

Table 88 **Sequence of STAGS runs** to produce a "cos(theta)" shaped dent by means of imposed normal **displacements**  $w$ , and to determine the collapse pressures for the optimized **unstiffened imperfect** shell with residual dents of depths 0.1777 and 0.2615 inch. The "crude 180 degree soccerball" model with 480 finite elements is used, and the "cos(theta)" dent is produced by imposition of point inward **imposed normal displacements**  $w$  applied along the junction between shell segments 3 and 4 (Fig 2) from circumferential coordinate zero to ninety degrees. (See Shell units 11 and 12 in Table a40) Compare this table with Table 87, which pertains to imposed normal **loads** instead of imposed normal **displacements**. See Figs. 193 and 200.

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**STAGS run 1: soccerball.bin1**

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optimized imperfect shell, nonlinear theory (INDIC=3)
3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, $ IPOST=1 means save displacements every IPOSTth step
0, $ ILIST =0 means normal batch-oriented output
0, $ ICOR  =0 means projection in; 1 means not in.
1, $ IMPTHE=index for imperfection theory.
0, $ IOPTIM=0 means bandwidth optimization will be performed
0, $ IFLU  =0 means no fluid interaction.
-1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
0.000E-02, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
0.000E-02, $ STEP(1) = load factor increment, System A
0.000E+00, $ FACM(1) = maximum load factor, System A
0.02, $ STLD(2) = starting load factor, System B
0.02, $ STEP(2) = load factor increment, System B
1.3, $ FACM(2) = maximum load factor, System B
0 $ ITEMP =0 means no thermal loads. END C-1 rec.
0, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
0,$ NSEC= number of CPU seconds before run termination
10,$ NCUT = number of times step size may be cut
-20, $ NEWT = number of refactorings allowed
-1,$ NSTRAT=-1 means path length used as independent parameter
0.00010,$ DELX=convergence tolerance
0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
0, 0, 0 $ NPATH=0: Riks, NEIGS=no.of eigs, NSOL=1 = discontin.ET-1

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soccerball.out2.1 (abridged)

LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
0	0.000000E+00	0.200000E-01	
1	0.000000E+00	0.200000E-01	
2	0.000000E+00	0.400000E-01	
3	0.000000E+00	0.529982E-01	
4	0.000000E+00	0.724864E-01	
5	0.000000E+00	0.101685E+00	
6	0.000000E+00	0.145361E+00	

7	0.000000E+00	0.210443E+00
8	0.000000E+00	0.294157E+00
9	0.000000E+00	0.393519E+00
10	0.000000E+00	0.510371E+00
11	0.000000E+00	0.578591E+00
12	0.000000E+00	0.645041E+00
13	0.000000E+00	0.684063E+00
14	0.000000E+00	0.714825E+00
15	0.000000E+00	0.745166E+00
16	0.000000E+00	0.769115E+00
17	0.000000E+00	0.792771E+00
18	0.000000E+00	0.816144E+00
19	0.000000E+00	0.839253E+00
20	0.000000E+00	0.862139E+00
21	0.000000E+00	0.875770E+00
22	0.000000E+00	0.896073E+00
23	0.000000E+00	0.920190E+00
24	0.000000E+00	0.939302E+00
25	0.000000E+00	0.967703E+00
26	0.000000E+00	0.990227E+00
27	0.000000E+00	0.101258E+01
28	0.000000E+00	0.104137E+01
29	0.000000E+00	0.106989E+01
30	0.000000E+00	0.109814E+01
31	0.000000E+00	0.113173E+01
32	0.000000E+00	0.117166E+01
33	0.000000E+00	0.119542E+01
34	0.000000E+00	0.122375E+01
35	0.000000E+00	0.125190E+01
36	0.000000E+00	0.128543E+01
37	0.000000E+00	0.130000E+01

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(save the file, soccerball.inp:  
cp soccerball.inp soccerball.inp1  
This file has the imposed w Load Set B,  
which is needed for the second load cycle.)

(edit the file, soccerball.inp:  
Remove the Load Set B entries from Shell Units 11 and 12,  
and change NSYS from 2 to 1 in Shell Units 11 and 12.  
Load Set B must not be present for this unloading phase  
nor for the subsequent loading by Load Set A (normal pressure).)

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**STAGS run 2:** soccerball.bin2  
optimized imperfect shell, nonlinear theory (INDIC=3)  
3, \$ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1

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1, $ IPOST=1 means save displacements every IPOSTth step
0, $ ILIST =0 means normal batch-oriented output
0, $ ICOR  =0 means projection in; 1 means not in.
1, $ IMPTHE=index for imperfection theory.
0, $ IOPTIM=0 means bandwith optimization will be performed
0, $ IFLU  =0 means no fluid interaction.
-1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
0.000E-02, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
1.000E-02, $ STEP(1) = load factor increment, System A
1.000E-02, $ FACM(1) = maximum load factor, System A
0., $ STLD(2) = starting load factor, System B
0., $ STEP(2) = load factor increment, System B
0.0, $ FACM(2) = maximum load factor, System B
0 $ ITEMP =0 means no thermal loads. END C-1 rec.
37, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
0,$ NSEC= number of CPU seconds before run termination
10,$ NCUT = number of times step size may be cut
-20, $ NEWT = number of refactorings allowed
0,$ NSTRAT=-1 means path length used as independent parameter
0.00010,$ DELX=convergence tolerance
0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
5, 0, 0 $ NPATH=0: Riks, NEIGS=no.of eigs, NSOL=1 = discontin.ET-1

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soccerball.out2.2 (abridged)

LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
37	0.000000E+00	0.130000E+01	
38	0.000000E+00	0.000000E+00	0.900000E+00
39	0.000000E+00	0.000000E+00	0.211655E+00
40	0.000000E+00	0.000000E+00	0.000000E+00
41	0.100000E-01	0.000000E+00	0.000000E+00

**STAGS run 3:** soccerball.bin3

optimized imperfect shell, nonlinear theory (INDIC=3)

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3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, $ IPOST=1 means save displacements every IPOSTth step
0, $ ILIST =0 means normal batch-oriented output
0, $ ICOR  =0 means projection in; 1 means not in.
1, $ IMPTHE=index for imperfection theory.
0, $ IOPTIM=0 means bandwith optimization will be performed
0, $ IFLU  =0 means no fluid interaction.
-1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
5.000E-02, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
5.000E-02, $ STEP(1) = load factor increment, System A
0.700, $ FACM(1) = maximum load factor, System A
0., $ STLD(2) = starting load factor, System B
0., $ STEP(2) = load factor increment, System B

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0.0, $ FACM(2) = maximum load factor, System B
0 $ ITEMP =0 means no thermal loads. END C-1 rec.
40, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
500,$ NSEC= number of CPU seconds before run termination
10,$ NCUT = number of times step size may be cut
-20, $ NEWT = number of refactorings allowed
0,$ NSTRAT=-1 means path length used as independent parameter
0.00010,$ DELX=convergence tolerance
0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
0, 0, 1 $ NPATH=0: Riks, NEIGS=no.of eigs, NSOL=1 = discontin.ET-1

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soccerball.out2.3 (abridged)

LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
40	0.000000E+00	0.000000E+00	
41	0.100000E+00	0.000000E+00	
42	0.164183E+00	0.000000E+00	
43	0.259183E+00	0.000000E+00	
44	0.398573E+00	0.000000E+00	
45	0.599189E+00	0.000000E+00	
46	0.700000E+00	0.000000E+00	

**STAGS run 4:** soccerball.bin4

optimized imperfect shell, nonlinear theory (INDIC=3)

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3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, $ IPOST=1 means save displacements every IPOSTth step
0, $ ILIST =0 means normal batch-oriented output
0, $ ICOR =0 means projection in; 1 means not in.
1, $ IMPTHE=index for imperfection theory.
0, $ IOPTIM=0 means bandwidth optimization will be performed
0, $ IFLU =0 means no fluid interaction.
-1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
0.7, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
1.000E-01, $ STEP(1) = load factor increment, System A
1.000, $ FACM(1) = maximum load factor, System A
0., $ STLD(2) = starting load factor, System B
0., $ STEP(2) = load factor increment, System B
0.0, $ FACM(2) = maximum load factor, System B
0 $ ITEMP =0 means no thermal loads. END C-1 rec.
46, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
300,$ NSEC= number of CPU seconds before run termination
10,$ NCUT = number of times step size may be cut
-20, $ NEWT = number of refactorings allowed
-1,$ NSTRAT=-1 means path length used as independent parameter
0.00010,$ DELX=convergence tolerance
0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
0, 0, 0 $ NPATH=0: Riks, NEIGS=no.of eigs, NSOL=1 = discontin.ET-1

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soccerball.out2.4 (abridged)

LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
46	0.700000E+00	0.000000E+00	
47	0.709744E+00	0.000000E+00	
48	0.724218E+00	0.000000E+00	
49	0.752640E+00	0.000000E+00	
50	0.793703E+00	0.000000E+00	
51	0.850358E+00	0.000000E+00	
52	0.915381E+00	0.000000E+00	
53	0.933311E+00	0.000000E+00	
54	0.893716E+00	0.000000E+00	
55	0.838651E+00	0.000000E+00	
56	0.782526E+00	0.000000E+00	
57	0.734753E+00	0.000000E+00	
58	0.694668E+00	0.000000E+00	

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(save the file, soccerball.inp:

cp soccerball.inp soccerball.inp2

This file does not have the imposed w Load Set B.

soccerball.inp2 is needed for the second unloading cycle.)

(restore the original soccerball.inp file:

cp soccerball.inp1 soccerball.inp

Load Set B must again be present for this continuation  
of the "dent" enlargement by means of imposed w .)

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**STAGS run 5:** soccerball.bin5

optimized imperfect shell, nonlinear theory (INDIC=3)

3, \$ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1

1, \$ IPOST=1 means save displacements every IPOSTth step

0, \$ ILIST =0 means normal batch-oriented output

0, \$ ICOR =0 means projection in; 1 means not in.

1, \$ IMPTHE=index for imperfection theory.

0, \$ IOPTIM=0 means bandwidth optimization will be performed

0, \$ IFLU =0 means no fluid interaction.

-1 \$ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec

0.0, \$ STLD(1) = starting load factor, System A. BEGIN C-1 rec.

0.0, \$ STEP(1) = load factor increment, System A

0.0, \$ FACM(1) = maximum load factor, System A

1.3, \$ STLD(2) = starting load factor, System B

1.0, \$ STEP(2) = load factor increment, System B

2.0, \$ FACM(2) = maximum load factor, System B

0 \$ ITEMP =0 means no thermal loads. END C-1 rec.

37, \$ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.

0,\$ NSEC= number of CPU seconds before run termination  
 10,\$ NCUT = number of times step size may be cut  
 -20, \$ NEWT = number of refactorings allowed  
 -1,\$ NSTRAT=-1 means path length used as independent parameter  
 0.00010,\$ DELX=convergence tolerance  
 0. \$ WUND = 0 means initial relaxation factor =1.END D-1 rec.  
 0, 0, 0 \$ NPATH=0: Riks, NEIGS=no.of eigs, NSOL=1 = discontin.ET-1

soccerball.out2.5 (abridged)

LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
37	0.000000E+00	0.130000E+01	
38	0.000000E+00	0.131452E+01	
39	0.000000E+00	0.133623E+01	
40	0.000000E+00	0.136435E+01	
41	0.000000E+00	0.138118E+01	
42	0.000000E+00	0.140301E+01	
43	0.000000E+00	0.143132E+01	
44	0.000000E+00	0.145389E+01	
45	0.000000E+00	0.147637E+01	
46	0.000000E+00	0.149877E+01	
47	0.000000E+00	0.152781E+01	
48	0.000000E+00	0.154523E+01	
49	0.000000E+00	0.156265E+01	
50	0.000000E+00	0.158875E+01	
51	0.000000E+00	0.160175E+01	
52	0.000000E+00	0.160953E+01	
53	0.000000E+00	0.162506E+01	
54	0.000000E+00	0.163669E+01	
55	0.000000E+00	0.164835E+01	
56	0.000000E+00	0.166001E+01	
57	0.000000E+00	0.167748E+01	
58	0.000000E+00	0.169142E+01	
59	0.000000E+00	0.170812E+01	
60	0.000000E+00	0.172810E+01	
61	0.000000E+00	0.175408E+01	
62	0.000000E+00	0.176707E+01	
63	0.000000E+00	0.178652E+01	
64	0.000000E+00	0.180983E+01	
65	0.000000E+00	0.183309E+01	
66	0.000000E+00	0.186326E+01	
67	0.000000E+00	0.189338E+01	
68	0.000000E+00	0.192345E+01	
69	0.000000E+00	0.196243E+01	
70	0.000000E+00	0.200000E+01	

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(restore the soccerball.inp with no Load Set B:

```
cp soccerball.inp2 soccerball.inp
Load Set B must not be present for this unloading phase
nor for the subsequent loading by Load Set A (normal pressure.).)
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**STAGS run 6: soccerball.bin6**

```
optimized imperfect shell, nonlinear theory (INDIC=3)
3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, $ IPOST=1 means save displacements every IPOSTth step
0, $ ILIST =0 means normal batch-oriented output
0, $ ICOR =0 means projection in; 1 means not in.
1, $ IMPTHE=index for imperfection theory.
0, $ IOPTIM=0 means bandwidth optimization will be performed
0, $ IFLU =0 means no fluid interaction.
-1 $ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec
0.000E-02, $ STLD(1) = starting load factor, System A. BEGIN C-1 rec.
1.000E-02, $ STEP(1) = load factor increment, System A
1.000E-02, $ FACM(1) = maximum load factor, System A
0., $ STLD(2) = starting load factor, System B
0., $ STEP(2) = load factor increment, System B
0.0, $ FACM(2) = maximum load factor, System B
0 $ ITEMP =0 means no thermal loads. END C-1 rec.
70, $ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.
0,$ NSEC= number of CPU seconds before run termination
10,$ NCUT = number of times step size may be cut
-20, $ NEWT = number of refactorings allowed
0,$ NSTRAT=-1 means path length used as independent parameter
0.00010,$ DELX=convergence tolerance
0. $ WUND = 0 means initial relaxation factor =1.END D-1 rec.
5, 0, 0 $ NPATH=0: Riks, NEIGS=no.of eigs, NSOL=1 = discontin.ET-1
```

**soccerball.out2.6 (abridged)**

LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
70	0.000000E+00	0.200000E+01	
71	0.000000E+00	0.000000E+00	0.900000E+00
72	0.000000E+00	0.000000E+00	0.881830E+00
73	0.000000E+00	0.000000E+00	0.864350E+00
74	0.000000E+00	0.000000E+00	0.818873E+00
75	0.000000E+00	0.000000E+00	0.457585E+00
76	0.000000E+00	0.000000E+00	0.000000E+00
77	0.100000E-01	0.000000E+00	0.000000E+00

**STAGS run 7: soccerball.bin7**

```
optimized imperfect shell, nonlinear theory (INDIC=3)
3, $ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1
1, $ IPOST=1 means save displacements every IPOSTth step
```

0, \$ ILIST =0 means normal batch-oriented output  
 0, \$ ICOR =0 means projection in; 1 means not in.  
 1, \$ IMPTHE=index for imperfection theory.  
 0, \$ IOPTIM=0 means bandwith optimization will be performed  
 0, \$ IFLU =0 means no fluid interaction.  
 -1 \$ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec  
 5.000E-02, \$ STLD(1) = starting load factor, System A. BEGIN C-1 rec.  
 5.000E-02, \$ STEP(1) = load factor increment, System A  
 0.500, \$ FACM(1) = maximum load factor, System A  
 0., \$ STLD(2) = starting load factor, System B  
 0., \$ STEP(2) = load factor increment, System B  
 0.0, \$ FACM(2) = maximum load factor, System B  
 0 \$ ITEMP =0 means no thermal loads. END C-1 rec.  
 76, \$ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.  
 500,\$ NSEC= number of CPU seconds before run termination  
 10,\$ NCUT = number of times step size may be cut  
 -20, \$ NEWT = number of refactorings allowed  
 0,\$ NSTRAT=-1 means path length used as independent parameter  
 0.00010,\$ DELX=convergence tolerance  
 0. \$ WUND = 0 means initial relaxation factor =1.END D-1 rec.  
 0, 0, 1 \$ NPATH=0: Riks, NEIGS=no.of eigs, NSOL=1 = discontin.ET-1

soccerball.out2.7 (abridged)

#### LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
76	0.000000E+00	0.000000E+00	
77	0.100000E+00	0.000000E+00	
78	0.163487E+00	0.000000E+00	
79	0.256079E+00	0.000000E+00	
80	0.387411E+00	0.000000E+00	
81	0.500000E+00	0.000000E+00	

**STAGS run 8:** soccerball.bin8

optimized imperfect shell, nonlinear theory (INDIC=3)

3, \$ INDIC=1 is bifur.buckling; INDIC=3 is nonlinear BEGIN B-1  
 1, \$ IPOST=1 means save displacements every IPOSTth step  
 0, \$ ILIST =0 means normal batch-oriented output  
 0, \$ ICOR =0 means projection in; 1 means not in.  
 1, \$ IMPTHE=index for imperfection theory.  
 0, \$ IOPTIM=0 means bandwith optimization will be performed  
 0, \$ IFLU =0 means no fluid interaction.  
 -1 \$ ISOLVR= 0 means original solver; -1 new solver.END B-1 rec  
 5.000E-01, \$ STLD(1) = starting load factor, System A. BEGIN C-1 rec.  
 1.000E-01, \$ STEP(1) = load factor increment, System A  
 0.700, \$ FACM(1) = maximum load factor, System A  
 0., \$ STLD(2) = starting load factor, System B  
 0., \$ STEP(2) = load factor increment, System B



0.0, \$ FACM(2) = maximum load factor, System B  
 0 \$ ITEMP =0 means no thermal loads. END C-1 rec.  
 81, \$ ISTART=restart from ISTARTth load step. BEGIN D-1 rec.  
 500,\$ NSEC= number of CPU seconds before run termination  
 10,\$ NCUT = number of times step size may be cut  
 -20, \$ NEWT = number of refactorings allowed  
 -1,\$ NSTRAT=-1 means path length used as independent parameter  
 0.00010,\$ DELX=convergence tolerance  
 0. \$ WUND = 0 means initial relaxation factor =1.END D-1 rec.  
 0, 0, 0 \$ NPATH=0: Riks, NEIGS=no.of eigs, NSOL=1 = discontin.ET-1

soccerball.out2.8 (abridged)

# LIST OF LOAD STEPS AND LOAD FACTORS

STEP	PA	PB	PX
81	0.500000E+00	0.000000E+00	
82	0.510160E+00	0.000000E+00	
83	0.524889E+00	0.000000E+00	
84	0.545845E+00	0.000000E+00	
85	0.574340E+00	0.000000E+00	
86	0.609212E+00	0.000000E+00	
87	0.641448E+00	0.000000E+00	
88	0.653428E+00	0.000000E+00	
89	0.645540E+00	0.000000E+00	
90	0.627836E+00	0.000000E+00	
91	0.606517E+00	0.000000E+00	
92	0.587700E+00	0.000000E+00	
93	0.573185E+00	0.000000E+00	
94	0.563285E+00	0.000000E+00	
95	0.555177E+00	0.000000E+00	
96	0.550265E+00	0.000000E+00	

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