ADDITION OF SPRINGS IN BIGBOSOR4 CONNECTING A "FAKE" RING TO GROUND

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ABSTRACT

Connection of an otherwise unconstrained shell structure to
ground by means of linear elastic springs pinned at their ends
simulates a strut-supported structure with pin-ended struts.
The springs are entered into the BIGBOSOR4 input file as
discrete elastic structures attached at one end to user-defined discrete
points around the circumference of a "fake" ring joined to the
shell and attached at the other end to user-defined discrete points at
ground. Even so, since BIGBOSOR4 can handle only axisymmetric structures,
the effect of the springs is "smeared out" by BIGBOSOR4 over the
circumference where the springs are attached to the "fake" ring.
Essentially, the springs act as a thick conical shell extending from
the "fake" ring where the springs are attached to the shell structure
to ground where the springs are attached to ground. The overall
extensional and shear stiffnesses of this imaginary conical shell match
those of the assemblage of springs. In a linear non-axisymmetric
stress and buckling analysis the springs contribute strain energy
to the structure only in the n = 0 and n = 1 circumferential
wave harmonics. The springs thus prevent rigid body displacements
of the structure. The internal concentrated loads applied
by the springs to the "fake" ring (and therefore to the
shell) are computed by BIGBOSOR4 and listed in the BIGBOSOR4
output file. These concentrated loads can be applied to the
same shell structure without springs in a separate and subsequent
execution of BIGBOSOR4 in order to determine local deformations
and stresses caused by them and in order to determine
lowered "effective" spring constants because the springs
react against a deformable structure, not against a rigid
structure. An example is given of a sequence of two
BIGBOSOR4 runs, the first run involving a spring-supported
cylindrical shell subjected to an overall static bending moment
at its top end and the second run involving the same shell
with the springs replaced by line loads applied to the
"fake" ring that simulate the concentrated spring reaction loads
applied by the springs to the bottom of the cylindrical
shell in the first execution of BIGBOSOR4.

THEORY

The theory is presented in SUBROUTINE SPRING, a copy of which follows:

C BEG MAR 2008

```
C=DECK        SPRING
      SUBROUTINE SPRING(IFILE4,K,IANGLE,TBAR,U)
C
C  March 16, 2008
C  Purpose is to add strain energy of the IANGLEth spring
C  attached to ring no. K.
C
C  For a complete description of the theory on which
C  BIGBOSOR4 is based, please see pp.485-508 of the paper:
C
C     Bushnell, D.,
C     "Computerized analysis of shells - governing
C     equations", Computers & Structures, Vol.18, No. 3,
C     pp.471-536 (1984)
C
C  Then you will understand better what goes on here.
C
C  NOTE: This subroutine only works if the springs are
C        attached to ground.
C
C  Meanings of variables:
C
C IFILE4 = file for listed output (<casename>.OUT)
C K      = global ring number
C IANGLE = number of spring attached to the "fake" ring
C
C TBAR   = transformation from ustar,v,wstar,beta to nodal
C          unknowns, q . Same as "D" in the calling routine.
C          See Eqs.(155,156) on p.499 of the paper cited below.
C
C U      = strain energy matrix divided by pi. The strain energy
C          of the assemblage of springs connected at this
C          particular meridional nodal point contributes to
C          this 7 x 7 local "finite element" stiffness matrix.
C          See Fig. 24 on p.498 of the paper, Bushnell, D.,
C          "Computerized analysis of shells - governing
C          equations", Computers & Structures, Vol.18, No. 3,
C          pp.471-536 (1984), for a schematic of an assemblage
C          of these local 7x7 "finite element" stiffness
C          matrices into the total stiffness matrix of a very
C          simple structure shown in Fig.20(b) on p. 493 of
C          the paper just cited.
C
C The following are input quantities relating to springs
C attached to this ring:
C
C NTYPAL = index for type of ring (NTYPAL = -1 means
C          a "fake" ring with springs attached to it.)
C NGROUN = 1 if springs are attached to ground,
C          0 if springs are attached to a previous
C          ring. (NOTE: The coding has not been
C          written for the NGROUN = 0 option.)
C NSPRNG = number of springs attached to this ring
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```
C SPRAXL = global axial coordinate of this ring
C SPRANG = circumferential angles of the NSPRNG
C          spring attachment points on this ring
C SPRKON = spring constant for each of the NSPRNG
C          springs attached to this ring
C SPREC1 = radial eccentricity e1 of the attachment
C          points of all the springs to this ring
C SPREC2 = axial  eccentricity e2 of the attachment
C          points of all the springs to this ring
C SPRAXG = global axial coordinate of the attachment
C          of all the springs associated with this
C          ring to ground
C SPRRAD = radius of spring ground attachment points
C SPRAGG = circumferential angles of NSPRNG spring
C          attachment points at ground for springs
C          associated with this ring.
C
C ***************** IMPORTANT NOTE *************************
C This model essentially smears out the springs. Only the n = 0
C (axisymmetric up-and-down displacement and/or uniform rolling
C about the axis of revolution) and n = 1 (uniform lateral
C displacement and/or pitching displacement) are predicted accurately.
C In order to obtain the static response for higher circumferential
C wavenumbers, n, than n = 0 and/or n = 1, you must include as
C BIGBOSOR4 input the concentrated forces that the springs apply
C to the "fake" ring and therefore to the shell where they are
C attached.
C ************************************************************
      COMMON/RING4/SPRAXL(198),SPRANG(30,198),SPRKON(30,198),SPRAXG(198)
      COMMON/RING5/SPREC1(198),SPREC2(198),SPRRAD(198),SPRAGG(30,198)
      COMMON/RING6/NSPRNG(198),ISPRSG(198),ISPRRG(198),NTYPAL(198)
      COMMON/RING7/NGROUN(198)
      COMMON/GGG/ R,RD,FK1,FK2,CURD,RDS,FN,H
      DOUBLE PRECISION  R,RD,FK1,FK2,CURD,RDS,FN,H
      DOUBLE PRECISION  TBAR,EBAR,XBAR,FKBAR,U,A,B,C,FKEFF
      DOUBLE PRECISION  THETRI,THETGI,CTHETR,STHETR,CTHETG,STHETG
      DOUBLE PRECISION  XRING,YRING,ZRING,XGROUN,YGROUN,ZGROUN
      DOUBLE PRECISION  FKX,FKXE
      DIMENSION TBAR(4,7),EBAR(3,4),XBAR(3,3),FKBAR(3,3),U(7,7)
      DIMENSION FKX(3,3),FKXE(4,4)
C
C     WRITE(IFILE4,'(A,2I5)')
C    1' Entering SUBROUTINE SPRING. K, IANGLE=',K, IANGLE
C
C  EBAR is the transformation matrix from axial, circumferential,
C       and radial displacements,
C       ustar(attach pt.), v(attach pt.), wstar(attach pt.)
C       at the attachment point of the IANGLEth spring to the "fake"
C       ring to the axial displacement, circumferential displacement,
C       radial displacement, and meridional rotation at the shell
C       reference surface:
C       ustar(shell ref. surf), v(shell ref. surf.),
C       wstar(shell ref. surf), and beta(merid. rot.):
```

```
C          See Eqs.(152,153) on p.499 of the paper cited above
C          in connection with the 7 x 7 local stiffness matrix, U.
C
C                                  3 x 4
C          |ustar(attach pt.)|   |          |  |ustar(shell ref. surf.)   |
C          |    v(attach pt.)| = |   EBAR   |* |    v(shell ref. surf.)   |
C          |wstar(attach pt.)|   |          |  |wstar(shell ref. surf.)   |
C                                                |beta(meridional rotation)|
C
C    FN is the number of circumferential waves
C     R is the radius of the parallel circle (at the ref. surface).
C
      EBAR(1,1) = 1.
      EBAR(1,2) = 0.
      EBAR(1,3) = 0.
      EBAR(1,4) = -SPREC1(K)
      EBAR(2,1) = -SPREC2(K)*FN/R
      EBAR(2,2) = 1. + SPREC1(K)/R
      EBAR(2,3) = -SPREC1(K)*FN/R
      EBAR(2,4) = 0.
      EBAR(3,1) = 0.
      EBAR(3,2) = 0.
      EBAR(3,3) = 1.
      EBAR(3,4) = SPREC2(K)
C
C     WRITE(IFILE4,'(/,A)')' EBAR(i,j)='
C     DO 10 I = 1,3
C        WRITE(IFILE4,'(1P4E12.4)') (EBAR(I,J),J=1,4)
C  10 CONTINUE
C
C  Next, find the length of each spring.
      PI = 3.1415927
      THETRI = SPRANG(IANGLE,K)*PI/180.
      CTHETR = DCOS(THETRI)
      STHETR = DSIN(THETRI)
      XRING  = (R + SPREC1(K))*CTHETR
      YRING  = SPRAXL(K)
      ZRING  = (R + SPREC1(K))*STHETR
      THETGI = SPRAGG(IANGLE,K)*PI/180.
      CTHETG = DCOS(THETGI)
      STHETG = DSIN(THETGI)
      XGROUN = SPRRAD(K)*CTHETG
      YGROUN = SPRAXG(K)
      ZGROUN = SPRRAD(K)*STHETG
      A = XRING - XGROUN
      B = YRING - YGROUN
      C = ZRING - ZGROUN
C
C     FLONG2 is the square of the undeformed length L of the IANGLEth
C     spring with spring constant SPRKON(IANGLE,K), where K = global
C     ring number. Each spring attached to a given ring may have a
C     different spring constant, SPRKON(IANGLE,K). Originally all the
C     spring constants at a given ring are the same. However, when we
```

```
C      take into account the softening effect of local shell deformation
C      on the "effective" stiffness of a spring, each spring may develop
C      a different "effective" spring constant. Usually the following
C      will happen: The "effective" stiffnesses of the springs at
C      circumferential coordinates 0 and 180 degrees will have one
C      "effective" spring constant and those at 90 and 270 degrees will
C      have a different "effective" spring constant.
C
C      FLONG2 = A*A + B*B + C*C
C
C      FKEFF is the "effective" stiffness divided by PI to be
C            consistent with the shell strain energy. It is also
C            divided by the square of the undeformed spring length,
C            L x L, because this quantity is common to all the
C            elements of the stiffness matrix. The 0.5 factor
C            comes from the strain energy being of the form,
C
C            U(spring) = 0.5*SPRKON(IANGLE,K)*(delta L)**2 .
C
C            in which "delta L" is the change in length of the
C            IANGLEth spring due to reference surface displacements
C            components, u,v,w, of the shell wall with which the
C            spring attachment points on the "fake" ring are
C            linked.
C
C      FKEFF = 0.5*SPRKON(IANGLE,K)/(PI*FLONG2)
C
C      FKBAR is the spring stiffness matrix for the IANGLEth spring
C            attached to global ring number K. This stiffness matrix
C            is valid only if one end of each spring is connected to
C            ground. All springs from a given "fake" ring must be
C            connected at their other ends to ground at the same
C            global axial coordinate, SPRAXG(K), and at the same
C            radial coordinate, SPRRAD(K).
C
C      The quantity, (delta L) in the expression for the strain
C      energy, U(spring), above is given by:
C
C      (delta L) =    (A*dx + B*dy + C*dz)/L
C
C      in which A, B, and C are the x-direction, y-direction, and
C      z-direction distances from the ring end of the spring to the
C      ground end of the spring, and x, y, and z are global cartesian
C      coordinates, with y containing the axis of revolution of the
C      shell. The undeformed spring length, L, is the square root
C      of (A*A + B*B + C*C).
C
C      The strain energy of the spring, U(spring), can be expressed
C      in the form,
C
C      U(spring) =
C      [0.5*SPRKON(IANGLE,K)/(L*L)]*[dx, dy, dz]*| A*A  A*B  A*C |  |dx|
C                                                | A*B  B*B  B*C |*|dy|
```

```
C                                                    |  A*C   B*C   C*C  |  |dz|
C
C      Accordingly, the 3 x 3 stiffness matrix, FKBAR, is given
C      as follows:
C
       FKBAR(1,1) = FKEFF*A*A
       FKBAR(1,2) = FKEFF*A*B
       FKBAR(1,3) = FKEFF*A*C
       FKBAR(2,1) = FKBAR(1,2)
       FKBAR(2,2) = FKEFF*B*B
       FKBAR(2,3) = FKEFF*B*C
       FKBAR(3,1) = FKBAR(1,3)
       FKBAR(3,2) = FKBAR(2,3)
       FKBAR(3,3) = FKEFF*C*C
C
C      WRITE(IFILE4,'(/,A)')' FKBAR(i,j)='
C      DO 20 I = 1,3
C         WRITE(IFILE4,'(1P3E12.4)') (FKBAR(I,J),J=1,3)
C   20 CONTINUE
C
C      XBAR is the transformation matrix from dx, dy, dz
C           to ustar(attach pt.), v(attach pt.), wstar(attach pt.),
C           as follows:
C
C  |dx|    |  0.0    -sin(THETRI)   cos(THETRI)|    |ustar(attach pt.)|
C  |dy| = |  1.0          0.0            0.0    | * |     v(attach pt.)|
C  |dz|    |  0.0     cos(THETRI)   sin(THETRI)|    |wstar(attach pt.)|
C
       XBAR(1,1) = 0.
       XBAR(1,2) = -STHETR
       XBAR(1,3) =  CTHETR
       XBAR(2,1) = 1.
       XBAR(2,2) = 0.
       XBAR(2,3) = 0.
       XBAR(3,1) = 0.
       XBAR(3,2) =  CTHETR
       XBAR(3,3) =  STHETR
C
C      WRITE(IFILE4,'(/,A)')' XBAR(i,j)='
C      DO 30 I = 1,3
C         WRITE(IFILE4,'(1P3E12.4)') (XBAR(I,J),J=1,3)
C   30 CONTINUE
C
C      We need one more transformation: from the
C      ustar(shell ref. surf.), v(shell ref. surf.)
C      wstar(shell ref. surf.), beta(meridional rotation)
C      to the nodal degrees of freedom, which are in this
C      analysis:
C
C        {q} = w(i-1), u(i-1), v(i-1), w(i), u(i), v(i), w(i+1)
C
C      That transformation is accomplished via the 4 x 7 matrix,
C      TBAR, defined near the beginning of this subroutine. TBAR
```

```
C      is the same as the D matrix used previously in SUBROUTINE
C      STABIL. TBAR is given in Eq.(156) on p.499 of the paper
C      cited above in connection with the 7 x 7 local stiffness
C      matrix, U .
C
C  Next we must obtain the strain energy, given now in the form:
C
C  U = q(transpose) x TBAR(transpose) x EBAR(transpose)
C       x XBAR(transpose) x FKBAR x XBAR x EBAR x TBAR x q
C
C  The next line gets FKX = XBAR(transpose) x FKBAR x XBAR
C
       CALL MATMU2(FKBAR,XBAR,FKX,3,3,0)
C
C     WRITE(IFILE4,'(/,A)')' FKX(i,j)='
C     DO 35 I = 1,3
C        WRITE(IFILE4,'(1P3E12.4)') (FKX(I,J),J=1,3)
C  35 CONTINUE
C
C  The next line gets FKXE = EBAR(transpose) x FKX x EBAR
C
       CALL MATMU2(  FKX,EBAR,FKXE,3,4,0)
C
C     WRITE(IFILE4,'(/,A)')' FKXE(i,j)='
C     DO 37 I = 1,4
C        WRITE(IFILE4,'(1P4E12.4)') (FKXE(I,J),J=1,4)
C  37 CONTINUE
C
C  The next line gets U = TBAR(transpose) x FKXE x TBAR
C
       CALL MATMU4(FKXE,TBAR,U,4,7,1)
C
C23456789012345678901234567890123456789012345678901234567890123456789012
C     WRITE(IFILE4,'(A,I5)')
C    1' In SUBROUTINE SPRING. strain energy computed for spring no.',
C    1  IANGLE
C     WRITE(IFILE4,'(/,A)')' U(i,j)='
C     DO 40 I = 1,7
C        WRITE(IFILE4,'(1P7E10.2)') (U(I,J),J=1,7)
C  40 CONTINUE
C
C   To obtain later the force in the spring, we have
C
C     (force in the spring) = SPRKON(IANGLE,K) * (delta L),
C
C   in which
C
C      (delta L) =    (A*dx + B*dy + C*dz)/L
C
C   and                                                  |w(i-1)|
C            3 x 3            3 x 4            4 x 7      |u(i-1)|
C  |dx|    |          |  |          |  |            |    |v(i-1)|
C  |dy|    |   XBAR   | *|   EBAR   | *|    TBAR    | *  | w(i) |
```

```
C  |dx|    |              |  |              |  |                |  | u(i) |
C                                           |                |  | v(i) |
C                                           |                |  |w(i+1)|
C    in which the w(i-1) etc. are the shell reference
C    surface nodal degrees of freedom associated with
C    the shell finite element to which the "fake" ring
C    that holds one spring end is attached. The force
C    in each spring is derived later in SUBROUTINES SPOSE
C    and SUPER and is given by:
C
C    F = SPRKON(IANGLE,K) x (delta L)
C
      RETURN
      END
C
C END MAR 2008
------------------------------------------------------------------
```

The theory outlined above is not quite correct concerning the
transformation,

```
 and                                                        |w(i-1)|
            3 x 3              3 x 4              4 x 7      |u(i-1)|
|dx|    |            |  |            |  |            |    |  |v(i-1)|
|dy|    |    XBAR    | *|    EBAR    | *|    TBAR    |  * |  w(i) |
|dx|    |            |  |            |  |            |    |  u(i) |
                                                          |  v(i) |
                                                          |w(i+1)|
```

The actual transformation computations are carried out
in SUBROUTINE RINGF as follows:
```
--------------------------------------------------------------------
         UC = ED(1,1)*U + ED(1,2)*V + ED(1,3)*W +ED(1,4)*CHI
         VC = ED(2,1)*U + ED(2,2)*V + ED(2,3)*W +ED(2,4)*CHI
         WC = ED(3,1)*U + ED(3,2)*V + ED(3,3)*W +ED(3,4)*CHI
C
C    in which U, V, W, CHI are the meridional, circumferential,
C    and normal shell reference surface displacement components
C    at the nodal point where the "fake" ring with the springs
C    attached to it is fastened to the shell reference surface.
C    CHI is the meridional rotation of the shell reference
C    surface at the same nodal point. UC, VC, WC are the axial,
C    circumferential, and radial displacement components of the
C    circumferential line in the "fake" ring to which the springs
C    are attached. ED is the matrix which transforms U, V, W, CHI
C    into UC, VC, WC.
C
         ARG = ABS(FN*THETRI)
         SNTHET = DSIN(ARG)
         CNTHET = DCOS(ARG)
C
C    FN is the number of circumferential waves in the deformation
```

```
C    pattern and THETRI is the value of the circumferential
C    coordinate of the attachement point of a spring to the "fake"
C    ring.
C
C    DXGLOB, DYGLOB, DZGLOB are the global cartesian coordinate
C    components of the displacement at the ring-end of the
C    spring. FN = number of circ. waves in the current harmonic.
C
        IF (FN.GT.0.0) THEN
           DXGLOB(IGROUN,IANGLE) = DXGLOB(IGROUN,IANGLE)
     1     +XBAR(1,1)*UC*SNTHET +XBAR(1,2)*VC*CNTHET
     1     +XBAR(1,3)*WC*SNTHET
C
           DYGLOB(IGROUN,IANGLE) = DYGLOB(IGROUN,IANGLE)
     1     +XBAR(2,1)*UC*SNTHET +XBAR(2,2)*VC*CNTHET
     1     +XBAR(2,3)*WC*SNTHET
C
           DZGLOB(IGROUN,IANGLE) = DZGLOB(IGROUN,IANGLE)
     1     +XBAR(3,1)*UC*SNTHET +XBAR(3,2)*VC*CNTHET
     1     +XBAR(3,3)*WC*SNTHET
        ENDIF
C
        IF (FN.LT.0.0) THEN
           DXGLOB(IGROUN,IANGLE) = DXGLOB(IGROUN,IANGLE)
     1     +XBAR(1,1)*UC*CNTHET +XBAR(1,2)*VC*SNTHET
     1     +XBAR(1,3)*WC*CNTHET
C
           DYGLOB(IGROUN,IANGLE) = DYGLOB(IGROUN,IANGLE)
     1     +XBAR(2,1)*UC*CNTHET +XBAR(2,2)*VC*SNTHET
     1     +XBAR(2,3)*WC*CNTHET
C
           DZGLOB(IGROUN,IANGLE) = DZGLOB(IGROUN,IANGLE)
     1     +XBAR(3,1)*UC*CNTHET +XBAR(3,2)*VC*SNTHET
     1     +XBAR(3,3)*WC*CNTHET
        ENDIF
C
        IF (FN.EQ.0.0) THEN
           DXGLOB(IGROUN,IANGLE) = DXGLOB(IGROUN,IANGLE)
     1     +XBAR(1,1)*UC +XBAR(1,2)*VC
     1     +XBAR(1,3)*WC
C
           DYGLOB(IGROUN,IANGLE) = DYGLOB(IGROUN,IANGLE)
     1     +XBAR(2,1)*UC +XBAR(2,2)*VC
     1     +XBAR(2,3)*WC
C
           DZGLOB(IGROUN,IANGLE) = DZGLOB(IGROUN,IANGLE)
     1     +XBAR(3,1)*UC +XBAR(3,2)*VC
     1     +XBAR(3,3)*WC
        ENDIF
-----------------------------------------------------------------


NEW INPUT DATA IN BIGBOSOR4
```

The BIGBOSOR4 user supplies input data interactively. These
user-provided data are elicited by means of prompting questions
and "help" paragraphs that are stored in files called
"PROMPT.DAT", "PROMPT2.DAT", and "PROMPT3.DAT" located in the
directory, ...bigbosor4/execute .

The PROMPT2.DAT file was modified to add a section relating to
springs, as follows:

------- NEW SECTION ADDED TO THE PROMPT2.DAT FILE --------------
800.0
        Input of NTYPER = -1 for ring type means that the ring is
        a "fake" ring, needed as a place to "hang" springs from.
        Let us call the end of the springs attached here "Ends 2"
        and the other ends of the springs "Ends 1". All of the
        springs attached to this ring must have the same spring
        constant and the same eccentricities, e1 and e2. The other
        ends of the springs,"Ends 1", must all be attached to the
        same previous ring or to ground at a global axial coordinate
        that is the same for all the springs at Ends 1 and at a
        radius from the axis of revolution that is the same for all
        the springs at Ends 1. If Ends 1 of the springs are
        connected to ground, then these springs are used to
        simulate elastic, pinned struts upon which the shell of
        revolution is supported. If Ends 1 of the springs are
        connected to a previous NTYPER=-1 type of "fake" ring,
        then these springs are used to represent elastic fasteners
        that join one part of the shell to another part in an
        intermittant manner.

        You will next be asked to provide the following input data
        relating to the attachment of springs to a "fake" ring:
        1. The global axial coordinate of the line of attachment of
           one end of the springs to this ring: SPRAXL
        2. The number of springs attached to this ring: NSPRNG
        3. The circumferential angles in degrees to the attachment
           point of each spring to this ring (use 0 to 360 degrees):
           SPRANG
        4. The spring constant k of each of the springs attached here:
           SPRKON
        5. The radial and axial eccentricities, e1 and e2, of the
           attachment points of spring to this ring measured
           from the line of attachment of the ring to the shell
           reference surface. See Fig. 18 of the paper, "Computerized
           analysis of shells - Governing equations...",p 490,
           Computers & Structures, 1984: e1=SPREC1; e2=SPREC2
        6. Are the other ends (Ends 1) of the springs that are
           attached to this ring (Ends 2) attached to ground?
           If yes, then:
           6a. The global axial coordinate of the attachment of
               Ends 1 of the springs to ground: SPRAXG
           6b. The radius from the shell axis of revolution to the

circumferential line of attachment of Ends 1 of the
springs to ground: SPRRAD
    6c. The circumferential angles in degrees of the
        attachment points of Ends 1 of the springs to ground.
        Use only positive values from 0 to 360 degrees:
        SPRAGG
7. Are the other ends (Ends 1) of the springs that are
   attached to this ring (Ends 2) attached to a previously
   identified NTYPER = -1 type of "fake" ring? If yes, then:
    7a. The shell segment number to which that previous
        NTYPER = -1 "fake" ring is attached: ISPRSG
    7b. The ring number in that shell segment: ISPRRG

815.1 Global axial coordinate of ring ends of springs, SPRAXL
815.2
     All springs attached here must have the same global
     axial coordinate. This global axial coordinate may
     differ from that of the circumferential line of
     attachment of the "fake" ring to the shell wall
     reference surface by an amount equal to the axial
     eccentricity e2. We are concerned here with the
     global axial coordinate of the ends of the springs
     that are attached to the ring.

820.1 Number of springs attached to this "fake" ring, NSPRNG
820.2
     Don't use more that 30 springs.

825.1 Circumfer.angles to spring attach points at ring, SPRANG
825.2
     Provide angles in degrees measured from the origin
     of the circumferential coordinate, theta. Use only
     positive values in the interval from 0 to 360 degrees.
     We are concerned here with the attachment points at
     the ends of the springs attached to the ring.

830.1 Spring constant (e.g. lb/in) of each spring, SPRKON
830.2
     All springs attached here originally probably have the
     same SPRKON. Each spring attached to a given ring MAY have
     a different spring constant, SPRKON(IANGLE,K). Originally
     all the spring constants at a given ring may be the same.
     However, when we take into account the softening effect of
     local shell deformation on the "effective" stiffness of a
     spring, each spring may develop a different "effective"
     spring constant. Usually the following will happen:
     The "effective" stiffnesses of the springs at
     circumferential coordinates 0 and 180 degrees will have
     one "effective" spring constant and those at 90 and 270
     degrees will have a different "effective" spring constant.
     We allow the user to supply a different spring constant
     for each spring attached to this ring because he/she may
     later want to account for the "softening" effect that

local deformation of the shell at the spring attachment point has on the "effective" spring constant.

835.1 Radial eccentricity of spring attachment point, SPREC1
835.2

SPREC1 is the radial distance measured from the shell wall reference surface at the line of attachment of the "fake" ring to the shell to the attachment point of each spring to the "fake" ring, positive if the spring attachment point lies at a greater radius from the axis of revolution than that of the shell wall reference surface to which the "fake" ring is attached. See e1 in Fig. 18 in the paper, "Computerized analysis of shells – Governing equations", p. 490, Computers & Structures, 1984

840.1 Axial eccentricity of spring attachment point, SPREC2
840.2

SPREC2 is the axial distance measured from the shell wall reference surface at the line of attachment of the "fake" ring to the shell to the attachment point of each spring to the "fake" ring, positive if the spring attachment point lies above the line of attachment of the "fake" ring to the shell wall reference surface. See e2 in Fig. 18 in the paper, "Computerized analysis of shells – Governing equations", p 490, Computers & Structures, 1984

845.1 Are the other ends of the springs attached to ground?
845.2

If the other ends of the springs are connected to ground, then these springs are used to simulate elastic, pinned struts upon which the shell of revolution is supported or otherwise constrained. Note: If you answer yes, all the springs attached to this ring must be attached to ground at the same global axial coordinate and at the same radius from the axis of revolution. This global axial coordinate and radius can, of course, differ from those of the ring to which the springs are attached.

850.1 Global axial coordinate of attachment to ground, SPRAXG
850.2

All springs attached at global axial coordinate, SPRAXL, must be attached at their other ends at the same global axial coordinate, SPRAXG. Of course, SPRAXG can be different from SPRAXL and usually is different.

855.1 Radius to the spring attachment point to ground, SPRRAD
855.2

This is the radius from the axis of revolution to the attachment point of the other ends of the springs to ground. All the springs attached to this ring must have the same SPRRAD. Of course, SPRRAD can differ from the radius of the "fake" ring and usually does differ.

860.1 Circumferential angles to spring attach points, SPRAGG
860.2
     Provide angles in degrees measured from the origin
     of the circumferential coordinate, theta. These are
     the circumferential angles of the ends of the springs
     that are attached to ground. Use only positive
     values in the interval from 0 to 360 degrees. It is
     emphasized that we are referring to the circumferential
     angle for a line from the AXIS OF REVOLUTION to the
     point at which the ground-ends of the springs are
     attached to ground, NOT the azimuthal angle of the
     spring for a line drawn from its attachment point to
     the ring to its attachment point to ground.

865.1 Are the other ends of the springs at a previous ring?
865.2
     Asked more clearly, are the other ends of the springs
     attached to a previously identified "fake" ring?
     If the other ends of the springs are connected to a
     previously identified NTYPER=-1 type of "fake" ring,
     then these springs are used to represent elastic fasteners
     that join one part of the shell to another part in an
     intermittant manner. Note: If you answer Y, then all
     the springs at the current ring must be connected to the
     same previous "fake" ring.

870.1 Previous shell segment number, ISPRSG
870.2
     This is the previous shell segment number to which
     a previously identified "fake" ring is attached, that
     is, where the other ends of the springs are attached.

875.1 Ring number in shell segment ISPRSG, ISPRRG
875.2
     Rings are numbered consecutively from the beginning of
     the shell segment to the end of the shell segment. In
     counting rings, include ALL rings, real and "fake".
     What is wanted here is the previously identified ring
     number to which the other ends of the springs are
     attached.
------------ End of new section of PROMPT2.DAT------------------

The section of PROMPT2.DAT just listed is invoked by means of
a control index, NTYPER (type of ring), as follows:

152.1 NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring no.
152.2
     -1 means fake ring, needed as a place to "hang" springs from
      0 means fake ring, needed as a place to "hang" a line load
      1 means read in E, A, Iy, Ix, Ixy, E1, E2, GJ, RM (see p.70)

```
         2 means read in E, A, Is, In, Isn, ZC, SC, GJ, RM (see fig.)
         3 do not use
         4 means read L(1), L(2), L(3),  T(1), T(2), T(3)
                   E, NU, X1P, Y(1), Y(2), Y(3), and RM (see p.72)
         5 means read same quantities, but in the (s,n) rather than
          in the (x,y) axis system (see bottom of p. 70 for the two
          axis systems.)
---------------------------------------------------------------
NOTE: A new option, NTYPER = -1, has been added. In this way, old
      BIGBOSOR4 input files remain valid.
```

A SIMPLE EXAMPLE

As mentioned previously we determine the effect of springs on the
behavior of a shell structure in two successive BIGBOSOR4 executions:

1. In the first BIGBOSOR4 execution the model includes springs but
no line loads that represent the concentrated reactions of the springs
on the shell. Circumferential wavenumbers used for the linear stress
analysis phase of the computations, that is, NSTART, NFIN, INCR, which
occur near the beginning of the <casename>.ALL file, have values
such as the following:

```
   0        $ NSTART= starting number of circ. waves (lin. stress analysis)
 -60        $ NFIN  = ending number of circ. waves (linear stress analysis)
  -1        $ INCR  = step in number of circ. waves (linear stress)
```

NOTE: n = 0 (axisymmetric up-and-down and/or rolling) and n = -1
(lateral and/or tilting) harmonics MUST be included, since these are
the only two harmonics for which the springs contribute strain energy.

2. In the second BIGBOSOR4 execution the model includes springs WITH
ZERO SPRING CONSTANTS, SPRKON(IANGLE,K), and line loads that represent
approximately (by Fourier series expansion) the concentrated reactions
from BIGBOSOR4 execution no. 1 of the springs acting on the shell
to which the springs are attached. The proper BIGBOSOR4 input for
these concentrated loads is printed out at the end of the
<casename>.OUT file generated by the first BIGBOSOR4 execution.
Only circumferential wave numbers the absolute values of which
are greater than or equal to 2 are explored in the linear stress
analysis phase of the computations, that is, NSTART, NFIN, INCR, which
occur near the beginning of the <casename>.ALL file, have values
such as the following:

```
  -2        $ NSTART= starting number of circ. waves (lin. stress analysis)
 -60        $ NFIN  = ending number of circ. waves (linear stress analysis)
  -1        $ INCR  = step in number of circ. waves (linear stress)
```

Here the two cases are called "cylspr1" and "cylspr2".

In the relatively simple example explored here a monocoque cylindrical

shell is modeled as consisting of two segments: the springs occur at the
bottom of the first segment, and the overall bending load [vertical
force, V, that varies around the circumference as cos(theta)] is
applied at the top of the second segment. We need two segments
because there is a BIGBOSOR4 rule that all rings in a given segment
that have line loads applied to them must have the same circumferential
distribution of line load, that is, the same g(theta). Since the
circumferential distribution, g1(THETA), of the line loads that
represent the reaction of the springs against the shell is different
from the simple cos(theta) distribution of the vertical line load, V,
at the top of the shell, g2(theta), the springs and the overall
applied moment, Vo x cos(theta), must occur in different shell segments.

The BIGBOSOR4 input file for the first of the two runs described above
is as follows:

```
---------------------- cylspr1.ALL --------------------------
 cylinder with springs
         3           $ INDIC = analysis type indicator
         2           $ NPRT = output options (1=minimum, 2=medium, 3=maximum)
         0           $ ISTRES= output control (0=resultants, 1=sigma, 2=epsilon)
         2           $ NSEG  = number of shell segments (less than 195)
         0           $ NSTART= starting number of circ. waves (lin. stress analysis)
        -1           $ NFIN  = ending number of circ. waves (linear stress analysis)
        -1           $ INCR  = step in number of circ. waves (linear stress)
   180.0000          $ THETAM= range of circumferential Fourier expansion & output
       H             $
       H             $ SEGMENT NUMBER     1    1    1    1    1    1    1    1
       H             $ NODAL POINT DISTRIBUTION FOLLOWS...
        97           $ NMESH = number of node points (5 = min.; 98 = max.)( 1)
         1           $ NTYPEH= control integer (1 or 3) for nodal point spacing
         4           $ NHVALU= number of callouts for nodal point spacing
         1           $ IHVALU(I)= Ith callout for nodal point spacing, IHVALU( 1)
        51           $ IHVALU(I)= Ith callout for nodal point spacing, IHVALU( 2)
        52           $ IHVALU(I)= Ith callout for nodal point spacing, IHVALU( 3)
        96           $ IHVALU(I)= Ith callout for nodal point spacing, IHVALU( 4)
   0.2000000         $ HVALU=meridional arc length between nodal points,HVALU( 1)
   0.2000000         $ HVALU=meridional arc length between nodal points,HVALU( 2)
    1.000000         $ HVALU=meridional arc length between nodal points,HVALU( 3)
    1.000000         $ HVALU=meridional arc length between nodal points,HVALU( 4)
       H             $ REFERENCE SURFACE GEOMETRY FOLLOWS...
         1           $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
       100           $ R1      = radius at beginning of segment (see p. 66)
         0           $ Z1      = global axial coordinate at beginning of segment
       100           $ R2      = radius at end of segment
        50           $ Z2      = global axial coordinate at end of segment
       H             $ IMPERFECTION SHAPE FOLLOWS...
         0           $ IMP    = indicator for imperfection (0=none, 1=some)
       H             $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
         3           $ NTYPEZ= control (1 or 3) for reference surface location
   0.5000000         $ ZVAL   = distance from leftmost surf. to reference surf.
       N             $ Do you want to print out r(s), r'(s), etc. for this segment?
```

```
     H              $ DISCRETE RING INPUT FOLLOWS...
        1           $ NRINGS= number (max=20) of discrete rings in this segment
        2           $ NTYPE = control for identification of ring location (2=z, 3=r)
        0           $ Z(I)  = axial coordinate of Ith ring, z( 1)
       -1           $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring
no.( 1)
        0           $ Global axial coordinate of ring ends of springs, SPRAXL( 1)
        8           $ Number of springs attached to this "fake" ring, NSPRNG( 1)
        0           $ Circumfer.angles to spring attach points at ring, SPRANG( 1)
        0           $ Circumfer.angles to spring attach points at ring, SPRANG( 2)
       90           $ Circumfer.angles to spring attach points at ring, SPRANG( 3)
       90           $ Circumfer.angles to spring attach points at ring, SPRANG( 4)
      180           $ Circumfer.angles to spring attach points at ring, SPRANG( 5)
      180           $ Circumfer.angles to spring attach points at ring, SPRANG( 6)
      270           $ Circumfer.angles to spring attach points at ring, SPRANG( 7)
      270           $ Circumfer.angles to spring attach points at ring, SPRANG( 8)
 100000.0           $ Spring constant (e.g. lb/in) of each spring, SPRKON( 1)
 100000.0           $ Spring constant (e.g. lb/in) of each spring, SPRKON( 2)
 100000.0           $ Spring constant (e.g. lb/in) of each spring, SPRKON( 3)
 100000.0           $ Spring constant (e.g. lb/in) of each spring, SPRKON( 4)
 100000.0           $ Spring constant (e.g. lb/in) of each spring, SPRKON( 5)
 100000.0           $ Spring constant (e.g. lb/in) of each spring, SPRKON( 6)
 100000.0           $ Spring constant (e.g. lb/in) of each spring, SPRKON( 7)
 100000.0           $ Spring constant (e.g. lb/in) of each spring, SPRKON( 8)
        0           $ Radial eccentricity of spring attachment point, SPREC1( 1)
        0           $ Axial eccentricity of spring attachment point, SPREC2( 1)
     Y              $ Are the other ends of the springs attached to ground?
       20           $ Global axial coordinate of attachment to ground, SPRAXG( 1)
 150.0000           $ Radius to the spring attachment point to ground, SPRRAD( 1)
       45           $ Circumferential angles to spring attach points, SPRAGG( 1)
      -45           $ Circumferential angles to spring attach points, SPRAGG( 2)
      135           $ Circumferential angles to spring attach points, SPRAGG( 3)
       45           $ Circumferential angles to spring attach points, SPRAGG( 4)
      225           $ Circumferential angles to spring attach points, SPRAGG( 5)
      135           $ Circumferential angles to spring attach points, SPRAGG( 6)
      315           $ Circumferential angles to spring attach points, SPRAGG( 7)
      225           $ Circumferential angles to spring attach points, SPRAGG( 8)
        0           $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
     H              $ LINE LOAD INPUT FOLLOWS...
        0           $ LINAB= indicator (0, 1, 2 or 3) for load set A and B
     H              $ DISTRIBUTED LOAD INPUT FOLLOWS...
        0           $ IDISAB= indicator (0, 1, 2 or 3) for load set A and B
     H              $ SHELL WALL CONSTRUCTION FOLLOWS...
        2           $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
 0.1000000E+08 $ E      = Young's modulus for skin
 0.3000000     $ U      = Poisson's ratio for skin
 0.2500000E-03 $ SM =mass density of skin (e.g. alum.=.00025 lb-sec**2/in**4)
        0           $ ALPHA = coefficient of thermal expansion
        0           $ NRS  = control (0 or 1) for addition of smeared stiffeners
        0           $ NSUR  = control for thickness input (0 or 1 or -1)
     N              $ Do you want to print out ref. surf. location and thickness?
     N              $ Do you want to print out the C(i,j) at meridional stations?
     N              $ Do you want to print out distributed loads along meridian?
```

```
        H              $
        H              $ SEGMENT NUMBER     2    2    2    2    2    2    2    2
        H              $ NODAL POINT DISTRIBUTION FOLLOWS...
       97              $ NMESH = number of node points (5 = min.; 98 = max.)( 2)
        3              $ NTYPEH= control integer (1 or 3) for nodal point spacing
        H              $ REFERENCE SURFACE GEOMETRY FOLLOWS...
        1              $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
      100              $ R1      = radius at beginning of segment (see p. 66)
       50              $ Z1      = global axial coordinate at beginning of segment
      100              $ R2      = radius at end of segment
      100              $ Z2      = global axial coordinate at end of segment
        H              $ IMPERFECTION SHAPE FOLLOWS...
        0              $ IMP     = indicator for imperfection (0=none, 1=some)
        H              $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
        3              $ NTYPEZ= control (1 or 3) for reference surface location
  0.5000000            $ ZVAL  = distance from leftmost surf. to reference surf.
        N              $ Do you want to print out r(s), r'(s), etc. for this segment?
        H              $ DISCRETE RING INPUT FOLLOWS...
        1              $ NRINGS= number (max=20) of discrete rings in this segment
        2              $ NTYPE = control for identification of ring location (2=z, 3=r)
      100              $ Z(I)  = axial coordinate of Ith ring, z( 1)
        0              $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring
no.( 1)
        0              $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
        H              $ LINE LOAD INPUT FOLLOWS...
        1              $ LINAB= indicator (0, 1, 2 or 3) for load set A and B
        H              $ LINE LOAD INPUT FOR LOAD SET "A" FOLLOWS
        1              $ LINTYP= indicator (0, 1, 2 or 3) for type of line loads
        4              $ NTYPEL=index (use 4) for input of nonsymmetric line loads
        1              $ NLOAD(1)=indicator for axial load or disp.(0=none,1=some)
        0              $ NLOAD(2)=indicator for shear load or disp.(0=none,1=some)
        0              $ NLOAD(3)=indicator for radial load or disp.(0 or 1)
        0              $ NLOAD(4)=indicator for line moment or rotation (0 or 1)
 -1000.000            $ V(i)=fixed or initial axial load or displacement, V( 1)
        7              $ NTHETA= number of circumferential callouts for load
        2              $ NOPT  = control for how g(THETA) is to be input (1,2,or 3)
        1              $ NODD  = control integer for oddness, evenness, of g(THETA)
        0              $ THETA = circumferential coordinate, in degrees, THETA( 1)
       30              $ THETA = circumferential coordinate, in degrees, THETA( 2)
       60              $ THETA = circumferential coordinate, in degrees, THETA( 3)
       90              $ THETA = circumferential coordinate, in degrees, THETA( 4)
      120              $ THETA = circumferential coordinate, in degrees, THETA( 5)
      150              $ THETA = circumferential coordinate, in degrees, THETA( 6)
      180              $ THETA = circumferential coordinate, in degrees, THETA( 7)
  1.000000            $ YPLUS = value of g(THETA) at THETA( 1)
  0.8660000            $ YPLUS = value of g(THETA) at THETA( 2)
  0.5000000            $ YPLUS = value of g(THETA) at THETA( 3)
        0              $ YPLUS = value of g(THETA) at THETA( 4)
 -0.5000000            $ YPLUS = value of g(THETA) at THETA( 5)
 -0.8660000            $ YPLUS = value of g(THETA) at THETA( 6)
 -1.000000            $ YPLUS = value of g(THETA) at THETA( 7)
        Y              $ Do you want to print out output Fourier expansion of load?
        H              $ DISTRIBUTED LOAD INPUT FOLLOWS...
```

```
      0           $ IDISAB= indicator (0, 1, 2 or 3) for load set A and B
   H              $ SHELL WALL CONSTRUCTION FOLLOWS...
      2           $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
0.1000000E+08 $ E     = Young's modulus for skin
0.3000000     $ U     = Poisson's ratio for skin
0.2500000E-03 $ SM =mass density of skin (e.g. alum.=.00025 lb-sec**2/in**4)
      0           $ ALPHA = coefficient of thermal expansion
      0           $ NRS  = control (0 or 1) for addition of smeared stiffeners
      0           $ NSUR  = control for thickness input (0 or 1 or -1)
   N              $ Do you want to print out ref. surf. location and thickness?
   N              $ Do you want to print out the C(i,j) at meridional stations?
   N              $ Do you want to print out distributed loads along meridian?
   H              $
   H              $ GLOBAL DATA BEGINS...
      1           $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
   N              $ Are there any regions for which you want expanded plots?
      2           $ NDIST = number of circ. stations for meridional output
 0.000000         $ THETA = circ. stations (in deg.) for meridional output.( 1)
 90.00000         $ THETA = circ. stations (in deg.) for meridional output.( 2)
      2           $ NCIRC = number of meridional stations for circ. distibutions
   1001           $ ITHETA= meridional location for circumferential output( 1)
   2097           $ ITHETA= meridional location for circumferential output( 2)
     61           $ NTHETA= number of output points along circ. from 0 to THETAM.
      0           $ THETAS= Nx & Ny along this meridian used in buckling analysis.
      0           $ OMEGA  = angular vel. about axis of revolution (rad/sec)
      1           $ IOMGAB = control for OMEGA as "A" or "B" load (1 or 2)
   N              $ Do you want response to harmonic forcing (INDIC = 3 or 4)?
   H              $ CONSTRAINT CONDITIONS FOLLOW....
      2           $ How many segments in the structure?
   H              $
   H              $ CONSTRAINT CONDITIONS FOR SEGMENT NO.    1    1    1    1
   H              $ POLES INPUT FOLLOWS...
      0           $ Number of poles (places where r=0) in SEGMENT( 1)
   H              $ INPUT FOR CONSTRAINTS TO GROUND FOLLOWS...
      0           $ At how many stations is this segment constrained to ground?
   H              $ JUNCTION CONDITION INPUT FOLLOWS...
   N              $ Is this segment joined to any lower-numbered segments?
   H              $
   H              $ CONSTRAINT CONDITIONS FOR SEGMENT NO.    2    2    2    2
   H              $ POLES INPUT FOLLOWS...
      0           $ Number of poles (places where r=0) in SEGMENT( 2)
   H              $ INPUT FOR CONSTRAINTS TO GROUND FOLLOWS...
      0           $ At how many stations is this segment constrained to ground?
   H              $ JUNCTION CONDITION INPUT FOLLOWS...
   Y              $ Is this segment joined to any lower-numbered segments?
      1           $ At how may stations is this segment joined to previous segs.?
      1           $ INODE = node in current segment (ISEG) of junction, INODE( 1)
      1           $ JSEG  = segment no. of lowest segment involved in junction
     97           $ JNODE = node in lowest segmnt (JSEG) of junction
      1           $ IUSTAR= axial displacement (0=not slaved, 1=slaved)
      1           $ IVSTAR= circumferential displacement (0=not slaved, 1=slaved)
      1           $ IWSTAR= radial displacement (0=not slaved, 1=slaved)
      1           $ ICHI  = meridional rotation (0=not slaved, 1=slaved)
```

```
        0          $ D1    = radial component of juncture gap
        0          $ D2    = axial component of juncture gap
      Y            $ Is this constraint the same for both prebuckling and buckling?
      H            $ RIGID BODY CONSTRAINT INPUT FOLLOWS...
      N            $ Given existing constraints, are rigid body modes possible?
      H            $ "GLOBAL3" QUESTIONS (AT END OF CASE)...
      Y            $ Do you want to list output for segment( 1)
      Y            $ Do you want to list output for segment( 2)
      Y            $ Do you want to list forces in the discrete rings, if any?
------------------------------------------------------------------------


The new output from BIGBOSOR4, contained in the cylspr1.OUT file, follows:

----------------- cylspr1.OUT file (abridged) ------------------------
 ***************** OUTPUT RELATING TO SPRINGS ****************
 The following output is for springs attached to ring no.   1
 ************************************************************
 The following are input quantities relating
 to all the springs attached to this ring:
 NTYPAL =              -1 =index for type of ring (NTYPAL = -1
                          means a ring with springs attached to it.)
 NGROUN =               1 = 1 if springs are attached to ground,
                          = 0 if springs are attached to a previous
                               ring. (NOTE: The coding has not been
                               written for the NGROUN = 0 option.)
 NSPRNG =               8 = number of springs attached to this
                            ring.
 SPRAXL =  0.0000E+00 = global axial coordinate of this
                            ring.
 SPRANG = 8 circumferential angles of spring attachment points on this ring:
  0.0000E+00   0.0000E+00   9.0000E+01   9.0000E+01   1.8000E+02
  1.8000E+02   2.7000E+02   2.7000E+02
 SPRKON = 8 spring constants for the 8 springs attached to this ring:
  1.0000E+05   1.0000E+05   1.0000E+05   1.0000E+05   1.0000E+05
  1.0000E+05   1.0000E+05   1.0000E+05
 SPREC1 =  0.0000E+00 = radial eccentricity e1 of the
          attachment points of all the springs to this ring.
 SPREC2 =  0.0000E+00 = axial  eccentricity e2 of the
          attachment points of all the springs to this ring.
 SPRAXG =  2.0000E+01 = global axial coordinate of the
          attachment of all the springs associated with this
          ring to ground.
 SPRRAD =  1.5000E+02 = radius of spring ground attachment
                            points
 SPRAGG = 8 circumferential angles of spring attachment points to ground:
  4.5000E+01 -4.5000E+01   1.3500E+02   4.5000E+01   2.2500E+02
  1.3500E+02   3.1500E+02   2.2500E+02


 QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO.  1 (LOAD SYSTEM "A")


            SPRANG(i)                              SPRKON(i)    SPRFCE(i)
 SPRING   CIRC. ANGLE    SPRING     CHANGE IN       SPRING       SPRING
```

NO.	OF ATTACHMENT POINT ON RING	LENGTH, L	LENGTH, dL	CONSTANT	FORCE
1	0.0000E+00	1.0811E+02	-4.1491E+00	1.0000E+05	-4.1491E+05
2	0.0000E+00	1.0811E+02	-4.1491E+00	1.0000E+05	-4.1491E+05
3	9.0000E+01	1.0811E+02	-2.3729E-01	1.0000E+05	-2.3729E+04
4	9.0000E+01	1.0811E+02	2.3729E-01	1.0000E+05	2.3729E+04
5	1.8000E+02	1.0811E+02	4.1491E+00	1.0000E+05	4.1491E+05
6	1.8000E+02	1.0811E+02	4.1491E+00	1.0000E+05	4.1491E+05
7	2.7000E+02	1.0811E+02	2.3729E-01	1.0000E+05	2.3729E+04
8	2.7000E+02	1.0811E+02	-2.3729E-01	1.0000E+05	-2.3729E+04

IN THE FOLLOWING LIST THE CONCENTRATED SPRING LOADS AT RING 1
ARE RESOLVED IN THE SHELL COORDINATE DIRECTIONS: RADIAL,
CIRCUMFERENTIAL, AND AXIAL. CONCENTRATED LOADS IN THESE
SHELL COORDINATE DIRECTIONS MAY BE CALLED FOR AS PART OF THE
INPUT DATA IN A SUBSEQUENT BIGBOSOR4 MODEL CONSTRUCTED BY
YOU IN ORDER TO DETERMINE THE CONTRIBUTION OF HIGH-CIRCUMFER-
ENTIAL-WAVENUMBER HARMONICS TO STRESS AND BUCKLING BEHAVIOR.

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO. 1 (LOAD SYSTEM "A")

SPRING NO.	AZIMUTHAL ANGLE RELATIVE TO RING	INCLINATION ANGLE RELATIVE TO RING	RADIAL FORCE ON RING	CIRCUMF. FORCE ON RING	VERTICAL FORCE ON RING
1	8.6727E+01	1.0661E+01	-2.3282E+04	-4.0708E+05	7.6761E+04
2	-8.6727E+01	1.0661E+01	-2.3282E+04	4.0708E+05	7.6761E+04
3	8.6727E+01	1.0661E+01	-1.3315E+03	-2.3282E+04	4.3900E+03
4	-8.6727E+01	1.0661E+01	1.3315E+03	-2.3282E+04	-4.3900E+03
5	8.6727E+01	1.0661E+01	2.3282E+04	4.0709E+05	-7.6761E+04
6	-8.6727E+01	1.0661E+01	2.3282E+04	-4.0708E+05	-7.6761E+04
7	8.6727E+01	1.0661E+01	1.3315E+03	2.3282E+04	-4.3900E+03
8	-8.6727E+01	1.0661E+01	-1.3315E+03	2.3282E+04	4.3900E+03

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO. 1 (LOAD SYSTEM "A")

SPRING NO.	AZIMUTHAL ANGLE RELATIVE TO RING	INCLINATION ANGLE RELATIVE TO RING	FORCES ON SPRING DERIVED FROM SHELL LOADS	SPRING CONSTANT DERIVED FROM SHELL LOADS
1	8.6727E+01	1.0661E+01	4.1491E+05	1.0000E+05
2	-8.6727E+01	1.0661E+01	4.1491E+05	1.0000E+05
3	8.6727E+01	1.0661E+01	2.3729E+04	1.0000E+05
4	-8.6727E+01	1.0661E+01	-2.3729E+04	1.0000E+05
5	8.6727E+01	1.0661E+01	-4.1491E+05	1.0000E+05
6	-8.6727E+01	1.0661E+01	-4.1491E+05	1.0000E+05
7	8.6727E+01	1.0661E+01	-2.3729E+04	1.0000E+05
8	-8.6727E+01	1.0661E+01	2.3729E+04	1.0000E+05

THE SPRINGS MAY BE ARRANGED IN PAIRS THAT MEET AT THE "FAKE"
RING. THEREFORE, SOME OF THE SPRING FORCES FROM INDIVIDUAL
SPRINGS MAY COMBINE TO CANCEL EACHOTHER OR TO DOUBLE THE
LOAD "SEEN" AT A PARTICULAR CIRCUMFERENTIAL LOCATION ON THE

"FAKE" RING. THIS COMBINING HAS BEEN ACCOUNTED FOR IN THE
FOLLOWING LIST OF CONCENTRATED LOADS RESOLVED IN THE SHELL
COORDINATE DIRECTIONS: RADIAL, CIRCUMFERENTIAL, AND AXIAL.

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO. 1 (LOAD SYSTEM "A")

CIRCUMFERENTIAL COORDINATE	NET RADIAL FORCE ON RING	NET CIRCUMFER. FORCE ON RING	NET VERTICAL FORCE ON RING	NET MERIDIONAL MOMENT ON RING
0.0000E+00	-4.6563E+04	0.0000E+00	1.5352E+05	0.0000E+00
9.0000E+01	2.1973E-03	-4.6563E+04	-1.6602E-02	0.0000E+00
1.8000E+02	4.6563E+04	6.2500E-02	-1.5352E+05	0.0000E+00
2.7000E+02	1.2207E-04	4.6563E+04	8.7891E-03	0.0000E+00

******************* IMPORTANT NOTE *************************
This model essentially smears out the springs. Only the n = 0
(axisymmetric up-and-down displacement and/or uniform rolling
about the axis of revolution) and n = 1 (uniform lateral
displacement and/or pitching displacement) are predicted
accurately. In order to obtain the static response for higher
circumferential wavenumbers, n, than n = 0 and/or n = 1, you
must include as BIGBOSOR4 input in another run the
concentrated forces that the springs apply to the "fake" ring
and therefore to the shell where they are attached.
****

THE FOLLOWING CAN BE USED AS A GUIDE FOR BIGBOSOR4 INPUT FOR
LINEAR NON-AXISYMMETRIC STATIC RESPONSE INCLUDING
CONCENTRATED LOADS APPLIED BY THE SPRINGS TO THE SHELL. IN
THE FOLLOWING OUTPUT THE CONCENTRATED SPRING LOADS ARE
MODELED AS LINE LOADS WITH TRIANGULAR-SHAPED "PULSES". THE
AREA UNDERNEATH EACH "PULSE" IS EQUAL TO THE CONCENTRATED
SPRING LOAD AS RESOLVED IN THE RADIAL, CIRCUMFERENTIAL, AND
AXIAL SHELL COORDINATE DIRECTIONS. THESE LINE LOADS ARE THE
"H", "S", "V", AND "M" LINE LOADS, INPUT FOR WHICH IS CALLED
FOR BY BIGBOSOR4.

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO. 1 (LOAD SYSTEM "A")

CIRCUMFERENTIAL COORDINATE	RADIAL LINE LOAD ON RING	CIRCUMFER.LINE LOAD ON RING	VERTICAL LINE LOAD ON RING	MERIDIONAL LINE MOMENT ON RING
0.0000E+00	-5.3357E+03	0.0000E+00	1.7592E+04	0.0000E+00
5.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8.5000E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0000E+01	2.5179E-04	-5.3357E+03	-1.9024E-03	0.0000E+00
9.5000E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.7500E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.8000E+02	5.3357E+03	7.1620E-03	-1.7592E+04	0.0000E+00
1.8500E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.6500E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2.7000E+02	1.3988E-05	5.3357E+03	1.0072E-03	0.0000E+00
2.7500E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

FOR EVEN AND ODD DISTRIBUTIONS OF LINE LOAD ABOUT THE ORIGIN

OF THE CIRCUMFERENTIAL COORDINATE, theta, BIGBOSOR4 REQUIRES
INPUT DATA ONLY IN THE RANGE: 0.0.LE.theta.LE.180. DEGREES.
ALSO, IT IS BEST TO SUPPLY THE CIRCUMFERENTIAL DISTRIBUTION
OF LINE LOAD AS NORMALIZED, THAT IS, WITH THE PEAK LINE LOAD
EQUAL TO UNITY AND THE ENTIRE DISTRIBUTION MULTIPLIED BY THE
ACTUAL VALUE OF THE PEAK LINE LOAD. THE FOLLOWING LIST
PRESENTS THE CIRCUMFERENTIAL DISTRIBUTION OF SPRING LOADS AT
THIS "FAKE" RING IN THIS MANNER.

IN BIGBOSOR4 THERE IS A RULE THAT THE CIRCUMFERENTIAL
DISTRIBUTIONS OF RADIAL LINE LOAD, H, AXIAL LINE LOAD, V, AND
MERIDIONAL LINE MOMENT, M, MUST BE THE SAME. THEREFORE, WE
TRY TO ARRANGE THE SIGNS OF THE LINE LOAD FACTORS SO THAT
THIS IS TRUE FOR THIS CASE. IF ANY CIRCUMFERENTIAL DISTRIBU-
TION CONSISTS ENTIRELY OF ZEROES, THAT DOES N0T COUNT.
IN THE BIGBOSOR4 INPUT YOU SIMPLY INDICATE THAT THERE IS NO
LINE LOAD OF THAT PARTICULAR TYPE. THE CIRCUMFERENTIAL
DISTRIBUTION OF THE CIRCUMFERENTIALLY ORIENTED LINE LOAD, S,
CAN BE DIFFERENT FROM THAT FOR H, V, AND M. NOTE: IF YOU HAVE
MORE THAN ONE RING WITH SPRINGS ATTACHED, MAKE SURE THAT IF
THE SPRINGS ARE ARRANGED DIFFERENTLY ON THE TWO RINGS THAT
EACH OF THE RINGS IS LOCATED IN A DIFFERENT SHELL SEGMENT.

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO. 1 (LOAD SYSTEM "A")

RADIAL LOAD FACTOR	CIRC.LOAD FACTOR	VERT.LOAD FACTOR	MOMENT LOAD FACTOR
−5.3357E+03	5.3357E+03	1.7592E+04	1.0000E−07

CIRCUMFERENTIAL COORDINATE	RADIAL LINE LOAD ON RING	CIRCUMFER.LINE LOAD ON RING	VERTICAL LINE LOAD ON RING	MERIDIONAL LINE MOMENT ON RING
0.0000E+00	1.0000E+00	0.0000E+00	1.0000E+00	0.0000E+00
5.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
8.5000E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
9.0000E+01	0.0000E+00	−1.0000E+00	0.0000E+00	0.0000E+00
9.5000E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.7500E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
1.8000E+02	−1.0000E+00	0.0000E+00	−1.0000E+00	0.0000E+00

******** NOTE ************* NOTE ************ NOTE *********
THE FOLLOWING SAMPLE BOSOR4 INPUT IS VALID ONLY IF:
1. ONLY LOAD SET A EXISTS. THERE IS NO LOAD SET B.
2. THE LINE LOADS, V, H, AND M, ARE EVEN FUNCTIONS OF THETA.
3. THE LINE LOAD, S, IS AN ODD FUNCTION OF THETA.
4. THERE IS ONLY ONE RING IN THIS SHELL SEGMENT WITH ATTACHED SPRINGS.
****

BOSOR4 INPUT FOR LINE LOADS CORRESPONDING TO THE OUTPUT JUST LISTED
H $ LINE LOAD INPUT FOLLOWS...
1     $ LINAB=indicator (0, 1, 2 or 3) for load set A and B
H $ LINE LOAD INPUT FOR LOAD SET "A" FOLLOWS
1     $ LINTYP=indicator (0,1,2 or 3) for type of line loads
4     $ NTYPEL=index (use 4) for input of nonsymmetric loads

```
   1     $ NLOAD(1)=indicator for axial load or disp. (1 = some)
   1     $ NLOAD(2)=indicator for shear load or disp. (1 = some)
   1     $ NLOAD(3)=indicator for radial load or disp.(1 = some)
   1     $ NLOAD(4)=indicator for line moment or rot. (1 = some)
  1.7592E+04 $ V(i)=fixed or initial axial load or disp.  V(1)
  5.3357E+03 $ S(i)=fixed or initial shear load or disp.  S(1)
 -5.3357E+03 $ H(i)=fixed or initial radial load or disp. H(1)
  1.0000E-07 $ M(i)=fixed or initial moment or rotation.  M(1)
     7 $ NTHETA=number of circumferential callouts for load
   2     $ NOPT=control for how g(THETA) is to be input
   1     $ NODD=control for the oddness or evenness of g(THETA)
  0.0000E+00 $ circumferential coordinate, THETA( 1)
  5.0000E+00 $ circumferential coordinate, THETA( 2)
  8.5000E+01 $ circumferential coordinate, THETA( 3)
  9.0000E+01 $ circumferential coordinate, THETA( 4)
  9.5000E+01 $ circumferential coordinate, THETA( 5)
  1.7500E+02 $ circumferential coordinate, THETA( 6)
  1.8000E+02 $ circumferential coordinate, THETA( 7)
  1.0000E+00 $ YPLUS=value of g(THETA) at THETA( 1)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 2)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 3)
 -1.0814E-07 $ YPLUS=value of g(THETA) at THETA( 4)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 5)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 6)
 -1.0000E+00 $ YPLUS=value of g(THETA) at THETA( 7)
   Y     $ Do you want to print out output Fourier expansion?
     7 $ NTHETA=number of circumferential callouts for load
   2     $ NOPT=control for how g(THETA) is to be input
   2     $ NODD=control for the oddness or evenness of g(THETA)
  0.0000E+00 $ circumferential coordinate, THETA( 1)
  5.0000E+00 $ circumferential coordinate, THETA( 2)
  8.5000E+01 $ circumferential coordinate, THETA( 3)
  9.0000E+01 $ circumferential coordinate, THETA( 4)
  9.5000E+01 $ circumferential coordinate, THETA( 5)
  1.7500E+02 $ circumferential coordinate, THETA( 6)
  1.8000E+02 $ circumferential coordinate, THETA( 7)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 1)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 2)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 3)
 -1.0000E+00 $ YPLUS=value of g(THETA) at THETA( 4)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 5)
  0.0000E+00 $ YPLUS=value of g(THETA) at THETA( 6)
  1.3423E-06 $ YPLUS=value of g(THETA) at THETA( 7)
   Y     $ Do you want to print out output Fourier expansion?


 JUST LEFT SUBROUTINE OUT2
 --------------- end of abridged cylspr1.OUT file ------------
```

Note that the end of the cylspr1.OUT file just listed contains
valid input data for BIGBOSOR4 for the second run in the
sequence of two runs, that is, for the BIGBOSOR4 run in
which the springs are replaced by the line loads that are
approximate representations of the concentrated reaction

forces of the springs acting at the bottom of the cylindrical
shell. This second case is called "cylspr2".

The following file repesents input for the second of the
two BIGBOSOR4 runs:
-------------------- cylspr2.ALL ---------------------------
cylinder with weak springs, with concentrated loads
          3        $ INDIC = analysis type indicator
          1        $ NPRT = output options (1=minimum, 2=medium, 3=maximum)
          0        $ ISTRES= output control (0=resultants, 1=sigma, 2=epsilon)
          2        $ NSEG = number of shell segments (less than 295)
          0        $ NSTART= starting number of circ. waves (lin. stress analysis)
        -60 $ NFIN = ending number of circ. waves (linear stress analysis)
         -1 $ INCR = step in number of circ. waves (linear stress)
   180.0000 $ THETAM= range of circumferential Fourier expansion & output
        H $
        H $ SEGMENT NUMBER   1   1   1   1   1   1   1   1
        H $ NODAL POINT DISTRIBUTION FOLLOWS...
         97        $ NMESH = number of node points (5 = min.; 98 = max.)(1)
          3        $ NTYPEH= control integer (1 or 3) for nodal point spacing
        H $ REFERENCE SURFACE GEOMETRY FOLLOWS...
          1        $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
        100        $ R1   = radius at beginning of segment (see p. 66)
          0        $ Z1   = global axial coordinate at beginning of segment
        100        $ R2   = radius at end of segment
         50        $ Z2   = global axial coordinate at end of segment
        H $ IMPERFECTION SHAPE FOLLOWS...
          0        $ IMP   = indicator for imperfection (0=none, 1=some)
        H $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
          3        $ NTYPEZ= control (1 or 3) for reference surface location
  0.5000000 $ ZVAL = distance from leftmost surf. to reference surf.
        N $ Do you want to print out r(s), r'(s), etc. for this segment?
        H $ DISCRETE RING INPUT FOLLOWS...
          1        $ NRINGS= number (max=20) of discrete rings in this segment
          2        $ NTYPE = control for identification of ring location (2=z, 3=r)
          0        $ Z(I) = axial coordinate of Ith ring, z(1)
         -1 $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring
no.(1)
          0        $ Global axial coordinate of ring ends of springs, SPRAXL(1)
          8        $ Number of springs attached to this "fake" ring, NSPRNG(1)
          0        $ Circumfer.angles to spring attach points at ring, SPRANG(1)
          0        $ Circumfer.angles to spring attach points at ring, SPRANG(2)
         90        $ Circumfer.angles to spring attach points at ring, SPRANG(3)
         90        $ Circumfer.angles to spring attach points at ring, SPRANG(4)
        180        $ Circumfer.angles to spring attach points at ring, SPRANG(5)
        180        $ Circumfer.angles to spring attach points at ring, SPRANG(6)
        270        $ Circumfer.angles to spring attach points at ring, SPRANG(7)
        270        $ Circumfer.angles to spring attach points at ring, SPRANG(8)
   0.000000 $ Spring constant (e.g. lb/in) of each spring, SPRKON(1)
   0.000000 $ Spring constant (e.g. lb/in) of each spring, SPRKON(2)
   0.000000 $ Spring constant (e.g. lb/in) of each spring, SPRKON(3)

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  0.000000      $ Spring constant (e.g. lb/in) of each spring, SPRKON(   4)
  0.000000      $ Spring constant (e.g. lb/in) of each spring, SPRKON(   5)
  0.000000      $ Spring constant (e.g. lb/in) of each spring, SPRKON(   6)
  0.000000      $ Spring constant (e.g. lb/in) of each spring, SPRKON(   7)
  0.000000      $ Spring constant (e.g. lb/in) of each spring, SPRKON(   8)
        0        $ Radial eccentricity of spring attachment point, SPREC1(   1)
        0        $ Axial eccentricity of spring attachment point, SPREC2(   1)
        Y        $ Are the other ends of the springs attached to ground?
       20        $ Global axial coordinate of attachment to ground, SPRAXG(   1)
  150.0000      $ Radius to the spring attachment point to ground, SPRRAD(   1)
       45        $ Circumferential angles to spring attach points, SPRAGG(   1)
      -45        $ Circumferential angles to spring attach points, SPRAGG(   2)
      135        $ Circumferential angles to spring attach points, SPRAGG(   3)
       45        $ Circumferential angles to spring attach points, SPRAGG(   4)
      225        $ Circumferential angles to spring attach points, SPRAGG(   5)
      135        $ Circumferential angles to spring attach points, SPRAGG(   6)
      315        $ Circumferential angles to spring attach points, SPRAGG(   7)
      225        $ Circumferential angles to spring attach points, SPRAGG(   8)
        0        $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
        H        $ LINE LOAD INPUT FOLLOWS...
        1        $ LINAB= indicator (0, 1, 2 or 3) for load set A and B
        H        $ LINE LOAD INPUT FOR LOAD SET "A" FOLLOWS
        1        $ LINTYP= indicator (0, 1, 2 or 3) for type of line loads
        4        $ NTYPEL=index (use 4) for input of nonsymmetric line loads
        1        $ NLOAD(1)=indicator for axial load or disp.(0=none,1=some)
        1        $ NLOAD(2)=indicator for shear load or disp.(0=none,1=some)
        1        $ NLOAD(3)=indicator for radial load or disp.(0 or 1)
        1        $ NLOAD(4)=indicator for line moment or rotation (0 or 1)
 17592.00      $ V(i)=fixed or initial axial load or displacement, V(   1)
 5335.700      $ S(i)=fixed or initial shear load or displacement, S(   1)
-5335.700      $ H(i)=fixed or initial radial load or displacement, H(   1)
 0.1000000E-06 $ M(i)=fixed or initial meridional moment or rot., M(   1)
        7        $ NTHETA= number of circumferential callouts for load
        2        $ NOPT  = control for how g(THETA) is to be input (1,2,or 3)
        1        $ NODD  = control integer for oddness, evenness, of g(THETA)
  0.000000      $ THETA = circumferential coordinate, in degrees, THETA(   1)
  5.000000      $ THETA = circumferential coordinate, in degrees, THETA(   2)
  85.00000      $ THETA = circumferential coordinate, in degrees, THETA(   3)
  90.00000      $ THETA = circumferential coordinate, in degrees, THETA(   4)
  95.00000      $ THETA = circumferential coordinate, in degrees, THETA(   5)
  175.0000      $ THETA = circumferential coordinate, in degrees, THETA(   6)
  180.0000      $ THETA = circumferential coordinate, in degrees, THETA(   7)
  1.000000      $ YPLUS = value of g(THETA) at THETA(   1)
  0.000000      $ YPLUS = value of g(THETA) at THETA(   2)
  0.000000      $ YPLUS = value of g(THETA) at THETA(   3)
-0.1081400E-06 $ YPLUS = value of g(THETA) at THETA(   4)
  0.000000      $ YPLUS = value of g(THETA) at THETA(   5)
  0.000000      $ YPLUS = value of g(THETA) at THETA(   6)
 -1.000000      $ YPLUS = value of g(THETA) at THETA(   7)
        Y        $ Do you want to print out output Fourier expansion of load?
        7        $ NTHETA= number of circumferential callouts for load
        2        $ NOPT  = control for how g(THETA) is to be input (1,2,or 3)
        2        $ NODD  = control integer for oddness, evenness, of g(THETA)
```

```
   0.000000       $ THETA = circumferential coordinate, in degrees, THETA(  1)
   5.000000       $ THETA = circumferential coordinate, in degrees, THETA(  2)
  85.00000        $ THETA = circumferential coordinate, in degrees, THETA(  3)
  90.00000        $ THETA = circumferential coordinate, in degrees, THETA(  4)
  95.00000        $ THETA = circumferential coordinate, in degrees, THETA(  5)
 175.0000         $ THETA = circumferential coordinate, in degrees, THETA(  6)
 180.0000         $ THETA = circumferential coordinate, in degrees, THETA(  7)
   0.000000       $ YPLUS = value of g(THETA) at THETA(  1)
   0.000000       $ YPLUS = value of g(THETA) at THETA(  2)
   0.000000       $ YPLUS = value of g(THETA) at THETA(  3)
  -1.000000       $ YPLUS = value of g(THETA) at THETA(  4)
   0.000000       $ YPLUS = value of g(THETA) at THETA(  5)
   0.000000       $ YPLUS = value of g(THETA) at THETA(  6)
   0.1342300E-05  $ YPLUS = value of g(THETA) at THETA(  7)
        Y         $ Do you want to print out output Fourier expansion of load?
        H         $ DISTRIBUTED LOAD INPUT FOLLOWS...
            0     $ IDISAB= indicator (0, 1, 2 or 3) for load set A and B
        H         $ SHELL WALL CONSTRUCTION FOLLOWS...
            2     $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
   0.1000000E+08  $ E     = Young's modulus for skin
   0.3000000      $ U     = Poisson's ratio for skin
   0.2500000E-03  $ SM =mass density of skin (e.g. alum.=.00025 lb-sec**2/in**4)
            0     $ ALPHA = coefficient of thermal expansion
            0     $ NRS  = control (0 or 1) for addition of smeared stiffeners
            0     $ NSUR  = control for thickness input (0 or 1 or -1)
        N         $ Do you want to print out ref. surf. location and thickness?
        N         $ Do you want to print out the C(i,j) at meridional stations?
        N         $ Do you want to print out distributed loads along meridian?
        H         $
        H         $ SEGMENT NUMBER   2   2   2   2   2   2   2   2
        H         $ NODAL POINT DISTRIBUTION FOLLOWS...
           97     $ NMESH = number of node points (5 = min.; 98 = max.)(  2)
            3     $ NTYPEH= control integer (1 or 3) for nodal point spacing
        H         $ REFERENCE SURFACE GEOMETRY FOLLOWS...
            1     $ NSHAPE= indicator (1,2 or 4) for geometry of meridian
          100     $ R1     = radius at beginning of segment (see p. 66)
           50     $ Z1     = global axial coordinate at beginning of segment
          100     $ R2     = radius at end of segment
          100     $ Z2     = global axial coordinate at end of segment
        H         $ IMPERFECTION SHAPE FOLLOWS...
            0     $ IMP   = indicator for imperfection (0=none, 1=some)
        H         $ REFERENCE SURFACE LOCATION RELATIVE TO WALL
            3     $ NTYPEZ= control (1 or 3) for reference surface location
   0.5000000      $ ZVAL  = distance from leftmost surf. to reference surf.
        N         $ Do you want to print out r(s), r'(s), etc. for this segment?
        H         $ DISCRETE RING INPUT FOLLOWS...
            1     $ NRINGS= number (max=20) of discrete rings in this segment
            2     $ NTYPE = control for identification of ring location (2=z, 3=r)
          100     $ Z(I)  = axial coordinate of Ith ring, z(  1)
            0     $ NTYPER= type (-1 or 0 or 1 or 2 or 4 or 5) of discrete ring
no.(  1)
            0     $ K=elastic foundation modulus (e.g. lb/in**3)in this seg.
        H         $ LINE LOAD INPUT FOLLOWS...
```

```
        1        $ LINAB= indicator (0, 1, 2 or 3) for load set A and B
     H           $ LINE LOAD INPUT FOR LOAD SET "A" FOLLOWS
        1        $ LINTYP= indicator (0, 1, 2 or 3) for type of line loads
        4        $ NTYPEL=index (use 4) for input of nonsymmetric line loads
        1        $ NLOAD(1)=indicator for axial load or disp.(0=none,1=some)
        0        $ NLOAD(2)=indicator for shear load or disp.(0=none,1=some)
        0        $ NLOAD(3)=indicator for radial load or disp.(0 or 1)
        0        $ NLOAD(4)=indicator for line moment or rotation (0 or 1)
 -1000.000       $ V(i)=fixed or initial axial load or displacement, V(  1)
        7        $ NTHETA= number of circumferential callouts for load
        2        $ NOPT  = control for how g(THETA) is to be input (1,2,or 3)
        1        $ NODD  = control integer for oddness, evenness, of g(THETA)
        0        $ THETA = circumferential coordinate, in degrees, THETA(  1)
       30        $ THETA = circumferential coordinate, in degrees, THETA(  2)
       60        $ THETA = circumferential coordinate, in degrees, THETA(  3)
       90        $ THETA = circumferential coordinate, in degrees, THETA(  4)
      120        $ THETA = circumferential coordinate, in degrees, THETA(  5)
      150        $ THETA = circumferential coordinate, in degrees, THETA(  6)
      180        $ THETA = circumferential coordinate, in degrees, THETA(  7)
 1.000000        $ YPLUS = value of g(THETA) at THETA(  1)
 0.8660000       $ YPLUS = value of g(THETA) at THETA(  2)
 0.5000000       $ YPLUS = value of g(THETA) at THETA(  3)
        0        $ YPLUS = value of g(THETA) at THETA(  4)
-0.5000000       $ YPLUS = value of g(THETA) at THETA(  5)
-0.8660000       $ YPLUS = value of g(THETA) at THETA(  6)
-1.000000        $ YPLUS = value of g(THETA) at THETA(  7)
     Y           $ Do you want to print out output Fourier expansion of load?
     H           $ DISTRIBUTED LOAD INPUT FOLLOWS...
        0        $ IDISAB= indicator (0, 1, 2 or 3) for load set A and B
     H           $ SHELL WALL CONSTRUCTION FOLLOWS...
        2        $ NWALL=index (1, 2, 4, 5, 6, 7, 8, 9, 10) for wall construction
 0.1000000E+08 $ E      = Young's modulus for skin
 0.3000000       $ U      = Poisson's ratio for skin
 0.2500000E-03 $ SM =mass density of skin (e.g. alum.=.00025 lb-sec**2/in**4)
        0        $ ALPHA = coefficient of thermal expansion
        0        $ NRS  = control (0 or 1) for addition of smeared stiffeners
        0        $ NSUR  = control for thickness input (0 or 1 or -1)
     N           $ Do you want to print out ref. surf. location and thickness?
     N           $ Do you want to print out the C(i,j) at meridional stations?
     N           $ Do you want to print out distributed loads along meridian?
     H           $
     H           $ GLOBAL DATA BEGINS...
        1        $ NLAST = plot options  (-1=none, 0=geometry, 1=u,v,w)
     N           $ Are there any regions for which you want expanded plots?
        2        $ NDIST = number of circ. stations for meridional output
 0.000000        $ THETA = circ. stations (in deg.) for meridional output.(  1)
 90.00000        $ THETA = circ. stations (in deg.) for meridional output.(  2)
        2        $ NCIRC = number of meridional stations for circ. distibutions
     1001        $ ITHETA= meridional location for circumferential output(  1)
     2097        $ ITHETA= meridional location for circumferential output(  2)
       61        $ NTHETA= number of output points along circ. from 0 to THETAM.
        0        $ THETAS= Nx & Ny along this meridian used in buckling analysis.
        0        $ OMEGA  = angular vel. about axis of revolution (rad/sec)
```

```
        1         $ IOMGAB = control for OMEGA as "A" or "B" load (1 or 2)
     N           $ Do you want response to harmonic forcing (INDIC = 3 or 4)?
     H           $ CONSTRAINT CONDITIONS FOLLOW....
        2         $ How many segments in the structure?
     H           $
     H           $ CONSTRAINT CONDITIONS FOR SEGMENT NO.    1    1    1    1
     H           $ POLES INPUT FOLLOWS...
        0         $ Number of poles (places where r=0) in SEGMENT(  1)
     H           $ INPUT FOR CONSTRAINTS TO GROUND FOLLOWS...
        1         $ At how many stations is this segment constrained to ground?
        1         $ INODE = nodal point number of constraint to ground, INODE(  1)
        0         $ IUSTAR=axial displacement constraint (0 or 1 or 2)
        0         $ IVSTAR=circumferential displacement(0=free,1=0,2=imposed)
        0         $ IWSTAR=radial displacement(0=free,1=constrained,2=imposed)
        0         $ ICHI=meridional rotation (0=free,1=constrained,2=imposed)
  0.000000        $ D1    = radial component of offset of ground support
  0.000000        $ D2    = axial component of offset of ground support
     Y           $ Is this constraint the same for both prebuckling and buckling?
     H           $ JUNCTION CONDITION INPUT FOLLOWS...
     N           $ Is this segment joined to any lower-numbered segments?
     H           $
     H           $ CONSTRAINT CONDITIONS FOR SEGMENT NO.    2    2    2    2
     H           $ POLES INPUT FOLLOWS...
        0         $ Number of poles (places where r=0) in SEGMENT(  2)
     H           $ INPUT FOR CONSTRAINTS TO GROUND FOLLOWS...
        0         $ At how many stations is this segment constrained to ground?
     H           $ JUNCTION CONDITION INPUT FOLLOWS...
     Y           $ Is this segment joined to any lower-numbered segments?
        1         $ At how may stations is this segment joined to previous segs.?
        1         $ INODE = node in current segment (ISEG) of junction, INODE(  1)
        1         $ JSEG  = segment no. of lowest segment involved in junction
       97         $ JNODE = node in lowest segmnt (JSEG) of junction
        1         $ IUSTAR= axial displacement (0=not slaved, 1=slaved)
        1         $ IVSTAR= circumferential displacement (0=not slaved, 1=slaved)
        1         $ IWSTAR= radial displacement (0=not slaved, 1=slaved)
        1         $ ICHI  = meridional rotation (0=not slaved, 1=slaved)
        0         $ D1    = radial component of juncture gap
        0         $ D2    = axial component of juncture gap
     Y           $ Is this constraint the same for both prebuckling and buckling?
     H           $ RIGID BODY CONSTRAINT INPUT FOLLOWS...
     Y           $ Given existing constraints, are rigid body modes possible?
     Y           $ Do you wish to prevent rigid body motion?
        1         $ ISEG  = segment no. at which to prevent rigid body motion
        1         $ INODE = node no. at which to prevent rigid body motion
        1         $ IUSTAR= axial n=0 rigid body constraint (0=none, 1=some)
        1         $ IVSTAR= circ. n=0 rigid body constraint (usually equals 1)
        0         $ IWSTAR= radial n=0 rigid body constraint (usually equals 0)
        0         $ ICHI  = meridional rot. rigid body constraint
        1         $ IUSTAR= axial n=1 rigid body constraint (usually equals 1)
        1         $ IVSTAR= circ. n=1 rigid body constraint (usually equals 1)
        0         $ IWSTAR= radial n=1 rigid body constraint (usually equals 0)
        0         $ ICHI  = meridional rot. rigid body constraint
     N           $ Do you want inertial reactions to Load Set A?
```

```
      N              $ Do you want inertial reactions to Load Set B?
      H              $ "GLOBAL3" QUESTIONS (AT END OF CASE)...
      Y              $ Do you want to list output for segment(  1)
      Y              $ Do you want to list output for segment(  2)
      Y              $ Do you want to list forces in the discrete rings, if any?
----------------------------------------------------------------------
```

NOTE: You can see where the end of the file, cylspr1.OUT, which contains
the valid line load input for BIGBOSOR4, has been copied into the proper
location with the input data for shell segment no. 1.

Abridged output from the case cylspr2.ALL, called cylspr2.OUT, follows:
------------------ abridged cylspr2.OUT file -------------------------
 **************** OUTPUT RELATING TO SPRINGS ****************
 The following output is for springs attached to ring no. 1
 ****
 The following are input quantities relating
 to all the springs attached to this ring:
 NTYPAL =   -1 =index for type of ring (NTYPAL = -1
                          means a ring with springs attached to it.)
 NGROUN =   1 = 1 if springs are attached to ground,
                        = 0 if springs are attached to a previous
                              ring. (NOTE: The coding has not been
                              written for the NGROUN = 0 option.)
 NSPRNG =   8 = number of springs attached to this
                            ring.
 SPRAXL = 0.0000E+00 = global axial coordinate of this
                            ring.
 SPRANG = 8 circumferential angles of spring attachment points on this ring:
  0.0000E+00 0.0000E+00 9.0000E+01 9.0000E+01 1.8000E+02
  1.8000E+02 2.7000E+02 2.7000E+02
 SPRKON = 8 spring constants for the 8 springs attached to this ring:
  0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
  0.0000E+00 0.0000E+00 0.0000E+00
 SPREC1 = 0.0000E+00 = radial eccentricity e1 of the
           attachment points of all the springs to this ring.
 SPREC2 = 0.0000E+00 = axial eccentricity e2 of the
           attachment points of all the springs to this ring.
 SPRAXG = 2.0000E+01 = global axial coordinate of the
           attachment of all the springs associated with this
           ring to ground.
 SPRRAD = 1.5000E+02 = radius of spring ground attachment
                          points
 SPRAGG = 8 circumferential angles of spring attachment points to ground:
  4.5000E+01 -4.5000E+01 1.3500E+02 4.5000E+01 2.2500E+02
  1.3500E+02 3.1500E+02 2.2500E+02

 QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO. 1 (LOAD SYSTEM "A")

           SPRANG(i)   SPRKON(i)   SPRFCE(i)
 SPRING   CIRC. ANGLE   SPRING   CHANGE IN   SPRING   SPRING
```

| NO. | OF ATTACHMENT LENGTH, L | LENGTH, dL | CONSTANT | FORCE |
|-----|------------------------|------------|----------|-------|
|     | POINT ON RING          |            |          |       |
| 1   | 0.0000E+00  1.0811E+02 | 1.6679E+00 | 0.0000E+00 | 0.0000E+00 |
| 2   | 0.0000E+00  1.0811E+02 | 1.6679E+00 | 0.0000E+00 | 0.0000E+00 |
| 3   | 9.0000E+01  1.0811E+02 | 5.6020E+00 | 0.0000E+00 | 0.0000E+00 |
| 4   | 9.0000E+01  1.0811E+02 | -5.6020E+00 | 0.0000E+00 | 0.0000E+00 |
| 5   | 1.8000E+02  1.0811E+02 | -1.6679E+00 | 0.0000E+00 | 0.0000E+00 |
| 6   | 1.8000E+02  1.0811E+02 | -1.6679E+00 | 0.0000E+00 | 0.0000E+00 |
| 7   | 2.7000E+02  1.0811E+02 | -5.6020E+00 | 0.0000E+00 | 0.0000E+00 |
| 8   | 2.7000E+02  1.0811E+02 | 5.6020E+00 | 0.0000E+00 | 0.0000E+00 |

IN THE FOLLOWING LIST THE CONCENTRATED SPRING LOADS AT RING  1
ARE RESOLVED IN THE SHELL COORDINATE DIRECTIONS: RADIAL,
CIRCUMFERENTIAL, AND AXIAL. CONCENTRATED LOADS IN THESE
SHELL COORDINATE DIRECTIONS MAY BE CALLED FOR AS PART OF THE
INPUT DATA IN A SUBSEQUENT BIGBOSOR4 MODEL CONSTRUCTED BY
YOU IN ORDER TO DETERMINE THE CONTRIBUTION OF HIGH-CIRCUMFER-
ENTIAL-WAVENUMBER HARMONICS TO STRESS AND BUCKLING BEHAVIOR.

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO.  1 (LOAD SYSTEM "A")

| SPRING | AZIMUTHAL | INCLINATION | RADIAL | CIRCUMF. | VERTICAL |
|--------|-----------|-------------|--------|----------|----------|
| NO.    | ANGLE     | ANGLE       | FORCE  | FORCE    | FORCE    |
|        | RELATIVE  | RELATIVE    | ON RING | ON RING | ON RING |
|        | TO RING   | TO RING     |        |          |          |
| 1 | 8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 2 | -8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 3 | 8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 4 | -8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 5 | 8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 6 | -8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 7 | 8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 8 | -8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO.  1 (LOAD SYSTEM "A")

| SPRING | AZIMUTHAL | INCLINATION | FORCES | SPRING |
|--------|-----------|-------------|--------|--------|
| NO.    | ANGLE     | ANGLE       | ON SPRING | CONSTANT |
|        | RELATIVE  | RELATIVE    | DERIVED FROM | DERIVED FROM |
|        | TO RING   | TO RING     | SHELL LOADS | SHELL LOADS |
| 1 | 8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 |
| 2 | -8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 |
| 3 | 8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 |
| 4 | -8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 |
| 5 | 8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 |
| 6 | -8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 |
| 7 | 8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 |
| 8 | -8.6727E+01 | 1.0661E+01 | 0.0000E+00 | 0.0000E+00 |

THE SPRINGS MAY BE ARRANGED IN PAIRS THAT MEET AT THE "FAKE"
RING. THEREFORE, SOME OF THE SPRING FORCES FROM INDIVIDUAL
SPRINGS MAY COMBINE TO CANCEL EACHOTHER OR TO DOUBLE THE
LOAD "SEEN" AT A PARTICULAR CIRCUMFERENTIAL LOCATION ON THE

"FAKE" RING. THIS COMBINING HAS BEEN ACCOUNTED FOR IN THE
FOLLOWING LIST OF CONCENTRATED LOADS RESOLVED IN THE SHELL
COORDINATE DIRECTIONS: RADIAL, CIRCUMFERENTIAL, AND AXIAL.

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO.  1 (LOAD SYSTEM "A")

| CIRCUMFERENTIAL COORDINATE | NET RADIAL FORCE ON RING | NET CIRCUMFER. FORCE ON RING | NET VERTICAL FORCE ON RING | NET MERIDIONAL MOMENT ON RING |
|---|---|---|---|---|
| 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 9.0000E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 1.8000E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 2.7000E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |

****************** IMPORTANT NOTE **************************
This model essentially smears out the springs. Only the n = 0
(axisymmetric up-and-down displacement and/or uniform rolling
about the axis of revolution) and n = 1 (uniform lateral
displacement and/or pitching displacement) are predicted
accurately. In order to obtain the static response for higher
circumferential wavenumbers, n, than n = 0 and/or n = 1, you
must include as BIGBOSOR4 input in another run the
concentrated forces that the springs apply to the "fake" ring
and therefore to the shell where they are attached.
**************************************************************

THE FOLLOWING CAN BE USED AS A GUIDE FOR BIGBOSOR4 INPUT FOR
LINEAR NON-AXISYMMETRIC STATIC RESPONSE INCLUDING
CONCENTRATED LOADS APPLIED BY THE SPRINGS TO THE SHELL. IN
THE FOLLOWING OUTPUT THE CONCENTRATED SPRING LOADS ARE
MODELED AS LINE LOADS WITH TRIANGULAR-SHAPED "PULSES". THE
AREA UNDERNEATH EACH "PULSE" IS EQUAL TO THE CONCENTRATED
SPRING LOAD AS RESOLVED IN THE RADIAL, CIRCUMFERENTIAL, AND
AXIAL SHELL COORDINATE DIRECTIONS. THESE LINE LOADS ARE THE
"H", "S", "V", AND "M" LINE LOADS, INPUT FOR WHICH IS CALLED
FOR BY BIGBOSOR4.

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO.  1 (LOAD SYSTEM "A")

| CIRCUMFERENTIAL COORDINATE | RADIAL LINE LOAD ON RING | CIRCUMFER.LINE LOAD ON RING | VERTICAL LINE LOAD ON RING | MERIDIONAL LINE MOMENT ON RING |
|---|---|---|---|---|
| 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 5.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 8.5000E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 9.0000E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 9.5000E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 1.7500E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 1.8000E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 1.8500E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 2.6500E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 2.7000E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 2.7500E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |

FOR EVEN AND ODD DISTRIBUTIONS OF LINE LOAD ABOUT THE ORIGIN

OF THE CIRCUMFERENTIAL COORDINATE, theta, BIGBOSOR4 REQUIRES
INPUT DATA ONLY IN THE RANGE: 0.0.LE.theta.LE.180. DEGREES.
ALSO, IT IS BEST TO SUPPLY THE CIRCUMFERENTIAL DISTRIBUTION
OF LINE LOAD AS NORMALIZED, THAT IS, WITH THE PEAK LINE LOAD
EQUAL TO UNITY AND THE ENTIRE DISTRIBUTION MULTIPLIED BY THE
ACTUAL VALUE OF THE PEAK LINE LOAD. THE FOLLOWING LIST
PRESENTS THE CIRCUMFERENTIAL DISTRIBUTION OF SPRING LOADS AT
THIS "FAKE" RING IN THIS MANNER.

IN BIGBOSOR4 THERE IS A RULE THAT THE CIRCUMFERENTIAL
DISTRIBUTIONS OF RADIAL LINE LOAD, H, AXIAL LINE LOAD, V, AND
MERIDIONAL LINE MOMENT, M, MUST BE THE SAME. THEREFORE, WE
TRY TO ARRANGE THE SIGNS OF THE LINE LOAD FACTORS SO THAT
THIS IS TRUE FOR THIS CASE. IF ANY CIRCUMFERENTIAL DISTRIBU-
TION CONSISTS ENTIRELY OF ZEROES, THAT DOES N0T COUNT.
IN THE BIGBOSOR4 INPUT YOU SIMPLY INDICATE THAT THERE IS NO
LINE LOAD OF THAT PARTICULAR TYPE. THE CIRCUMFERENTIAL
DISTRIBUTION OF THE CIRCUMFERENTIALLY ORIENTED LINE LOAD, S,
CAN BE DIFFERENT FROM THAT FOR H, V, AND M. NOTE: IF YOU HAVE
MORE THAN ONE RING WITH SPRINGS ATTACHED, MAKE SURE THAT IF
THE SPRINGS ARE ARRANGED DIFFERENTLY ON THE TWO RINGS THAT
EACH OF THE RINGS IS LOCATED IN A DIFFERENT SHELL SEGMENT.

QUANTITIES RELATED TO SPRINGS ATTACHED TO RING NO.  1 (LOAD SYSTEM "A")

| | RADIAL LOAD FACTOR | CIRC.LOAD FACTOR | VERT.LOAD FACTOR | MOMENT LOAD FACTOR |
|---|---|---|---|---|
| | 1.0000E-07 | 1.0000E-07 | 1.0000E-07 | 1.0000E-07 |

| CIRCUMFERENTIAL COORDINATE | RADIAL LINE LOAD ON RING | CIRCUMFER.LINE LOAD ON RING | VERTICAL LINE LOAD ON RING | MERIDIONAL LINE MOMENT ON RING |
|---|---|---|---|---|
| 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 5.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 8.5000E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 9.0000E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 9.5000E+01 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 1.7500E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| 1.8000E+02 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |

------------------------------------------------------------------------

Note that most of the sping-related output is a bunch of zeroes. This is
because the spring constants, SPRKON(i), i = 1,8, are set equal to zero
in the input file for the second BIGBOSOR4 case, cylspr2.ALL.

********** IMPORTANT NOTE ************* IMPORTANT NOTE ***************
The number of circumferential waves starts at -2 and goes to -60 in
steps of -1 . (Negative wave numbers correspond to V, H, and M line
loads being even with respect to the circumferential coordinate, THETA).
We leave out n = 0 and n = -1 because these harmonics were accounted for
in the first BIGBOSOR4 case, cylspr1.
********************************************************************

One of the main reasons we wanted to run
this second case, cylspr2, is to obtain ADDITIONAL shell wall displacement
components, u, v, w, that represent the displacements that occur at the
ring-end of each spring that are generated because the cylindrical shell
is flexible and therefore deforms under the concentrated spring reaction
loads. These ADDITIONAL displacements, not accounted for in the first
BIGBOSOR4 case, cylspr1, are now used to compute additional changes
in length, dL(i), of the springs. The additional lengths, dL(i), i=1,8,
are used in the computation of "effective" spring constants for each spring.

The "effective" spring constants are less than the original spring constants,
SPRKON(i), i = 1,8, because each original spring effectively acts in series
with a second spring: the flexible shell. The "effective" spring stiffnesses
of the flexible-shell-spring combination may be different for each spring
because the additional change in length, dL(i), may be different for each
spring and the spring forces listed in the output from the first BIGBOSOR4
execution, cylspr1.OUT, are all different.

For two springs in series, the "effective" spring constant of the combination
can be shown to be given by:

K(effective) = 1/[1/K(shell) + 1/K(spring)]

in which K(spring), the original spring constant, is equal to SPRKON(i),
and K(shell) is given by:

K(shell) =
    ABS{[ith spring force, SPRFCE(i)]/[ith additional change in length, dL(i)]}

where the index, i, is the number of the spring attached at the "fake"
ring. The quantities, SPRFCE(i), are listed in the output from the first case,
cylspr1.OUT, as follows:

| SPRING NO. | SPRANG(i) CIRC. ANGLE OF ATTACHMENT POINT ON RING | SPRING LENGTH, L | CHANGE IN LENGTH, dL | SPRKON(i) SPRING CONSTANT | SPRFCE(i) SPRING FORCE |
|---|---|---|---|---|---|
| 1 | 0.0000E+00 | 1.0811E+02 | -4.1491E+00 | 1.0000E+05 | -4.1491E+05 |
| 2 | 0.0000E+00 | 1.0811E+02 | -4.1491E+00 | 1.0000E+05 | -4.1491E+05 |
| 3 | 9.0000E+01 | 1.0811E+02 | -2.3729E-01 | 1.0000E+05 | -2.3729E+04 |
| 4 | 9.0000E+01 | 1.0811E+02 | 2.3729E-01 | 1.0000E+05 | 2.3729E+04 |
| 5 | 1.8000E+02 | 1.0811E+02 | 4.1491E+00 | 1.0000E+05 | 4.1491E+05 |
| 6 | 1.8000E+02 | 1.0811E+02 | 4.1491E+00 | 1.0000E+05 | 4.1491E+05 |
| 7 | 2.7000E+02 | 1.0811E+02 | 2.3729E-01 | 1.0000E+05 | 2.3729E+04 |
| 8 | 2.7000E+02 | 1.0811E+02 | -2.3729E-01 | 1.0000E+05 | -2.3729E+04 |

The additional changes in length, dL(i), are listed in the output from
the second case, cylspr2.OUT, as follows:

|  | SPRANG(i) |  |  | SPRKON(i) | SPRFCE(i) |
|---|---|---|---|---|---|

| SPRING<br>NO. | CIRC. ANGLE<br>OF ATTACHMENT<br>POINT ON RING | SPRING<br>LENGTH, L | CHANGE IN<br>LENGTH, dL | SPRING<br>CONSTANT | SPRING<br>FORCE |
|---|---|---|---|---|---|
| 1 | 0.0000E+00 | 1.0811E+02 | 1.6679E+00 | 0.0000E+00 | 0.0000E+00 |
| 2 | 0.0000E+00 | 1.0811E+02 | 1.6679E+00 | 0.0000E+00 | 0.0000E+00 |
| 3 | 9.0000E+01 | 1.0811E+02 | 5.6020E+00 | 0.0000E+00 | 0.0000E+00 |
| 4 | 9.0000E+01 | 1.0811E+02 | -5.6020E+00 | 0.0000E+00 | 0.0000E+00 |
| 5 | 1.8000E+02 | 1.0811E+02 | -1.6679E+00 | 0.0000E+00 | 0.0000E+00 |
| 6 | 1.8000E+02 | 1.0811E+02 | -1.6679E+00 | 0.0000E+00 | 0.0000E+00 |
| 7 | 2.7000E+02 | 1.0811E+02 | -5.6020E+00 | 0.0000E+00 | 0.0000E+00 |
| 8 | 2.7000E+02 | 1.0811E+02 | 5.6020E+00 | 0.0000E+00 | 0.0000E+00 |

We are permitted to use the spring force SPRFCE(i) from the first case, cylspr1, because the ith set of two springs act in series. Therefore, the spring force in the second spring (the one that represents the flexible shell) is the same as the spring force from the first case, cylspr1.

Computing the "effective" spring constants as outlined above, we obtain the following values:

71327.0, 71327.0, 4063.0, 4063.0, 71327.0, 71327.0, 4063.0, 4063.0

Note that all eight of the original values are the same and equal to 100000.

We see that in this case the original spring constants are considerably reduced by the flexibility of the shell.