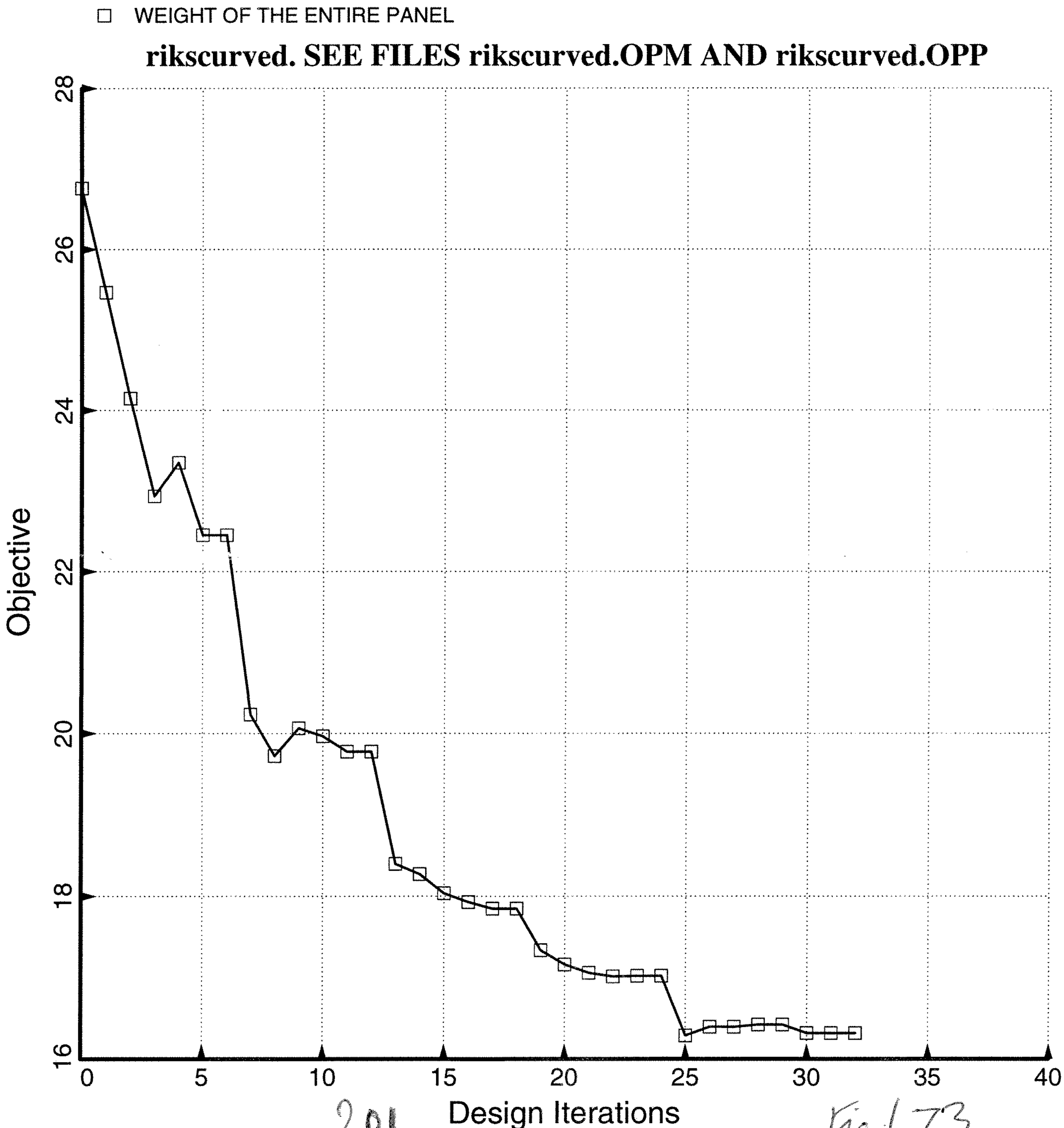
rikscurved.5.ps

output from DIPLOT



201

Fig. 1.73

riksc urved.OPM (output from fixed design; analysis type ITYPE = 2

15 pages

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```
     n        $ Do you want a tutorial session and tutorial output?
  -1000.      $ 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?
 1.0000000    $ 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)
  0.010000    $ 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)
        1     $ 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)
```

rikscurved.OPT file

```
************ END OF THE  rikscurved.OPT  FILE ***********
************ July, 2007 VERSION OF PANDA2    ************
******** BEGINNING OF THE  rikscurved.OPM  FILE *********


*****************************************
ITERATION NO., LOAD SET NO., SUBCASE NO. =   0   1   1     PANEL MIDLENGTH
*****************************************
*****************************************
ENTERING STRUCT. IMOD= 0
ITERATION NO., LOAD SET NO., SUBCASE NO. =   0   1   1      CURRENT DESIGN
*****************************************
```

The numbers of the references [ ] given in the CHAPTER
headings correspond to those listed at the end of the paper:
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

The overall structure of PANDA2 and its use are described in
the first PANDA2 paper, Ref.[1A], cited in the April 2007
paper just identified. Ref.[1A] is the following paper:
Bushnell, D.,
"PANDA2 - Program for minimum weight design of stiffened,

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composite, locally buckled panels", COMPUTERS AND STRUCTURES, Vol. 25, No. 4, pp 469-605, 1987

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Concepts such as "wide-column" buckling, "discretized module model", "stringer pop-off", "constitutive matrices" "reduction factor for transverse shear deformtion (t.s.d.)" "smeared stiffeners", "neutral surface", "overall and local static response to uniform pressure", "knockdown factors for anisotropy and in-plane shear loading", "crippling of stiffener parts", and "local postbuckling" are described there, with many early PANDA2 examples provided.

The string, "PANDA-type theory" often occurs. This refers to the theory presented in Ref. [1B] of the April 2007 citation listed first. Ref.[1B] contains the theory given in the paper:
Bushnell, D.,
"Theoretical basis of the PANDA computer program for preliminary design of stiffened panels under combined in-plane loads", COMPUTERS & STRUCTURES, v. 27, No. 4, pp 541-563 (1987).

The theory used for local postbuckling behavior appears in Ref. [1C] of the April 2007 paper cited first (above).
Ref. [1C] is the following paper:
Bushnell, D.,
"Optimization of composite, stiffened, imperfect panels under combined loads for service in the postbuckling regime", Computer Methods in Applied Mechanics and Engineering, Vol. 103 (1993) 43-114

The theory used for imperfection sensitivity appears in Refs. [1E] and [1D] of the first-cited paper above.
Refs. [1E] and [1D] are the following two papers:

Bushnell, D. and Bushnell, W. D.,
"Approximate method for the optimum design of ring and stringer stiffened cylindrical panels and shells with local, inter-ring, and general buckling modal imperfections" Computers and Structures, Vol. 59, No. 3, pp 489-527 (1996)

Bushnell, D.,
"Recent enhancements to PANDA2" AIAA Paper 96-1337-CP, Proc. of the AIAA 37th Structures, Structural Dynamics and Materials Conference, pp 126-182, April, 1996.

The last paper cited also describes the "global" optimizer, "SUPEROPT", implementation of Sanders shell equations into PANDA2, implementation of the Arbocz theory for imperfection sensitivity, implementation of isogrid geometry, and implementation of various truss-core geometries, with examples.

The theories used in PANDA2 for the analysis of sandwich walls are given in Ref.[1F] of the first-cited paper above.
Ref. [1K] is the following paper:
Bushnell, D.,
"Optimum design via PANDA2 of composite sandwich panels with honeycomb or foam cores", AIAA Paper 97-1142, Proc. 38th AIAA Structures, Structural Dynamics and Materials Conference, pp 2163-2202, April, 1997

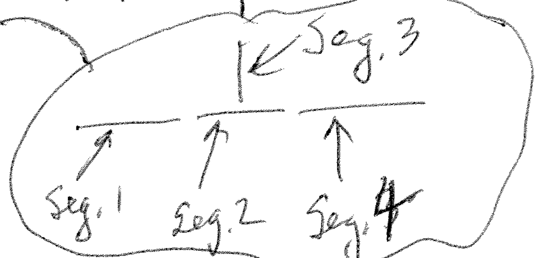
The "alternate" (double-trigonometric series expansion buckling theory) and the discretized "skin"-ring module model are described in Ref. [1G] of the first-cited paper.
Ref. [1G] is the following paper:
Bushnell, D., Jiang, H., and Knight, N.F.,
"Additional buckling solutions in PANDA2", Proceedings of the 40th AIAA SDM Conference, AIAA Paper 99-1233, pp 302-345 April 1999

Details of the strategy used in PANDA2 for accounting for initial buckling modal imperfections are described and listed in a table in Ref. [1K]. Ref. [1K] is the following paper:
Bushnell, D. and Rankin, C.C.,
"Difficulties in optimization of imperfect stiffened cylindrical shells",
AIAA Paper 1943, 47th AIAA Structures, Structural Dynamics and Materials Meeting, Newport RI, April 2006

Table 1.70


```
 ************************************************************
 CHAPTER 1  Compute the 6 x 6 constitutive matrices [C] for
            individual model segments and various combinations
            thereof (skin with smeared stiffener sets [1A]).
            See Section 8 in [1A], Eq.(8.1) on p.495 of [1A].

*** BEGIN SUBROUTINE GETCIJ (CONSTIT. LAW: SEGS AND SMEARED ***
 See Section 8, pp 494-503 of Reference [1A]. First the 6 x 6
 integrated constitutive coefficients Cij (Eq.8.1) and thermal
 loading are found for each segment in the skin-stringer module
 then for the skin-ring module, then for the skin with smeared
 stringers only, then for the skin with smeared rings only,
 and finally for the skin with both stringers and rings smeared.
 **** END   SUBROUTINE GETCIJ (CONSTIT. LAW: SEGS AND SMEARED ***

 ************************************************************
 CHAPTER 2  Do PANDA-type [1B] general buckling analysis to
            get Donnell factors for later use, if appropriate.

 ** BEGIN SUBROUTINE BUCPAN (GENERAL PANDA-TYPE BUCKL.) ***
 PURPOSE IS TO GET DONNELL FACTORS FOR LATER USE IN SUB.DONELL.
 *** END  SUBROUTINE BUCPAN (EIGENVALUES. PANDA-TYPE BUCKL.) ***

 ************************************************************
 CHAPTER 3  Do various PANDA-type [1B] general buckling
            analyses needed for later computation of effective
            length of the panel. Compute the effective length.

 User-specified axial length of the panel, AXIAL=  5.0000E+01
 Computed factor to modify the length, AXIAL: LENMOD=  1.0000E+00
 Axial length of "equivalent" simply-supported panel, LENMOD*AXIAL=  5.0000E+01

 ************************************************************
 CHAPTER NEW Compute wide-column buckling from discretized
            skin-stringer module model (Figs. 20b,c & 22b,c in
            [1A]) with only Nx (Ny=0, Nxy=0). The purpose is to
            obtain a knockdown factor, WIDKNK, for smearing
            the stringers in an inter-ring buckling mode

 ******* Begin the section where WIDKNK is computed *********
 ******* See ..panda2/doc/panda2.news Items 724 & 725.*******

  WIDE COLUMN PANEL BUCKLING LOAD FACTOR =   5.8044E-01
 ISKINX = 0. MODE OF BUCKLING IS THE PANEL SKIN IF ISKINX = 1.
 ITIPWX = 0. MODE OF BUCKLING IS STRINGER SIDESWAY IF ITIPWX=1
 ICWBWX = 0. MODE OF BUCKLING IS THE STRINGER WEB IF ICWBWX=1
 IFLGWX = 0. MODE OF BUCKLING IS STRINGER OUTSTANDING FLANGE IF IFLGWX=1
 ICRWNX = 0. MODE OF BUCKLING IS THE CROWN OF THE HAT IF ICRWNX=1

 Mode number  1 IS a wide column mode and is therefore acceptable.

 SMEARED STRINGER KNOCKDOWN FROM SKIN-STRINGER DISCRETE MODEL
 (See ..panda2/doc/panda2.news Items 724 and 725):
 Buckling axial resultant Nx from simple Euler model,   EULER =  6.8268E+02
 Buckling axial resultant Nx from discretized  model,   EIGWID=  5.8044E+02
 Knockdown factor for cross section rigidity & t.s.d.,  WIDKNK=  8.5024E-01
 Effective axial length of the wide column model,       AXLEFF=  5.0000E+01

 Axial resultant, Nx, in each of the segments of the
 discretized skin-stringer cross-section before any deformation
 -4.0740E+02 -4.0740E+02 -1.5431E+03 -4.0740E+02
 ******* End of the section where WIDKNK is computed ********
 ******* See ..panda2/doc/panda2.news Items 724 & 725.*******
```

compare with STAGS linear prediction: Fig. 1.86




```
 ************************************************************
 CHAPTER 4  Compute axisymmetric prebuckling "hungry-horse"
            state of the curved panel or cylindrical shell.
            (See Ref.[1E], especially Fig. 1 and pp.495-498).

 ***** BEGIN COMPUTATIONS FOR AXISYMMETRIC PREBUCKLING
 ***** STATE OF THE PANEL. (See pp 495-498 of journal
 ***** article, COMPUTERS & STRUCTURES vol 59, no.3, 1996
 ***** Computations carried out in SUBROUTINE SKIN.
 ***** Axisymmetric response of the curved panel to the loads in Load Set A *****

 ***** Axisymmetric response of the curved panel to the loads in Load Set B *****
```

Table 1.70

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*************************************************************
CHAPTER 5  Get static response of panel to normal pressure
           [1A], especially Section 9 and Section 20.5 and
           Figs. 55 - 60 in [1A].

Begin static response of entire panel to normal pressure:
Axial length of panel, AXLEN=  5.0000E+01

** NOTE ** If the panel is curved it is treated as a complete
(360-degree) cylindrical shell. The axisymmetric
"hungry-horse" deformed state is computed for a single ring
spacing in Chapter 4. For curved panels, therefore, no
computations are performed for the entire panel here.
End of equilibrium calculations for entire panel
with smeared stiffeners under uniform normal pressure,
p = -2.0000E-05
***** NOTE ****** See Chapter 4 for static response of a
single "skin"-ring module of the curved panel, which is
modelled as a complete (360-degree) cylindrical shell there.

**** CHAPTER 5b ****:
Next, find bending of a single skin-stringer panel
module under uniform normal pressure, p= -2.0000E-05, See
Section 9 of Ref.[1A].The panel skin is assumed to be flat
Also see Fig. 56 on p. 555 of [1A] for an example.
 LABEL NO. IN STRUCT= 9100

***** BEGIN SUBROUTINE FORCES (MODULE PRESSURE RESPONSE) *****
Purpose is to obtain resultants in each segment of the skin-
stringer single module model for input to the nonlinear static
response of single skin-stringer module to normal pressure.
See Section 10, pp 506-509, of Reference [1A].
****** END SUBROUTINE FORCES (MODULE PRESSURE RESPONSE) *******

****** BEGIN SUBROUTINE BUCKLE (MODULE PRESSURE RESPONSE) *****
****** END SUBROUTINE BUCKLE (MODULE PRESSURE RESPONSE) *******

*** NOTE ****** NOTE ****** NOTE ****** NOTE ****** NOTE ***
Because the stringers are relatively weak, the local
amplitude of "pillowing" between stringers is being reduced
by the factor, PLOCF =   1.0000E+00. See news ITEM 117(g).
*** END NOTE ***** END NOTE ***** END NOTE ***** END NOTE ***


****** BEGIN SUBROUTINE BUCKLE (MODULE PRESSURE RESPONSE) *****
See Fig. 56 in Ref.[1A] for the model and its behavior.
****** END SUBROUTINE BUCKLE (MODULE PRESSURE RESPONSE) *******

****** BEGIN SUBROUTINE MODE (MODULE PRESSURE RESPONSE) *****
****** END SUBROUTINE MODE (MODULE PRESSURE RESPONSE) *******

****** BEGIN SUBROUTINE OUTPRS (MODULE PRESSURE RESPONSE) *****
****** END SUBROUTINE OUTPRS (MODULE PRESSURE RESPONSE) *******
End of nonlinear equilibrium calculations for
panel module with uniform normal pressure, p= -2.0000E-05


*************************************************************
CHAPTER 5c (prebuckling bending between rings with beam
model) is not executed because:
(PEDG.OR.P.EQ.0.0.OR.ISKIPL.NE.0.OR.ISTIF(2).EQ.0
.OR.ISOGRD.NE.0.OR.ISTIF(1).EQ.5.OR.AXIAL.LT.2.5*B(2))

*************************************************************
CHAPTER 6  Do PANDA-type [1B] general and inter-ring buckling
           analyses to permit later computation of
           amplification of panel bowing.

**** BEGIN SUBROUTINE BUCPAN (PRELIM. PANDA-TYPE BUCKLING) ****
**** This execution of BUCPAN is used to find the general
**** buckling load factor that is used to compute the
**** amplification of bowing from all sources except pressure.

GENERAL BUCKLING LOAD FACTOR USED FOR CALCULATION OF THE
AMPLIFICATION OF BOWING FROM ALL SOURCES EXCEPT PRESSURE.
EIGBOW(M,N)=  1.2262E+00(  1,   6)
**** END SUBROUTINE BUCPAN (PRELIM. PANDA-TYPE BUCKLING) *******
```

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```
 *************************************************************
 CHAPTER 7  Compute distribution of loads in panel module
            skin-stringer segments, neglecting redistribution
            due to initial buckling modal imperfections
            (See Section 10 of [1A]).

 *** BEGIN SUBROUTINE FORCES (LOAD DISTRIB. IN SEGMENTS) *****
 Resultants in each segment of the skin-stringer and skin-ring
 modules are computed. The effect of prebuckling bending due to
 initial buckling modal imperfections is ignored at this time,
 but will be accounted for later when buckling load factors and
 stresses are computed. See Section 10, pp 506-509 of Ref.[1A]
 **** END SUBROUTINE FORCES (LOAD DISTRIB. IN SEGMENTS) *******

 *************************************************************
 CHAPTER 8  Do PANDA-type local, inter-ring, general buckling
            analyses and PANDA-type stringer web and ring web
            buckling analyses to get knockdown factors to
            compensate for lack of in-plane shear Nxy loading
            and anisotropy in discretized BOSOR4-type models.
            (See Section 11 of [1A] and Item No. 81 in [1L]).

*** BEGIN SUBROUTINE BUCPAN (KNOCKDOWN PANDA-TYPE BUCKLING) ***
**** The purpose of the following BUCPAN execution is to find:
*** LOCAL BUCKLING (buckling of skin between stiffeners):
**** a.with in-plane shear Nxy and anisotropic effects included
**** b.without in-plane shear Nxy and anisotropic effects
*** INTER-RING BUCKLING (stringers smeared out):
**** a.with in-plane shear Nxy and anisotropic effects included
**** b.without in-plane shear Nxy and anisotropic effects
*** GENERAL INSTABILITY (rings and stringers smeared out):
**** a.with in-plane shear Nxy and anisotropic effects included
**** b.without in-plane shear Nxy and anisotropic effects
*** THE PURPOSE IS TO FIND KNOCKDOWN FACTORS TO COMPENSATE
*** FOR THE ABSENCE OF IN-PLANE SHEAR AND ANISOTROPY IN BOSOR4-
*** TYPE MODELS (DISCRETIZED MODULE MODELS).
**** See Section 11, p. 509, of Reference [1].
*** NOTE: This set of calculations does NOT include the effect
***       of initial geometric buckling modal imperfections.

 Entering ALTSOL: radius, axial, circ. dimensions =  5.0000E+01  5.0000E+01  3.6236E+00
 See ITEMs 438, 444  in the file ..panda2/doc/panda2.news .
 and AIAA paper 99-1233, Proc. 40th AIAA SDM Meeting, 1999
 pp 302-345, especially pp 304-316 and associated figures.
 *** BUCKLING BETW MAJOR STIFFENERS, SMEARED SUBSTIFFENERS ***
        Number of discrete stringers, rings: NUMSTR, NUMRNG=  0  0

 No alternative solution sought because user did not want one.
 (IALTSN was set equal to zero in MAINSETUP)

 Label No. in STRUCT= 9140: Modifiers for knockdowns
 generated from use of the alternative buckling soln.(if any)
  General Instability, FKNOCK(1), EIGRT9 =  1.0000E+00  1.0000E+00
  Local Buckling,      FKNOCK(2), EIGRT7 =  9.9996E-01  1.0000E+00
**** END SUBROUTINE BUCPAN (KNOCKDOWN PANDA-TYPE BUCKL.) ******
**** Knockdown factors to account for anisotropy and/or the
**** presence of in-plane shear, in order to compensate for the
**** neglect of these in the BOSOR4-type discretized models for
**** buckling.
***************************************************************


 Conservativeness indicator, ICONSV= 1 (See panda2.news Item No. 676)
 Initial imperfections for general, panel, local buckling=
 Total out-of-roundness + modal,    W0GLOB =  0.0000E+00
 Out-of-roundness,                     WG1  =  0.0000E+00
 General buckling modal,               WG2  =  0.0000E+00
 Inter-ring buckling modal,          W0PAN =  0.0000E+00
 Local buckling modal,               W0LOC =  1.0000E-02

 *************************************************************
 CHAPTER 9 ("skin"-ring buckling) is not executed because:
 (IMOD.NE.0.OR.FNY.GE.0.0.OR. .NOT.PEDG.OR.ISTIF(2).EQ.0)

 *************************************************************
 CHAPTER 10 Compute knockdown factors and prebuckling bending
            associated with initial general, inter-ring, local
            buckling modal imperfections. (See Ref.[1E].
```

Table 1.70


```
        Also see Sections 13 and 14 and Tables 9 and 10
        of Ref.[1K]).

*************************************************************
CHAPTER 10.2 Compute knockdown factor and prebuckling bending
             associated with INTER-RING buckling modal
             initial imperfection.
**** WARNING ***** WARNING ***** WARNING ****
YOU SHOULD CONSIDER USING THE "REDUCED SKIN STIFFNESS"
OPTION IN THE "MAINSETUP" INTERACTIVE SESSION,
ESPECIALLY IF THE GENERAL BUCKLING FACTOR OF SAFETY,
FSGEN, IS GREATER THAN THE LOCAL BUCKLING F.S., FSLOC.
**** END WARNING *** END WARNING *** END WARNING ****
INTER-RING BUCKLING EIGENV. OF "PERFECT" PANEL, IMOD= 0
  EILC81(m,dm,n,dn,s)=  1.2011E+00(  1, 0.000E+00, 19,-2.900E-01, 0.000E+00)


************ ITERATION LOOP FOR IMPERFECT PANEL ***********
Begin iteration loop for inter-ring buckling of the imperfect
panel. The inter-ring imperfection is amplified by the factor
WYYAMP, which increases from iteration to iteration.

*************** ITERATION NUMBER  1 *****************
INTER-RING BUCKLING EIGENV. OF IMPERFECT PANEL, IMOD= 0
  EILOC8(m,dm,n,dn,s)=  1.2011E+00(  1, 0.000E+00, 19,-2.900E-01, 0.000E+00)
INTER-RING IMPERFECTION AMPLITUDE FACTOR, WYYAMP=  4.0000E+00
EIGEFF =FACIM1*EILOC8 +FACIM2*FMULT2*EILC81)/(FACIM1+FMULT2*FACIM2)=  1.2011E+00
in which FACIM1, FACIM2, and EILC81 are given by:
FACIM1=1./(EILOC8 - 1.) =  4.9718E+00
FACIM2=1./(EILC81 - 1.) =  4.9718E+00
EILC81                  =  1.2011E+00
FMULT2                  =  1.0000E+00

*** NOTE: The number of circumfer. halfwaves in the inter-ring
          buckling mode of the PERFECT panel is greater
          than that for the IMPERFECT panel or ICONSV=-1  .
          Hence,the PERFECT panel mode is used for computation
          of deformations Wxx, Wyy, Wxy in SUBROUTINE CURIMP.
ICD81, ICD8  = indicators for coordinate direction
               in which the inter-ring portion of the
               panel is longest.
Inter-ring buckling mode for the PERFECT panel (PANDA theory):
(m=  1, dm=  0.00E+00, n= 19, dn= -2.90E-01, slope=  0.00E+00, ICD81= 1)
Inter-ring buckling mode for IMPERFECT panel (PANDA theory):
(m=  1, dm=  0.00E+00, n= 19, dn= -2.90E-01, slope=  0.00E+00 ICD8= 1)

(0.1 radian)/(shell wall rotation), AMPTST =  1.0000E+00
QUANTITIES USED FOR INTER-RING BENDING OF IMPERFECT PANEL
(used for generation of WXX8,WYY8,WXY8), IMOD= 0:
 Amplitude of overall ovalization,              WG1=  0.0000E+00
 Amplitude of inter-ring buckling modal imp.,AMWIMP=  0.0000E+00
 Effective load factor for inter-ring buck., EIGEFF=  1.2011E+00
 Number of  axial halfwaves in inter-ring mode,   m=    1
 Fractional axial halfwaves in inter-ring mode,  dm=  0.0000E+00
 Number of  circ. halfwaves in inter-ring mode,   n=   19
 Fractional circ. halfwaves in inter-ring mode,  dn= -2.8996E-01
 Slope of nodal lines in inter-ring buck.mode,slope=  0.0000E+00
 Additional amplitude factor,                FACIM3=  1.0000E+00
 Original imperfection is increased by 1/(EIGEFF-1)=  4.9718E+00

********* NOTE ********* NOTE ********** NOTE *********
Prebuckling bending and twist from inter-ring imperfection growth:
   Wxx8,Wyy8,Wxy8,ICD8=  0.0000E+00  0.0000E+00  0.0000E+00    1
*****************************************************

*************************************************************
CHAPTER 10.3 Compute knockdown factor and prebuckling bending
             associated with LOCAL buckling modal initial
             imperfection.
LOCAL BUCKLING EIGENV. OF "PERFECT" PANEL, IMOD= 0
  EILC71(m,dm,n,dn,s)=  2.1377E-01( 14,-1.711E-01,  1, 0.000E+00, 0.000E+00)


************ ITERATION LOOP FOR IMPERFECT PANEL ***********
Begin iteration loop for local buckling of the imperfect
panel. The local imperfection is amplified by the factor
WYYAMP, which increases from iteration to iteration.
```

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```
*************** ITERATION NUMBER  1 *****************
The radius of curvature is modified by initial imperfections:
Orig.radius  Mod.radius   WYYGEN     WYYOUT     WYYPAN     CURCHG
 5.000E+01  5.000E+03  0.000E+00  0.000E+00  0.000E+00  1.980E-02
LOCAL BUCKLING EIGENV. OF IMPERFECT PANEL, IMOD= 0
  EILOC7(m,dm,n,dn,s)=  1.2707E-01( 14,-1.701E-01,  1, 0.000E+00, 1.000E-02)
LOCAL IMPERFECTION AMPLITUDE FACTOR, WYYAMP=  4.0000E+00
EIGEFF =(FACIM1*EILOC7 +FACIM2*FMULT2*EILC71)/(FACIM1+FMULT2*FACIM2)=  1.7042E-01
in which FACIM1, FACIM2, and EILC71 are given by:
FACIM1=1./(EILOC7 - 1.) =  1.0000E+02
FACIM2=1./(EILC71 - 1.) =  1.0000E+02
EILC71                  =  2.1377E-01
FMULT2                  =  1.0000E+00

*** NOTE: The number of circ. halfwaves in the local
          buckling mode of the PERFECT panel is less than or
          equal to that for the IMPERFECT panel. Therefore,
          the IMPERFECT panel mode is used for computation
          of deformations Wxx, Wyy, Wxy in SUBROUTINE CURIMP.
ICD71, ICD7  = indicators for coordinate direction
               in which the "local" portion of the
               panel is longest.
Local buckling mode for the PERFECT panel (PANDA theory):
(m= 14, dm= -1.71E-01, n=  1, dn=  0.00E+00, slope=  0.00E+00, ICD71= 1)
Inter-ring buckling mode for IMPERFECT panel (PANDA theory):
(m= 14, dm= -1.70E-01, n=  1, dn=  0.00E+00, slope=  1.00E-02 ICD7= 1)
(0.1 radian)/(shell wall rotation), AMPTST =  1.1508E+01
QUANTITIES USED FOR LOCAL BENDING OF IMPERFECT PANEL
(used for generation of WXX7,WYY7,WXY7), IMOD= 0:
 Amplitude of overall ovalization,                WG1=  0.0000E+00
 Amplitude of  local  buckling modal imperf.,AMWIMP=  1.0000E-02
 Effective load factor for  local  buckling, EIGEFF=  1.7042E-01
 Number of  axial halfwaves in  local  mode,      m=   14
 Fractional axial halfwaves in  local  mode,     dm= -1.7007E-01
 Number of  circ. halfwaves in  local  mode,      n=    1
 Fractional circ. halfwaves in  local  mode,     dn=  0.0000E+00
 Slope of nodal lines in local buckling mode, slope=  1.0000E-02
 Additional amplitude factor,                FACIM3=  5.8679E+00
 Original imperfection is increased by 1/(EIGEFF-1)=  1.2054E+00

********* NOTE ********* NOTE ********** NOTE *********
Prebuckling bending and twist from local imperfection growth:
 Wxx7(1),Wyy7(1),Wxy7(1),ICD7=  1.3292E-01  1.3234E-01  1.3292E-03    1
*****************************************************

==========================================================
BUCKLING LOAD FACTORS AND IMPERFECTION SENSITIVITY SUMMARY
----------------------------------------------------------
                           LOCAL      INTER-RING      GENERAL
                         BUCKLING      BUCKLING      BUCKLING
RATIOS OF BUCKLING LOADS FROM ARBOCZ THEORY TO THOSE FROM
PANDA2 THEORY FOR THE PERFECT STRUCTURE:
   (ARBOCZ/PANDA2):    9.7672E-01   1.0000E+00   1.0000E+00
----------------------------------------------------------
KNOCKDOWN FACTORS FOR IMPERFECTIONS DERIVED FROM
PANDA2 THEORY VS THOSE FROM ARBOCZ 1992 UPDATE OF KOITERs
1963 SPECIAL THEORY:
FROM PANDA2 THEORY:    5.9440E-01   1.0000E+00   1.0000E+00
FROM ARBOCZ THEORY:    5.9706E-01   1.0000E+00   1.0000E+00
THE GOVERNING KNOCKDOWN FACTOR FOR EACH TYPE OF BUCKLING
(LOCAL, INTER-RING, GENERAL) IS SET EQUAL TO THE MINIMUM
KNOCKDOWN FACTOR FOR THAT TYPE OF BUCKLING, REDUCED
FURTHER BY THE RATIO (ARBOCZ/PANDA2) FOR THE PERFECT PANEL
IF THE RATIO (ARBOCZ/PANDA2) IS LESS THAN UNITY:
The ARBOCZ theory is used only if ICONSV=1. ICONSV= 1

USED NOW IN PANDA2:    5.8057E-01   1.0000E+00   1.0000E+00

FACTOR APPLIED TO   1.0000E+00 FOR ALTERNATIVE SOLUTION FOR
GENERAL    BUCKLING WITH DISCRETE STIFFENERS, FKNMLT=  1.0000E+00
FACTOR APPLIED TO   1.0000E+00 FOR ALTERNATIVE SOLUTION FOR
INTER-RING BUCKLING WITH DISCRETE STIFFENERS, FKNMLS=  1.0000E+00

***NOTE*** IF THERE IS INTERNAL PRESSURE THESE KNOCKDOWN
           FACTORS MAY BE CHANGED AS NOTED BELOW.
==========================================================

************************************************************
```

Table 1.70


```
CHAPTER 11 Get change in stress resultants, Nx, Ny, Nxy in
           various segments of the skin-stringer module
           during prebuckling bending of the imperfect shell.
           Also, do PANDA-type [1B] local, inter-ring, gen-
           eral buckling analyses and PANDA-type stringer web
           and ring web buckling analyses to get knockdown
           factors to compensate for the lack of in-plane
           shear Nxy loading and anisotropy in discretized
           BOSOR4-type models. (See Section 11 in [1A])

In-plane shear and anisotropy are not directly accounted for
in any of the BOSOR4-type of discretized models. In order to
compensate for this error, knockdown factors are established
as given below for various types of buckling. These knockdowns
account for:
 1. the effect of in-plane shear, and
 2. anisotropy [e.g. C(4,6), C(5,6)] in the panel skin.
Knockdown factors from PANDA-type analysis are as follows:
   Knockdown factor for general instability=   9.9997E-01
   Knockdown factor for local instability=     9.9996E-01
   Knockdown factor (under hat crippling)=     1.0000E+00
   Knockdown factor for inter-ring buckling=   9.9997E-01
   Knockdown factor for stringer web bucklng=  1.0000E+00
   Knockdown factor for   ring   web bucklng=  1.0000E+00
Please note that the purpose of these knockdown factors is NOT
to compensate for initial imperfections.  You can account for
initial imperfections by assigning amplitudes of local, inter-
ring, and general imperfections in the forms of the local,
inter-ring and general buckling modes. And/or you can use
appropriate factors of safety (different for different
buckling modes) to compensate for initial imperfections.


************************************************************
CHAPTER 12 Obtain prebuckled state of the initially imperfect
           and loaded and bent panel or shell. This section
           includes the redistribution of Nx, Ny, Nxy in the
           various segments of the stiffened shell structure.

************************************************************
CHAPTER 13 Get prebuckling stress resultants, Nx, Ny, needed
           for the discretized single-module skin-stringer
           model used for local buckling and bending-torsion
           buckling (BOSOR4-type model: see Figs. 18, 20,
           22, 97, and 98 of [1A], for examples of the
           discretized single skin-stringer BOSOR4-type
           module model.).

Effective circumferential radius of curvature, RADNEW=  5.0000E+03
      External Stringer

     MODULE WITH RECTANGULAR STIFFENER...

                                         !   ^
          Segment No. 3 -----> !   !
                               !   !
              Seg. No. 2-.     !   h
                          .    !   !
     Segment No. 1-.       .   !   !       .-Seg. No. 4
                  .         .  !   V      .(same as Seg. 1)
       ------------------==================----------------
                     !<------ b2 ------->!
       !<--- Module width  =  stiffener spacing, b --->!


   EXPLODED VIEW, SHOWING LAYERS and (SEGMENT, NODE) NUMBERS

                               (3,11)
                                 !
         Layer No. 1 -----> ! <----------- Layer No. k
                                 !
      Layer No. 1-.              !
                   .             !
   Layer No. 1-.      .          !               .-Layer No. 1
              .         .        !              .
             .            .   (3,1)              .
   --------------    ====================    --------------
 (1,1)    .    (1,11)(2,1)    . (2,6)     (2,11)(4,1)   .    (4,11)
```

Note Segment & layer numbering conventions in model pt.

Table 1.70

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```
Layer No. m       Layer No. n    Layer No. m

==============================================
BEGIN: PREBUCKLING STRESS RESULTANTS USED IN THE
DISCRETIZED SINGLE MODULE MODEL WITH IQUICK = 0...
----------------------------------------------------------
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 1 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -4.0740E+02 -9.7017E-04  5.0000E+00
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 2 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -4.0740E+02 -9.7017E-04  5.0000E+00
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 3 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -1.5431E+03  9.3502E-32  2.3014E-06
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00

PREBUCKLING AXIAL RESULTANTS IN STRINGER WEB: SEGMENT NO.  3
 "Eigenvalue" axial resultant, Nx(var)=
-1.5431E+03 -1.5431E+03 -1.5431E+03 -1.5431E+03 -1.5431E+03 -1.5431E+03
-1.5431E+03 -1.5431E+03 -1.5431E+03 -1.5431E+03 -1.5431E+03
 "  fixed   " axial resultant, Nx(fix)=
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
 0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
PREBUCKLING STRESS RESULTANTS AT THE FIRST NODE
IN THE DISCRETIZED SINGLE MODULE SEGMENT NO. 4 .....
 "Total." loads, Nx(var),Ny(var),Nxy(var)= -4.0740E+02 -9.7017E-04  5.0000E+00
 "Fixed " loads, Nx(fix),Ny(fix),Nxy(fix)=  0.0000E+00  0.0000E+00  0.0000E+00
------------------------------------------------
END:  PREBUCKLING STRESS RESULTANTS USED IN THE
DISCRETIZED SINGLE MODULE MODEL WITH IQUICK = 0...
==========================================================

************************************************************
CHAPTER 14 Compute local buckling from BOSOR4-type
           discretized skin-stringer single module model.
           See Section 12.2 (upper table on p. 511) and
           Figs. 46c and 98b in [1A], for examples.

**** BEGIN SUBROUTINE LOCAL (INITIAL LOCAL BUCKLING SEARCH) ****

Value of dm used in SUBROUTINE ARRAYS=  0.0000E+00
IMOD= 0; Eigenvalue passed to STRUCT=  2.3148E-01
Knockdown for transverse shear deformation=  9.9889E-01
Buckling load factor from SUB. LOCAL, EIGITR(1)=  2.3148E-01
Number of axial halfwaves between rings, N=   21
****  END  SUBROUTINE LOCAL (INITIAL LOCAL BUCKLING SEARCH) ****
 **** END OF LOCAL BUCKLING EIGENVALUE CALC.****

**** BEGIN SUBROUTINE MODE (LOCAL BUCKLING MODE SHAPE) ****
 **** END SUBROUTINE MODE (LOCAL BUCKLING MODE SHAPE) ******
 *******************************************
 *******************************************
Margin=  1.5736E-01  Local buckling from discrete model-1.,M=21  axial halfwaves;FS=0.2

************************************************************
CHAPTER 15 Compute bending-torsion (low-m) buckling from
           BOSOR4-type discretized skin-stringer single
           module model. See Section 12.2 (lower table on
           p. 511) in [1A], for example.

**** BEGIN SUBROUTINE LOCAL (LOW-M LOCAL BUCKLING SEARCH) ****
Buckling load factor from SUB. LOCAL, EIGITR(4)=  2.3148E-01
Number of axial halfwaves between rings, NLOW=   21
**** END SUBROUTINE LOCAL (LOW-M LOCAL BUCKLING SEARCH) ******
Margin=  4.2601E+00  Bending-torsion buck.(bypassed low-m mode);M=3  ;FS=0.2

************************************************************
CHAPTER 16 Compute post-local buckling from the Koiter
           theory given in Ref.[1C]. See Figs. 23, 24, and
           Figs. 47-49 in [1A], Fig. 6 in [1C], and Fig. 4 in
Bushnell, D.
"Optimization of an axially compressed ring and stringer
stiffened cylindrical shell with a general buckling modal
```

local buckling

compare with BIGBOSOR4 & STAGS 0.318 0.289

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```
imperfection", AIAA Paper 2007-2216, 48th AIAA SDM Meeting,
Honolulu, Hawaii, April 2007

*** BEGIN CALCULATIONS RELATING TO THE KOITER THEORY ***
*** See Ref.[3]: Bushnell, D., "Optimization of composite,
*** stiffened, imperfect panels under combined loads for
*** service in the posbuckling regime", CMAME, vol.103,
*** pp 43-114 (1993)
** BEGIN SUBROUTINE INTMOD (INTEGRALS OF PRODUCTS OF MODES) **
 SUB.INTMOD computes the quantities given on pp 58 and 59 of
 the paper just cited.
 **** END SUBROUTINE INTMOD (INTEGRALS OF PRODUCTS OF MODES) ****
  BEFORE POSSIBLE CHANGE: INITIAL LOCAL IMPERFECTION W0=  0.00265957881
  AFTER POSSIBLE CHANGE: INITIAL LOCAL IMPERFECTION W0=  0.00265957881

***** BEGIN SUBROUTINE KOIT2 (KOITER THEORY POSTBUCKLING) ****

 ******** ENTERING KOITER BRANCH, SUBROUTINE KOIT2 *********   note
 This subroutine is an implementation of the theory described
 in the PANDA2 paper by David Bushnell:
     "Optimization of composite, stiffened, imperfect panels
      under combined loads for service in the postbuckling
      regime", Computer Methods in Applied Mechanics and
      Engineering, Vol. 103 (1993) 43-114 (volume in honor of
      Besselings 65th birthday).

 LOCAL BIFURCATION BUCKLING LOAD FACTOR ESTIMATES
 AND AMPLITUDE Wo OF LOCAL IMPERFECTION, Wo*(buckling mode)
 Critical number of axial half-waves                   = 21
 Slope of buckling nodal lines from Koiter Theory, m=  7.24E-03
 Knockdown factor for C44, C45, C55 for transv.shear=  9.99E-01
 Local buckling load Factor from Koiter-type Theory =  2.27E-01
 Load Factor from BOSOR4-type panel module model    =  2.31E-01
 BOSOR4-type load factor without knockdowns for
   effects of anisotropy [e.g. C(4,6)] of the skin,
   transverse shear def., or in-plane shear loading =  2.32E-01
 Amplitude Wo of local imperfection                 =  2.6596E-03

 Even if the load factor from Koiter-type theory is greater
 than unity, the panel is in a "post-locally-buckled" state
 because there is always a finite local imperfection in the
 panel skin and stringer that grows under the applied loads.

 Margin=  1.3380E-01  Local buckling from Koiter theory,M=21  axial halfwaves;FS=0.2

 LOCAL DEFORMATION CHARACTERISTICS:
 Average axial strain(not including thermal),EXAVE = -1.8744E-03
 Initial local imperfection amplitude,           Wo=  2.6596E-03
 Slope of local buckling nodal lines in skin      M =  3.3738E-02
 Parameter "a" in the expression f*(phi +a*phi**3) = -1.0000E-04
 Amplitude  f  in the expression f*(phi +a*phi**3) =  6.4681E-02
 Normal displacement amplitude between stringers W =  6.4674E-02
 Number of axial halfwaves at local bifurcation    =    21
 Number of axial halfwaves in postbuckled regime   =  2.1624E+01
 Convergence characteristic,              NOCONV   =  0


 RESULTS FOR  2.1624E+01 AXIAL WAVES...
 LOCAL DEFORMATION PARAMETERS:
    SLOPE, a, f        =  3.3738E-02 -1.0000E-04  6.4681E-02
 APPLIED STRESS RESULTANTS (Load set A):
    Nx, Ny, Nxy        = -1.0000E+03 -1.0000E-03  5.0000E+00
 APPLIED STRESS RESULTANTS (Load set B):
   Nxo, Nyo, Nxyo      =  0.0000E+00  0.0000E+00  0.0000E+00
 STRAIN AND STRESS FROM APPLIED LOADS:
 AVERAGE STRAIN COMPONENTS:
   EPS1, EPS2, EPS12   = -1.8744E-03 -1.1509E-04  1.0556E-04
 AVERAGE RESULTANTS IN SKIN:
 N1SKIN,N2SKIN,N12SKIN= -2.7487E+02 -1.0013E-03  5.0000E+00
 NOTE: N1SKIN includes average of Nx in skin and stringer base.


 TANGENT STIFFNESS AFTER SYMMETRIZATION
 AVERAGE SKIN TANGENT STIFFNESS MATRIX
 (Segments 1 and 2 averaged),    CTAN...
  1.2544E+05 -2.8788E+04  1.1295E+03
 -2.8788E+04  2.1070E+05  5.7608E+03
  1.1295E+03  5.7608E+03  4.7528E+04
```

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```
 (APPLIED LOAD)/(BUCKLING LOAD)=  4.4099E+00

 NORMALIZED AVERAGE SKIN TANGENT STIFFNESS MATRIX
 (CTAN(i,i)/CX(i,i,1), i=1,2,3) =   4.2921E-01  7.2095E-01  4.6463E-01
 TANGENT POISSON RATIO
 CTAN(1,2)/CTAN(1,1) =  -2.2950E-01
 NORMALIZED AVERAGE (N1skin,N12skn) COUPLING
 CTAN(1,3)/CX(1,1,1) =    3.8648E-03
 NORMALIZED AVERAGE (N2skin,N12skn) COUPLING
 CTAN(2,3)/CX(2,2,1) =    1.9711E-02
 ***** END SUBROUTINE KOIT2 (KOITER THEORY POSTBUCKLING) ******
 ********** END OF NONLINEAR EQUILIBRIUM CALCS.************

 ************************************************************
 CHAPTER 17 Compute stresses in layers and at various
            locations in skin-stringer module model, including
            local post-buckling, if any. Compute stringer
            popoff constraints (Figs. 5 - 7 in [1A]). Local
            post-buckling such as that shown in Figs. 48 & 49
            of [1A] is included. Therefore, SUBROUTINE STRTHK
            is used.

***** BEGIN SUBROUTINE STRTHK (POSTBUCKLING STRESSES) ******
 Margin=  2.7895E+01  eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=0.0133; MID.;FS=1.
 Margin=  2.8859E+04  stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 Margin=  1.9634E+00  eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0504; MID.;FS=1.
 ***** END SUBROUTINE STRTHK (POSTBUCKLING STRESSES) ********

***** BEGIN SUBROUTINE STRCON (STRESSES IN RINGS) ******
 ***** END   SUBROUTINE STRCON (STRESSES IN RINGS) ******

 ************************************************************
 CHAPTER 18 Present summary of state of loaded imperfect panel
            and give effective stiffnesses of possibly locally
            postbuckled skin-stringer module. These effective
            stiffnesses are used later for overall buckling
            and inter-ring buckling. See Table 12 in the paper
 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

 PANEL OVERALL & LOCAL IMPERFECTIONS AND DEFORMATION
 General out-of-roundness of cylindrical panel,WIMPG1 =  0.0000E+00
 General initial buckling modal imperfection amplitude=  0.0000E+00
 General modified imperfection amplitude, Wimp(global)=  0.0000E+00
 Local   initial imperfection amplitude, Wimp(local)  =  2.6596E-03
 Panel (inter-ring) initial imp. amplt., Wimp(panel)  =  1.0000E-10
 Bowing due to temperature effects,     W(residual)   =  0.0000E+00
 Overall (inter-ring in cyl) bowing from pressure ,Wp =  0.0000E+00
 Inter-ring bowing (flat panel) from pressure, WPRESR =  0.0000E+00
 Maximum local "pillowing" between stringers,  WLPRES = -1.5133E-05
 Inter-ring bowing due to postbucking effects, WDELKP =  0.0000E+00
 Amplitude factor for bowing except from press,AMPLIT =  5.4201E+00
 Amplitude factor for bowing due to pressure,  AMPLT2 =  1.1632E+00
 Amplitude factor for inter-ring bowing,       AMPLT3 =  1.0000E+00
 Eccentricity of application of axial loads,     ECC  =  0.0000E+00

 *** BEGIN SUBROUTINE LOCAL (HI-M POST-POSTBUCKLING SEARCH) ***
 Buckling load factor from SUB. LOCAL, EIGITR(6)=  9.9981E-01
 Number of axial halfwaves between rings,NPP=   42
  **** END SUBROUTINE LOCAL (HI-M POST-POSTBUCKLING SEARCH) ****

 **** BEGIN SUBROUTINE  MODE (HI-M POST-POSTBUCKLING MODE) ****
  **** END SUBROUTINE  MODE (HI-M POST-POSTBUCKLING MODE) ****
 Margin= -2.3824E-04  Hi-axial-wave post-post-buckling of module - 1;    M=42 ;FS=1.

*** BEGIN SUBROUTINE DEFCIJ (POST-LOCALLY BUCKLED CS(I,J)) ****
 Effective stiffnesses of undeformed and of
 locally deformed module segments:
                                                  Undeformed   Deformed
    Effective axial stiffness of panel SKIN + BASE =  2.9226E+05  1.4433E+05
    Effective hoop  stiffness of panel SKIN + BASE =  2.9226E+05  2.1001E+05
    Effective (1,2) stiffness of panel SKIN + BASE =  8.7678E+04  5.1258E+03
    Effective axial stiffness of stringer   WEB    =  1.1070E+06  1.1065E+06
    Effective axial stiffness of stringer   FLANGE =  0.0000E+00  0.0000E+00
```

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```
    Effective shear stiffness of panel SKIN + BASE =  1.0229E+05  4.7365E+04
    Effective shear stiffness of stringer   WEB    =  3.8744E+05  3.8744E+05
    Effective shear stiffness of stringer   FLANGE =  0.0000E+00  0.0000E+00

Integrated stringer stiffnesses...
    Effective axial stiffness of stringer,    STIFL =  3.8671E+05
    Effective first moment, Int[STIF*zdz],    STIFM =  2.7418E+05
    Effective second moment,Int[STIF*z**2dz],STIFMM=  2.5680E+05

Constitutive law, CS(i,j), for locally deformed
panel with smeared stringers and rings.....
      5.3263E+05  5.1247E+03  0.0000E+00  2.7418E+05  0.0000E+00  0.0000E+00
      5.1247E+03  2.1001E+05  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
      0.0000E+00  0.0000E+00  4.7365E+04  0.0000E+00  0.0000E+00  0.0000E+00
      2.7418E+05  0.0000E+00  0.0000E+00  2.5682E+05  5.1682E+00  0.0000E+00
      0.0000E+00  0.0000E+00  0.0000E+00  5.1682E+00  1.7227E+01  0.0000E+00
      0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.3185E+02
*** END   SUBROUTINE DEFCIJ (POST-LOCALLY BUCKLED CS(I,J)) ****

************************************************************
CHAPTER 19 Do wide-column inter-ring buckling analysis with
           possibly locally postbuckled skin-stringer module
           model. (See Figs. 20c, 22c, 46d, and 67 of [1A],
           for examples.).

*** BEGIN SUBROUTINE BUCKLE (WIDE-COLUMN BUCKLING - MODULE) ****
*** END SUBROUTINE BUCKLE (WIDE-COLUMN BUCKLING - MODULE) ****

*** BEGIN SUBROUTINE MODE (WIDE-COLUMN BUCKLING MODE SHAPE) ****
 *** END SUBROUTINE MODE (WIDE-COLUMN BUCKLING MODE SHAPE) ****
  KNOCKDOWN FACTOR FOR INTER-RING BUCKLING
  HAS BEEN CHANGED FROM FKNOCK(4)=  0.999971807
  TO A NEW VALUE,          FTEMP =  0.999989867
  BECAUSE OF DEVELOPMENT OF A DIAGONAL TENSION
  FIELD, WHICH IS ACCOUNTED FOR IN SUB. KOIT2.

  WIDE COLUMN PANEL BUCKLING LOAD FACTOR =          4.6268E-01
 ISKIN = 0. WIDE COLUMN BUCKLING IS IGNORED IF ISKIN = 1.
 IWIDE = 0. WIDE COLUMN BUCKLING IS IGNORED IF IWIDE = 0.
 ITIP  = 0. MODE OF BUCKLING IS STRINGER SIDESWAY IF ITIP=1

************************************************************
CHAPTER 20 Compute width-wise wide column buckling and
           lateral-torsional buckling load factors from the
           possibly locally postbuckled skin-stringer module
           model (inter-ring buckling modes).
           See panda2.news Item Numbers 379 and 381 in [1L].
Number of axial halfwaves=  1; Buckling load factor=  3.5567E+00
Number of axial halfwaves=  2; Buckling load factor=  1.6258E+00
Number of axial halfwaves=  3; Buckling load factor=  1.2749E+00
Number of axial halfwaves=  4; Buckling load factor=  1.1599E+00
Number of axial halfwaves=  5; Buckling load factor=  1.1148E+00
Number of axial halfwaves=  6; Buckling load factor=  1.0985E+00
Number of axial halfwaves=  7; Buckling load factor=  1.0965E+00
Number of axial halfwaves=  8; Buckling load factor=  1.1023E+00
Margin= -3.1653E-03  (m=7   lateral-torsional buckling load factor)/(FS)-1;FS=1.1

************************************************************
CHAPTER 21 (smeared ring knockdown factor) and
CHAPTER 22 ("skin"-ring buckling) are not executed because
the panel is flat or there are no rings or the rings are
either hats or truss-core configuration.

************************************************************
CHAPTER 23 Compute stresses in layers and at various
           locations in modules for both positive and
           negative imperfection amplitudes from SUBROUTINE
           STRCON (local postbuckling neglected). See [1L]
           (panda2.news) Items 36b,d,w, 41b, and Section E
           of Table 122.6 in Item 122.

***** BEGIN SUBROUTINE STRCON (IQUICK = 1 TYPE STRESSES) ******
 Margin=  2.7203E+01  eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.0133;-MID.;FS=1.
 Margin=  2.9169E+00  eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
 ***** END   SUBROUTINE STRCON (IQUICK = 1 TYPE STRESSES) ******

************************************************************
CHAPTER 24 Present short summary of redistribution of stress
```

Table 1.70

```
          resultants, Nx, Ny, Nxy, caused by prebuckling
          bending of an initially imperfect shell.
          See Section 6.0 in [1K], for example.

 Additional resultants (Nx,Ny) in panel skin from
 global and inter-ring bending of imperfect panel:
          Additional axial resultant, dNx =  0.0000E+00
          Additional  hoop resultant, dNy =  0.0000E+00
   Additional in-plane shear resultant, dNxy=  0.0000E+00

 Additional axial resultants dNx along webs and flanges of
 stringers from global and inter-ring bending of imperfect panel:
     Additional Nx in  base  of stringer, dNx =  0.0000E+00
     Additional Nx at webtip of stringer, dNx =  0.0000E+00
     Additional Nx in flange of stringer, dNx =  0.0000E+00

 ************************************************************
 CHAPTER 25 Compute buckling load factors from PANDA-type
            theory for the various segments of a stringer and
            a ring. Typical buckling modes are displayed in
            Figs. 5 and 6 of Ref.[1B].

***** BEGIN SUBROUTINE STFEIG (BUCKLING IN STIFFENERS) ******
 Margin=  4.4727E-01  buckling margin stringer Iseg.3 . Local halfwaves=14 .MID.;FS=1.
 ***** END   SUBROUTINE STFEIG (BUCKLING IN STIFFENERS) ******

***** BEGIN SUBROUTINE STFEIG (NO POSTBUCKLING EFFECT) ******
 Margin=  7.7002E-01  buckling margin stringer Iseg.3 . Local halfwaves=14 .NOPO;FS=1.
 ******* END SUBROUTINE STFEIG (NO POSTBUCKLING EFFECT) ******

 ************************************************************
 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) ****

 Sanders theory is used for these buckling calculations in this case.
 Local buckling load factors & mode shapes before any knockdown factors applied:
 EIGMNC=  3.95E-01  1.00E+17  3.93E-01  1.00E+17  3.93E-01  3.93E-01  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=   12         0        13         0        13        13         0
 NWAVEX=    1         0         1         0         1         1         0
 NOTE: The buckling nodal line slopes, SLOPEX, are as
 defined in Fig. 9a or Fig. 9b of the 1987 "Theoretical
 basis of the PANDA...",if NWAVEX > 0; that is, there
 has not yet been any inversion of SLOPEX when 9b holds.

 LOCAL BUCKLING FROM PANDA-TYPE THEORY [1B] AFTER KNOCKDOWN FOR t.s.d.:
 EIGLOC =    3.9284E-01(m=  13,n=   1)

 Entering ALTSOL: radius, axial, circ. dimensions =  5.0000E+01  5.0000E+01  2.1741E+01
 See ITEMs 438, 444  in the file ..panda2/doc/panda2.news .
 and AIAA paper 99-1233, Proc. 40th AIAA SDM Meeting, 1999
 pp 302-345, especially pp 304-316 and associated figures.
 *** GENERAL BUCKLING, N x M BAY PATCH, SMEARED SUBSTIFFRS ***
        Number of discrete stringers, rings: NUMSTR, NUMRNG=  7  0

 No alternative solution sought because user did not want one.
 (IALTSN was set equal to zero in MAINSETUP)
 General buckling loads AFTER knockdown for t.s.d.
 Number of circumferential halfwaves in buckling pattern=  5.0000E+00
 Buckling load factor BEFORE knockdown for smeared stringers=  1.2883E+00
 Buckling load factor AFTER  knockdown for smeared stringers=  1.1009E+00

 General buckling load factor before and after knockdown:
 EIGGEN(before modification by 5 factors below)      =  1.1009E+00
 Knockdown factor from modal imperfection(s)         =  1.0000E+00
 Knockdown factor for smearing rings on cyl. shell   =  1.0000E+00
 Knockup factor to avoid twice accounting for t.s.d.=  1.0000E+00
 1st modifying factor, FKNMOD=1 or 1/(EIG9X*FMDKD9)  =  1.0000E+00
 2nd modifying factor, EIGMR9=1 or EIGGNX/EIGGEN     =  1.0000E+00
 After knockdn,EIGGEN*FKNOCK(9)*(RNGKNK/SHRFCT)*FKNMOD*EIGMR9=  1.1009E+00
 in which
 EIG9X  = lambda(ARBOCZ)/lambda(original PANDA-type theory)=  1.0000E+00
       lambda(ARBOCZ)=perfect panel buckling from ARBOCZ theory
```

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Table 1.70


```
   lambda(PANDA) =perfect panel buckling from PANDA  theory
FMDKD9 = 1 or 0.9/EIG9X =  1.0000E+00
EIGGNX = eigenvalue for perfect panel from alternate solution
Margin=  7.7856E-04  buck.(SAND);simp-support general buck;M=1;N=5;slope=0.;FS=1.1
Margin=  1.3892E+00  buck.(SAND);rolling only of stringers;M=23;N=0;slope=0.;FS=1.4

Stringer rolling from PANDA-type theory [1B]:
PANDA-type buckling load factor, EIGRLL(2)(m,n,slope)=  3.3449E+00(  23,0,0)
****  END SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS) ****
*** END   SUBROUTINE BUCPAN (PANDA-TYPE BUCKLING LOADS) ****
Margin=  5.3250E+02  (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.

*************************************************************
CHAPTER 27 Compute the objective function (e.g. WEIGHT).

Objective (weight of PANDA2 model of panel), OBJ =  1.6320E+01

*************************************************************
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

ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 1:
LOADING: Nx, Ny, Nxy, Mx, My =  -1.00E+03 -1.00E-03  5.00E+00  0.00E+00  0.00E+00
         Nxo, Nyo, pressure  =   0.00E+00  0.00E+00 -2.00E-05
BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
 Local buckling load factor from KOITER theory =  2.2676E-01 (flat skin)
 Local buckling load factor from BOSOR4 theory =  2.3147E-01 (flat skin)
0
MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
MAR. MARGIN
NO.  VALUE              DEFINITION
 1  1.57E-01 Local buckling from discrete model-1.,M=21  axial halfwaves;FS=0.2
 2  4.26E+00 Bending-torsion buck.(bypassed low-m mode);M=3  ;FS=0.2
 3  1.34E-01 Local buckling from Koiter theory,M=21  axial halfwaves;FS=0.2
 4  2.79E+01 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=0.0133; MID.;FS=1.
 5  2.89E+04 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6  1.96E+00 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0504; MID.;FS=1.
 7 -2.38E-04 Hi-axial-wave post-post-buckling of module - 1;   M=42 ;FS=1.
 8 -3.17E-03 (m=7   lateral-torsional buckling load factor)/(FS)-1;FS=1.1
 9  2.72E+01 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.0133;-MID.;FS=1.
10  2.92E+00 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11  4.47E-01 buckling margin stringer Iseg.3 . Local halfwaves=14 .MID.;FS=1.
12  7.70E-01 buckling margin stringer Iseg.3 . Local halfwaves=14 .NOPO;FS=1.
13  7.79E-04 buck.(SAND);simp-support general buck;M=1;N=5;slope=0.;FS=1.1
14  1.39E+00 buck.(SAND);rolling only of stringers;M=23;N=0;slope=0.;FS=1.4
15  5.33E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ***********  ALL 1 LOAD SETS PROCESSED  ***********
*****************************************************
```

note

```
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     N     N      0    0.00E+00  3.00E+00 3.6236E+00  1.00E+01        B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N     Y      1    3.33E-01  0.00E+00 1.2077E+00  0.00E+00        B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N     N      0    0.00E+00  2.00E-01 1.3916E+00  1.00E+01        H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y     N      0    0.00E+00  1.00E-02 2.6596E-02  1.00E+00    T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     Y     N      0    0.00E+00  1.00E-02 1.0074E-01  1.00E+00    T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
0
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER    CURRENT
 NO.  RNG  NO.   NO.      VALUE          DEFINITION
            0     0    1.632E+01    WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                          =    6.6489E+00
  TOTAL WEIGHT OF SUBSTIFFENERS                 =    0.0000E+00
  TOTAL WEIGHT OF STRINGERS                     =    9.6715E+00
```

optimum design

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Table 1.70 (end)

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```
 TOTAL WEIGHT OF RINGS                            =    0.0000E+00
 SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=    6.5282E-03
IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
rikscurved.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
RUN SUPEROPT.
******************** END OF rikscurved.OPM FILE ****************
```

Table 171 rikscurved.PAN (input for PANEL)

```
n         $ Do you want a tutorial session and tutorial output?
  50      $ Panel length in the plane of the screen, L2
   1      $ Enter control (0 or 1) for stringers at panel edges
   1      $ Enter ILOCAL=0 for panel buckling; 1 for local buckling, ILOCAL
  21      $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
   3      $ How many eigenvalues (get at least 3) do you want?
```

This number is obtained from the local buckling mode identified ~~as~~ in Margin No. 1 on p. 14 of the previous table.

Table 1.72 Modify BIGBOSOR4 input file

Table 1.72 Modify the rikscurved.ALL file in order to find minimum buckling load factor with respect to circumferential wave number

Part of the rikscurved.ALL file after "cleanup" BEFORE modification of N0B, NMINB, NMAXB, INCREB, NVEC::

```
      H          $
      H          $ GLOBAL DATA BEGINS...
         0       $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
      N          $ Are there any regions for which you want expanded plots?
      2100       $ N0B   = starting number of circ. waves (buckling analysis)
      2100       $ NMINB = minimum number of circ. waves  (buckling analysis)
      2100       $ NMAXB = maximum number of circ. waves  (buckling analysis)
      2100       $ INCRB = increment in number of circ. waves (buckling)
         3       $ NVEC  = number of eigenvalues for each wave number
      H          $ CONSTRAINT CONDITIONS FOLLOW....
        44       $ How many segments in the structure?
      H          $
      H          $ CONSTRAINT CONDITIONS FOR SEGMENT NO.    1    1    1    1
```

Part of the rikscurved.ALL file AFTER modification of N0B, NMINB, NMAXB, INCREB, NVEC::

```
      H          $
      H          $ GLOBAL DATA BEGINS...
         0       $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
      N          $ Are there any regions for which you want expanded plots?
      1500       $ N0B   = starting number of circ. waves (buckling analysis)
      1500       $ NMINB = minimum number of circ. waves  (buckling analysis)
      2500       $ NMAXB = maximum number of circ. waves  (buckling analysis)
       100       $ INCRB = increment in number of circ. waves (buckling)
         1       $ NVEC  = number of eigenvalues for each wave number
      H          $ CONSTRAINT CONDITIONS FOLLOW....
        44       $ How many segments in the structure?
      H          $
      H          $ CONSTRAINT CONDITIONS FOR SEGMENT NO.    1    1    1    1
```

Table 1.73 output from BIGBOSOR4

rikscurved.OUT (abridged)

```
 **** CRITICAL EIGENVALUE AND WAVENUMBER ****
 EIGCRT=  3.1799E-01; NO. OF CIRC. WAVES, NWVCRT= 2400
 ****************************************************

 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    3.7411E-01(1500)
    3.6033E-01(1600)
    3.4909E-01(1700)
    3.4001E-01(1800)
    3.3278E-01(1900)
    3.2718E-01(2000)
    3.2303E-01(2100)
    3.2019E-01(2200)
    3.1854E-01(2300)
    3.1799E-01(2400)
    3.1846E-01(2500)
 =======================================
```

"2400" means "24 axial halfwaves between rings" See Fig. 23b, p. 97, of ~~Ref.~~ AIAA paper 2007-2216, 48th AIAA SDM Meeting, 2007

critical value from bigbosor4.

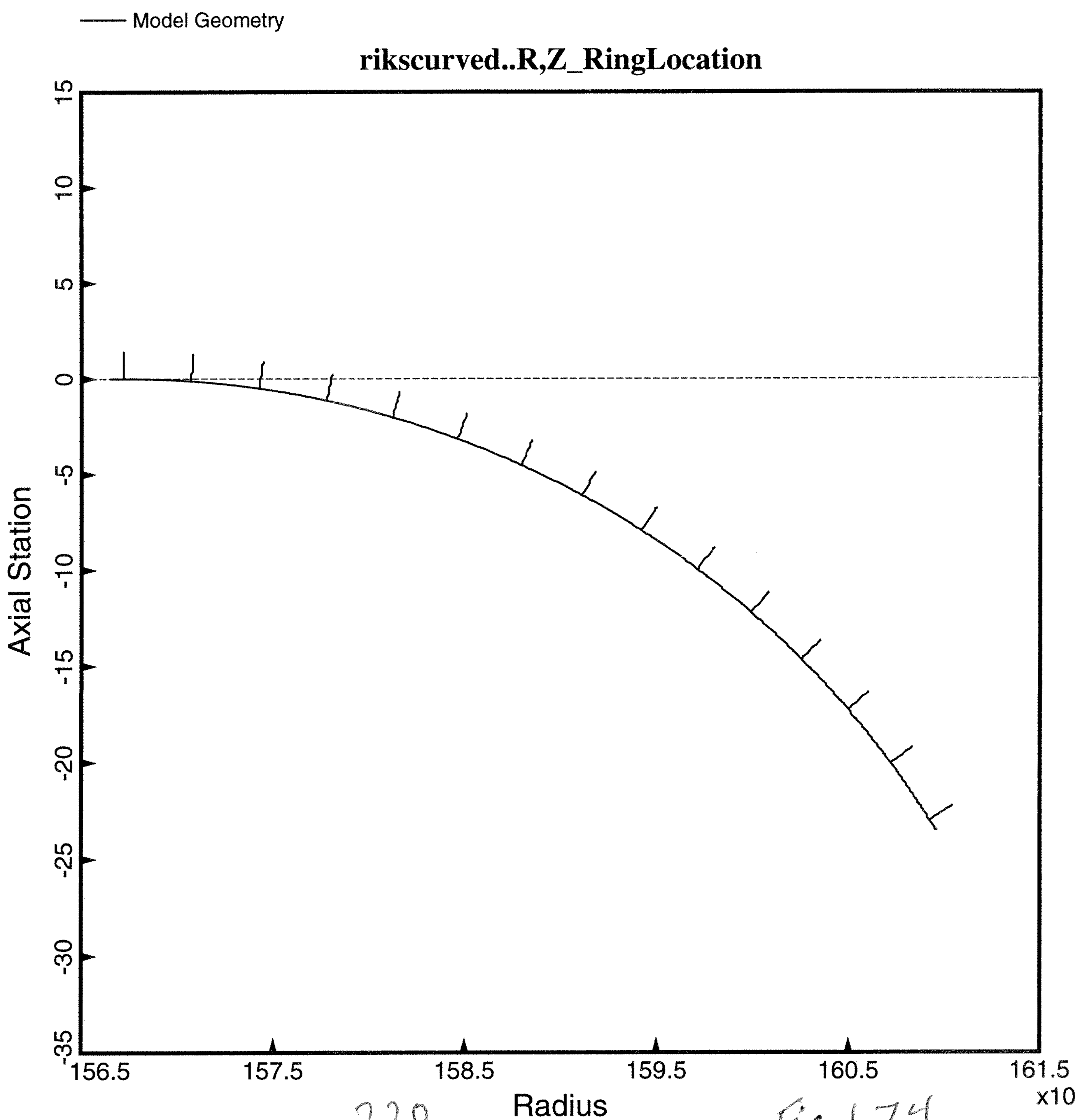
compare with PANDA2 prediction.

BIGBOSOR4's result is higher than PANDA2's (0.2314 on p.9 of Table 1.70) because in the PANDA2 model the skin between stiffeners is assumed to be flat.

note!

rikscurved.bigbosor4.undeformed.ps

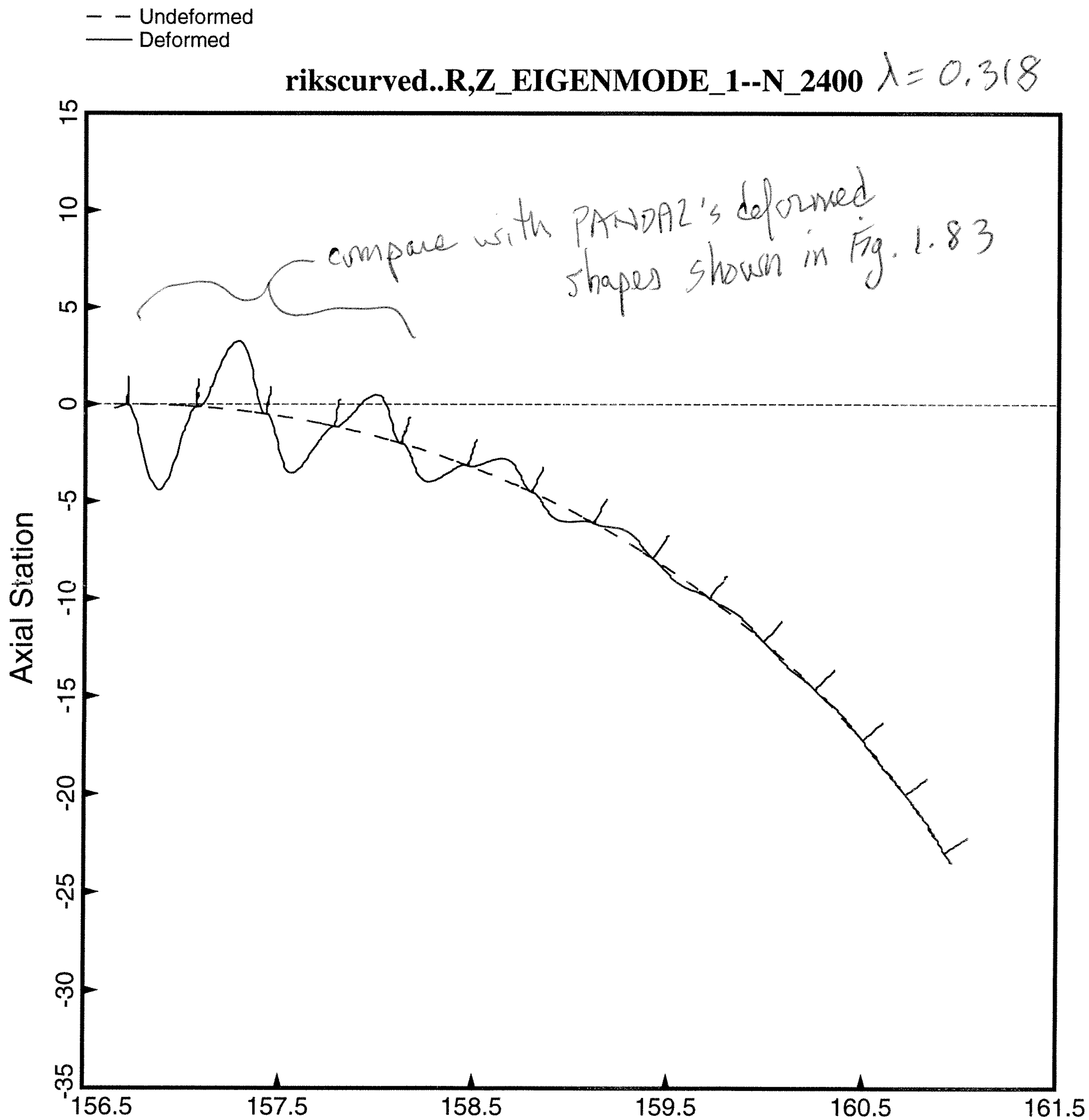
output from BOSORPLOT



220

Fig. 1.74

rikscurved.bigbosor4.bucklingmode.ps
output from BOSORPLOT



221

Fig. 1.75

Table 1.74 rikscurved. STG (input for STAGSUNIT)

```
     n          $ Do you want a tutorial session and tutorial output?
        1       $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
        0       $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
0.2600000       $ Local buckling load factor from PANDA2, EIGLOC
     y          $ Are the dimensions in this case in inches?
        0       $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
        0       $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
       50       $ X-direction length of the STAGS model of the panel: XSTAGS
       50       $ Panel length in the plane of the screen, L2
     y          $ Is the nodal point spacing uniform along the stringer axis?
      201       $ Number of nodes in the X-direction: NODEX
-1000.000       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
        0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
        0       $ In-plane shear in load set A,                        Nxy
        0       $ Normal pressure in STAGS model in Load Set A, p
        0       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
        0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
        0       $ Normal pressure in STAGS model in Load Set B, p0
        1       $ Starting load factor for Load System A, STLD(1)
        0       $ Load factor increment for Load System A, STEP(1)
        1       $ Maximum load factor for Load System A, FACM(1)
        0       $ Starting load factor for Load System B, STLD(2)
        0       $ Load factor increment for Load System B, STEP(2)
        0       $ Maximum load factor for Load System B, FACM(2)
        1       $ How many eigenvalues do you want? NEIGS
      480       $ Choose element type (410 or 411 or 480) for panel skin
     n          $ Have you obtained buckling modes from STAGS for this case?
       90       $ Number of stringers in STAGS model of 360-deg. cylinder
        0       $ Number of rings in the STAGS model of the panel
     n          $ Are there rings at the ends of the panel?
        3       $ Number of finite elements between adjacent stringers
      100       $ Number of finite elements between adjacent rings
        3       $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
        3       $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
        0       $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
     n          $ Do you want to use fasteners (they are like rigid links)?
     n          $ Are the stringers to be "smeared out"?
     y          $ Are the rings to be "smeared out"?
        5       $ Number of nodes over height of stiffener webs, NODWEB
        5       $ Number of nodes over width of stringer flange, NDFLGS
        5       $ Number of nodes over width of ring flange, NDFLGR
     n          $ Do you want stringer(s) with a high nodal point density?
     n          $ Do you want ring(s) with a high nodal point density?
     n          $ Is there plasticity in this STAGS model?
     n          $ Do you want to use the "least-squares" model for torque?
     n          $ Is stiffener sidesway permitted at the panel edges?
     n          $ Do you want symmetry conditions along the straight edges?
        0       $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

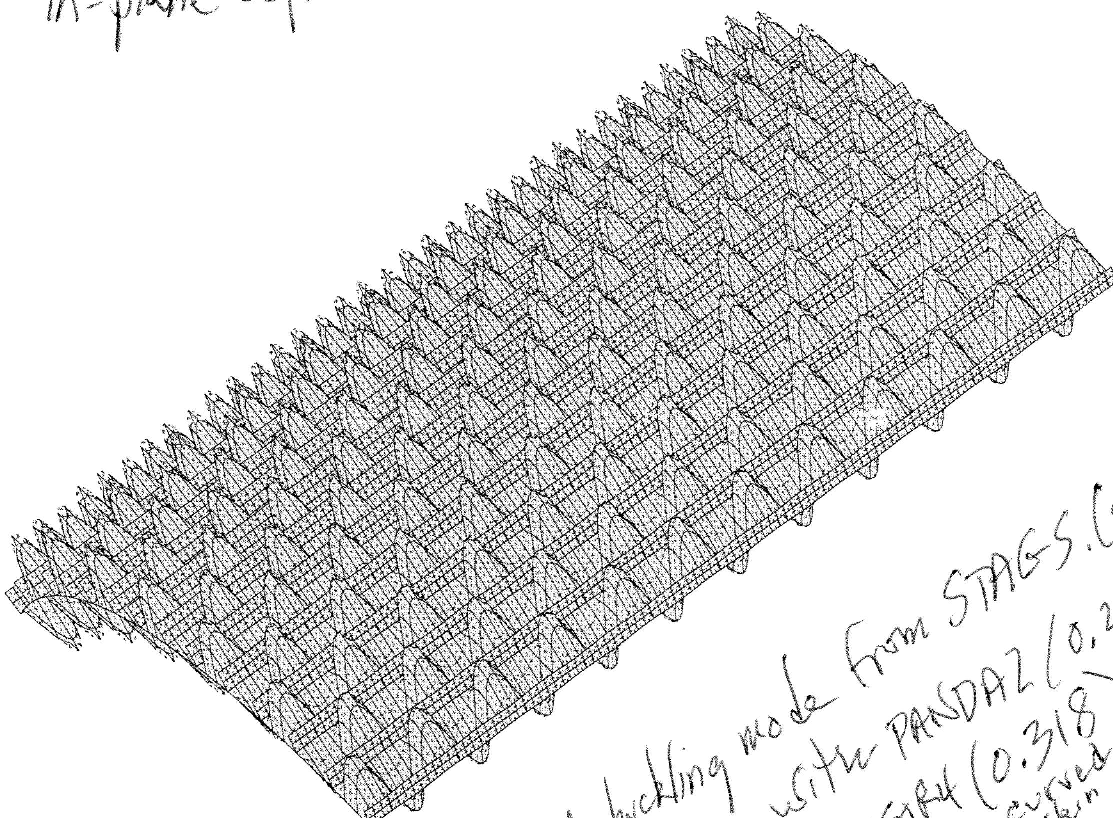
note!

STAGSUNIT produces input files for STAGS: rikscurved.bin & rikscurved.inp for linear theory (INDIC = 1) rikscurved.linbuck.pdf

output from STAGS processor called STAPL

Compare with Fig. 1.87

2 straight edges are in-plane deformable



P. 9 of Table 1.70

local buckling mode from STAGS (curved skin)

Compare with PANDA2 (0.23148) (flat skin)

& BIGBOSOR4 (0.318) curved skin ← Fig. 1.75

solution scale = 0.3636E+01

mode 1, $\boxed{\text{pcr = 0.28859E+00}}$

step 0 eigenvector deformed geometry

linear buckling of perfect shell

Θ x -35.84

Θ y -13.14

Θ z 35.63

y z x

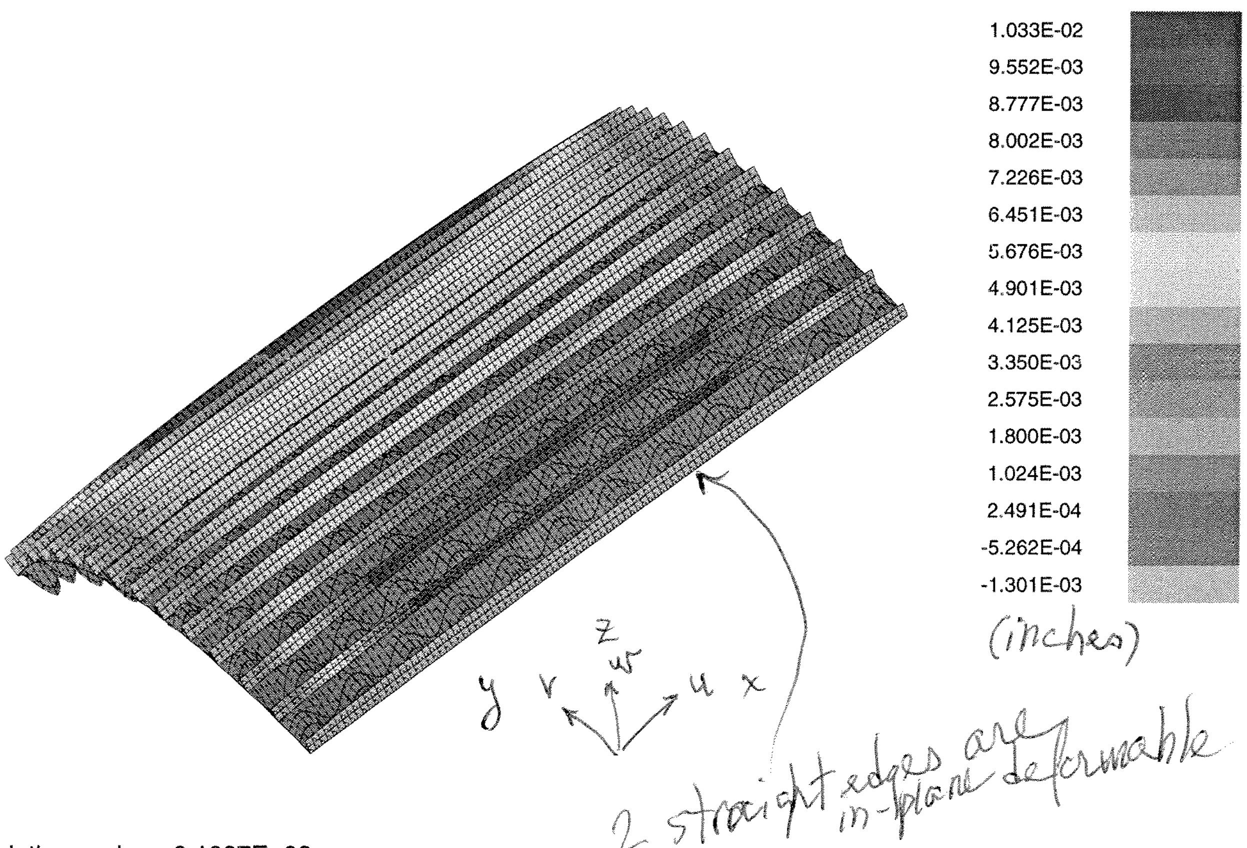
9.858E+00

Fig 1.76

rikscurved.postbuck.step5.vdisp.pdf

output from STAGS nonlinear run.

straight edges are in-plane deformable.



solution scale = 0.1087E+03

PA= 2.03632E-01 PB= 0.00000E+00 PX= 0.00000E+00

step 5 displacement v contours

nonlinear v same view as linear buckling mode

Minimum value = -1.30142E-03, Maximum value = 1.03273E-02

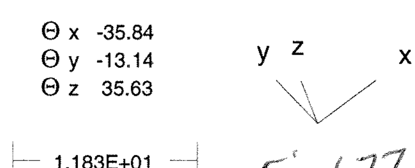
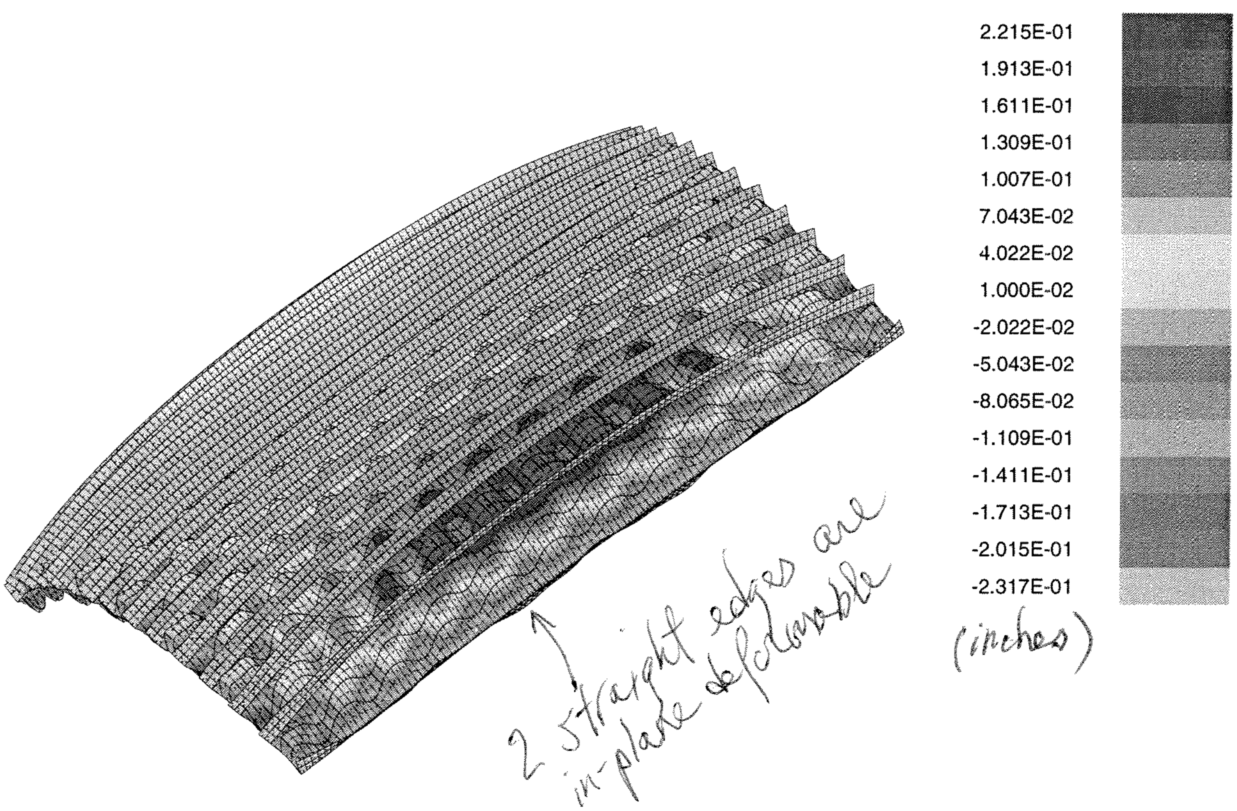


Fig. 1.77

rikscurved.postbuck.step19.pdf

output from STAGS nonlinear run.

(skin + stringers)



solution scale = 0.1260E+02

PA= 8.57690E-01 PB= 0.00000E+00 PX= 0.00000E+00

step 19 displacement w contours

nonlinear w same view as linear buckling mode

Minimum value = -2.31735E-01, Maximum value = 2.21519E-01

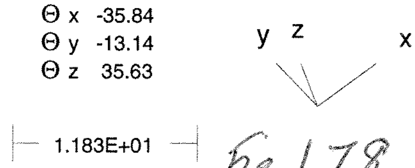
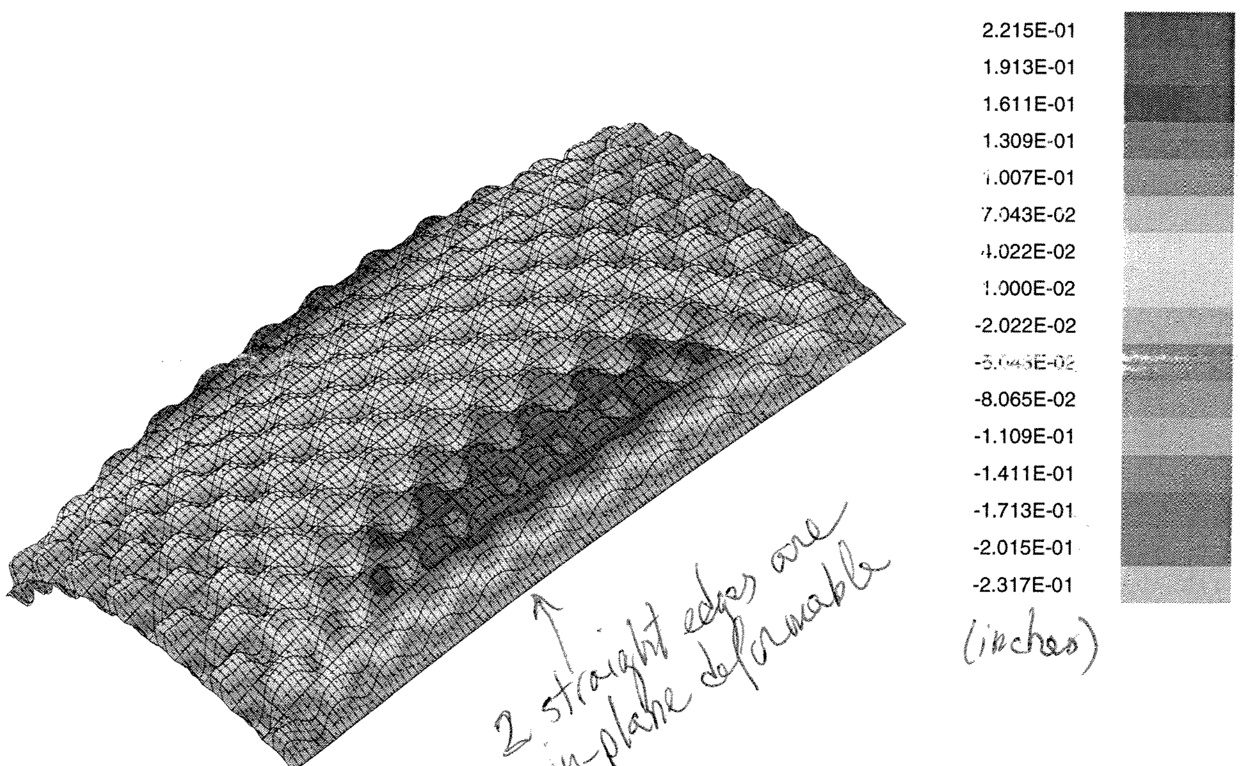


Fig. 1.78

rikscurved.postbuck.step19.skinonly.pdf

output from STAGS nonlinear run
(skin only)

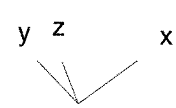


2 straight edges are in-plane deformable

(inches)

solution scale = 0.1242E+02
PA= 8.57690E-01 PB= 0.00000E+00 PX= 0.00000E+00
step 19 displacement w contours
nonlinear w in skin only; same view as linear buckling mode
Minimum value = -2.31735E-01, Maximum value = 2.21519E-01

Θ x -35.84
Θ y -13.14
Θ z 35.63



1.166E+01

Fig. 1.79

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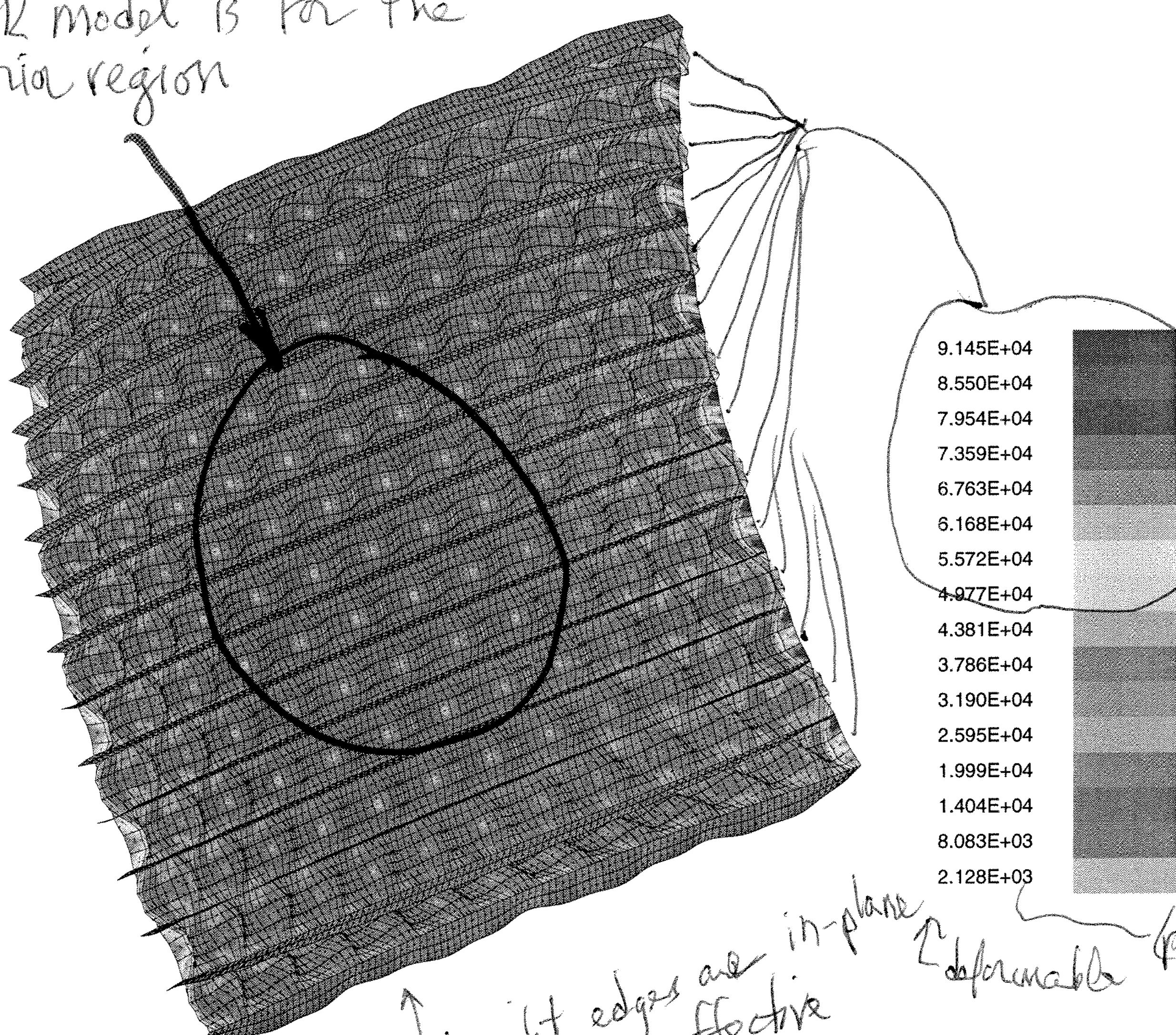
rikscurved.postbuck.step19.pdf

output from STAGS nonlinear run

PANDA2 model is for the interior region



(psi)

2 straight edges are in-plane deformable

effective stress

solution scale = 0.1344E+02
PA= 8.57690E-01 PB= 0.00000E+00 PX= 0.00000E+00
step 19 fabrication system seff, layer 1, inner fiber
nonlinear effective stress - inner fiber
Minimum value = 2.12815E+03, Maximum value = 9.14502E+04

Θ x 24.00
Θ y -22.00
Θ z 30.00

1.054E+01

y x z

Fig. 1.80

Table 1.75 rikscurved.CHG (input for CHANGE)

```
     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, . .)
  3.623600      $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        2       $ Number of parameter to change (1, 2, 3, . .)
  1.207700      $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        3       $ Number of parameter to change (1, 2, 3, . .)
  1.391600      $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        4       $ Number of parameter to change (1, 2, 3, . .)
 0.2659600E-01  $ New value of the parameter
     y          $ Want to change any other parameters in this set?
        5       $ Number of parameter to change (1, 2, 3, . .)
 0.1007400      $ 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?
```

optimum design is saved in rikscurved.CHG

Table 1.76 rikscurved.OPT for ITYPE=3

```
       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?
1.0000000        $ 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)
 0.010000        $ 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)
       1         $ 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
       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
```

test simulation analysis type

Input for MAINSETUP & PANDAOPT

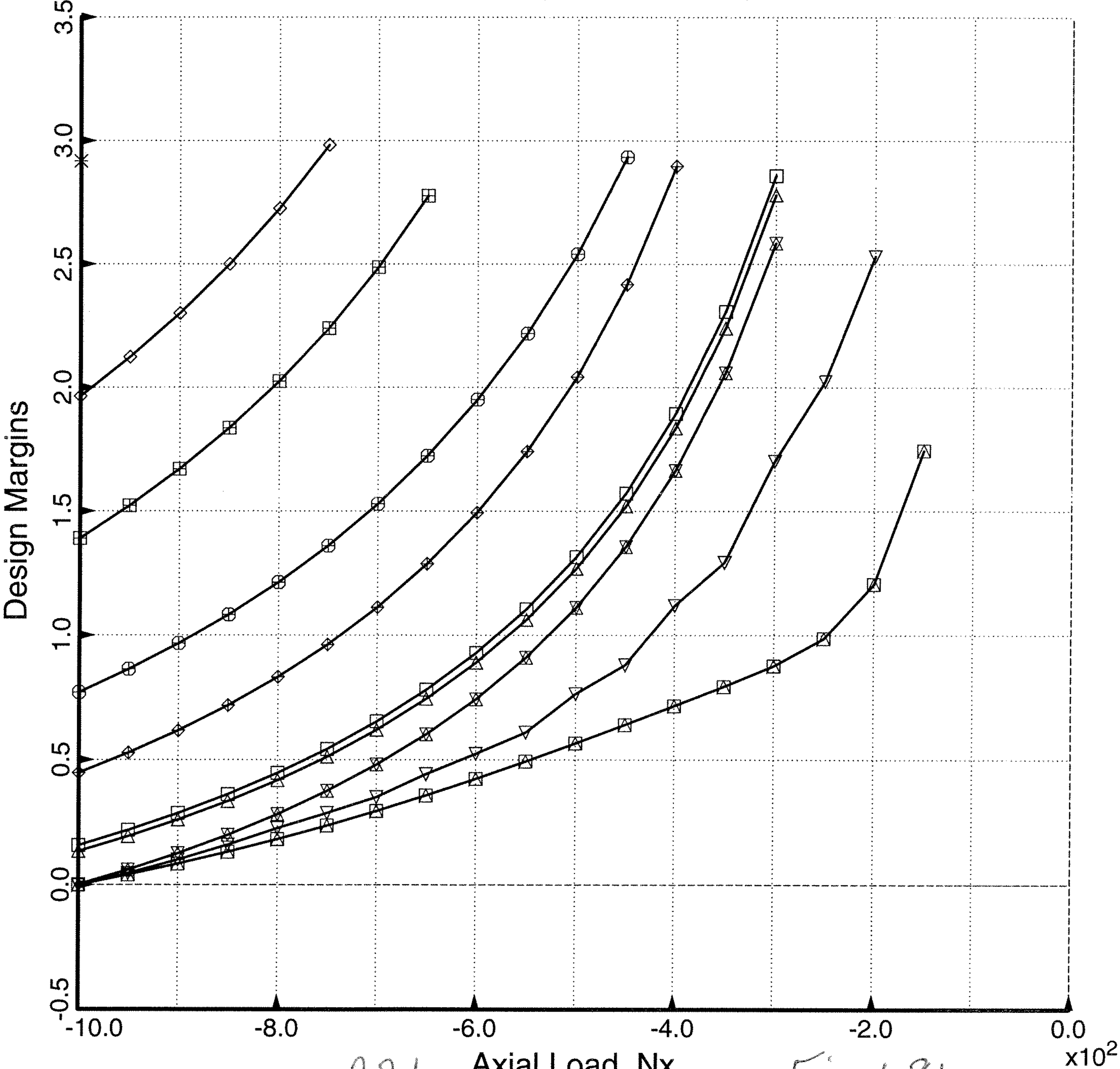
Table 1.77 ribscurved.CPL (input for CHOOSEPLOT)

```
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)?
n        $ Any extreme fiber strains to be plotted v. load steps?
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,..)
y        $ Any more margins to be plotted (Y or N) ?
   8     $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
   9     $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  10     $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  11     $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  12     $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  13     $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  14     $ Choose a margin to be plotted v. iterations (1,2,3,..)
y        $ Any more margins to be plotted (Y or N) ?
  15     $ Choose a margin to be plotted v. iterations (1,2,3,..)
n        $ Any more margins to be plotted (Y or N) ?
   3     $ Give maximum value (positive) to be included in plot frame.
y        $ Any deformed panel module cross sections to be plotted?
   0     $ 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)?
  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)?
  15     $ 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)?
```

rikscurved.3.ps. (output from DIPLOT)

□ 1 .1.1 Local buckling: discrete model
△ 3 .1.1 Local buckling: Koiter theory.
◇ 6 .1.1 eff.stress:matl=2; MID.
▽ 7 .1.1 m=? lateral-torsional buckling
✳ 9 .1.1 eff.stress:matl=2;-MID.
10.1.1 buckling: stringer seg.3 . MIDLENGTH
⊕ 11.1.1 buckling: stringer seg.3 . NO POSTBK
12.1.1 buck(SAND)simp-support general buck; MIDLENGTH
⊞ 13.1.1 buck(SAND)rolling only of stringers; MIDLENGTH
15.1.1 Hi-axial-wave post-post-buckling of module

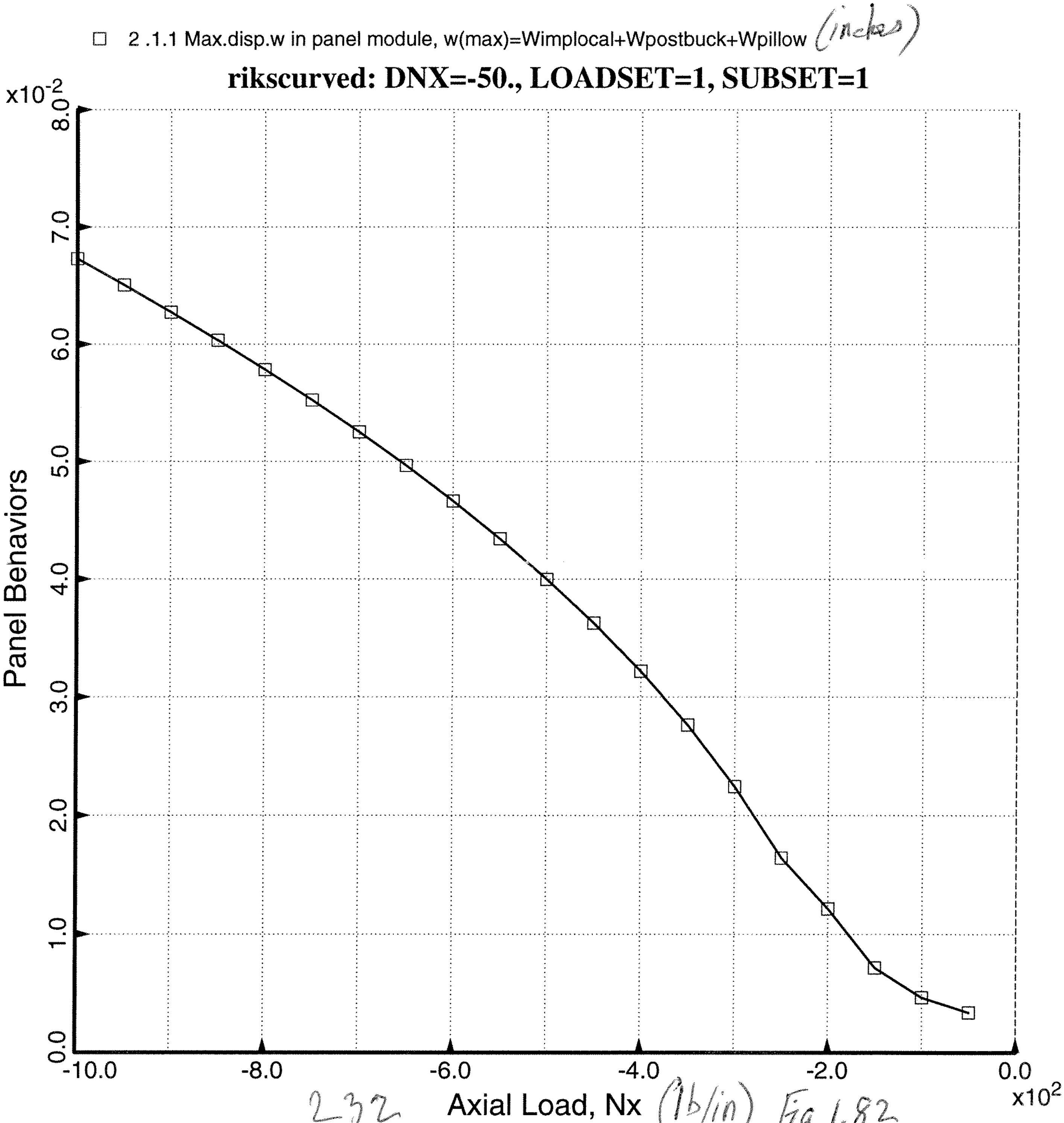
rikscurved: DNX=-50., LOADSET=1, SUBSET=1



231

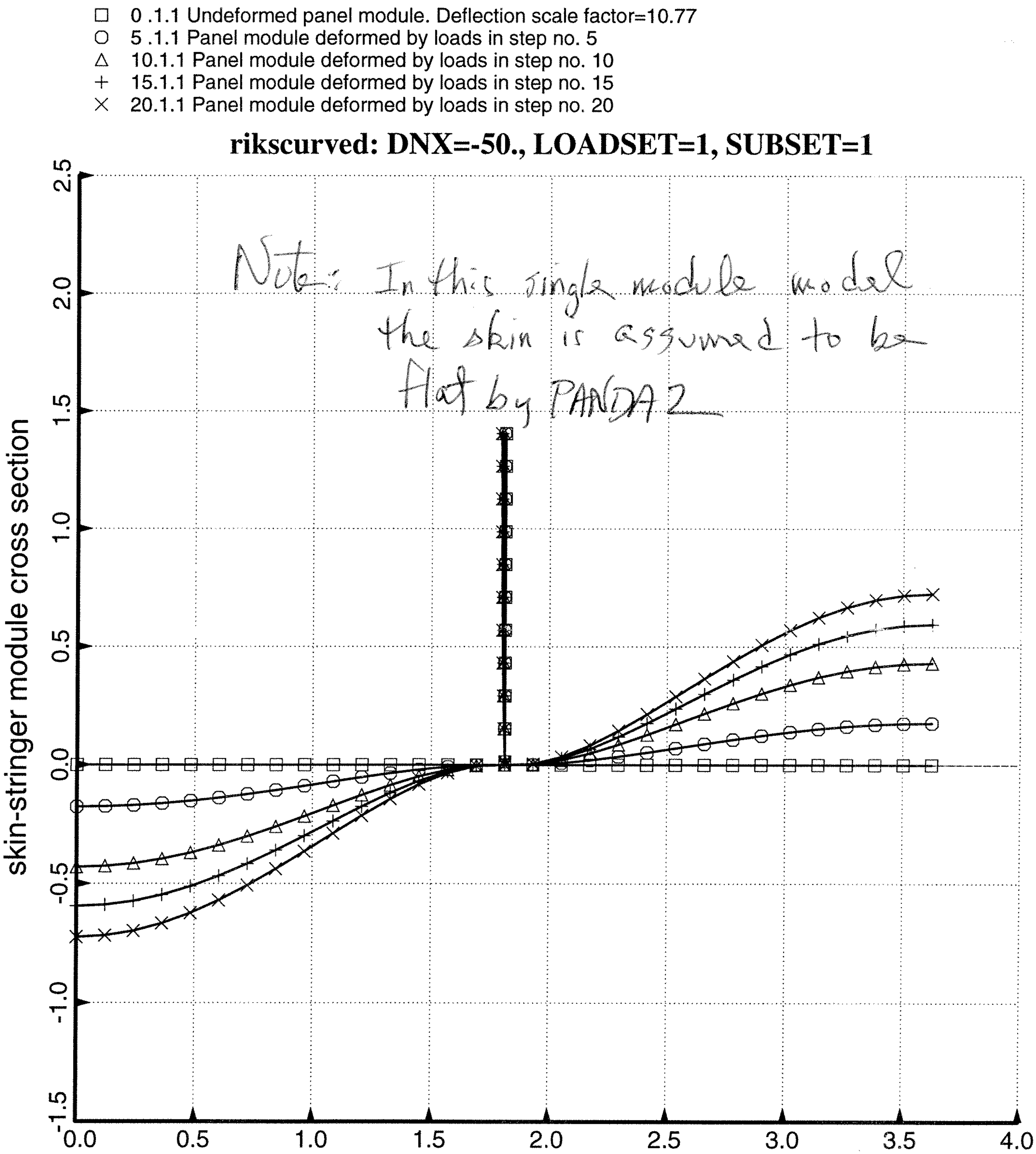
Fig. 1.81

rikscurved.4.ps (output from DIPLOT)



232 Fig. 1.82

rikscurved.5.ps (output from DIPLOT)



233

Fig. 1.83

rikscurved.7.ps (output from DIPLOT)

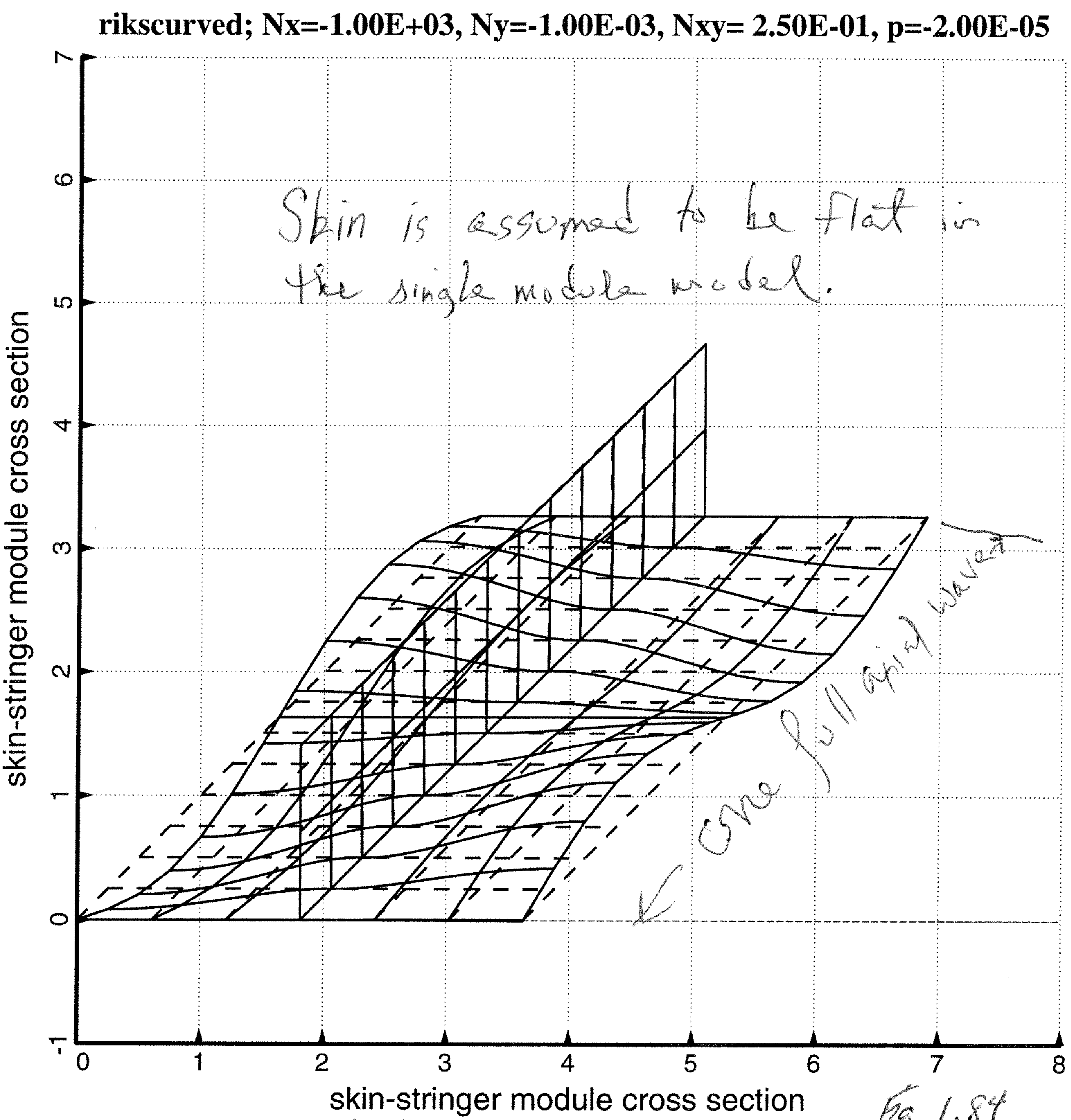


Fig. 1.84

234

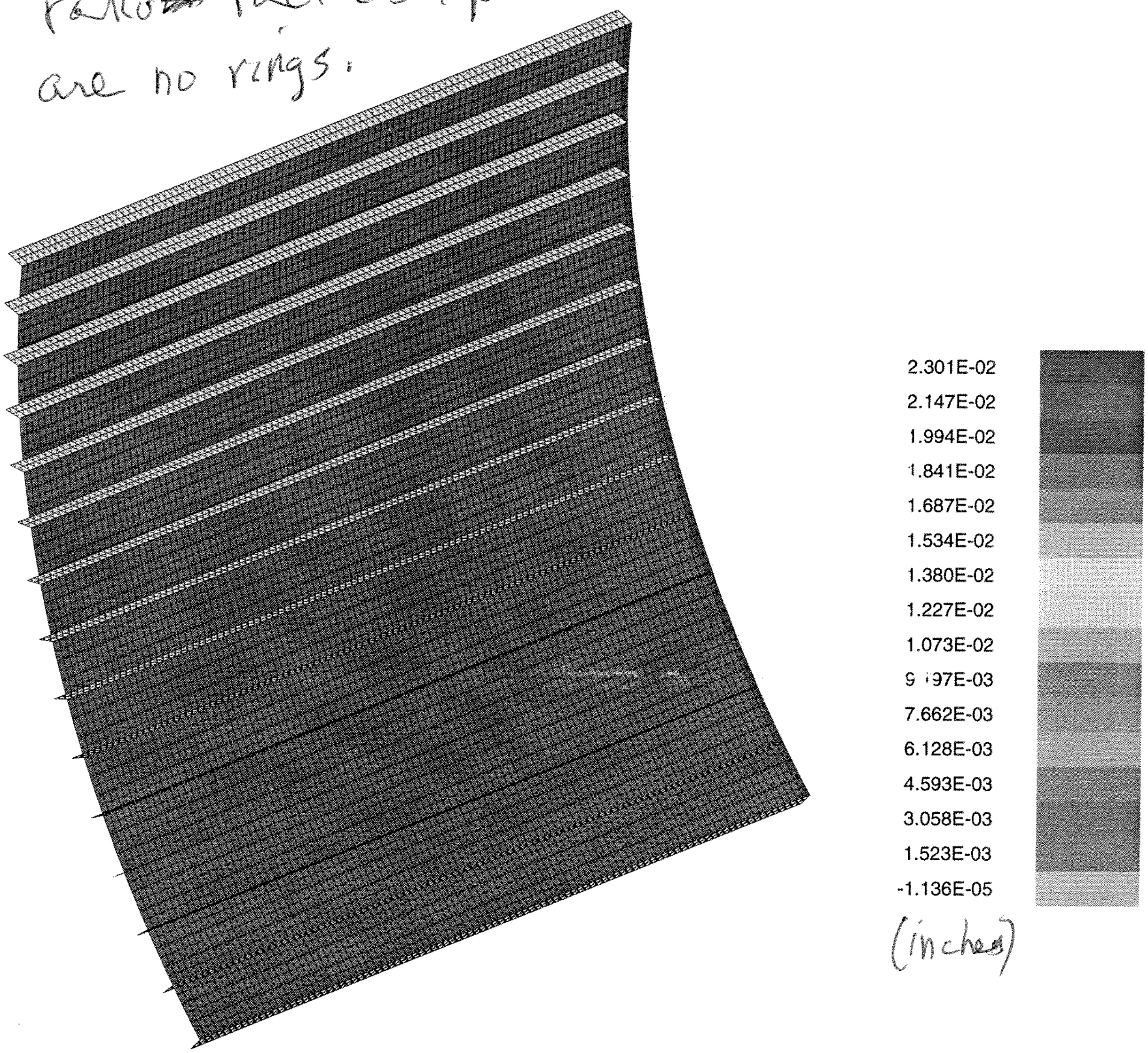
Table 1.78 rikscurved.STG (input for STAGSUNIT)

```
      n          $ Do you want a tutorial session and tutorial output?
         1       $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
         0       $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
 0.2600000       $ Local buckling load factor from PANDA2, EIGLOC
      y          $ Are the dimensions in this case in inches?
         0       $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
         0       $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
        50       $ X-direction length of the STAGS model of the panel: XSTAGS
        50       $ Panel length in the plane of the screen, L2
      y          $ Is the nodal point spacing uniform along the stringer axis?
       201       $ Number of nodes in the X-direction: NODEX
 -1000.000       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
         0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
         0       $ In-plane shear in load set A,                       Nxy
         0       $ Normal pressure in STAGS model in Load Set A, p
         0       $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
         0       $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
         0       $ Normal pressure in STAGS model in Load Set B, p0
         1       $ Starting load factor for Load System A, STLD(1)
         0       $ Load factor increment for Load System A, STEP(1)
         1       $ Maximum load factor for Load System A, FACM(1)
         0       $ Starting load factor for Load System B, STLD(2)
         0       $ Load factor increment for Load System B, STEP(2)
         0       $ Maximum load factor for Load System B, FACM(2)
         1       $ How many eigenvalues do you want? NEIGS
       480       $ Choose element type (410 or 411 or 480) for panel skin
      n          $ Have you obtained buckling modes from STAGS for this case?
        90       $ Number of stringers in STAGS model of 360-deg. cylinder
         0       $ Number of rings in the STAGS model of the panel
      n          $ Are there rings at the ends of the panel?
         3       $ Number of finite elements between adjacent stringers
       100       $ Number of finite elements between adjacent rings
         3       $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
         3       $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
         0       $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
      n          $ Do you want to use fasteners (they are like rigid links)?
      n          $ Are the stringers to be "smeared out"?
      y          $ Are the rings to be "smeared out"?
         5       $ Number of nodes over height of stiffener webs, NODWEB
         5       $ Number of nodes over width of stringer flange, NDFLGS
         5       $ Number of nodes over width of ring flange, NDFLGR
      n          $ Do you want stringer(s) with a high nodal point density?
      n          $ Do you want ring(s) with a high nodal point density?
      n          $ Is there plasticity in this STAGS model?
      n          $ Do you want to use the "least-squares" model for torque?
      n          $ Is stiffener sidesway permitted at the panel edges?
      n          $ Do you want symmetry conditions along the straight edges?
         1       $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

note

rikscurved.linear.w.pdf
output from STAGS for linear theory

PANDA2 model has uniform Poisson ~~ratio~~ radial expansion if there are no rings.



solution scale = 0.5382E+02
PA= 1.00000E+00 PB= 0.00000E+00 PX= 0.00000E+00
step 0 displacement w contours ← normal disp. w
linear distribution of prebuckling w from INDIC=1 STAGS run
Minimum value = -1.13627E-05, Maximum value = 2.30096E-02

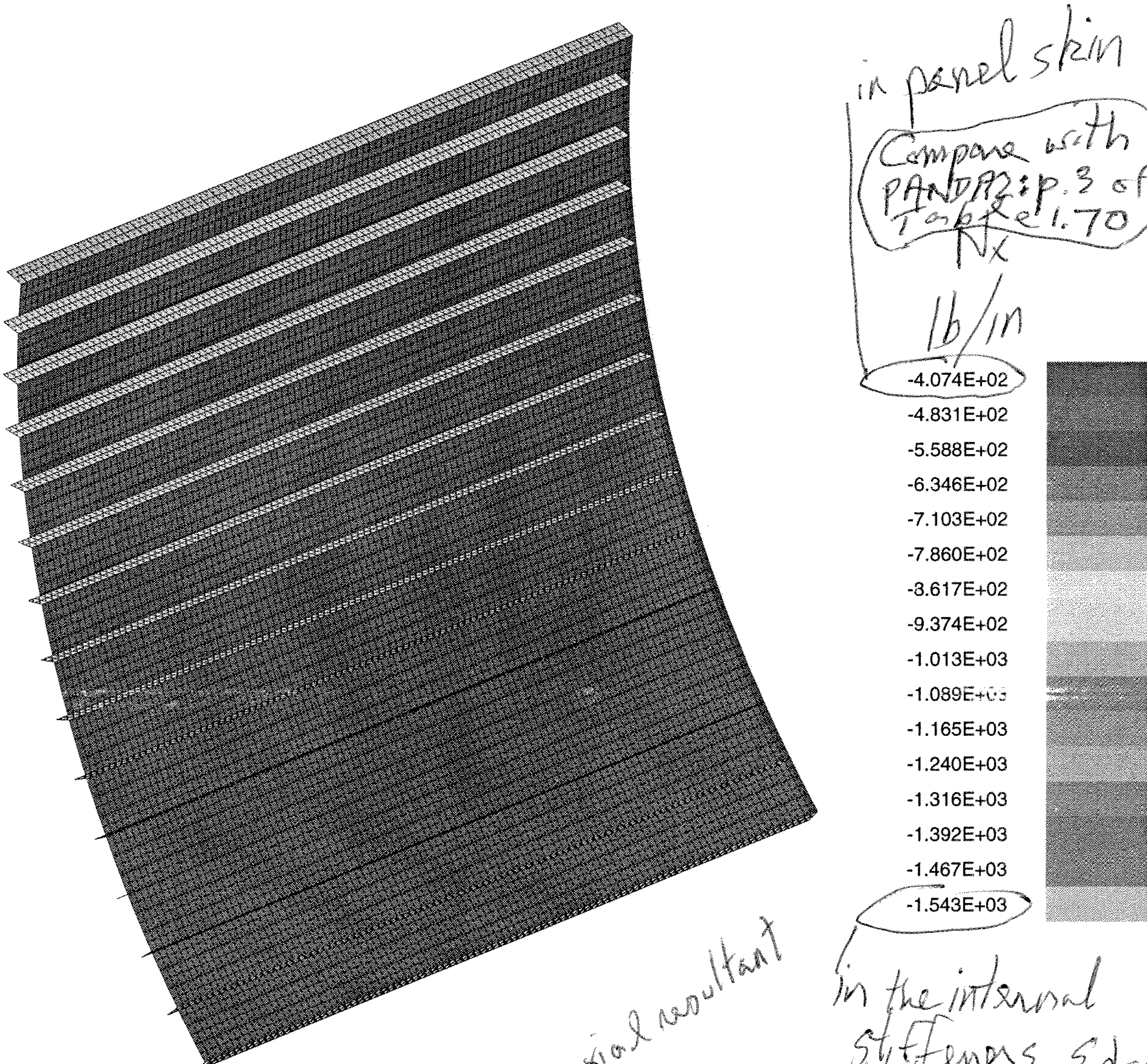
Θ x 24.00
Θ y -22.00
Θ z 30.00

1.054E+01

y, v
x, w
z, w

Fig. 1.85

rikscurved.linear.Nx.pdf
output from STAGS linear theory



in panel skin

Compare with PANDA2: p. 3 of Table 1.70

Nx lb/in

in the internal stiffeners. Edge stiffeners have $\frac{-1543}{2}$

N_x = axial resultant

solution scale = 0.5382E+02
PA= 1.00000E+00 PB= 0.00000E+00 PX= 0.00000E+00
step 0 resultant nx contours
linear distribution of prebuckling Nx from INDIC=1 STAGS run
Minimum value = -1.54321E+03, Maximum value = -4.07394E+02

Θ x 24.00
Θ y -22.00
Θ z 30.00

1.054E+01

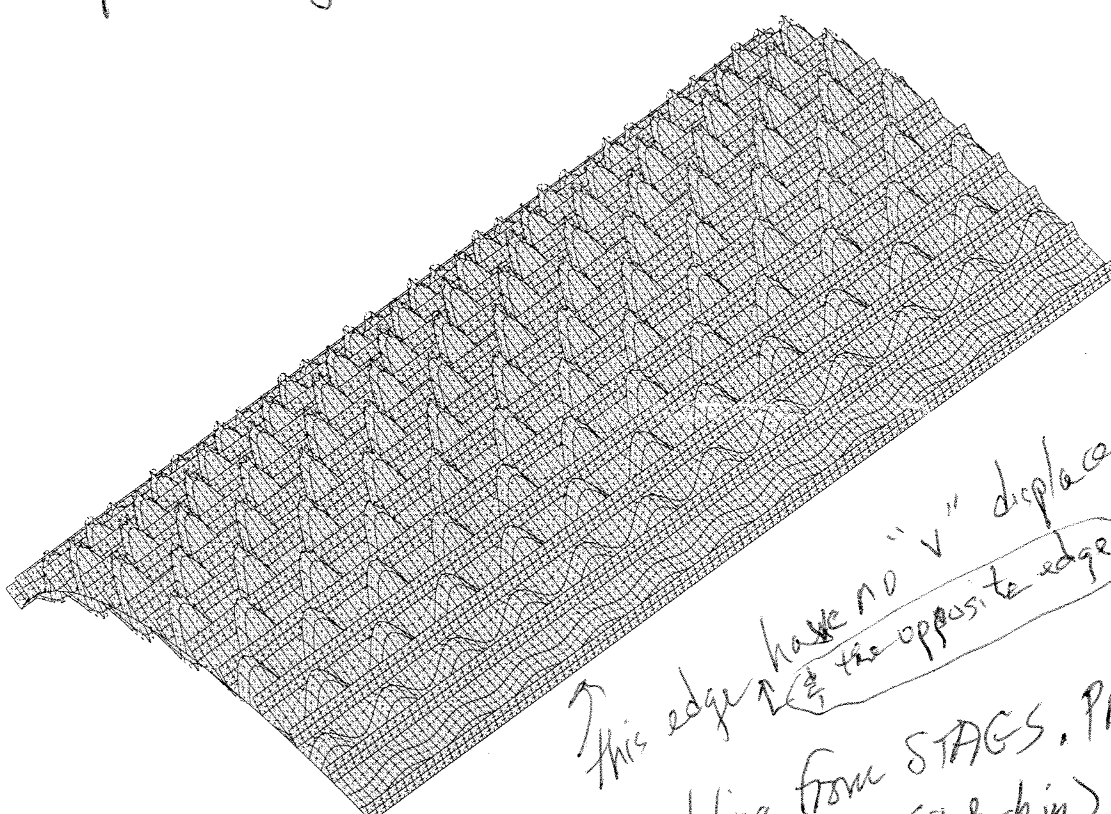
y x z

Fig. 1.86

rikscurved.linbuck.rigidedges.pdf
output from STAGS linear buckling

Compare with Fig. 1.76

2 straight edges are
in-plane rigid



this edge has no "v" displacement
& the opposite edge

local buckling from STAGS. PANDA2
gets 0.23148 (flat skin) p. 9 of Table 1.70
BIGBOSOR4 gets 0.318 (See Fig 1.75)

solution scale = 0.3750E+01
mode 1, $\boxed{\text{pcr} = 0.28898E+00}$
step 0 eigenvector deformed geometry
linear buckling of perfect shell

Θ x -35.84
Θ y -13.14
Θ z 35.63

y z x

9.858E+00

Fig. ~~1.87~~ ~~1.90~~ 1.87

rikscurved.postbuck.step42.rigidedges.defonly.sideview.pdf

2 straight edges are in-plane rigid

$\boxed{\text{rv is free}}$ in panel skin along the two curved edges in the nonlinear analysis.

PANDA2 is designed to predict what happens away from the curved ends

Compare with Fig. 1.91

Curved from neutral axis shift (typical)

PANDA2 model

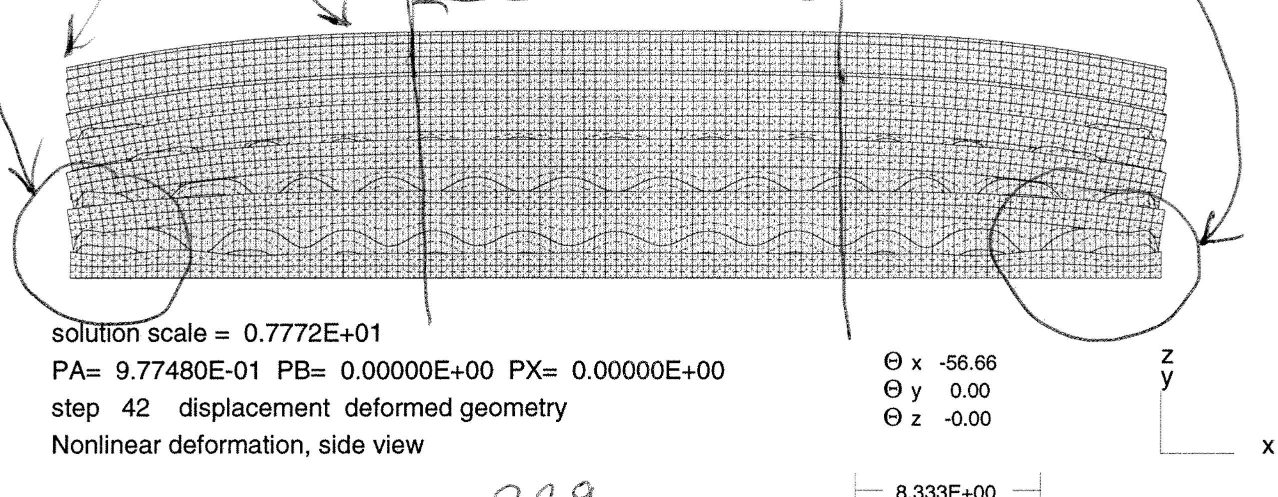
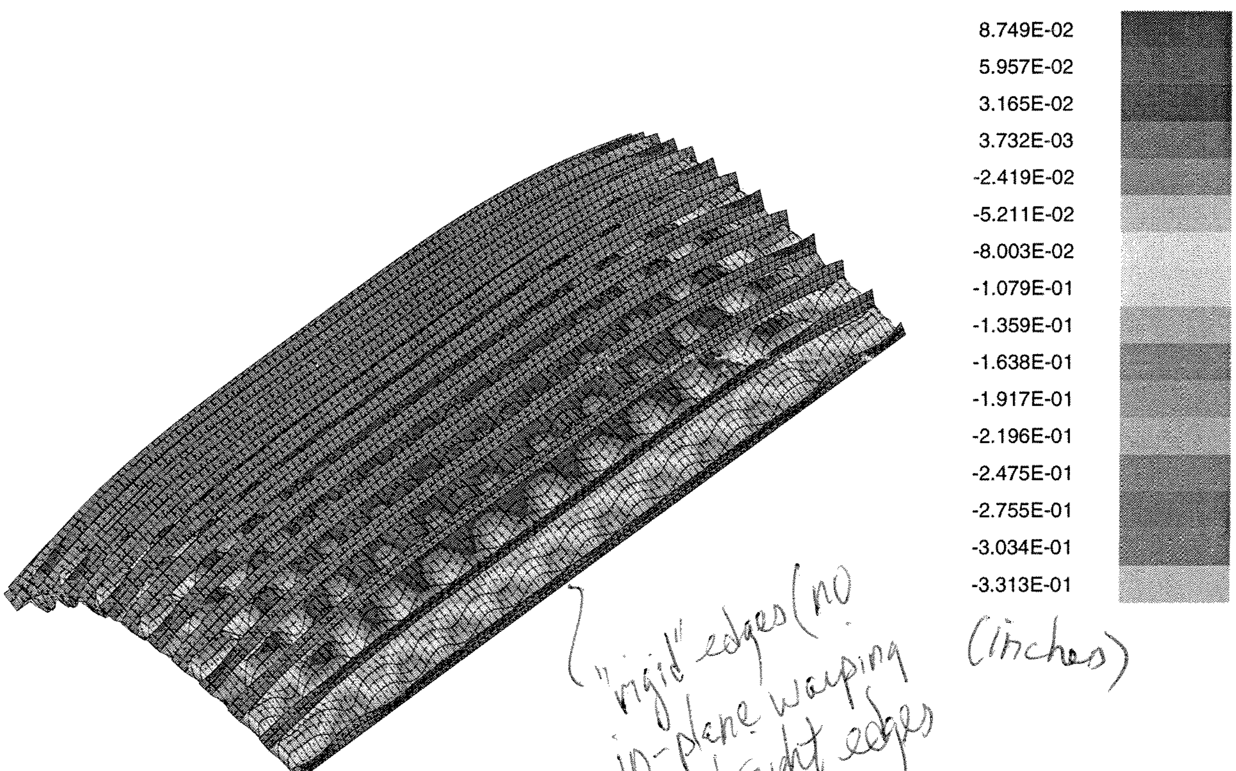


Fig. 1.88

rikscurved.postbuck.step42.rigidedges.pdf

rv is free along the two curved edges in the nonlinear analysis.



solution scale = 0.1025E+02
PA= 9.77480E-01 PB= 0.00000E+00 PX= 0.00000E+00
step 42 displacement w contours
nonlinear w same view as linear buckling mode
Minimum value = -3.31305E-01, Maximum value = 8.74919E-02

Θ x -35.84
Θ y -13.14
Θ z 35.63

y z x

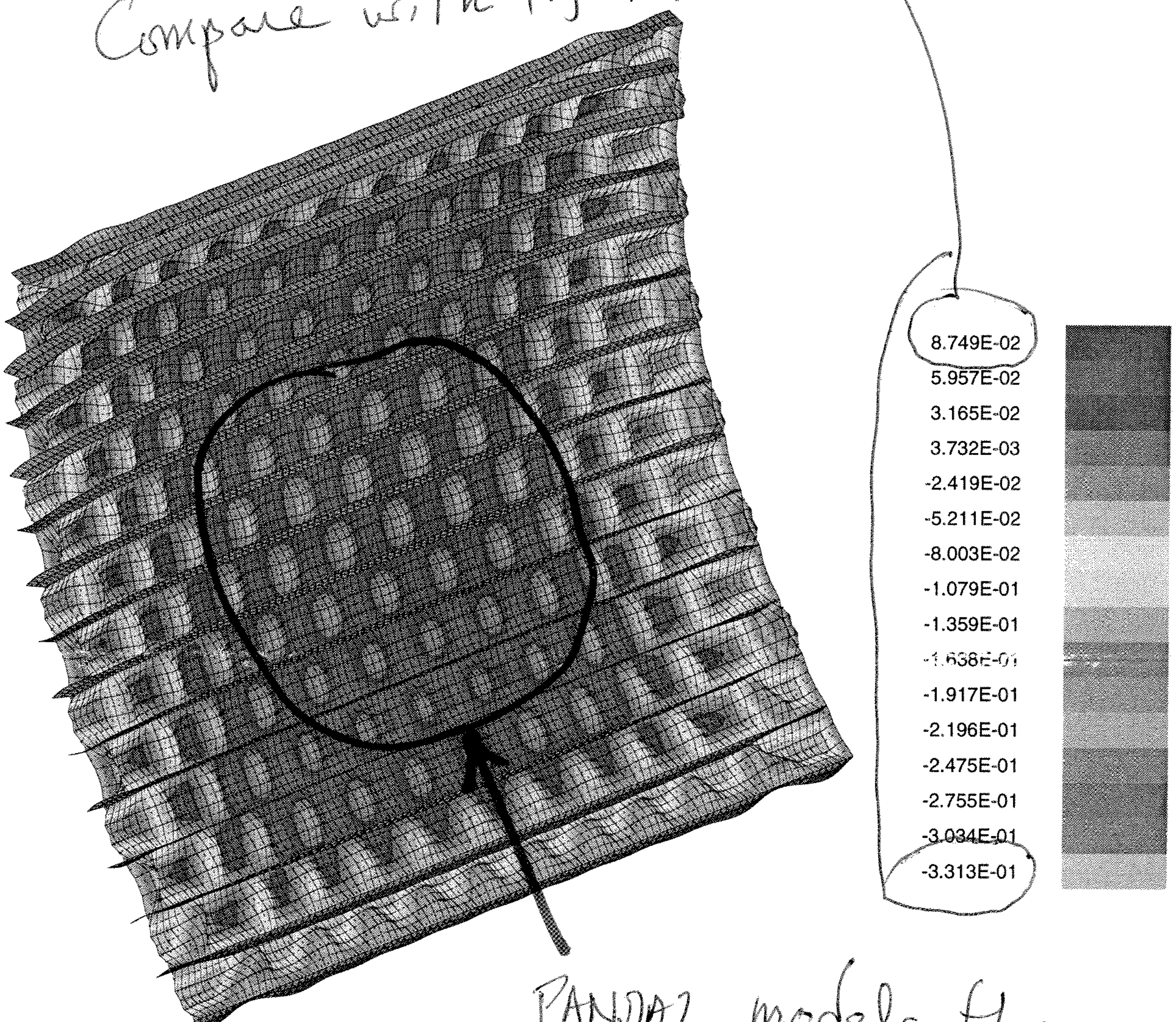
1.183E+01

Fig. ~~1.88~~ 1.89

rikscurved.postbuck.step42.rigidedges.anotherview.pdf

rv is free in the panel skin along the two curved edges in the nonlinear analysis

Compare with Fig. 1.93



PANDA2 models the interior region

2 straight edges are in-plane rigid

solution scale = 0.1080E+02

PA= 9.77480E-01 PB= 0.00000E+00 PX= 0.00000E+00

step 42 displacement w contours

nonlinear w

Minimum value = -3.31305E-01, Maximum value = 8.74919E-02

Θ x 24.00

Θ y -22.00

Θ z 30.00

1.054E+01

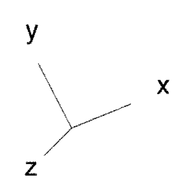


Fig. ~~1.89~~ 1.90

Table 1.79 rikscurved. STG (input for STAGSUNIT)

```
note →     n         $ Do you want a tutorial session and tutorial output?
           3         $ Choose type of STAGS analysis (1,3,4,5,6),INDIC
           0         $ Restart from ISTARTth load step (0=1st nonlinear soln), ISTART
   0.2800000         $ Local buckling load factor from PANDA2, EIGLOC
       y             $ Are the dimensions in this case in inches?
           0         $ Nonlinear (0) or linear (1) kinematic relations?, ILIN
           0         $ Type 1 for closed (360-deg) cyl. shell, 0 otherwise, ITOTAL
    50.00000         $ X-direction length of the STAGS model of the panel: XSTAGS
    50.00000         $ Panel length in the plane of the screen, L2
       y             $ Is the nodal point spacing uniform along the stringer axis?
         201         $ Number of nodes in the X-direction: NODEX
   -1000.000         $ Resultant (e.g. lb/in) normal to the plane of screen, Nx
           0         $ Resultant (e.g. lb/in) in the plane of the screen,    Ny
           0         $ In-plane shear in load set A,                       Nxy
           0         $ Normal pressure in STAGS model in Load Set A, p
           0         $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0
           0         $ Resultant (e.g. lb/in) in the plane of the screen,    Ny0
           0         $ Normal pressure in STAGS model in Load Set B, p0
0.5000000E-01        $ Starting load factor for Load System A, STLD(1)
0.5000000E-01        $ Load factor increment for Load System A, STEP(1)
    1.000000         $ Maximum load factor for Load System A, FACM(1)
           0         $ Starting load factor for Load System B, STLD(2)
           0         $ Load factor increment for Load System B, STEP(2)
           0         $ Maximum load factor for Load System B, FACM(2)
           2         $ How many eigenvalues do you want? NEIGS
         480         $ Choose element type (410 or 411 or 480) for panel skin
       y             $ Have you obtained buckling modes from STAGS for this case?
       y             $ Do you want to provide initial imperfection(s)?
0.1000000E-01        $ Amplitude of initial buckling modal imperfection, WIMPL( 1)
           1         $ Run number for which this buckling mode was computed, IRUN( 1)
           0         $ Load step number at which this buckling mode was computed, ISTEP( 1)
           1         $ Mode number at the load step ISTEP of the run IRUN: IMODE( 1)
       n             $ Do you want to provide another imperfection?
          90         $ Number of stringers in STAGS model of 360-deg. cylinder
           0         $ Number of rings in the STAGS model of the panel
       n             $ Are there rings at the ends of the panel?
           3         $ Number of finite elements between adjacent stringers
         100         $ Number of finite elements between adjacent rings
           3         $ Stringer model: 1 or 2 or 3 or 4 or 5(Type H(elp))
           3         $ Ring model: 1 or 2 or 3 or 4 or 5 (Type H(elp))
           0         $ Reference surface of cyl: 1=outer, 0=middle, -1=inner
       n             $ Do you want to use fasteners (they are like rigid links)?
       n             $ Are the stringers to be "smeared out"?
       y             $ Are the rings to be "smeared out"?
           5         $ Number of nodes over height of stiffener webs, NODWEB
           5         $ Number of nodes over width of stringer flange, NDFLGS
           5         $ Number of nodes over width of ring flange, NDFLGR
       n             $ Do you want stringer(s) with a high nodal point density?
       n             $ Do you want ring(s) with a high nodal point density?
note → y             $ Do you want to impose rv=0 along the two curved edges? ← only asked if INDIC=3 & panel is curved
       n             $ Is there plasticity in this STAGS model?
       n             $ Do you want to use the "least-squares" model for torque?
       n             $ Is stiffener sidesway permitted at the panel edges?
       n             $ Do you want symmetry conditions along the straight edges?
           1         $ Edges normal to screen (0) in-plane deformable; (1) rigid
```

note

rikscurved.postbuck.step16.rigidedges.defonly.sideview.rv=0.pdf

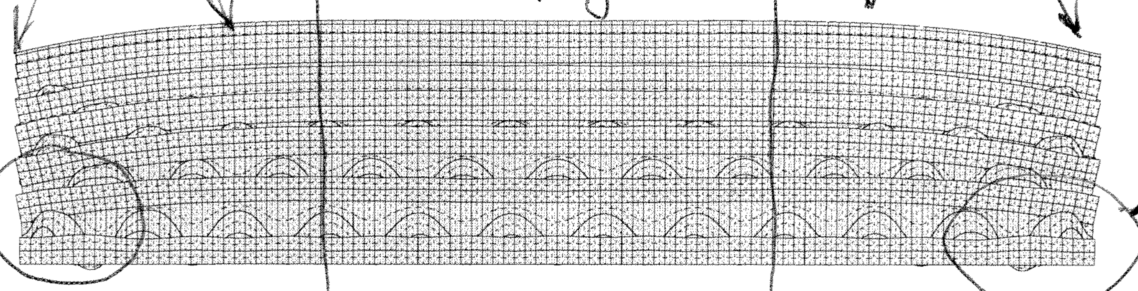
2 straight edges are in-plane rigid

$\boxed{\text{rv}=0}$ in panel skin along the two curved edges in the nonlinear analysis.

Compare with Fig. 1.88

Curvature is from neutral axis shift

PANDAL models behavior in the interior region



solution scale = 0.1481E+02
PA= 1.00000E+00 PB= 0.00000E+00 PX= 0.00000E+00
step 16 displacement deformed geometry
Nonlinear deformation, side view

Θ x -56.66
Θ y 0.00
Θ z -0.00

z
y
x

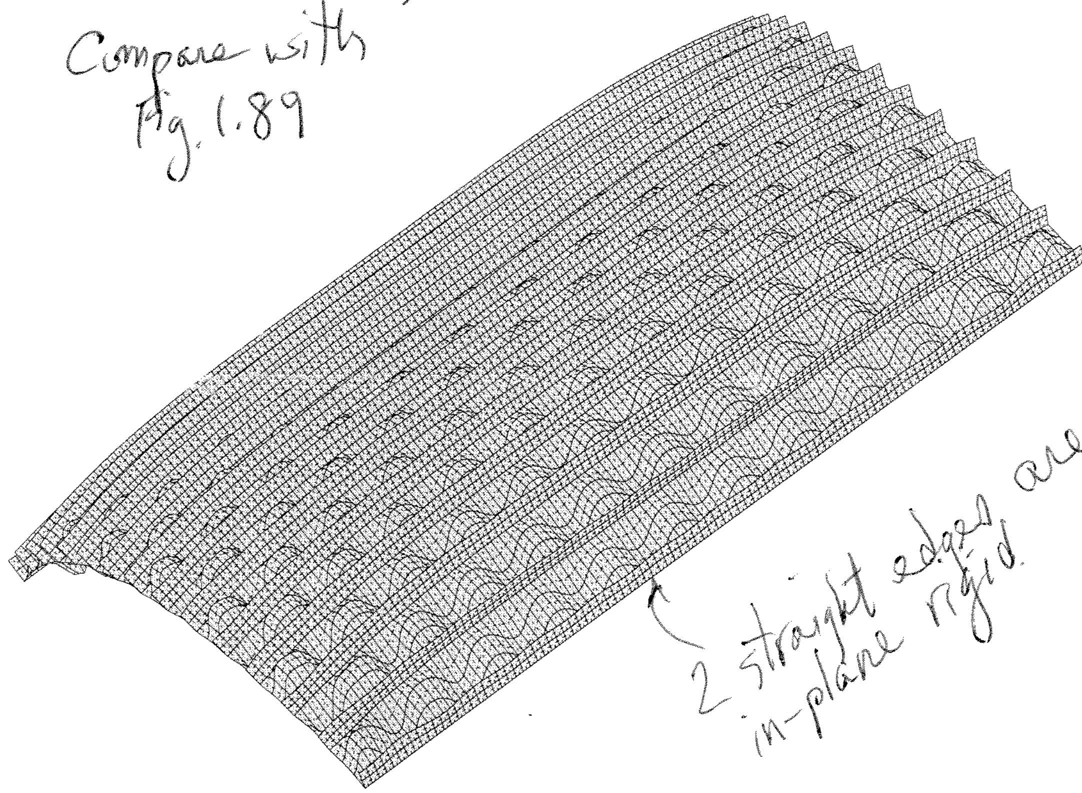
8.333E+00

Fig. 1.91

rikscurved.postbuck.step16.rigidedges.defonly.rv=0.pdf

rv=0 in the panel skin along the two curved edges in the nonlinear analysis.

Compare with Fig. 1.89



2 straight edges are in-plane rigid.

solution scale = 0.1605E+02
PA= 1.00000E+00 PB= 0.00000E+00 PX= 0.00000E+00
step 16 displacement deformed geometry
Nonlinear deformation, side view

Θ x -35.84
Θ y -13.14
Θ z 35.63

y z x

9.858E+00

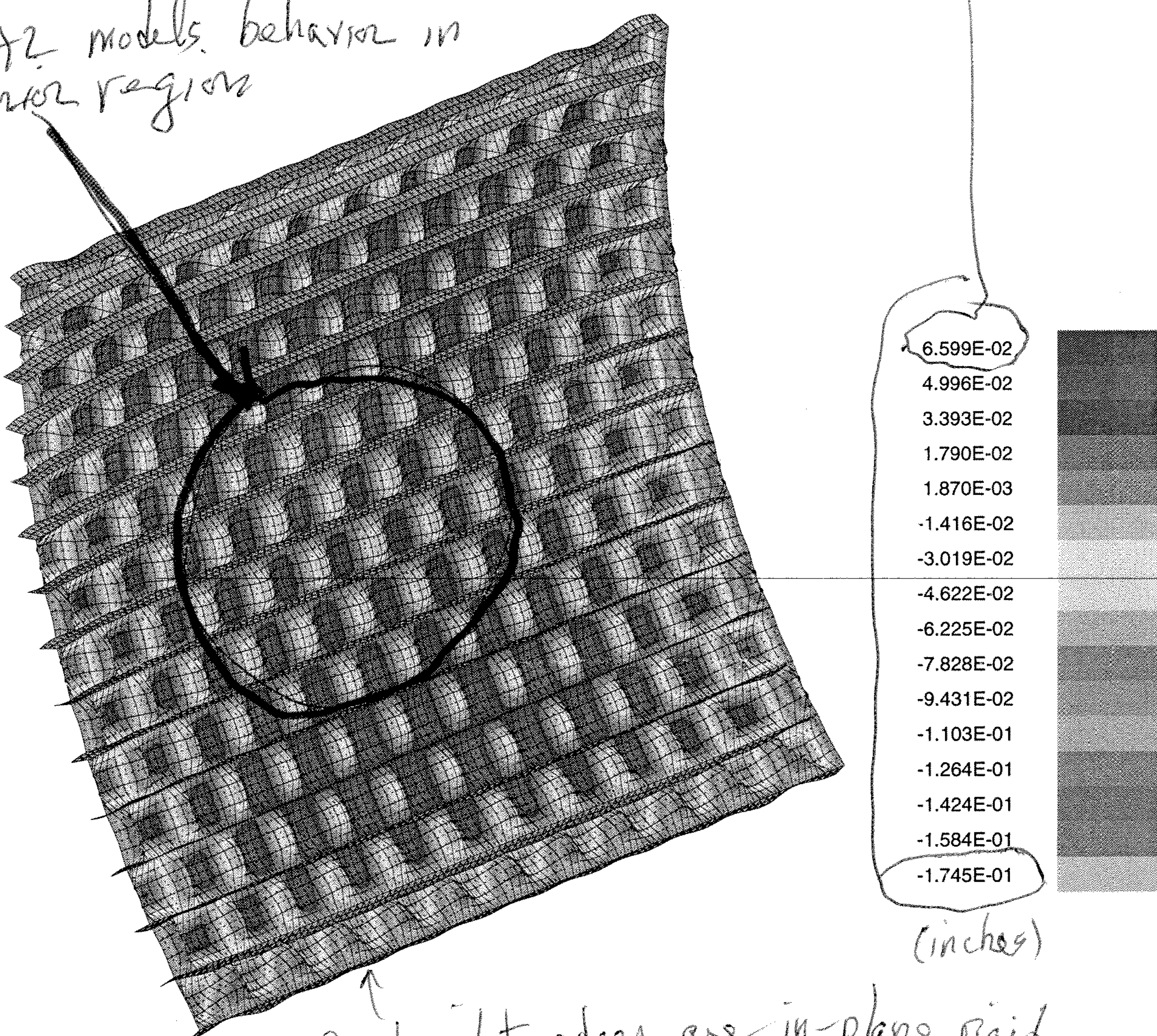
Fig. 1.92

rikscurved.postbuck.step16.rigidedges.anotherview.rv=0.pdf

$\boxed{rv=0}$ in the panel skin along the two curved edges in the nonlinear analysis.

Compare with Fig. 1.90

PANDA2 models behavior in the interior region



(inches)

2 straight edges are in-plane rigid

solution scale = 0.1672E+02
PA= 1.00000E+00 PB= 0.00000E+00 PX= 0.00000E+00
step 16 displacement w contours
nonlinear w
Minimum value = -1.74453E-01, Maximum value = 6.59876E-02

Θ x 24.00
Θ y -22.00
Θ z 30.00

y x z

1.054E+01

245

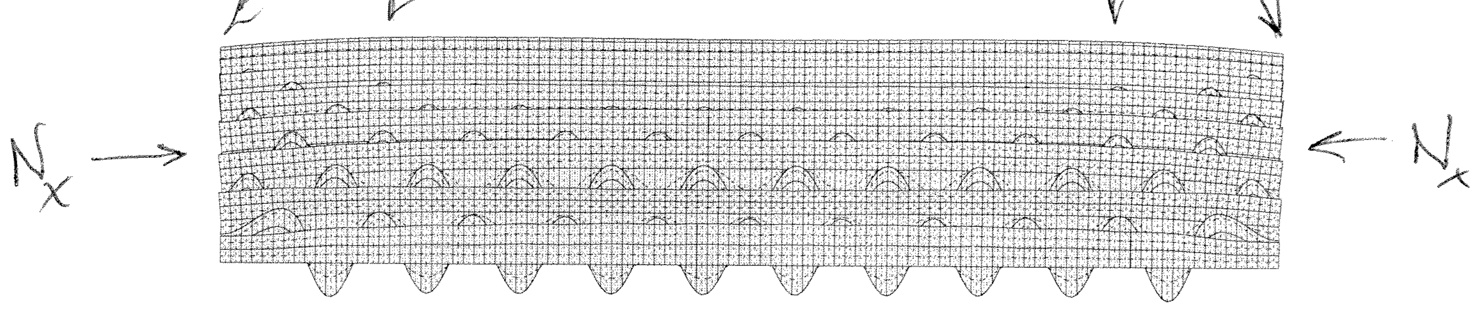
Fig. 1.93

Curved panel, side view

Imperfection amplitude, WIMP = 0.01 inch

2 straight edges are in-plane rigid

Note some axial curvature from shift in neutral axis due to local skin deformation



solution scale = 0.6548E+02

$\boxed{\text{PA= 3.89225E-01}}$ PB= 0.00000E+00 PX= 0.00000E+00

step 8 displacement deformed geometry

Nonlinear deformation, side view

Θ x -56.66
Θ y 0.00
Θ z -0.00

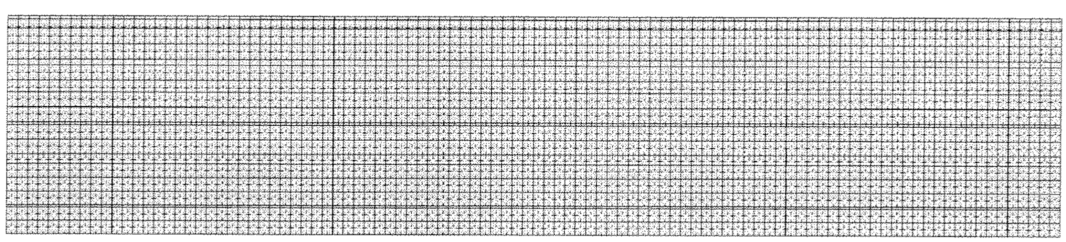
z
y
x

8.333E+00

Fig 1.94

Curved panel, side view

Imperfection amplitude = 0.0 inch



solution scale = 0.9368E+02

PA= 3.48498E-01 PB= 0.00000E+00 PX= 0.00000E+00

step 8 displacement deformed geometry

Nonlinear deformation, side view

Θ x -56.66
Θ y 0.00
Θ z -0.00

z
y
x

8.333E+00

247

Fig. 1.95

riksccurved.5.ps from SUPEROPT run

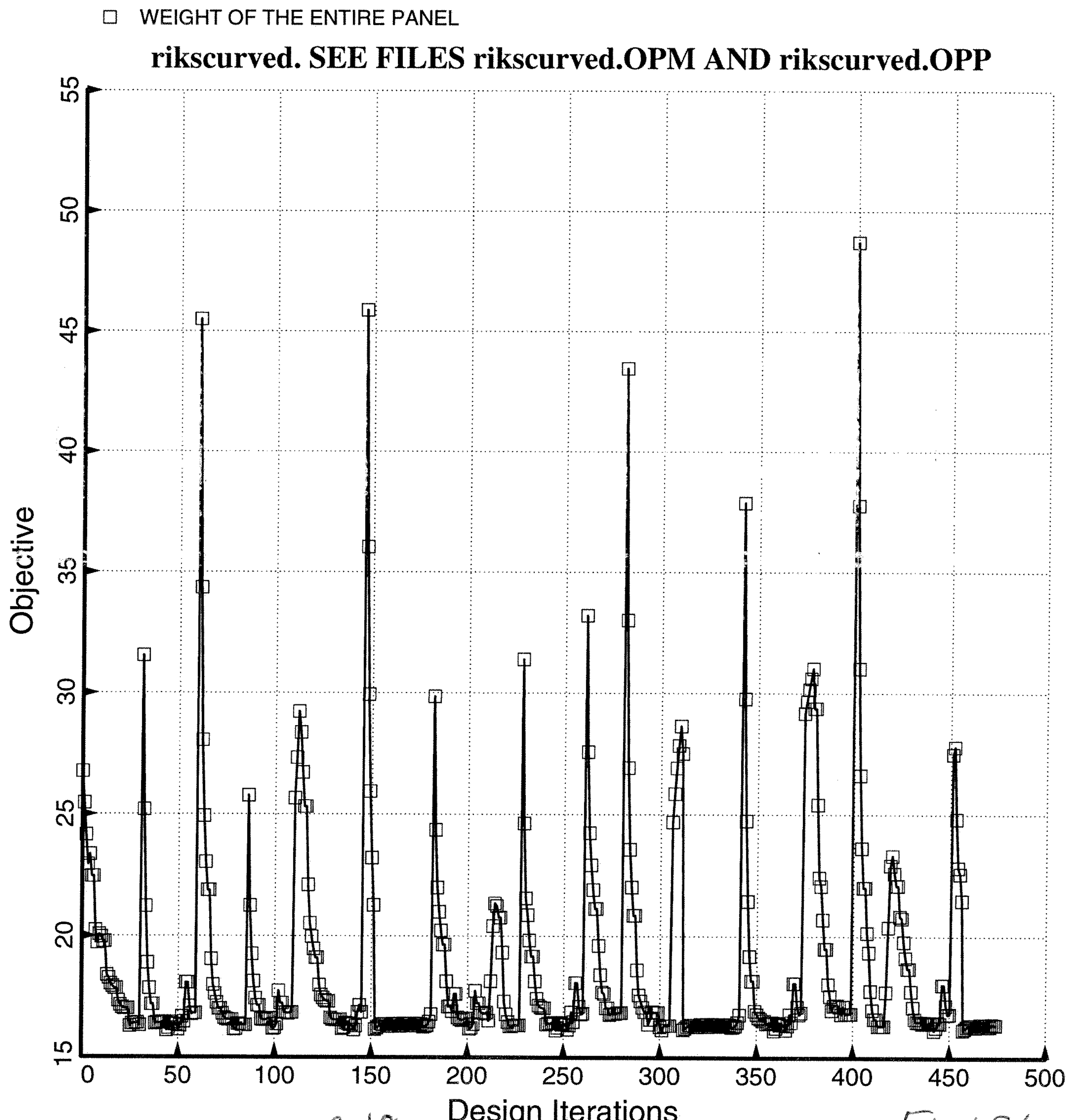


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Fig. 1.96

Table 1.80   Optimum design from SUPEROPT run

rikscurved.OPM (abridged) after a SUPEROPT execution

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 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

 ANALYSIS: ITYPE=2;  IQUICK=0;  LOAD SET 1;  SUBCASE 1:
 LOADING: Nx, Ny, Nxy, Mx, My =  -1.00E+03 -1.00E-03  5.00E+00  0.00E+00  0.00E+00
          Nxo, Nyo, pressure  =   0.00E+00  0.00E+00 -2.00E-05
 BUCKLING LOAD FACTORS FOR LOCAL BUCKLING FROM KOITER v. BOSOR4 THEORY:
  Local buckling load factor from KOITER theory =  2.1422E-01 (flat skin)
  Local buckling load factor from BOSOR4 theory =  2.1859E-01 (flat skin)
0
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE                DEFINITION
 1   9.29E-02 Local buckling from discrete model-1.,M=22  axial halfwaves;FS=0.2
 2   4.25E+00 Bending-torsion buck.(bypassed low-m mode);M=3  ;FS=0.2
 3   7.11E-02 Local buckling from Koiter theory,M=22  axial halfwaves;FS=0.2
 4   2.79E+01 eff.stress:matl=1,SKN,Dseg=2,node=6,layer=1,z=0.0127; MID.;FS=1.
 5   3.16E+04 stringer popoff margin:(allowable/actual)-1, web 1  MID.;FS=1.
 6   1.99E+00 eff.stress:matl=2,STR,Dseg=3,node=11,layer=1,z=0.0502; MID.;FS=1.
 7  -2.58E-02 Hi-axial-wave post-post-buckling of module - 1;   M=43 ;FS=1.
 8   9.78E-06 (m=6   lateral-torsional buckling load factor)/(FS)-1;FS=1.1
 9   2.61E+01 eff.stress:matl=1,SKN,Iseg=1,at:n=1,layer=1,z=0.0127;-MID.;FS=1.
10   2.88E+00 eff.stress:matl=2,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
11   4.39E-01 buckling margin stringer Iseg.3 . Local halfwaves=14 .MID.;FS=1.
12   7.51E-01 buckling margin stringer Iseg.3 . Local halfwaves=14 .NOPO;FS=1.
13  -1.76E-02 buck.(SAND);simp-support general buck;M=1;N=5;slope=0.;FS=1.1
14   1.38E+00 buck.(SAND);rolling only of stringers;M=23;N=0;slope=0.;FS=1.4
15   5.30E+02 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
 ***********  ALL 1 LOAD SETS PROCESSED  ***********
 ****************************************************

         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     N     N      0     0.00E+00  3.00E+00 3.5522E+00  1.00E+01        B(STR):stiffener s»
pacing, b: STR seg=NA, layer=NA
   2   N     N     Y      1     3.33E-01  0.00E+00 1.1839E+00  0.00E+00        B2(STR):width of st»
ringer base, b2 (must be > 0, see
   3   Y     N     N      0     0.00E+00  2.00E-01 1.3867E+00  1.00E+01        H(STR):height of s»
tiffener (type H for sketch), h:
   4   Y     Y     N      0     0.00E+00  1.00E-02 2.5421E-02  1.00E+00     T(1 )(SKN):thickness f»
or layer index no.(1 ): SKN seg=1
   5   Y     Y     N      0     0.00E+00  1.00E-02 1.0044E-01  1.00E+00     T(2 )(STR):thickness f»
or layer index no.(2 ): STR seg=3
0
   CURRENT VALUE OF THE OBJECTIVE FUNCTION:
 VAR. STR/ SEG. LAYER   CURRENT
 NO.  RNG  NO.   NO.     VALUE            DEFINITION
            0     0    1.616E+01   WEIGHT OF THE ENTIRE PANEL

  TOTAL WEIGHT OF SKIN                            =    6.3553E+00
  TOTAL WEIGHT OF SUBSTIFFENERS                   =    0.0000E+00
  TOTAL WEIGHT OF STRINGERS                       =    9.8023E+00
  TOTAL WEIGHT OF RINGS                           =    0.0000E+00
  SPECIFIC WEIGHT (WEIGHT/AREA) OF STIFFENED PANEL=    6.4631E-03
 IN ORDER TO AVOID FALSE CONVERGENCE OF THE DESIGN, BE SURE TO
 RUN  PANDAOPT  MANY TIMES DURING AN OPTIMIZATION. INSPECT THE
 rikscurved.OPP  FILE AFTER EACH OPTIMIZATION RUN. OR BETTER YET,
 RUN SUPEROPT.
 ******************** END OF rikscurved.OPM FILE *****************
```

optimum after SUPEROPT

Compare with p.14 of Table 1.70.

The optimum design is similar in this simple case, but that will not always be so.

(The PANDA2 user should always use SUPEROPT!)

Section 2

Buckling & Post-buckling of Flat Unstiffened Plate Under Combined Axial Compression & In-Plane Shear

$N_x = -30 \text{ lb/in}$

$N_{xy} = +300 \text{ lb/in}$