Table 27 **2005 modifications to BIGBOSOR4** to compute maximum stress in a stringer or isogrid member and minimum local buckling load factors for skin and smeared stiffeners. For the purposes of computing maximum stress and minimum buckling load in an isogrid member the isogrid is modeled as a stringer, that is, a stiffener that runs in the meridional coordinate direction. For the purpose of modeling the stiffness of the shell wall, that is, the computation of the 6 x 6 integrated constitutive matrix, C_{ij}, the isogrid is modeled as an isotropic shell wall layer with Poisson ratio equal to 1/3 and modulus equal to the actual material modulus multiplied by the isogrid stiffener wall thickness divided by the isogrid member spacing, which is taken to be the altitude of the equilateral triangle formed by adjacent three sets of isogrid stiffening members.

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bigbosor4 was modified to permit computation of the following additional behaviors:

a. Local buckling of the small triangular piece of skin of a shell when that skin is stiffened by an isogrid. The small triangular piece of skin is assumed to be flat.

b. Buckling of a stiffener in a model in which the set of like stiffeners (stringers or isogrid or rings) is smeared out in the BIGBOSOR4 model.

c. Maximum stress in a stiffener in a manner analogous to **b**

For each shell segment BIGBOSOR4 now computes the minimum skin buckling load factor, the minimum stiffener buckling load factor, and the maximum effective stress in a smeared stiffener.

NOTE: BIGBOSOR4 does this ONLY FOR AXISYMMETRICALLY LOADED SHELLS: (Analysis types, INDIC = -2, -1, 0, 1, 2). The smeared stiffeners (stringers, rings, isogrid) MUST HAVE RECTANGULAR CROSS SECTIONS.

The new output (for an externally pressurized isogrid-stiffened torispherical head, for example) in the *.OUT file appears as follows:

```
 ISEG,ISOGRD(IS)=    1    1
 Segment no.1 Minimum skin buckling load factor,BUCMIN(IS)=  2.4114E+01
 Segment no.1 Minimum isogrid member buckling load factor,
                                                 BUCMNS(IS)=  9.8306E-01
 Segment no.1 Maximum stringer (or isogrid member) stress,
                                                 STFMXS(IS)=  2.0268E+05
 ISEG,ISOGRD(IS)=    2    1
 Segment no.2 Minimum skin buckling load factor,BUCMIN(IS)=  8.2028E+00
 Segment no.2 Minimum isogrid member buckling load factor,
                                                 BUCMNS(IS)=  3.0349E-01
 Segment no.2 Maximum stringer (or isogrid member) stress,
                                                 STFMXS(IS)=  4.2003E+05
```

```
Minimum local skin buckling load factor      BUCSKN=  8.2028E+00
Minimum local stiffener buckling load factor BUCSTF=  3.0349E-01
Maximum local stiffener stress               STRSTF=  4.2003E+05
```

This modification was implemented by adding new code to SUBROUTINES **WALLCF**, **CFB1**, and **PLOCAL**, as follows:

```
C=DECK      WALLCF                (Integrated constitutive matrix,
(lines skipped to save space)    Cij, i=1,6, j=1,6 computed here)
```

```
C=DECK      CFB1                  (smeared stiffener stiffness is
C                                  added to the shell skin stiffness)
     STFPRP(1,1,I) = T1 (stringer or isogrid stiffener thickness)
     STFPRP(2,1,I) = H1 (stringer or isogrid stiffener height)
     STFPRP(3,1,I) = D1 (stringer or isogrid stiffener spacing)
     STFPRP(4,1,I) = E1 (stringer or isogrid stiffener modulus)
C
     STFPRP(1,2,I) = T2 (  ring   or isogrid stiffener thickness)
     STFPRP(2,2,I) = H2 (  ring   or isogrid stiffener height)
     STFPRP(3,2,I) = D2 (  ring   or isogrid stiffener spacing)
     STFPRP(4,2,I) = E2 (  ring   or isogrid stiffener modulus)
C
     CSKIN(1,1,I) = C11 (CSKIN = 6 x 6 Cij for shell skin) (I=nodal pt.)
(lines skipped to save space)
C
     IF (ISOGRD(ISEGMT).EQ.0) THEN        (ISOGRD = 1 for isogrid
(lines skipped to save space)                                stiffening)
     ELSE                           (isogrid branch of "IF" follows)
        EEFF = E1*T1/D1             (EEFF = "effective" modulus)
        FNUEFF = 0.3                (Poisson's ratio)
        FNUDEN = 1. - FNUEFF**2
        C11ISO = EEFF*H1/FNUDEN     (CijISO = added wall stiffness from
        C12ISO = FNUEFF*C11ISO                the isogrid stiffeners)
        C22ISO = C11ISO
        C33ISO = EEFF*H1/(2.*(1.+FNUEFF))
        C44ISO = EEFF*H1**3/(12.*FNUDEN)
        C55ISO = C44ISO
        C45ISO = FNUEFF*C44ISO
        C66ISO = C33ISO*H1**2/12.
        SMPA = SMPA + 3.0*STIFMD*A1/D1 + RGMD*A2/D2  (wall mass/area)
        IF (K1.EQ.1) DSHIFT = -(H1/2. + TD - Z)      (internal stiff.)
        IF (K1.EQ.0) DSHIFT = H1/2. + Z              (external stiff.)
        C11 = C11 + C11ISO                (Cij = wall stiffness with
        C22 = C22 + C22ISO                       smeared isogrid)
        C12 = C12 + C12ISO
        C33 = C33 + C33ISO
        C14 = C14 + DSHIFT*C11ISO
        C15 = C15 + DSHIFT*C12ISO
```

```
        C24 = C24 + DSHIFT*C12ISO
        C25 = C25 + DSHIFT*C22ISO
        C36 = C36 - DSHIFT*C33ISO
        C44 = C44 + C44ISO + DSHIFT*DSHIFT*C11ISO
        C45 = C45 + C45ISO + DSHIFT*DSHIFT*C12ISO
        C55 = C55 + C55ISO + DSHIFT*DSHIFT*C22ISO
        C66 = C66 + C66ISO + DSHIFT*DSHIFT*C33ISO
       ENDIF
C END SEP 2005
     RETURN
     END

------------------------------------------------------------------
C=DECK      PLOCAL              (local skin and stiffener stress
(lines skipped to save space)  and buckling load factors are computed
C BEG SEP 2005                 for axisymmetrically deformed shell)
C new stuff when there are smeared stiffeners...
     IF (I.EQ.1.AND.(ISTSMR(1,IS).NE.0.OR.ISTSMR(2,IS).NE.0)) THEN
        BUCMIN(IS) = 10.E+16      (IS = segment no.; I = nodal pt.)
        BUCMNS(IS) = 10.E+16
        BUCMNR(IS) = 10.E+16
        STFMXS(IS) = 0.
        STFMXR(IS) = 0.
        CALL GASP(STFPRP,800,3,ISTFPR(IS)) (retrieve stiffener
                                            properties and shell skin
        CALL GASP(CSKIN,3600,3,ICSKIN(IS))  stiffnesses)
     ENDIF
C
     IF (I.EQ.1) CALL MOVER(0.,0,FNSKIN,1,200)
     IF (ISTSMR(1,IS).NE.0.OR.ISTSMR(2,IS).NE.0) THEN (IS=segment no.)
C      N1SKIN, N2SKIN are meridional, hoop resultants in the skin...
C      I=nodal point number; EPS1, EPS2, K1, K2 = reference surface
C      meridional and circumferential strains and curvature changes.
        N1SKIN = CSKIN(1,1,I)*EPS1 + CSKIN(1,2,I)*EPS2
    1           +CSKIN(1,4,I)*K1   + CSKIN(1,5,I)*K2
        N2SKIN = CSKIN(1,2,I)*EPS1 + CSKIN(2,2,I)*EPS2
    1           +CSKIN(2,4,I)*K1   + CSKIN(2,5,I)*K2
        FNSKIN(1,I) = N1SKIN
        FNSKIN(2,I) = N2SKIN
        IF (I.EQ.I5.AND.IFIX.EQ.0) CALL GASP(FNSKIN,200,1,INSKIN(1,IS))
        IF (I.EQ.I5.AND.IFIX.EQ.1) CALL GASP(FNSKIN,200,1,INSKIN(2,IS))
C
        STRSTR = 0.
        STRRNG = 0.
        BUCLOD = 10.E+16
        BUCSTR = 10.E+16
        BUCRNG = 10.E+16
C
        IF (ISOGRD(IS).EQ.1.AND.(N1SKIN.LT.0.0.OR.N2SKIN.LT.0.0)) THEN
```

```
C
C  Following section is for buckling of shell skin between isogrid.
C  Get buckling load factor for flat equilateral triangular piece of
C  skin. Formula is from NACA TN-3781, July 1957 by Gerard & Becker,
C  "Handbook of Structural Stability, Part I - Buckling of Flat Plates".
C  Formula is for buckling of equilateral flat plate with
C          N1SKIN = N2SKIN (compression).
C  NOTE: result is approximate here because in general N1SKIN is not
C  equal to N2SKIN, and in general the skin is not isotropic.
C
           FCOEF = 5.0
           SIDE = STFPRP(3,1,I)*2./SQRT(3.) (SIDE=length of side of
           PI = 3.1415927                    isogrid equilateral triangle)
C      The critical buckling resultant is NSCRIT.
C                                          BUCLOD = buckling load factor:
           NSCRIT = FCOEF*PI**2*CSKIN(4,4,I)/SIDE**2
           NSMAX  = MIN(N1SKIN,N2SKIN)
           BUCLOD = NSCRIT/ABS(NSMAX)
           BUCMIN(IS) = MIN(BUCMIN(IS),BUCLOD)
(lines skipped to save space)
         ENDIF
C
C  STRSTR = maximum stress in a (smeared) stringer
C           or isogrid member..
C  BUCMNS = minimum buckling load factor in (smeared) stringer
C           or isogrid member
C  INTEXT(1,IS) = 0 means internal stiffener; 1 means external stif.)
C
         IF (ISTSMR(1,IS).EQ.1.AND.IRECT(1,IS).EQ.1) THEN
            IF (INTEXT(1,IS).EQ.0) ZTIP = -(STFPRP(2,1,I) + Z(I))
            IF (INTEXT(1,IS).EQ.1) ZTIP = STFPRP(2,1,I) + T(I) - Z(I)
            STRTIP = STFPRP(4,1,I)*(EPS1 - ZTIP*K1)  (stress at tip
                                                        of stiff.)
C  Critical buckling load of stiffener. Use formulas from ROARK:
C  FORMULAS FOR STRESS AND STRAIN, 3rd Edition, McGraw-Hill, 1954,
C  Table XVI, p. 312, Formulas 4 (s.s.,free) and 5 (clamped,free).
C  Roark gives: SIGCR = k*[ESTIFF/(1-NUSTIF**2)]*(TSTIFF/HEIGHT)**2
C  in which k is a coefficient that depends on the aspect ratio of the
C  plate (stiffener), For long, uniformly axially compressed plates:
C  a. k= 0.375 if the plate is s.s.( MDC G4295, 4.1.7)
C  b. k= 1.1 if the plate is clamped,free (Roark, Table XVI, Formula 5)
C
           EDGSTF = 0.5
           NUSTIF = 0.3
           SIGCR = (0.375+0.7*EDGSTF)*(STFPRP(4,1,I)/(1.-NUSTIF**2))*
     1                                (STFPRP(1,1,I)/STFPRP(2,1,I))**2
           IF (STRTIP.LT.0.0) THEN
              BUCSTR = SIGCR/ABS(STRTIP)
              BUCMNS(IS) = MIN(BUCMNS(IS),BUCSTR)
```

```
           ENDIF
C  INTEXT(1,IS) = 0 means internal stiffener; 1 means external stif.)
           IF (INTEXT(1,IS).EQ.0) ZROOT = -Z(I)
           IF (INTEXT(1,IS).EQ.1) ZROOT =  T(I) - Z(I)
           STRROT = STFPRP(4,1,I)*(EPS1 - ZROOT*K1)
           STRSTR = MAX(ABS(STRTIP),ABS(STRROT))
           STFMXS(IS) = MAX(STFMXS(IS),STRSTR)  (maximum stress in
(lines skipped to save space)                      shell segment IS)
         ENDIF
C
C      STRRNG = maximum stress in a (smeared) ring...
C      BUCMNR = minimum buckling load factor in (smearee) ring
         IF (ISTSMR(2,IS).EQ.1.AND.IRECT(2,IS).EQ.1) THEN
           IF (INTEXT(2,IS).EQ.0) ZTIP = -(STFPRP(2,2,I) + Z(I))
           IF (INTEXT(2,IS).EQ.1) ZTIP = STFPRP(2,2,I) + T(I) - Z(I)
           STRTIP = STFPRP(4,2,I)*(EPS2 - ZTIP*K2)
C
C  Critical buckling load of stiffener. Use formulas from ROARK:
C  FORMULAS FOR STRESS AND STRAIN, 3rd Edition, McGraw-Hill, 1954,
C  Table XVI, p. 312, Formulas 4 (s.s.,free) and 5 (clamped,free).
C  Roark gives: SIGCR = k*[ESTIFF/(1-NUSTIF**2)]*(TSTIFF/HEIGHT)**2
C  in which k is a coefficient that depends on the aspect ratio of the
C  plate (stiffener), For long, uniformly axially compressed plates:
C  a. k= 0.375 if the plate is s.s.( MDC G4295, 4.1.7)
C  b. k= 1.1 if the plate is clamped,free (Roark, Table XVI, Formula 5)
C
           EDGSTF = 0.5
           NUSTIF = 0.3
           SIGCR = (0.375+0.7*EDGSTF)*(STFPRP(4,2,I)/(1.-NUSTIF**2))*
     1                                 (STFPRP(1,2,I)/STFPRP(2,2,I))**2
           IF (STRTIP.LT.0.0) THEN
              BUCRNG = SIGCR/ABS(STRTIP)
              BUCMNR(IS) = MIN(BUCMNR(IS),BUCRNG)
           ENDIF
           IF (INTEXT(2,IS).EQ.0) ZROOT = -Z(I)
           IF (INTEXT(2,IS).EQ.1) ZROOT =  T(I) - Z(I)
           STRROT = STFPRP(4,2,I)*(EPS2 - ZROOT*K2)
           STRRNG = MAX(ABS(STRTIP),ABS(STRROT))
           STFMXR(IS) = MAX(STFMXR(IS),STRRNG)
(lines skipped to save space)
         ENDIF
       ENDIF
C END SEP 2005
=====================================================================
```