Use of PANDA2 and BIGBOSOR4 to obtain linear buckling loads of an orthogrid stiffened cylindrical shell with and without a weld land.

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April 30, 2009

ABSTRACT

PANDA2 and BIGBOSOR4 are used to obtain linear buckling load factors for Thornburgh's Design No. 1.* PANDA2 is first used to obtain buckling load factors for Thornburgh's Design No. 1. Then a new PANDA2 processor called "PANEL3" is used to generate input files for BIGBOSOR4 in which a weld land is present. Buckling load factors are obtained from BIGBOSOR4 for the shell with and without a weld land. Four cases with a weld land are run: 1. a case in which the outer surface of the weld land is flush with the outer surface of the stiffened cylindrical shell; 2. a case in which the inner surface of the weld land is flush with the inner surface of the stiffened shell; 3. a case in which local buckling between adjacent rings is explored; and 4. a case in which there is an "extra" Tee-shaped stringer present at the junction between the weld land and the rest of the stiffened cylindrical shell. In all BIGBOSOR4 models the prebuckled state is assumed to be undeformed and the axial compression Nx in the weld land is assumed to be equal to the axial compression in the skin of the cylindrical shell times the ratio of the thickness of the weld land to the thickness of the skin of the stiffened cylindrical shell.

← Note!

*Thornburgh, Robert P., "Axial Weld Land Buckling in Compression-Loaded Orthogrid Cylinders"

NOTE: in the "detailed" BIGBOSOR4 models the rings are smeared except for the inter-ring buckling model on pp. 16–18, in which there are no rings.

April 30, 2009

```
The run stream used to produce the results in
this report. The case name is "thorndesign1".
-----------------------------------------------
panda2log       (activate PANDA2 command set)
begin           (provide Thornburgh's Design No. 1: thorndesign1.BEG, p. 3)
setup
decide          (choose decision variables, etc.: thorndesign1.DEC, p. 4)
mainsetup       (choose loading, strategy, analysis: thorndesign1.OPT, p.5))
pandaopt        (execute PANDAOPT. Results are listed in Table 0)
panel3  (generate BIGBOSOR4 "torus" model with weld land: thorndesign1.PAN, p.7)
(copy thorndesign1.ALL to directory where you want to run BIGBOSOR4.
 Then go to that directory and execute BIGBOSOR4.)
bigbosor4log    (activate BIGBOSOR4 command set)
bigbosorall     (execute BIGBOSOR4; thorndesign1.ALL is the input file)
cleanup         (clean up BIGBOSOR4 files)
(Edit the thorndesign1.ALL file to change N0B, NMINB, NMAXB, INCRB
 in order to get buckling over a range of axial halfwaves)
bigbosorall     (execute BIGBOSOR4)
(Inspect the thorndesign1.OUT file. Table 1 is an abridged version)
bosorplot       (choose what to plot. See Fig. 1)
```
pp. 3-9

```
(cd back to where you were running PANDA2)
panel3  (generate another BIGBOSOR4 "torus" model with weld land; p.10)
(copy thorndesign1.ALL to directory where you want to run BIGBOSOR4.
 Then go to that directory and execute BIGBOSOR4.)
bigbosorall     (execute BIGBOSOR4)
cleanup         (clean up BIGBOSOR4 files)
(Edit the thorndesign1.ALL file to change N0B, NMINB, NMAXB, INCRB
 in order to get buckling over a range of axial halfwaves)
bigbosorall     (execute BIGBOSOR4)
(Inspect the thorndesign1.OUT file. Table 2 is an abridged version)
bosorplot       (choose what to plot. See Fig. 2)
```
pp. 10-12

```
(cd back to where you were running PANDA2)
(Next, we want to get BIGBOSOR4 prediction for the "torus" model
 WITHOUT any weld land)
panel   (generate BIGBOSOR4 "torus" model without any weld land; p. 13)
(copy thorndesign1.ALL to directory where you want to run BIGBOSOR4.
 Then go to that directory and execute BIGBOSOR4.)
bigbosorall     (execute BIGBOSOR4)
cleanup         (clean up BIGBOSOR4 files)
(Edit the thorndesign1.ALL file to change N0B, NMINB, NMAXB, INCRB
 in order to get buckling over a range of axial halfwaves)
bigbosorall     (execute BIGBOSOR4)
(Inspect the thorndesign1.OUT file. Table 3 is an abridged version)
bosorplot       (choose what to plot. See Fig. 3)
```
pp. 13-15

```
(cd back to where you were running PANDA2)
(Next, we want to get BIGBOSOR4 prediction for the "torus" model
 of the shell with the weld land for BUCKLING BETWEEN ADJACENT RINGS)
panel3  (generate another BIGBOSOR4 "torus" model with weld land; p. 16)
(copy thorndesign1.ALL to directory where you want to run BIGBOSOR4.
 Then go to that directory and execute BIGBOSOR4.)
bigbosorall     (execute BIGBOSOR4)
cleanup         (clean up BIGBOSOR4 files)
(Edit the thorndesign1.ALL file to change N0B, NMINB, NMAXB, INCRB
 in order to get buckling over a range of axial halfwaves)
bigbosorall     (execute BIGBOSOR4)
(Inspect the thorndesign1.OUT file. Table 4 is an abridged version)
bosorplot       (choose what to plot. See Fig. 4)
```
pp. 16-18

```
(cd back to where you were running PANDA2)
(Next, we want to add a Tee-shaped stringer at the edge of the
 weld land.)
panel3  (generate another BIGBOSOR4 "torus" model with weld land; p.19)
(copy thorndesign1.ALL to directory where you want to run BIGBOSOR4.
 Then go to that directory and execute BIGBOSOR4.)
bigbosorall     (execute BIGBOSOR4)
cleanup         (clean up BIGBOSOR4 files)
(Edit the thorndesign1.ALL file to change N0B, NMINB, NMAXB, INCRB
 in order to get buckling over a range of axial halfwaves)
bigbosorall     (execute BIGBOSOR4)
(Inspect the thorndesign1.OUT file. Table 5 is an abridged version)
bosorplot       (choose what to plot. See Fig. 5)
```
pp. 19-21

E = 11, ν = 0.33

From Thornburgh's paper

Tables 0 – 4
Figs 1 – 4

Table 1 Dimensions (inches) and predicted buckling loads for specific orthogrid designs

$r_{outer} = 108$
$l = 162$
0.325

$(h = H - t)$

	Design 1	Design 2	Design 3
t	0.100	0.140	0.060
H	1.30	1.50	0.70
br	7.0	7.0	9.0
t_r	0.100	0.140	0.060
bs	3.0	4.0	3.0
t_s	0.100	0.140	0.060
br	7.0	7.0	9.0
Smeared P_{cr} (kip)	3034	4898	698
Smeared with Weld Land P_{cr} (kip)	2693	4326	599
Reduction (%)	11.2	11.7	14.2
Detailed Model P_{cr} (kip)	2487	4146	564
Reduction (%)	18.0	15.4	19.2

2495

rings smeared → BIGBOSOR4

BIGBOSOR4 gets $P_{cr} = 2805$ (kip) for "detailed" without Weld Land (rings smeared)

Table 1 Predicted buckling loads for specific orthogrid designs

	Smeared	Smeared with Weld Land		Detailed Model	
Design	P_{cr} (kip)	P_{cr} (kip)	Reduction (%)	P_{cr} (kip)	Reduction (%)
1	3034	2693	11.2	2487	18.0
2	4898	4326	11.7	4146	15.4
3	698	599	14.2	564	19.2

I think I decided I like the first table better

$\frac{.325}{2} - .05$

I get only a 3% improvement

Table 2 Predicted buckling loads for orthogrid designs with flanged reinforced stiffeners near the axial weld lands

Tables Figs 5

	Initial	1 Flanged Stiffener		2 Flanged Stiffeners		3 Flanged Stiffeners	
Design	P_{cr} (kip)	P_{cr} (kip)	Improvement (%)	P_{cr} (kip)	Improvement (%)	P_{cr} (kip)	Improvement (%)
1	2487	2742	10.2	2793	12.3	2819	13.3
2	4146	4305	3.8	4357	5.1	4406	6.3
3	564	611	8.4	623	10.5	629	11.5

Table 3 Predicted buckling loads for externally stiffened orthogrid designs

	Smeared	Smeared with Weld Land		Detailed Model	
Design	P_{cr} (kip)	P_{cr} (kip)	Reduction (%)	P_{cr} (kip)	Reduction (%)
1	4429	4077	8.0	3329	24.9
2	7079	6532	7.7	5432	23.3

FIG. 0

2

thorndesign1.BEG

```
 n            $ Do you want a tutorial session and tutorial output?
 162          $ Panel length normal to the plane of the screen, L1
 339.2920     $ Panel length in the plane of the screen, L2  = π×108 = πr
 r            $ Identify type of stiffener along L1 (N,T,J,Z,R,A,C,G)
 3.000000     $ stiffener spacing, b
 1.000000     $ width of stringer base, b2 (must be > 0, see Help)
 1.200000     $ height of stiffener (type H for sketch), h
 n            $ Are the stringers cocured with the skin?
 1000000.     $ What force/(axial length) will cause web peel-off?
 n            $ Is the next group of layers to be a "default group" (12 layers!)?
 1            $ number of layers in the next group in Segment no.( 1)
 n            $ Can winding (layup) angles ever be decision variables?
 1            $ layer index (1,2,...), for layer no.( 1)
 y            $ Is this a new layer type?
 0.1000000    $ thickness for layer index no.( 1)
 0            $ winding angle (deg.) for layer index no.( 1)
 1            $ material index (1,2,...) for layer index no.( 1)
 n            $ Any more layers or groups of layers in Segment no.( 1)
 n            $ Is the next group of layers to be a "default group" (12 layers!)?
 1            $ number of layers in the next group in Segment no.( 2)
 n            $ Can winding (layup) angles ever be decision variables?
 1            $ layer index (1,2,...), for layer no.( 1)
 n            $ Is this a new layer type?
 n            $ Any more layers or groups of layers in Segment no.( 2)
 n            $ Is the next group of layers to be a "default group" (12 layers!)?
 1            $ number of layers in the next group in Segment no.( 3)
 n            $ Can winding (layup) angles ever be decision variables?
 2            $ layer index (1,2,...), for layer no.( 1)
 y            $ Is this a new layer type?
 0.1000000    $ thickness for layer index no.( 2)
 0            $ winding angle (deg.) for layer index no.( 2)
 1            $ material index (1,2,...) for layer index no.( 2)
 n            $ Any more layers or groups of layers in Segment no.( 3)
 1            $ choose external (0) or internal (1) stringers
 r            $ Identify type of stiffener along L2  (N, T, J, Z, R, A)
 7.000000     $ stiffener spacing, b
 0            $ width of ring base, b2 (zero is allowed)
 1.200000     $ height of stiffener (type H for sketch), h
 n            $ Are the rings cocured with the skin?
 n            $ Is the next group of layers to be a "default group" (12 layers!)?
 1            $ number of layers in the next group in Segment no.( 3)
 n            $ Can winding (layup) angles ever be decision variables?
 3            $ layer index (1,2,...), for layer no.( 1)
 y            $ Is this a new layer type?
 0.1000000    $ thickness for layer index no.( 3)
 0            $ winding angle (deg.) for layer index no.( 3)
 1            $ material index (1,2,...) for layer index no.( 3)
 n            $ Any more layers or groups of layers in Segment no.( 3)
 1            $ choose external (0) or internal (1) rings
 y            $ Is the panel curved in the plane of the screen (Y for cyls.)?
 108.0000     $ Radius of curvature (cyl. rad.) in the plane of screen, R
 n            $ Is panel curved normal to plane of screen? (answer N)
 y            $ Is this material isotropic (Y or N)?
 0.1100000E+08 $ Young's modulus,                E( 1)
 0.3300000    $ Poisson's ratio,                NU( 1)
 4135338.     $ transverse shear modulus,      G13( 1)
 0            $ Thermal expansion coeff.,    ALPHA( 1)
 0            $ residual stress temperature (positive),TEMPTUR( 1)
 n            $ Want to supply a stress-strain "curve" for this mat'l (H)?
 y            $ Want to specify  maximum effective stress ?
 70000.00     $ Maximum allowable effective stress in material type( 1)
 n            $ Do you want to take advantage of "bending overshoot"?
 0.1000000    $ weight density (greater than 0!) of material type( 1)
 n            $ Is lamina cracking permitted along fibers (type H(elp))?
 2            $ Prebuckling: choose 0=bending included; 2=use membrane theory
 1            $ Buckling: choose 0=simple support or 1=clamping
```

Input for BEGIN (PANDA2 processor)

thorndesign1.DEC

```
    n          $ Do you want a tutorial session and tutorial output?
    n          $ Want to use default for thickness decision variables (type H(elp)?
       1       $ Choose a decision variable (1,2,3,...)
 1.000000      $ Lower bound of variable no.( 1)
 10.00000      $ Upper bound of variable no.( 1)
    y          $ Any more decision variables (Y or N) ?
       3       $ Choose a decision variable (1,2,3,...)
0.3000000      $ Lower bound of variable no.( 3)
 3.000000      $ Upper bound of variable no.( 3)
    y          $ Any more decision variables (Y or N) ?
       4       $ Choose a decision variable (1,2,3,...)
0.1000000E-01  $ Lower bound of variable no.( 4)
0.3000000      $ Upper bound of variable no.( 4)
    y          $ Any more decision variables (Y or N) ?
       5       $ Choose a decision variable (1,2,3,...)
0.1000000E-01  $ Lower bound of variable no.( 5)
0.3000000      $ Upper bound of variable no.( 5)
    y          $ Any more decision variables (Y or N) ?
       6       $ Choose a decision variable (1,2,3,...)
 2.000000      $ Lower bound of variable no.( 6)
 15.00000      $ Upper bound of variable no.( 6)
    y          $ Any more decision variables (Y or N) ?
       9       $ Choose a decision variable (1,2,3,...)
0.1000000E-01  $ Lower bound of variable no.( 9)
0.3000000      $ Upper bound of variable no.( 9)
    n          $ Any more decision variables (Y or N) ?
    y          $ Any linked variables (Y or N) ?
       2       $ Choose a linked variable (1,2,3,...)
       1       $ To which variable is this variable linked?
0.3333000      $ Assign a value to the linking coefficient, C(j)
    n          $ Any other decision variables in the linking expression?
    n          $ Any constant C0 in the linking expression (Y or N)?
    y          $ Any more linked variables (Y or N) ?
       8       $ Choose a linked variable (1,2,3,...)
       3       $ To which variable is this variable linked?
 1.000000      $ Assign a value to the linking coefficient, C(j)
    n          $ Any other decision variables in the linking expression?
    n          $ Any constant C0 in the linking expression (Y or N)?
    n          $ Any more linked variables (Y or N) ?
    n          $ Any inequality relations among variables? (type H)
    y          $ Any escape variables (Y or N) ?
    y          $ Want to have escape variables chosen by default?
```

See Table 0 for correspondance between variable number and what the variable is.

Input for DECIDE (PANDA2 processor)

thorndesign1.OPT

Note

```
      n         $ Do you want a tutorial session and tutorial output?
 -100.0000      $ 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      $ Applied axial moment resultant (e.g. in-lb/in), Mx( 1)
         0      $ Applied hoop moment resultant (e.g. in-lb/in), My( 1)
      y         $ Want to include effect of transverse shear deformation?
         0      $ IQUICK = quick analysis indicator (0 or 1)
      y         $ Do you want to vary M for minimum local buckling load?
      n         $ Do you want to choose a starting M for local buckling?
      y         $ Do you want to perform a "low-axial-wavenumber" search?
 0.9990000      $ Factor of safety for general instability, FSGEN( 1)
 0.9990000      $ Factor of safety for panel (between rings) instability, FSPAN( 1)
 0.9990000      $ 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      $ Resultant (e.g. lb/in) normal to the plane of screen, Nx0( 1)
         0      $ 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      $ Uniform applied pressure [positive upward. See H(elp)], p( 1)
         0      $ Out-of-roundness, Wimpg1=(Max.diameter-Min.diam)/4, Wimpg1( 1)
         0      $ Initial buckling modal general imperfection amplitude, Wimpg2( 1)
         0      $ Initial buckling modal inter-ring imperfection amplitude,Wpan( 1)
         0      $ Initial local imperfection amplitude (must be positive), Wloc( 1)
      n         $ Do you want PANDA2 to change imperfection amplitudes (see H(elp))?( 1)
      y         $ Do you want PANDA2 to find the general imperfection shape?( 1)
         1      $ 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         $ 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)?
         2      $ 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]?
         1      $ Choose (0=transverse inextensional; 1=transverse extensional)
        -1      $ Choose ICONSV = -1 or 0 or 1 or H(elp), ICONSV
         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?
```

input for MAINSETUP/PANDAOPT
(PANDA2 processors)

The applied load is $N_x = -100$ lb/in

This is the __least__ conservative PANDA2 model

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Table 0

thorndesign1.OPM (abridged)

Table 0

PANDA2 prediction for Rob Thornburgh's Design No. 1

```
 DIMENSIONS OF  CURRENT  DESIGN...
 VARIABLE   CURRENT
  NUMBER     VALUE                DEFINITION
     1     3.0000E+00        B(STR):stiffener spacing, b: STR seg=NA, layer=NA
     2     1.0000E+00       B2(STR):width of stringer base, b2 (must be > 0, see
     3     1.2000E+00        H(STR):height of stiffener (type H for sketch), h: S
     4     1.0000E-01    T(1 )(SKN):thickness for layer index no.(1 ): SKN seg=1
     5     1.0000E-01    T(2 )(STR):thickness for layer index no.(2 ): STR seg=3
     6     7.0000E+00        B(RNG):stiffener spacing, b: RNG seg=NA, layer=NA
     7     0.0000E+00       B2(RNG):width of ring base, b2 (zero is allowed): RNG
     8     1.2000E+00        H(RNG):height of stiffener (type H for sketch), h: R
     9     1.0000E-01    T(3 )(RNG):thickness for layer index no.(3 ): RNG seg=3
```

Fig 4

```
 MARGINS FOR CURRENT DESIGN: LOAD CASE NO. 1, SUBCASE NO. 1
 MAR. MARGIN
 NO.  VALUE                 DEFINITION
  1  5.45E+01 Local buckling from discrete model-1.,M=2   axial halfwaves;FS=0.99
  2  5.46E+01 Bending-torsion buckling; M=2  ;FS=0.999
  3  5.49E+01 Bending-torsion buckling: Koiter theory,M=2   axial halfwav;FS=0.99
  4  9.81E+01 eff.stress:matl=1,STR,Dseg=3,node=11,layer=1,z=0.05; MID.;FS=1.
  5  5.51E+01 (m=2   lateral-torsional buckling load factor)/(FS)-1;FS=0.999
  6  3.31E+02 Inter-ring bucklng, discrete model, n=37  circ.halfwaves;FS=0.999
  7  9.81E+01 eff.stress:matl=1,STR,Iseg=3,at:TIP,layer=1,z=0.;-MID.;FS=1.
  8  4.00E+01 buck.(SAND);simp-support general buck;M=4;N=10;slope=0.;FS=0.999
  9  2.72E+02 buck.(SAND);rolling with smear rings; M=166;N=1;slope=0.;FS=0.999
 10  9.03E+01 buck.(SAND);rolling only of stringers;M=84;N=0;slope=0.;FS=1.4
 11  1.56E+04 (Max.allowable ave.axial strain)/(ave.axial strain) -1; FS=1.
```

Fig.3 →

Compare Margins 1, 2, 3, and 5 with the BIGBOSOR4 results in Fig. 4. Note that buckling load factor = (margin + 1) x factor of safety.

Compare Margin 8 with the BIGBOSOR4 results in Fig. 3. Note that buckling load factor = (margin + 1) x factor of safety.

The general buckling mode shape listed in Margin 8 agrees with Thornburgh's STAGS prediction for the critical buckling mode without a weld land.

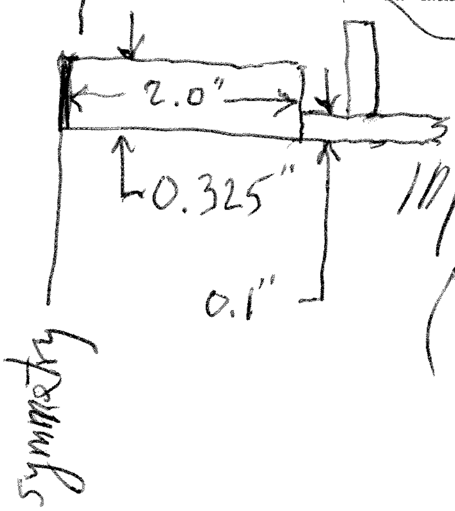
Output from PANDAOPT (abridged) for "thorndesign1"

~~thors~~ thorsdesign1.PAN (produces Table1)

$\approx \frac{\pi r}{2} =$

```
       n         $ Do you want a tutorial session and tutorial output?
171.0000         $ Panel length in the plane of the screen, L2
       1         $ Enter control ILAND for weldland (0=none or 1=weldland)
       1         $ Number of BOSOR4-type segments in the weld land, KLAND
4.000000         $ Width of the weld land, WLAND
0.3250000        $ Thickness of the weld land, TLAND
0.1125000        $ Eccentricity of the weld land outer surface, ECLAND
       1         $ Enter control (1=sym; 2=s.s.) for boundary condition
      -1         $ Enter ILOCAL=0 or 1 or -1 (Type (H)elp), ILOCAL
       4         $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
       1         $ How many eigenvalues (get at least 3) do you want?
```

rings are smeared



Input for PANEL3

(See Item No, 792 in panda2.news (included in the Appendix here))

PANEL3 is a new PANDA2 processor that generates BIGBOSOR4 models that include a weld land.

$\boxed{\text{Rings are smeared.}}$

Table 1 thorndesign1.OUT

```
April 30, 2009
Table 1 Buckling of Design 1 with weld land.
Outer surface of weld land flush with outer surface of skin.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
Rings are smeared, stringers are shell branches.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    5.8713E+01( 100)
    4.5254E+01( 200)
    3.9120E+01( 300)
    3.6770E+01( 400) <--critcal load factor (400 means 4 axial halfwaves)
    3.6930E+01( 500) <--close to critical load factor
    3.8778E+01( 600)
    4.1784E+01( 700)
    4.5556E+01( 800)
 =======================================
```

see Appendix 2

Output from BIGBOSOR4 (abridged)

See Appendix 2 for an explanation of the "huge torus" BIGBOSOR4 model of a stiffened cylindrical shell.

rings are smeared

Compare with Figs. 2 & 3

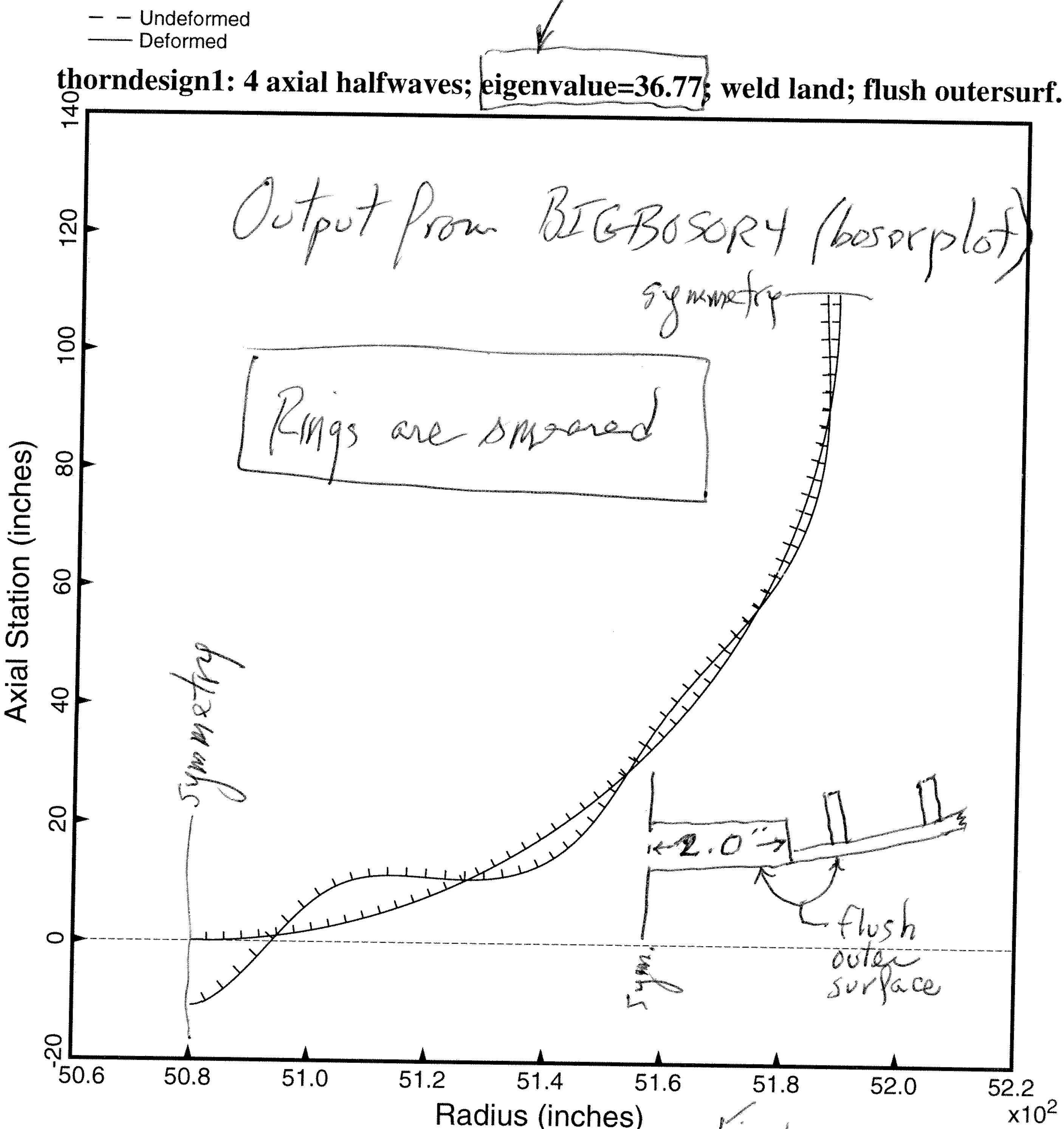


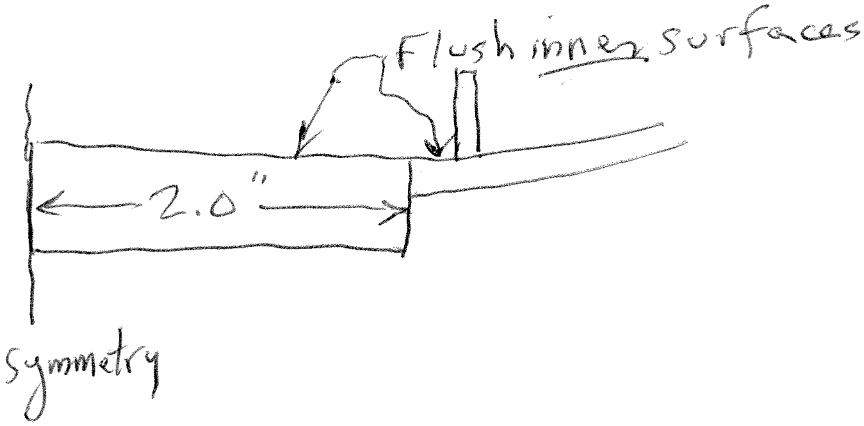
Fig. 1

thorndesign1.PAN (produces Table 2)

```
         n          $ Do you want a tutorial session and tutorial output?
  171.0000          $ Panel length in the plane of the screen, L2
         1          $ Enter control ILAND for weldland (0=none or 1=weldland)
         1          $ Number of BOSOR4-type segments in the weld land, KLAND
  4.000000          $ Width of the weld land, WLAND
 0.3250000          $ Thickness of the weld land, TLAND
 -0.112500          $ Eccentricity of the weld land outer surface, ECLAND
         1          $ Enter control (1=sym; 2=s.s.) for boundary condition
        -1          $ Enter ILOCAL=0 or 1 or -1 (Type (H)elp), ILOCAL
         4          $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
         1          $ How many eigenvalues (get at least 3) do you want?
```

smeared rings:

Input for PANEL3



Rings are smeared.

Table 2

```
April 30, 2009
Table 2 Buckling of Design 1 with weld land.
Inner surface of weld land flush with inner surface of skin.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
Rings are smeared, stringers are shell branches.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
     5.9746E+01( 100)
     4.6911E+01( 200)
     4.1232E+01( 300)
     3.9649E+01( 400) <--critical load factor (400 means 4 axial halfwaves)
     4.1103E+01( 500)
     4.4631E+01( 600)
     5.0410E+01( 700)
     5.6917E+01( 800)
 =======================================
```

See Appendix 2

Output from BIGBOSOR4

thorndesign1.OUT (abridged)

Rings are smeared

Compare with Fig. 1

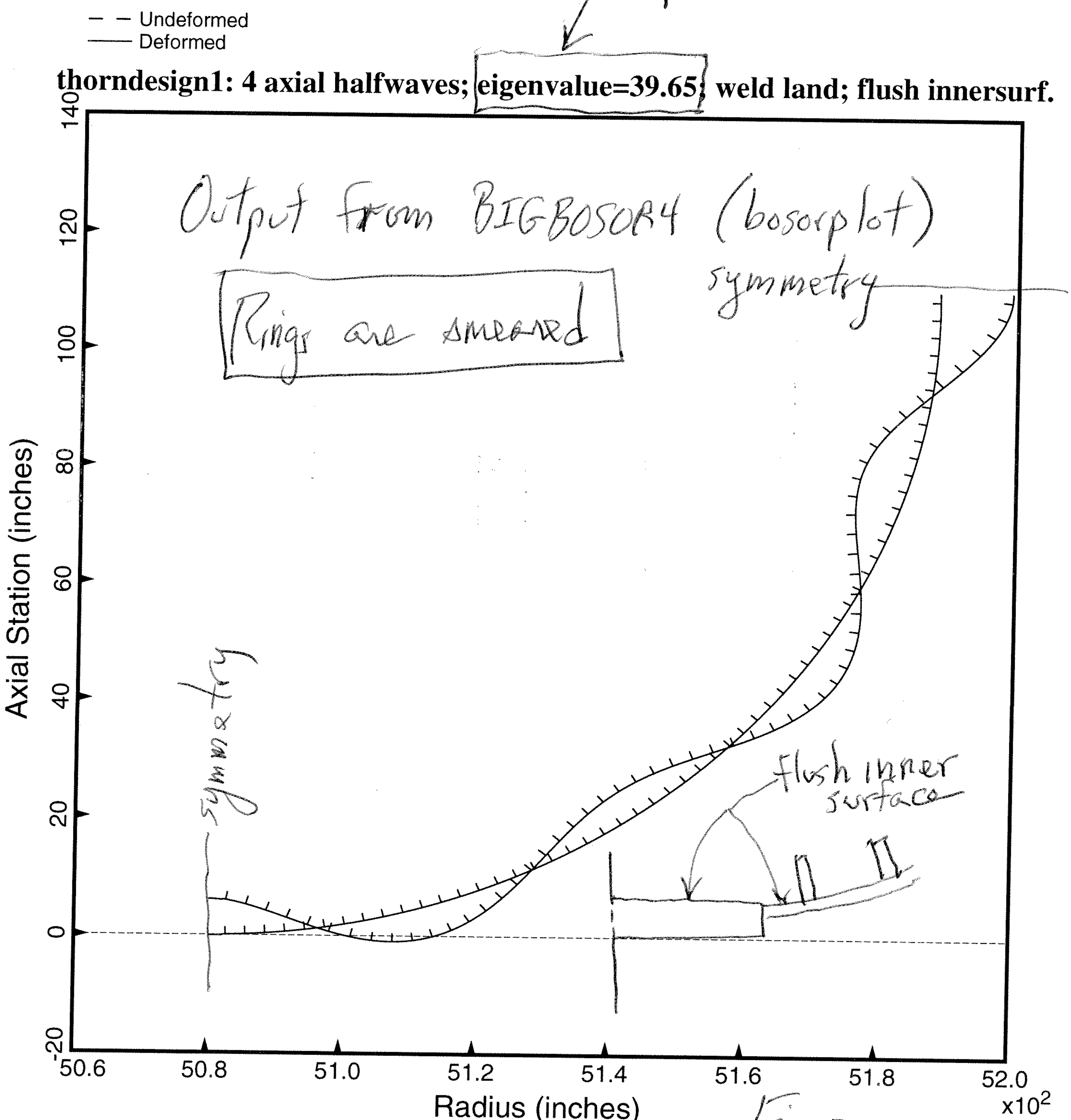


Fig. 2

12

thorndesign1.PAN (produces Table 3)

```
n            $ Do you want a tutorial session and tutorial output?
171.0000     $ Panel length in the plane of the screen, L2
   0         $ Enter control (0 or 1) for stringers at panel edges
   1         $ Enter control (1=sym; 2=s.s.) for boundary condition
  -1         $ Enter ILOCAL=0 or 1 or -1 (Type (H)elp), ILOCAL
   4         $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
   1         $ How many eigenvalues (get at least 3) do you want?
```

Input for PANEL3

(~~the old "torus" model PANDA2 processor~~ – No Weld land.)

Rings are smeared.

Table 3

```
April 30, 2009
Table 3 Buckling of Design 1 without weld land.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
Rings are smeared, stringers are shell branches.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    6.3077E+01( 100)
    4.9296E+01( 200)
    4.3415E+01( 300)
    4.1343E+01( 400) <--critical load factor (400 means 4 axial halfwaves)
    4.2933E+01( 500)
    4.6353E+01( 600)
    5.2232E+01( 700)
    5.9905E+01( 800)
 =======================================
```

See Appendix 2

Output from BIGBOSOR4
thorndesign1.OUT (abridged)

Rings are smeared

Compare with Figs 1 & 2

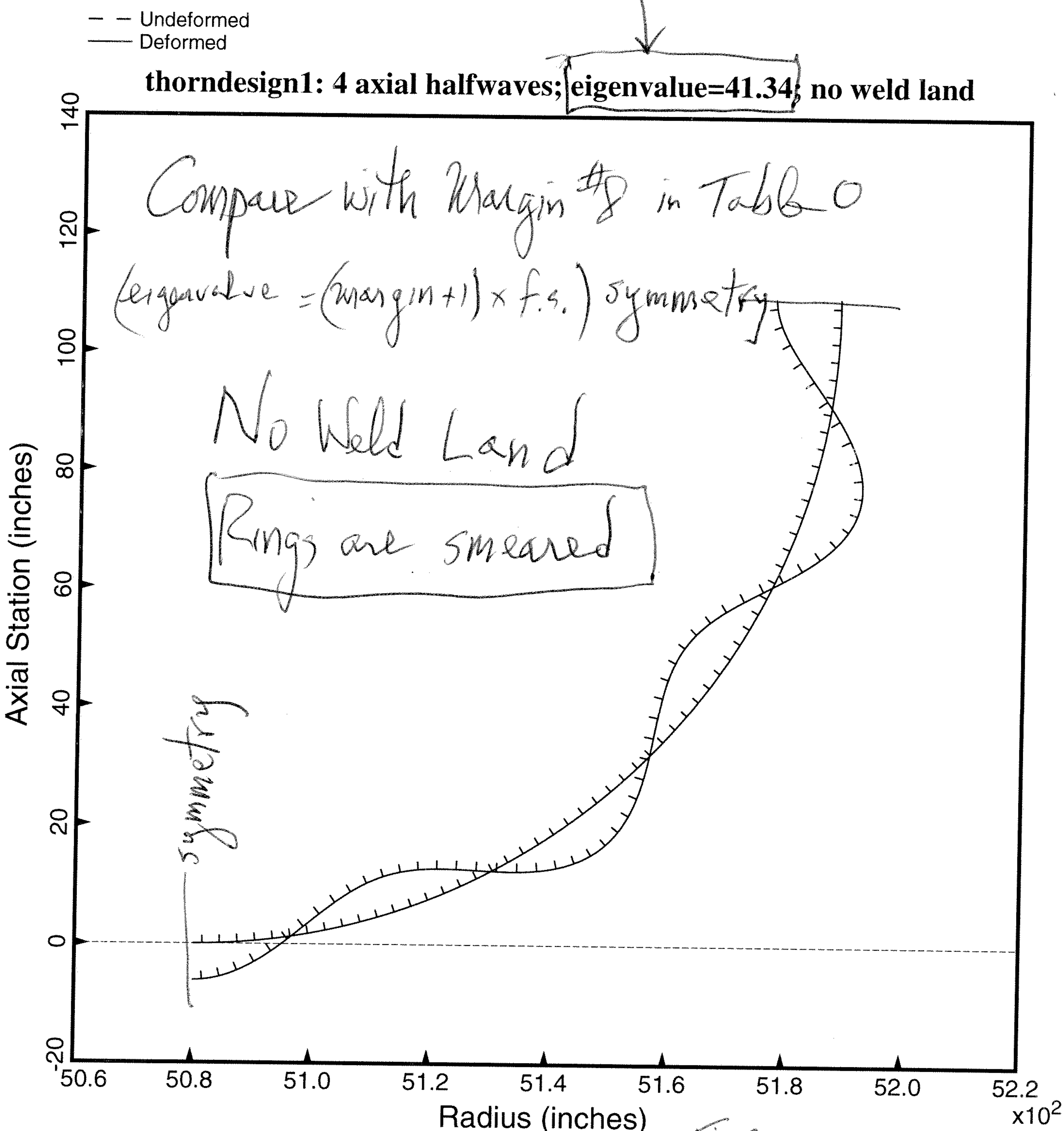


Fig. 3

thermdesign1.PAN (produces Table 4)

```
     n         $ Do you want a tutorial session and tutorial output?
 171.0000      $ Panel length in the plane of the screen, L2
        1      $ Enter control ILAND for weldland (0=none or 1=weldland)
        1      $ Number of BOSOR4-type segments in the weld land, KLAND
 4.000000      $ Width of the weld land, WLAND
0.3250000      $ Thickness of the weld land, TLAND
0.1125000      $ Eccentricity of the weld land outer surface, ECLAND
        1      $ Enter control (1=sym; 2=s.s.) for boundary condition
        1      $ Enter ILOCAL=0 or 1 or -1 (Type (H)elp), ILOCAL
        1      $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
        1      $ How many eigenvalues (get at least 3) do you want?
```

Input for PANEL3

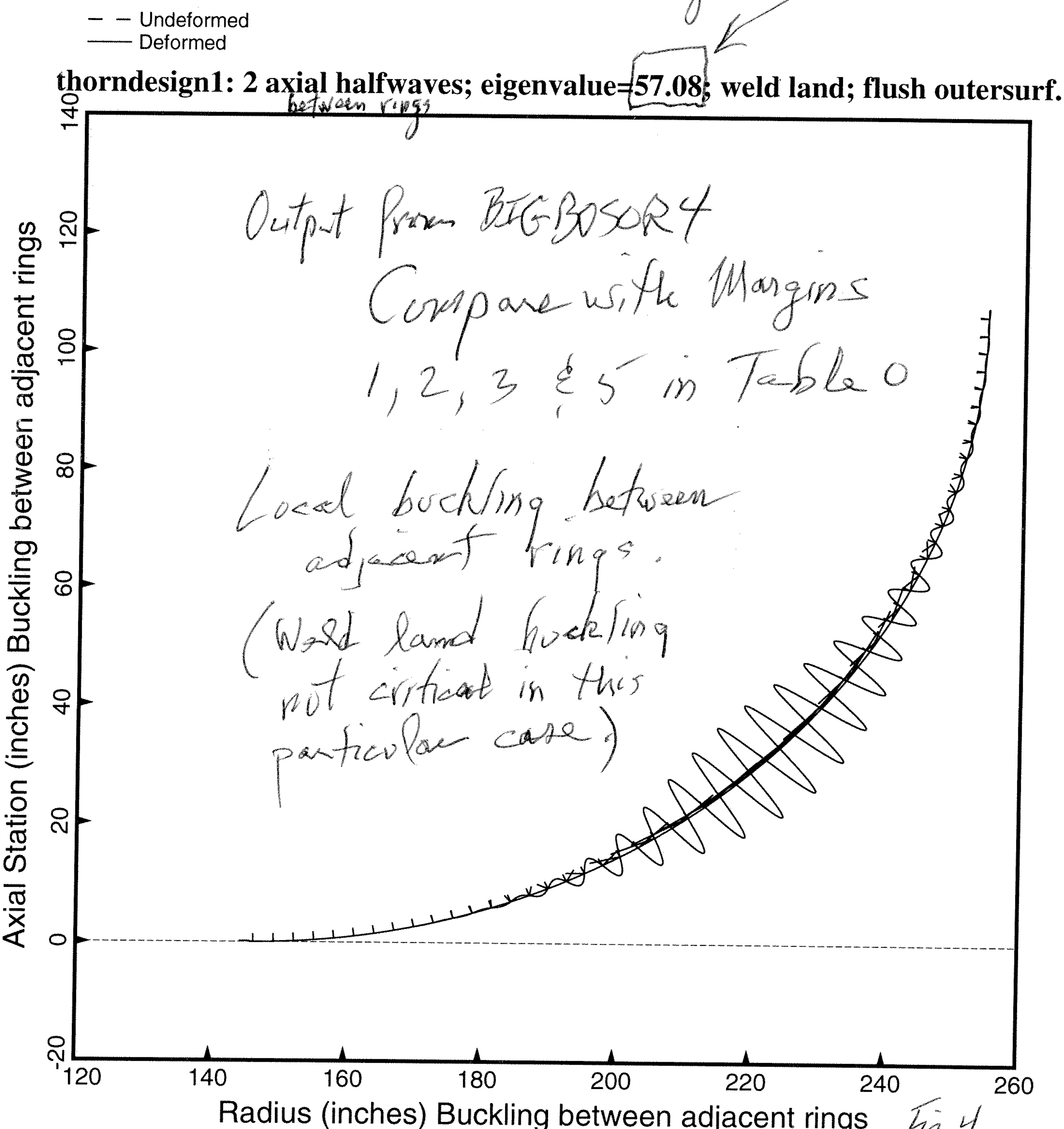
Part of the shell between adjacent rings is being modeled with BIGBOSOR4.

Table 4

```
April 30, 2009
Table 4 Buckling of Design 1 with weld land.
Outer surface of weld land flush with outer surface of skin.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
Buckling is between adjacent rings. stringers are shell branches.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 ======================================
    6.3244E+01( 100)
    5.7085E+01( 200) <--critical value (2 axial halfwaves between rings)
    6.0506E+01( 300)
    7.2784E+01( 400)
    9.1088E+01( 500)
    1.1449E+02( 600)
    1.4266E+02( 700)
    1.7546E+02( 800)
    2.1280E+02( 900)
 ======================================
```

Output from BIGBOSOR4
Part of cylindrical shell between adjacent rings.

buckling load factor = margin + 1



Output from BIGBOSOR4
Compare with Margins 1, 2, 3 & 5 in Table 0

Local buckling between adjacent rings.
(Weld land buckling not critical in this particular case.)

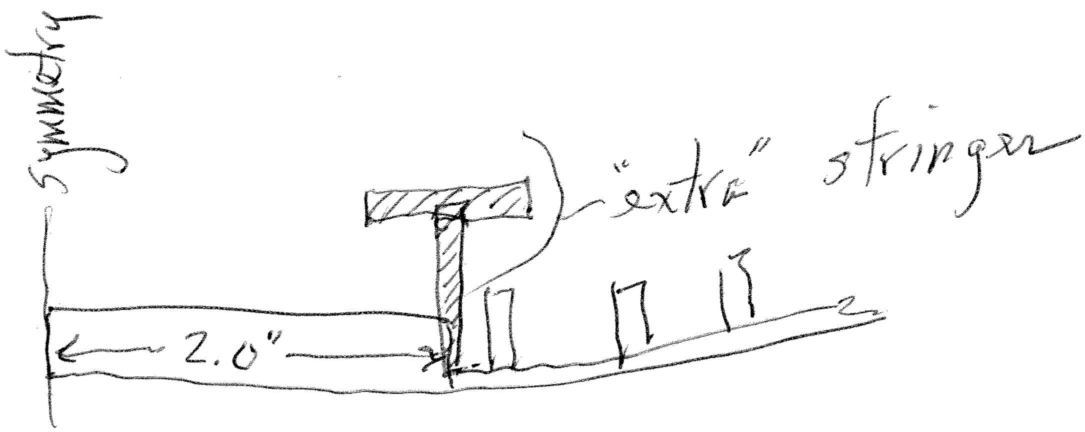
Fig. 4

thorndesign1.PAN (produces Tables)

```
    n        $ Do you want a tutorial session and tutorial output?
 171.0000    $ Panel length in the plane of the screen, L2
       1     $ Enter control ILAND for weldland (0=none or 1=weldland)
       3     $ Number of BOSOR4-type segments in the weld land, KLAND
 4.000000    $ Width of the weld land, WLAND
0.3250000    $ Thickness of the weld land, TLAND
0.1000000    $ Thickness of "extra" weld land edge stringer web, TWLAND
 1.200000    $ Height of "extra" weld land stringer web, HWLAND
0.1000000    $ Thickness of outstanding flange of weld land stringer, TFLAND
 1.200000    $ Width of outstanding flange of weld land stringer, WFLAND
0.1125000    $ Eccentricity of the weld land outer surface, ECLAND
       1     $ Enter control (1=sym; 2=s.s.) for boundary condition
      -1     $ Enter ILOCAL=0 or 1 or -1 (Type (H)elp), ILOCAL
       4     $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
       1     $ How many eigenvalues (get at least 3) do you want?
```

Input for PANEL3

Next, include an "extra" Tee-shaped stringer at the edge of the weld land. (where the weld land meets the shell)



Rings are smeared

Table 5

```
April 30, 2009
Table 5 Buckling of Design 1 with weld land and "extra" Tee-shaped stringer
Outer surface of weld land flush with outer surface of skin.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
Rings are smeared, stringers are shell branches.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    5.6716E+01( 100)
    4.3387E+01( 200)
    3.8287E+01( 300)
    3.7951E+01( 400) <--critical load factor (400 means 4 axial halfwaves)
    4.0961E+01( 500)
    4.4791E+01( 600)
    5.0735E+01( 700)
    5.8408E+01( 800)
 =======================================
```

See Appendix 2

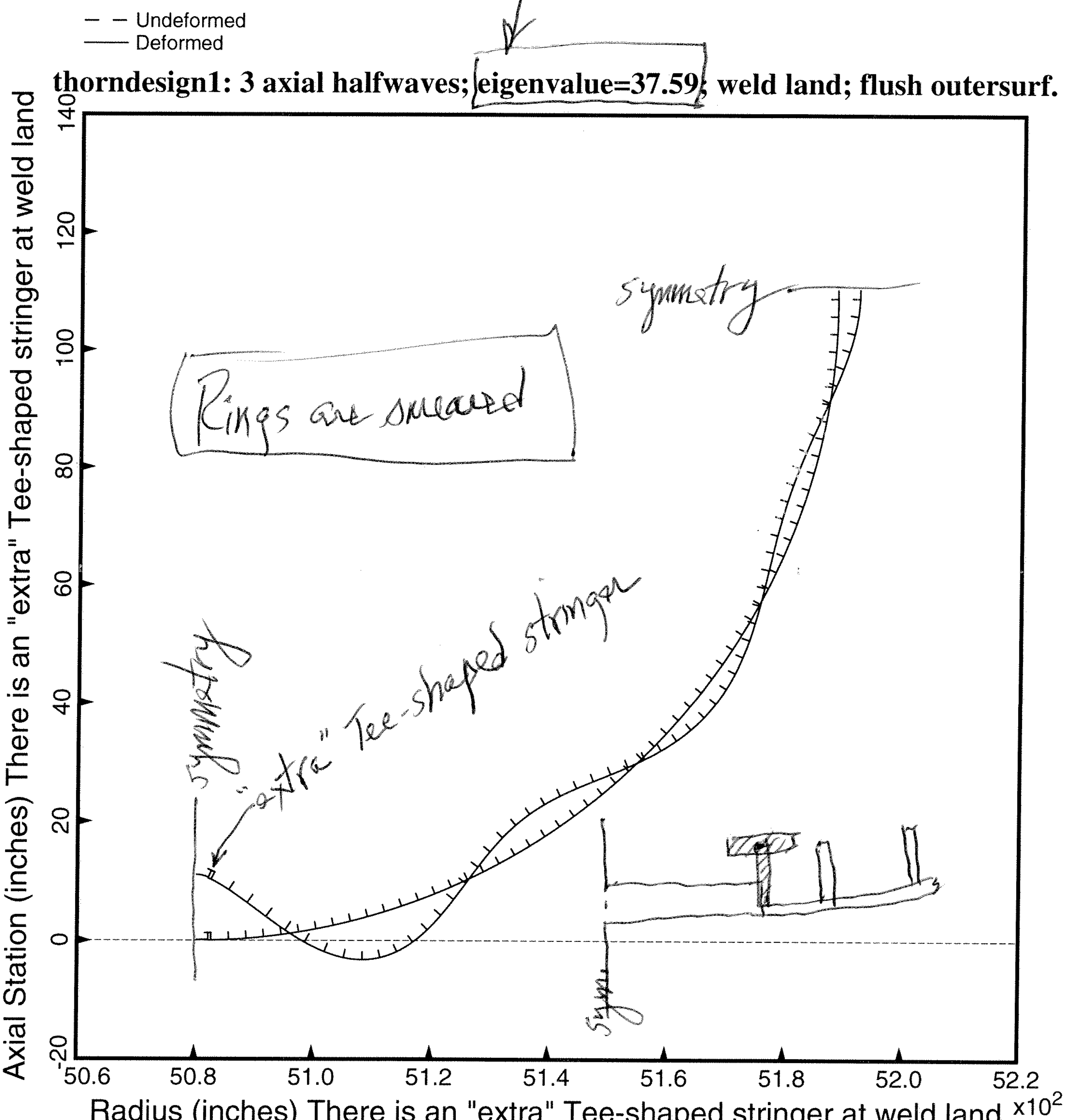
Output from BIGBOSOR4

thorndesign1.OUT (abridged)

rings are smeared

Compare with Table 1

Compare with Fig. 1



21

Fig. 5

thorndesign1.PAN (previous Table 6)

```
    n         $ Do you want a tutorial session and tutorial output?
 171.0000     $ Panel length in the plane of the screen, L2
       1      $ Enter control ILAND for weldland (0=none or 1=weldland)
       1      $ Number of BOSOR4-type segments in the weld land, KLAND
       4      $ Width of the weld land, WLAND
0.3250000     $ Thickness of the weld land, TLAND
0.1125000     $ Eccentricity of the weld land outer surface, ECLAND
       1      $ Enter control (1=sym; 2=s.s.) for boundary condition
      -2      $ Enter ILOCAL=0 or 1 or -1 or -2 (Type (H)elp), ILOCAL
       4      $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
       1      $ How many eigenvalues (get at least 3) do you want?
```

all stiffeners smeared

Compare with p.7

Table 6

```
May 2, 2009
Table 6 Buckling of Design 1 with weld land.
Outer surface of weld land flush with outer surface of skin.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
All stiffeners are smeared.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    6.0184E+01( 100)
    4.6477E+01( 200)
    4.0012E+01( 300)
    3.7278E+01( 400) <---close to critical
    3.7123E+01( 500) <---critical load factor (500 means 5 axial halfwaves)
    3.8551E+01( 600)
    4.0949E+01( 700)
    4.3948E+01( 800)
 =======================================
```

Compare with Table 1 on p. 8

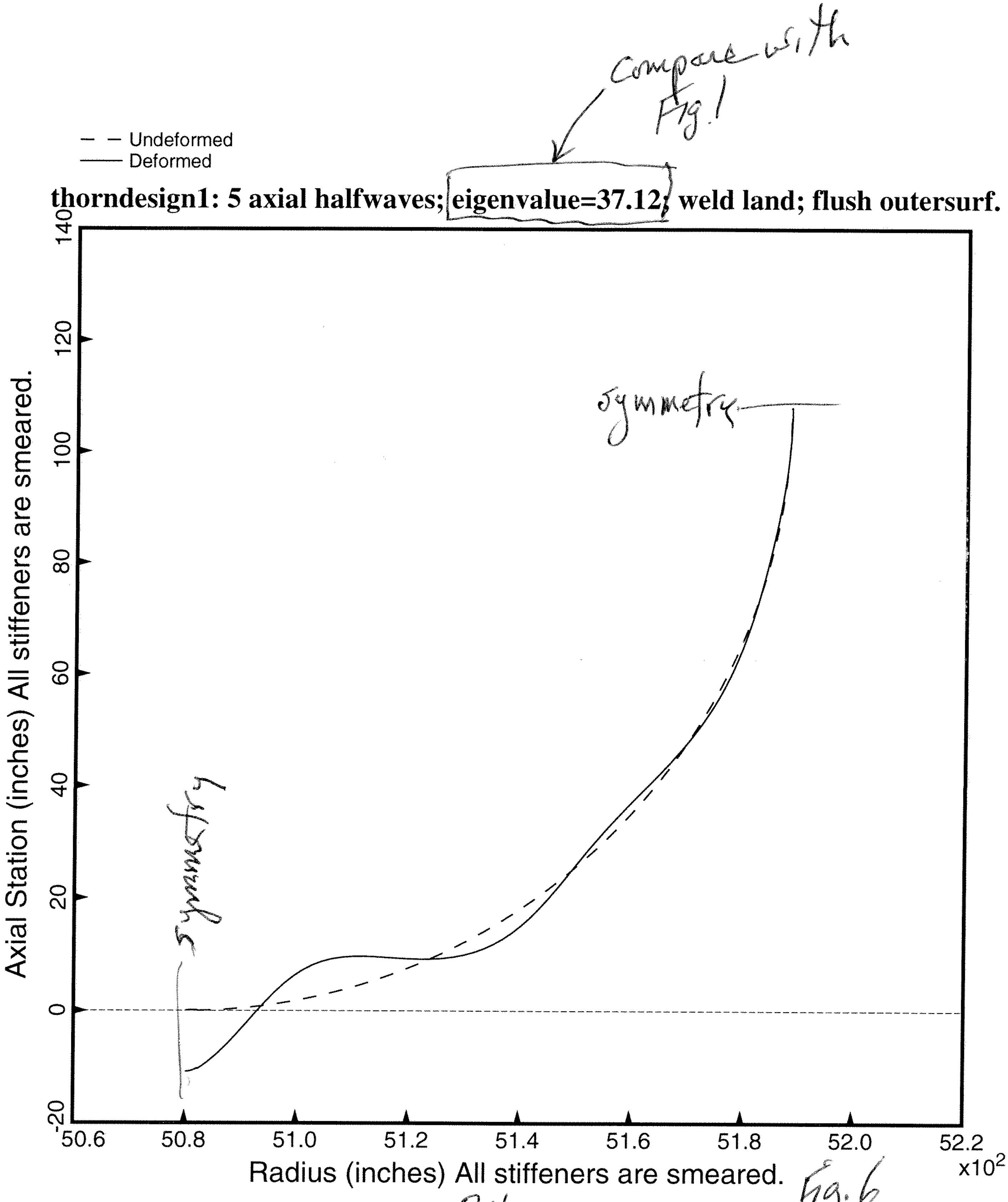

compare with Fig. 1
– – Undeformed
—— Deformed
thorndesign1: 5 axial halfwaves; eigenvalue=37.12; weld land; flush outersurf.
Axial Station (inches) All stiffeners are smeared.
-20
0
20
40
60
80
100
120
140
symmetry
symmetry
50.6
50.8
51.0
51.2
51.4
51.6
51.8
52.0
52.2
x10^2
Radius (inches) All stiffeners are smeared.

Fig. 6

thorndesign1.PAN (produces Table 7)

```
        n       $ Do you want a tutorial session and tutorial output?
 171.0000       $ Panel length in the plane of the screen, L2
        1       $ Enter control ILAND for weldland (0=none or 1=weldland)
        1       $ Number of BOSOR4-type segments in the weld land, KLAND
        4       $ Width of the weld land, WLAND
0.3250000       $ Thickness of the weld land, TLAND
-0.1125000      $ Eccentricity of the weld land outer surface, ECLAND
        1       $ Enter control (1=sym; 2=s.s.) for boundary condition
       -2       $ Enter ILOCAL=0 or 1 or -1 or -2 (Type (H)elp), ILOCAL
        4       $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
        1       $ How many eigenvalues (get at least 3) do you want?
```

All stiffeners are smeared

Compare with p. 10

Table 7

```
May 2, 2009
Table 7 Buckling of Design 1 with weld land.
Inner surface of weld land flush with inner surface of skin.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
All stiffeners are smeared.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    6.1319E+01( 100)
    4.8480E+01( 200)
    4.2870E+01( 300)
    4.1161E+01( 400) <---critical load factor (400 means 4 axial halfwaves)
    4.2486E+01( 500)
    4.5701E+01( 600)
    5.0457E+01( 700)
    5.5928E+01( 800)
 =======================================
```

Compare with Table 2

Compare with Fig. 2

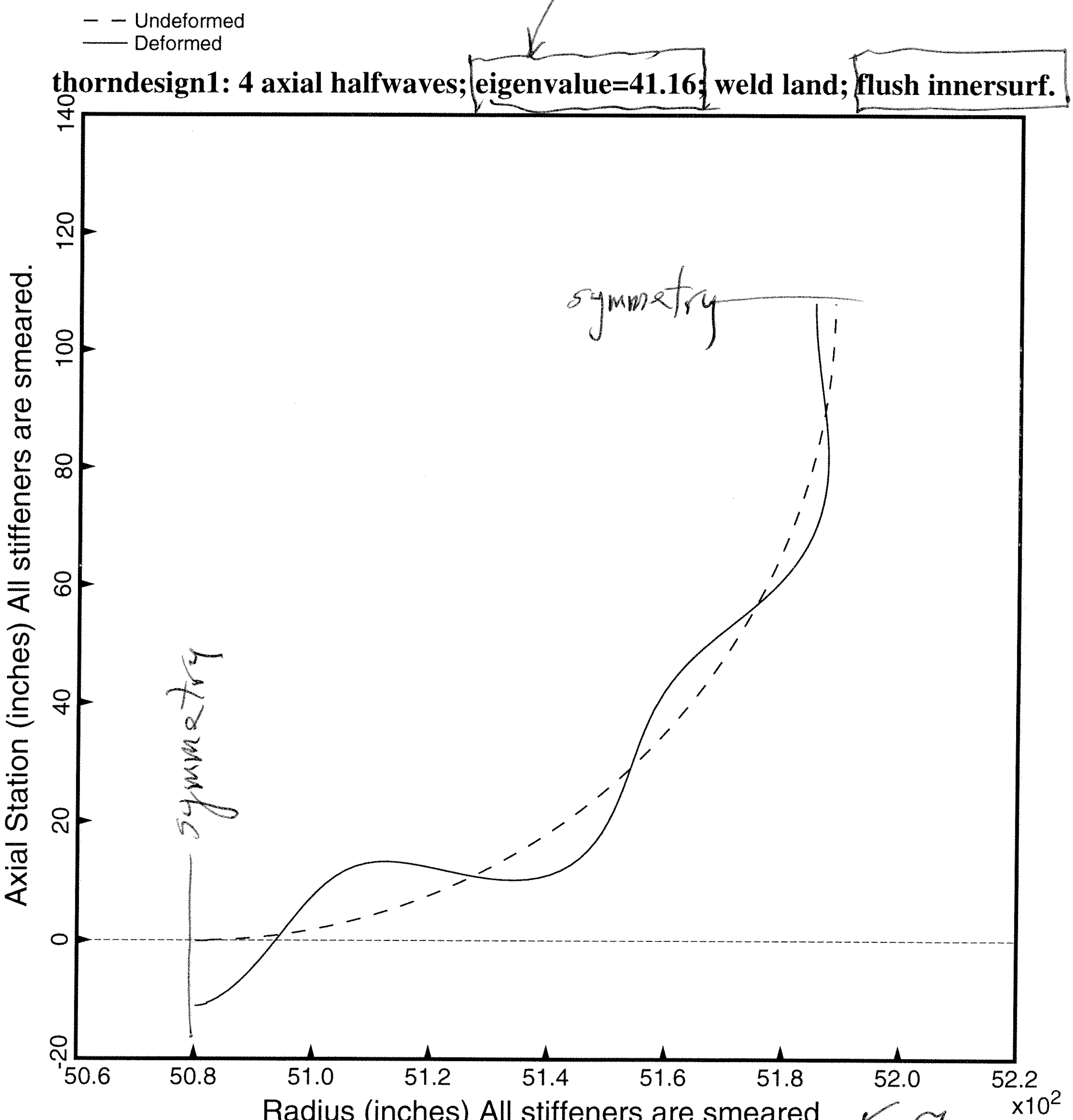


Fig. 7

thorndesign1.PAN (produces table 8)

```
  n        $ Do you want a tutorial session and tutorial output?
 171       $ Panel length in the plane of the screen, L2
   0       $ Enter control ILAND for weldland (0=none or 1=weldland)
   1       $ Enter control (1=sym; 2=s.s.) for boundary condition
  -2       $ Enter ILOCAL=0 or 1 or -1 or -2 (Type (H)elp), ILOCAL
   4       $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
   1       $ How many eigenvalues (get at least 3) do you want?
```

No weld land

All stiffeners are smeared

Compare with p.13

Table 8

```
May 2, 2009
Table 8 Buckling of Design 1 with NO weld land.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
All stiffeners are smeared.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    6.4277E+01( 100)
    5.0513E+01( 200)
    4.4711E+01( 300)
    4.2664E+01( 400) <--critical load factor. 400 means 4 axial halfwaves)
    4.4809E+01( 500)
    4.8349E+01( 600)
    5.4871E+01( 700)
    6.3600E+01( 800)
 =======================================
```

Compare with Table 3

Compare with Fig. 3

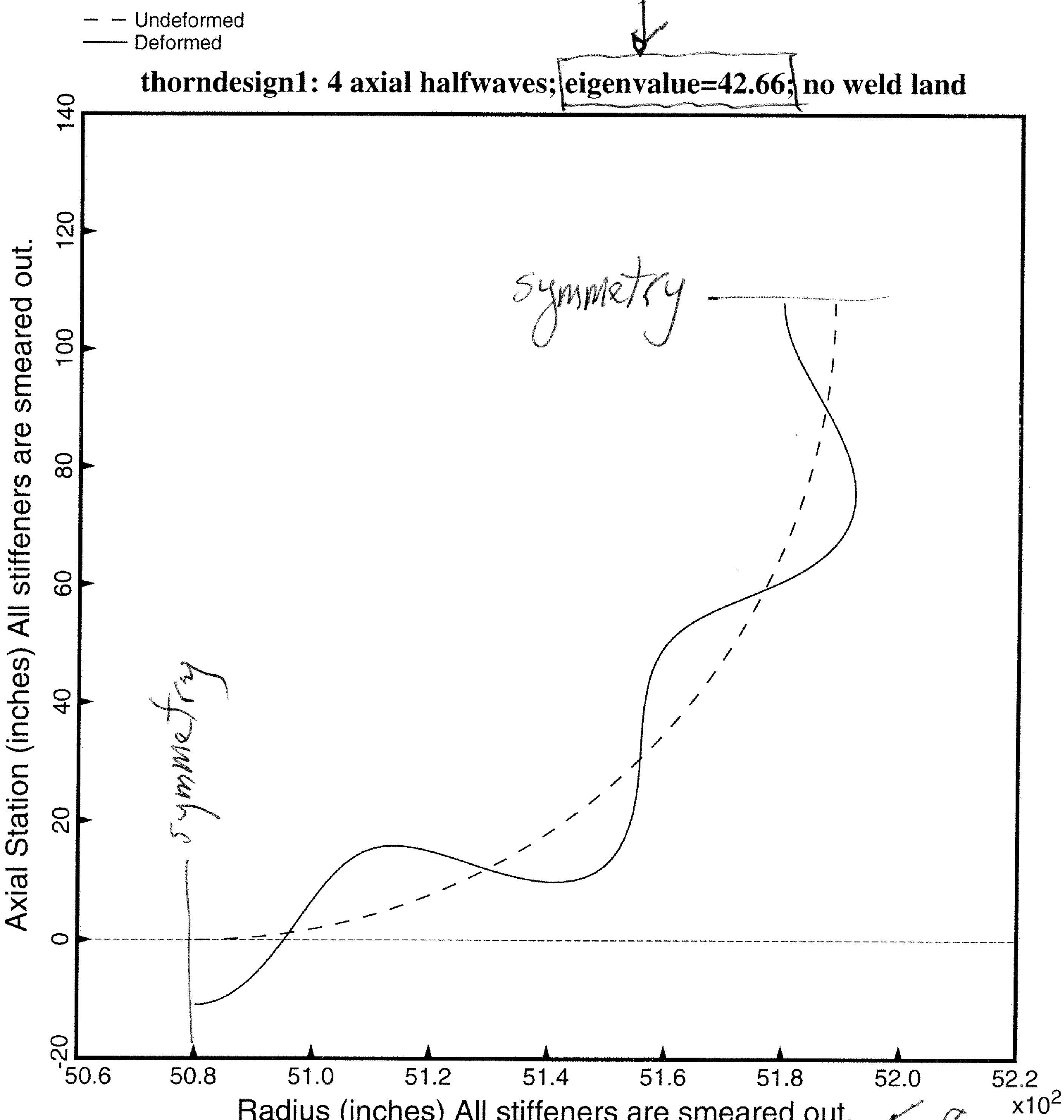


Fig. 8

thorndesign1.PAN (produces Table ~~10~~ 9)

```
    n          $ Do you want a tutorial session and tutorial output?
  171          $ Panel length in the plane of the screen, L2
    1          $ Enter control ILAND for weldland (0=none or 1=weldland)
    3          $ Number of BOSOR4-type segments in the weld land, KLAND
    4          $ Width of the weld land, WLAND
0.3250000      $ Thickness of the weld land, TLAND
0.1000000      $ Thickness of "extra" weld land edge stringer web, TWLAND
 1.200000      $ Height of "extra" weld land stringer web, HWLAND
0.1000000      $ Thickness of outstanding flange of weld land stringer, TFLAND
 1.200000      $ Width of outstanding flange of weld land stringer, WFLAND
0.1125000      $ Eccentricity of the weld land outer surface, ECLAND
    1          $ Enter control (1=sym; 2=s.s.) for boundary condition
   -2          $ Enter ILOCAL=0 or 1 or -1 or -2 (Type (H)elp), ILOCAL
    4          $ Number of halfwaves in the axial direction [see H(elp)],NWAVE
    1          $ How many eigenvalues (get at least 3) do you want?
```

All stiffeners are smeared.
Compare with p.19

Table 9

```
May 2, 2009
Table 9 Buckling of Design 1 with weld land and "extra" Tee-shaped stringer
Outer surface of weld land flush with outer surface of skin.
thorndesign1.OUT (output from BIGBOSOR4)
Applied axial resultant, Nx = 100 lb/in
All stiffeners are smeared.
 ***** EIGENVALUES AND MODE SHAPES *****
  EIGENVALUE(CIRC. WAVES)
 =======================================
    5.7954E+01( 100)
    4.4329E+01( 200)
    3.9036E+01( 300)
    3.8602E+01( 400) <---critical load factor (400 means 4 axial halfwaves)
    4.1801E+01( 500)
    4.7326E+01( 600)
    5.4733E+01( 700)
    6.3670E+01( 800)
 =======================================
```

Compare with Table 5

Compare with Fig. 5

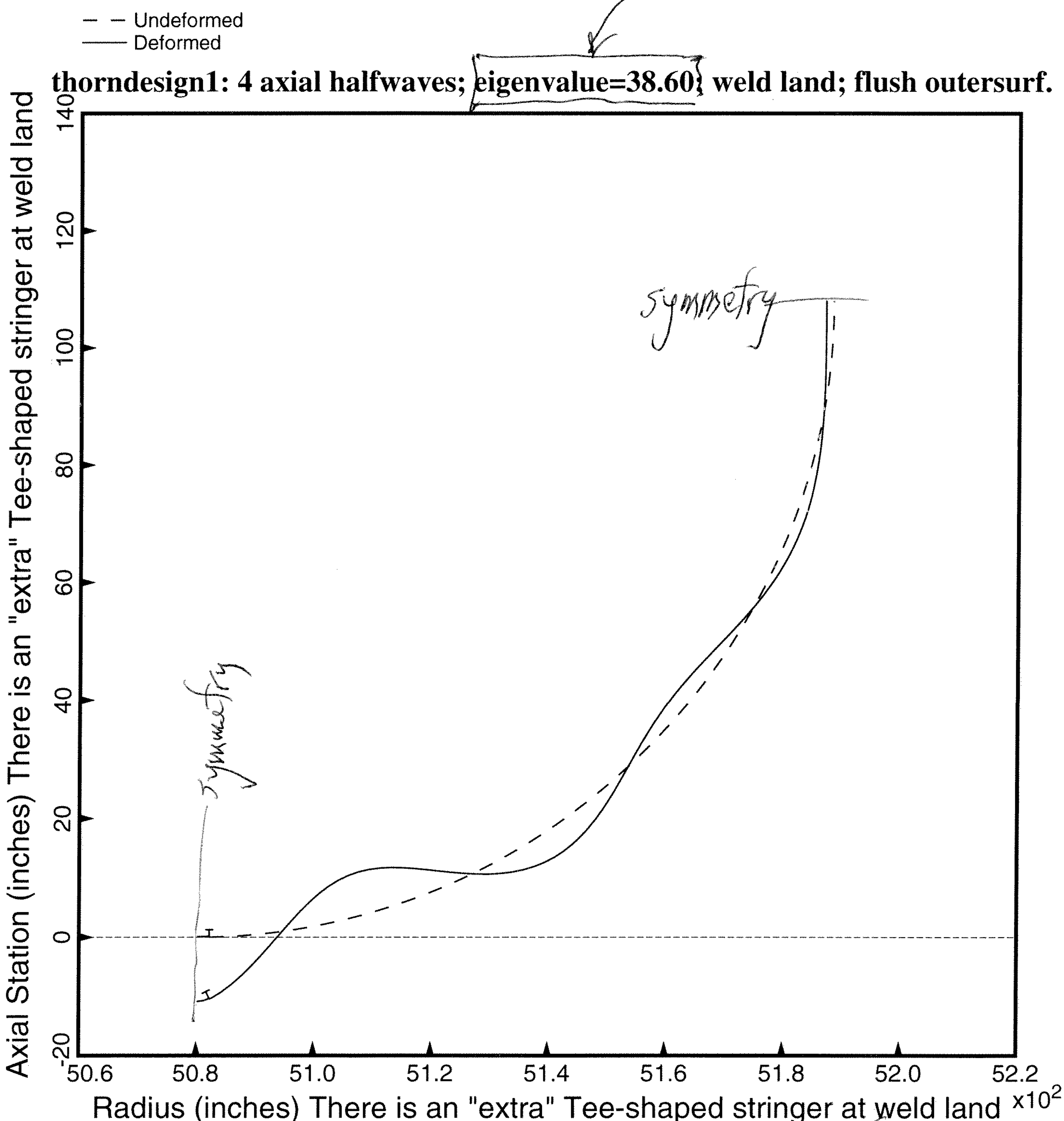


Fig. 9

APPENDIX 1

```
Item 792 from the file, ...panda2/doc/panda2.news

This item is about the new PANDA2 processor called "PANEL3",
which generates BIGBOSOR4 models of stiffened cylindrical shells
including a weld land


792. April, 2009
A new PANDA2 processor called "bospn3" was created. This processor
is executed via a new PANDA2 command, "panel3". The purpose of the
new library, bospn3.src, is to set up a BIGBOSOR4 model of an
optimized stiffened cylindrical shell with a weld land in it.
bospn3.src was created starting from a copy of bospan.src. bospn3.src
is similar to bospan.src. The new command, "panel3", corresponds to
a new "*.com" file called "panel3.com", located in the directory,
...panda2/bin. Because there is a new command there is also a new
version of the "*.com" file called "panda2.com", also located in the
directory, ...panda2/bin. Because of the new library, "bospn3.src",
there is a new version of makefile.linux and a new version of
makefile.hp700. Also, new prompts were added to the file,
...panda2/execute/PROMPT.DAT.

The new prompts in the file, ...panda2/execute/PROMPT.DAT, are
as follows:
-----------------------------------------------------------------
810.1 Enter control ILAND for weldland (0=none or 1=weldland)
810.2
      ILAND = 0 means this BOSOR4 model has no weldland segment.
      ILAND = 1 means this BOSOR4 model has one or more weldland
                segments.
-----------------------------------------------------------------

and
-----------------------------------------------------------------
781.0
      Next you will be asked to supply properties of the weld land:
      KLAND = number of BOSOR4-type segments in the weld land:
              If there is no extra stringer along the generator
              at the edges of the weld land, KLAND = 1
              If there is a Tee-shaped stringer, KLAND = 3
              If there is a rectangular stringer, KLAND = 2
      WLAND = width of the weld land in the circumferential direction.
      TLAND = thickness of the weld land (uniform)
      TWLAND= thickness of the web of the extra weld land stringer
      HWLAND= height of the web of the extra weld land stringer
      TFLAND= thickness of the outstanding flange of the weld land stringer
      WFLAND= width of the outstanding flange of the weld land stringer
      ECLAND= eccentricity of the weld land middle surface relative to
              the middle surface of the rest of the cylindrical shell

782.1 Number of BOSOR4-type segments in the weld land, KLAND
782.2
      KLAND = 1 if there are no "extra" stringers along its two
                generators (axially oriented edges)
      KLAND = 2 if there are extra edge stringers with rectangular
                cross sections
      KLAND = 3 if there are extra edge stringers with Tee-shaped
                cross sections

783.1 Width of the weld land, WLAND
783.2
      For NASA-type launch vehicles the width should be something
      like 4 inches.
      NOTE: in the BOSOR4-type model we assume no tapering of the
      weld land thickness. The weld land has uniform thickness.

784.1 Thickness of the weld land, TLAND
784.2
      We assume the thickness is uniform. No tapering accounted for
      in the BOSOR4-type model.

785.1 Thickness of "extra" weld land edge stringer web, TWLAND
785.2
      If KLAND > 1 there are "extra" stringers along the two
      axially oriented edges of the weld land, where the weld
      land is joined to the rest of the cylindrical shell. These
      "extra" stringers may have either rectangular (KLAND = 2)
      or Tee-shaped (KLAND = 3) cross sections.
```

```
786.1 Height of "extra" weld land stringer web, HWLAND
786.2
      If KLAND > 1 there are "extra" stringers along the two
      axially oriented edges of the weld land, where the weld
      land is joined to the rest of the cylindrical shell. These
      "extra" stringers may have either rectangular (KLAND = 2)
      or Tee-shaped (KLAND = 3) cross sections.

787.1 Thickness of outstanding flange of weld land stringer, TFLAND
787.2
      If KLAND > 1 there are "extra" stringers along the two
      axially oriented edges of the weld land, where the weld
      land is joined to the rest of the cylindrical shell. These
      "extra" stringers may have either rectangular (KLAND = 2)
      or Tee-shaped (KLAND = 3) cross sections.

788.1 Width of outstanding flange of weld land stringer, WFLAND
788.2
      If KLAND > 1 there are "extra" stringers along the two
      axially oriented edges of the weld land, where the weld
      land is joined to the rest of the cylindrical shell. These
      "extra" stringers may have either rectangular (KLAND = 2)
      or Tee-shaped (KLAND = 3) cross sections.

789.1 Eccentricity of the weld land outer surface, ECLAND
789.2
      ECLAND = 0.0 means middle surface of weld land is flush with
                   the middle surface of the rest of the cylindrical
                   shell
      ECLAND = positive means middle surface of the weld land lies
               inside the middle surface of the rest of the shell.
      ECLAND = negative means middle surface of the weld lane lies
               outside the middle surface of the rest of the shell.

      Units of ECLAND should be length (such as inches, for example).
----------------------------------------------------------------------
```

Appendix 2
From AIAA paper AIAA-2007-2216, 48th AIAA SDM meeting 2007

halfwaves, **dm**, in the PANDA2 model, as listed in Part 1 of Table 8 for example, the imperfection amplitude used by PANDA2 is different in this particular case from that to be used in the STAGS nonlinear models. With the "yes change imperfection" option, the amplitude of the general buckling modal imperfection in the PANDA2 models is plus or minus **0.25/(m+dm),** in which **dm** can be either positive, zero, or negative. From part 1 of Table 8 we see that in this particular case the amplitude of the general buckling modal imperfection in the PANDA2 model is **0.25/(m+dm) = 0.25/(5 – 0.41628) = 0.054541 inches.** The STAGS model of the imperfect shell is somewhat conservative relative to the PANDA2 model in this case because it has a general buckling modal imperfection with a somewhat higher amplitude, Wimp = 0.0625 inch, compared to the PANDA2 amplitude, Wimp = 0.054541 inch.

12.2.2 Results from linear buckling analyses with BIGBOSOR4 [14F]

There are PANDA2 processors, PANEL (Fig. 36, p. 539 of [1A]) and PANEL2 (Fig. 33 of [1G]), by means of which input files for BOSOR4 (or BIGBOSOR4) [14] are generated automatically. Figures 20b, 21b, and 23b pertain to this sub-section.

Huge torus model (BIGBOSOR4)

The **PANEL** processor generates an input file, *.ALL, for the BIGBOSOR4 [14F] **buckling analysis of the portion of the optimized stiffened cylindrical shell between rings** (multiple skin-stringer modules each module of which is similar to the one module shown in Fig. 4). The sector of the stringer-stiffened portion of the cylindrical shell shown in Figs. 20b and 23b is modeled as a segment of a toroidal shell ([26], also see Fig. 192, p. 221 of [8]) with a large radius R to the center of meridional curvature. (R is close to 286 inches in this case). Figures 23b and 20b display **local** and **bending-torsion** buckling modes, respectively, predicted by BIGBOSOR4. BIGBOSOR4 computes buckling load factors (eigenvalues) over a user-specified range of circumferential wave numbers, N, as listed in the table inserted on the right-hand side of Fig. 23b. In the BIGBOSOR4 model generated by PANEL there are no rings. The rings are replaced by anti-symmetry (simple support) boundary conditions, that is, two adjacent rings are replaced by two nodal lines in the trigonometric circumferential variation of buckling modal displacements. These two nodal lines lie parallel to the plane of the paper. The spacing between them is equal to the ring spacing, of course. In Figs. 23b and 20b **m**, the number of axial halfwaves between rings, is listed in the title: **m** = 11 in Fig. 23b and **m** = 2 in Fig. 20b. N = 100 x **m** is the number of **full** waves around the entire circumference of the huge toroidal shell. N = 100 corresponds a circumferential **halfwavelength** equal to the ring spacing, which is 9.375 inches in Case 2 (Table 4). (NOTE: the ring spacing and the circumferential halfwavelength of a buckling mode in this "huge torus" model are measured **normal** to the plane of the paper. The average horizontal radius, R(ave), from the axis of revolution of the huge torus to the halfway point along the meridional arc of the multi-module model displayed in Figs. 23b and 20b can be computed as follows: 2 x pi x R(ave) = 2 x 100 x 9.375 inches. Therefore, R(ave) = 298.4 inches.) The critical **local** buckling mode (Fig. 23b) has N = 1100 circumferential full waves around the circumference of the huge toroidal shell. Hence, there are **m** = 11 halfwaves between rings. The critical **bending-torsion** buckling mode (Fig. 20b) has 200 circumferential full waves around the circumference of the huge toroidal shell. Therefore **m** = 2 halfwaves between rings. The buckling load factors (eigenvalues), Eig(local) = 1.0862 (Fig. 23b) and Eig(bending-torsion) = 1.289 (Fig. 20b), agree well with the PANDA2 margins listed in Table 7: Margin No. 1 (Sub-case 1) = 0.0636 (corresponding load factor = 1.0636) and Margin No. 2 (Sub-case 2) = 0.291 (corresponding load factor= 1.291), respectively. The small inserts in Figs. 20b and 23b show buckling modes that correspond to **edge buckling**. These modes have eigenvalues that are lower than that corresponding to buckling over the entire toroidal sector. However, they are not of interest in the comparison of predictions from BIGBOSOR4 with those from PANDA2 and STAGS because edge buckling of the types displayed in the small inserts in Figs. 20b and 23b is not permitted in the PANDA2 and STAGS models.

PANEL3 is like PANEL
PANEL3 has welds added

The **PANEL2** processor generates a BIGBOSOR4 input file, *.ALL, for the **buckling analysis of the entire optimized stiffened shell**. In this model the stringers are smeared out in the manner of Baruch and Singer [12] and the rings are modeled as branched shell structures. The shell is simply supported along the two curved ends. Figure 21b shows the critical **general** buckling mode predicted by BIGBOSOR4. The mode shape, **(m,n)** = (M,N) = (4,6), agrees with that predicted by PANDA2, as seen from Margin No. 11 in the top part of Table 7. Margin No. 11 = 0.890, which corresponds to a load factor 1.890. This load factor agrees very well with the load factor from BIGBOSOR4: Eig(general) = 1.8767, listed in both the title and in the small table inserted in Fig. 21b.

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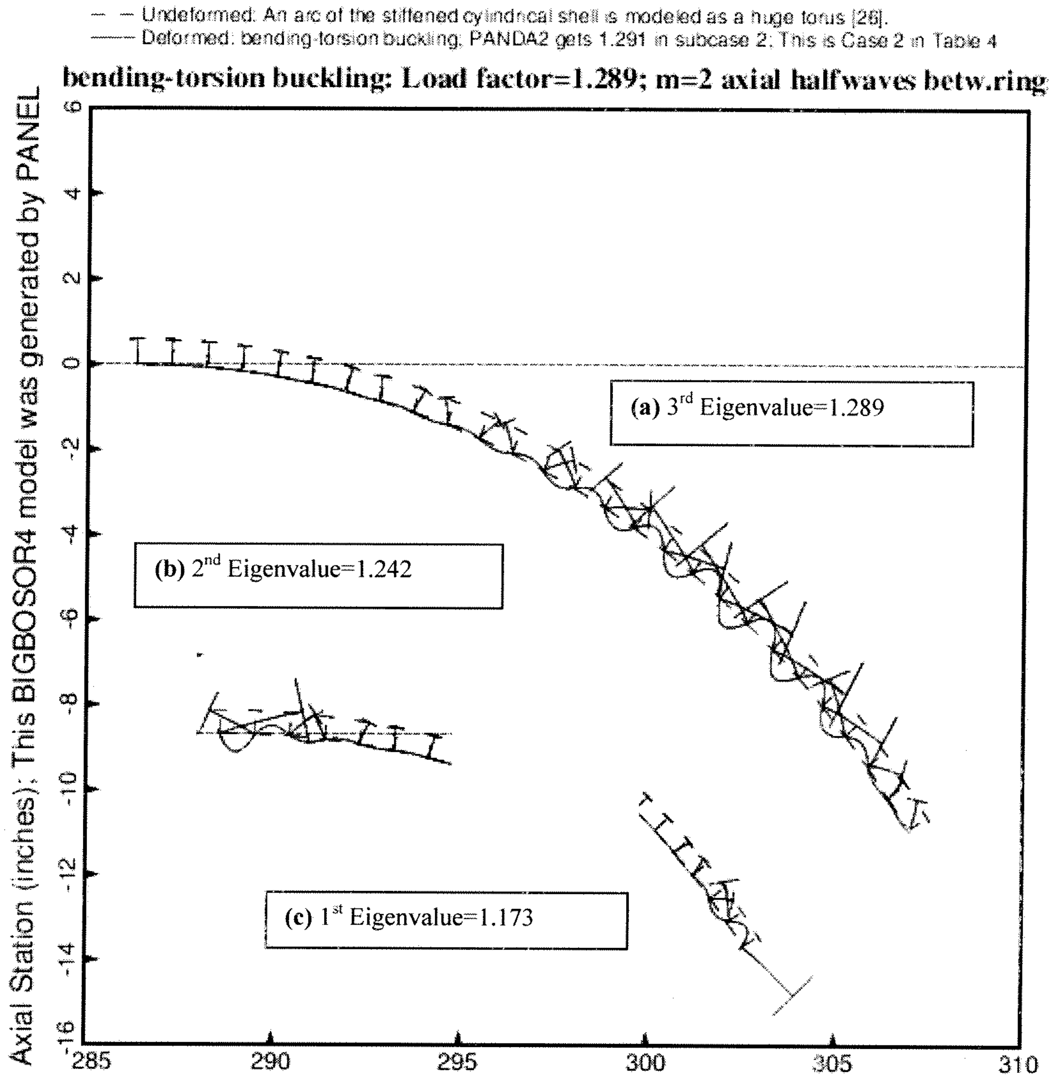

FIG. 20b BIGBOSOR4 [14] model of buckling between rings; Radius (inche

FIG. 20b BIGBOSOR4 model of Case 2 in Table 4: Results from a BIGBOSOR4 model generated by the PANDA2 processor called PANEL. This figure shows bending-torsion buckling between rings (same buckling mode as that corresponding to PANDA2's Margin 2 in both the upper and lower parts of Table 7). This BIGBOSOR4 model is a huge toroidal segment [26] with radius to the center of meridional curvature of about 286 inches. The axial variation of the critical buckling modal displacement is trigonometric with **m** = 2 axial halfwaves between rings (N=200 circumferential waves around the huge torus). The axial coordinate direction for the cylindrical shell is normal to the plane of the paper in this figure. The "critical" buckling mode of interest **(a)** happens to correspond, in this particular case, to the 3rd eigenvalue computed for N = 200. The 1st and 2nd eigenvalues for N = 200, inserts **(c)** and **(b)**, correspond to edge buckling, not permitted in the PANDA2 or STAGS models and therefore not of interest in the comparison of predictions from BIGBOSOR4 with those from PANDA2 and STAGS.

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