behavior/margins?
    1       $ Choose a sub-case (1 or 2) within this load set
    1       $ Indicate which load component to use in plots (1,2,...7)
y           $ Any behaviors to be plotted v. load steps (Y or N)?
    7       $ Choose a behavior to be plotted v. load steps
y           $ Any more behaviors to be plotted v. load steps (Y/N)?
    8       $ Choose a behavior to be plotted v. load steps
y           $ Any more behaviors to be plotted v. load steps (Y/N)?
    9       $ Choose a behavior to be plotted v. load steps
n           $ Any more behaviors to be plotted v. load steps (Y/N)?
n           $ Any extreme fiber strains to be plotted v. load steps?
n           $ Any design margins to be plotted (Y or N)?
n           $ Any deformed panel module cross sections to be plotted?
n           $ Do you want to plot layers in skin-stringer module (Y/N)?
n           $ Do you want a "3-D" plot of the buckled panel module (Y/N)?
```

input for CHOOSEPLOT

flat.4.ps (from flat.axial Cpl32)
(imperfection amplitude = 0.0)

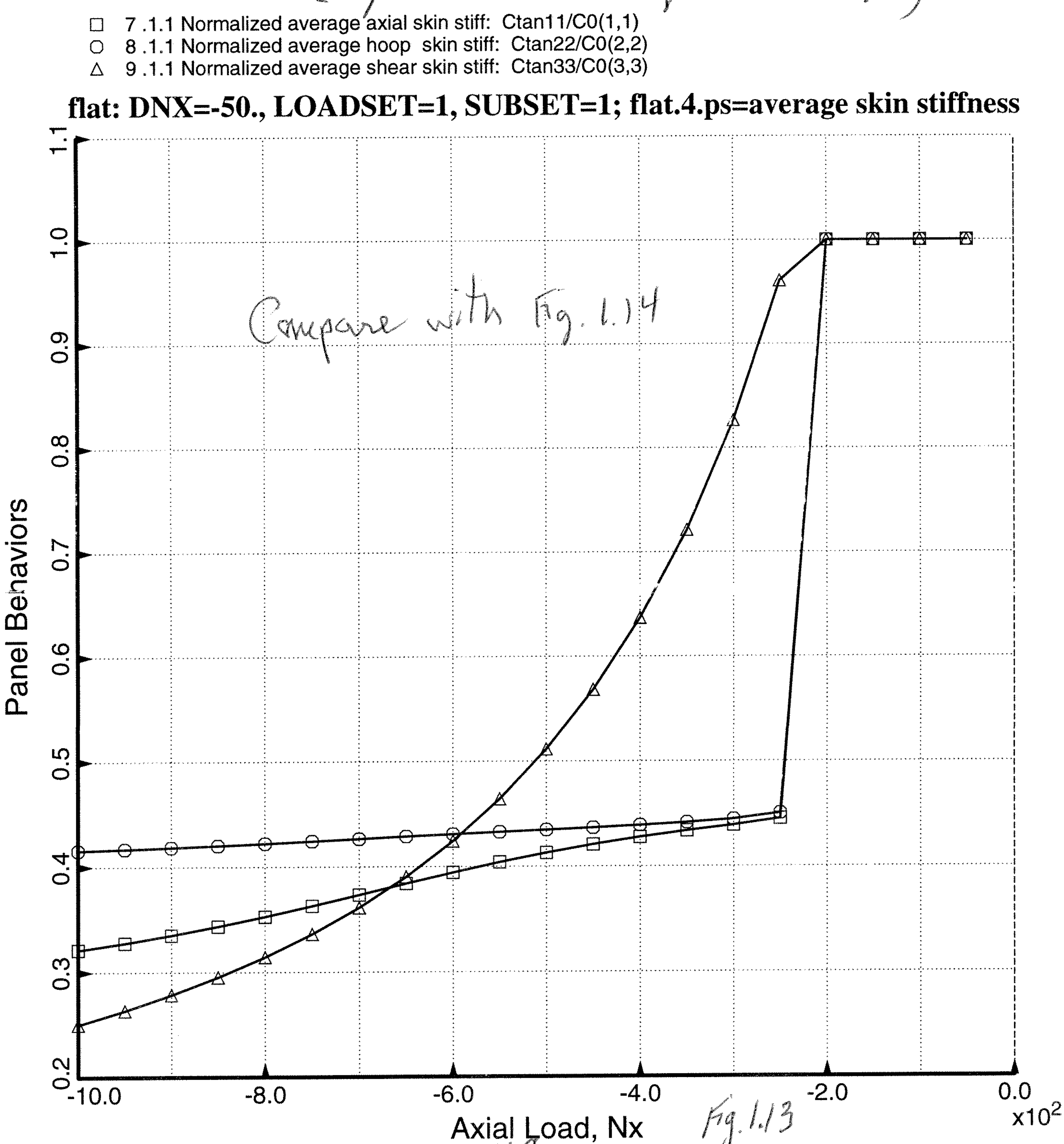



Fig. 1.13

Table 1.14 flat.OPT (with bigger initial imperfection)

```
      n         $ Do you want a tutorial session and tutorial output?
  -50.000       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx( 1)
        0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny( 1)
        0       $ In-plane shear in load set A,                      Nxy( 1)
      n         $ Does the axial load vary in the L2 direction?
  0.000000      $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
  0.000000      $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
      Y         $ Want to include effect of transverse shear deformation?
        0       $ IQUICK = quick analysis indicator (0 or 1)
      Y         $ Do you want to vary M for minimum local buckling load?
      N         $ Do you want to choose a starting M for local buckling?
      Y         $ Do you want to perform a "low-axial-wavenumber" search?
 0.2000000      $ Factor of safety for general instability, FSGEN( 1)
 0.2000000      $ Minimum load factor for local buckling (Type H for HELP), FSLOC( 1)
  1.000000      $ Minimum load factor for stiffener buckling (Type H), FSBSTR( 1)
  1.000000      $ Factor of safety for stress, FSSTR( 1)
      Y         $ Do you want "flat skin" discretized module for local buckling?
      N         $ Do you want wide-column buckling to constrain the design?
  0.000000      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
  0.000000      $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0( 1)
        0       $ Axial load applied along the (0=neutral plane), (1=panel skin)
  0.000000      $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
  0.000000      $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
note  0.100000  $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
 0.1000000      $ Initial local imperfection amplitude (must be positive), Wloc( 1)
      Y         $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
       50       $ Axial halfwavelength of typical general buckling mode, AXLWAV( 1)
      Y         $ Do you want PANDA2 to find the general imperfection shape?( 1)
  1.000000      $ Maximum allowable average axial strain (type H for HELP) ( 1)
      N         $ Is there any thermal "loading" in this load set (Y/N)?
      Y         $ Do you want a "complete" analysis (type H for "Help")?
      N         $ Want to provide another load set ?
      N         $ Do you want to impose minimum TOTAL thickness of any segment?
      N         $ Do you want to impose maximum TOTAL thickness of any segment?
      N         $ Use reduced effective stiffness in panel skin (H(elp), Y or N)?
        0       $ NPRINT= output index (-1=min. 0=good, 1=ok, 2=more, 3=too much)
        0       $ Index for type of shell theory (0 or 1 or 2), ISAND
      Y         $ Does the postbuckling axial wavelength of local buckles change?
      Y         $ Want to suppress general buckling mode with many axial waves?
      N         $ Do you want to double-check PANDA-type eigenvalues [type (H)elp]?
        0       $ Choose (0=transverse inextensional; 1=transverse extensional)
        1       $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
Note    3       $ Choose type of analysis (ITYPE = 1 or 2 or 3 or 4 or 5)
      Y         $ Do you want to prevent secondary buckling (mode jumping)?
      n         $ Do you want to use the "alternative" buckling solution?
        1       $ Choose one of the load sets:  ILOAD
        1       $ Choose one of the sub cases (1  or  2):  ICASE
 -50.00000      $ Increment in axial resultant Nx:  DNX
        0       $ Increment in hoop resultant Ny:  DNY
        0       $ Increment in shear resultant Nxy:  DNXY
        0       $ Increment in axial moment resultant Mx:  DMX
        0       $ Increment in circumferential moment resultant My:  DMY
        0       $ Increment in pressure, p:  DP
        0       $ Starting multiplier for temperature distribution, TMULT
        0       $ Multiplier increment for temperature distribution, DTMULT
       20       $ Maximum number of load steps, NSTEPS
```

input for MAINSETUP

Table 1.15 flat.CPL (flat.axial.cpl32)

```
n         $ Do you want a tutorial session and tutorial output?
   1      $ For which load set (1 - 5) do you want behavior/margins?
   1      $ Choose a sub-case (1 or 2) within this load set
   1      $ Indicate which load component to use in plots (1,2,...7)
y         $ Any behaviors to be plotted v. load steps (Y or N)?
   7      $ Choose a behavior to be plotted v. load steps
y         $ Any more behaviors to be plotted v. load steps (Y/N)?
   8      $ Choose a behavior to be plotted v. load steps
y         $ Any more behaviors to be plotted v. load steps (Y/N)?
   9      $ Choose a behavior to be plotted v. load steps
n         $ Any more behaviors to be plotted v. load steps (Y/N)?
n         $ Any extreme fiber strains to be plotted v. load steps?
n         $ Any design margins to be plotted (Y or N)?
n         $ Any deformed panel module cross sections to be plotted?
n         $ Do you want to plot layers in skin-stringer module (Y/N)?
n         $ Do you want a "3-D" plot of the buckled panel module (Y/N)?
```

input for CHOOSEPLOT

flat.4.ps (from flat.axial.cpl32)
with 0.1" imperfection

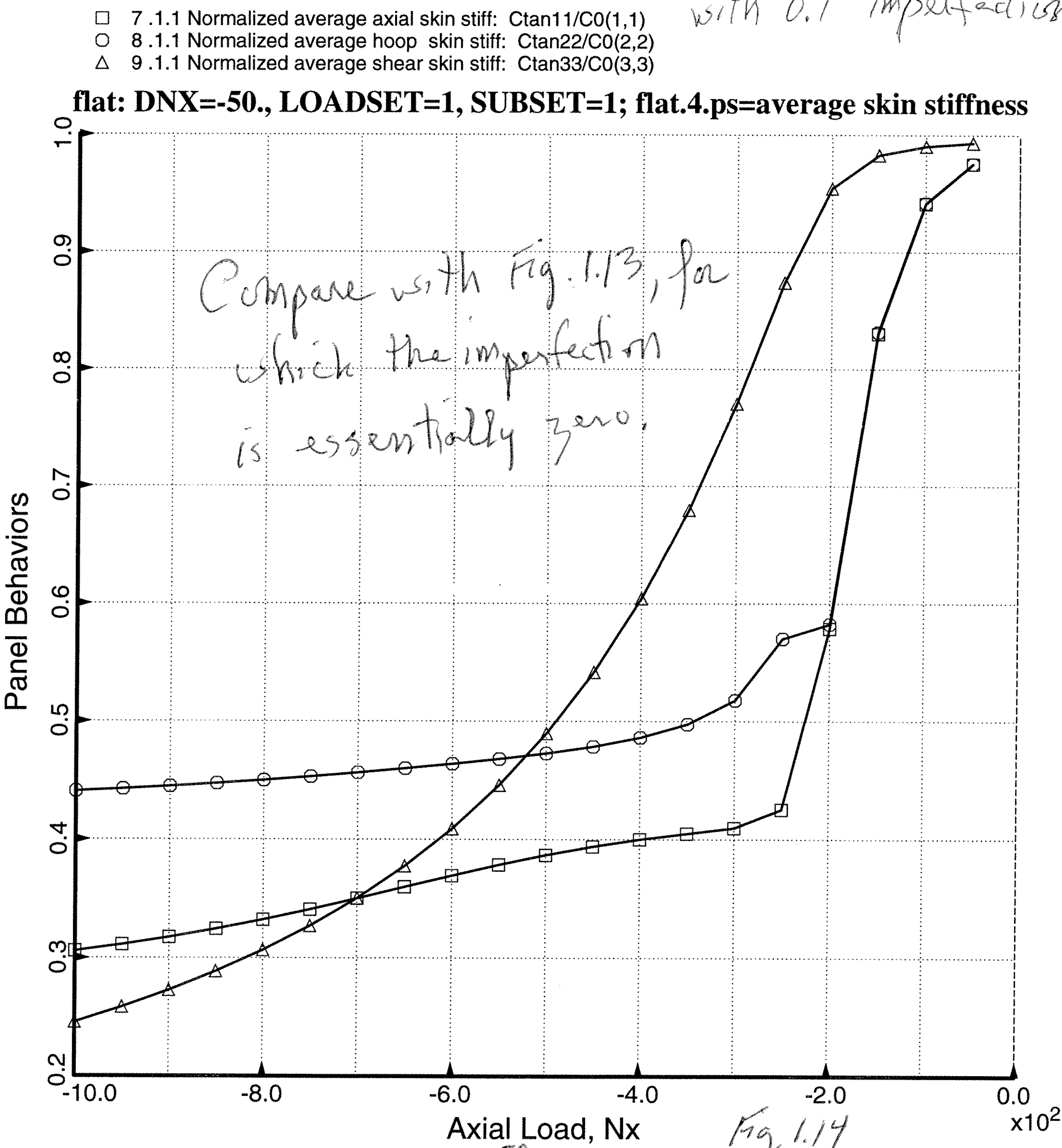



Fig. 1.14

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