Appendix B: ANSYS® Life Prediction Code

```
! 4-pt loading at 40 ft span: Fatigue Life Prediction for Compression Failure Mode
!
finish
/clear
*CFOPEN, fatigue_output,txt
*VLEN,1
*vwrite,'cycles','Fa(unis)','Fr(unis)','wmax'
(1x,a8,2x,a8,2x,a8,2x,a8,2x,a8)
*cfclos
/FILNAME,DWB,1
resume,DWB_taper_global_LP_stresses_new,db
eplot,all
!
*DIM,flangethick,ARRAY,57
*DIM,subflangethick,ARRAY,57
*DIM,matl,ARRAY,57
*DIM,real,ARRAY,57
*DIM,angle,ARRAY,57
*DIM,ztop,ARRAY,57
*DIM,zbot,ARRAY,57
*dim,ex,array,3
*dim,ey,array,3
*dim,ez,array,3
*dim,prxy,array,3
*dim,pryz,array,3
*dim,prxz,array,3
*dim,gxy,array,3
*dim,gyz,array,3
*dim,gxz,array,3
*dim,alphax,array,3
*dim,alphay,array,3
*dim,alphaz,array,3
*dim,exzone,array,10,4,2
*dim,eyzone,array,10,4,2
*dim,ezzone,array,10,4,2
*dim,prxyzone,array,10,4,2
*dim,pryzzone,array,10,4,2
*dim,prxzzone,array,10,4,2
*dim,gxyzone,array,10,4,2
*dim,gyzzone,array,10,4,2
*dim,gxzzone,array,10,4,2
*dim,alphaxzone,array,10,4,2
```

```
*dim,alphayzone,array,10,4,2
*dim,alphazzone,array,10,4,2
*dim,zoneelems,array,50,10,4
*dim,firstply,array,4
*dim,secondply,array,4
*dim,faglobal,array,10,4,2
*dim,numzoneelems,array,10,4
*dim,fibertype,array,4,2
*dim,x1t,array,3
*dim,x2t,array,3
*dim,x1c,array,3
*dim,x2c,array,3
*dim,x12s,array,3
*dim,x23s,array,3
*dim,x3,array,3
*dim,x13,array,3
*dim,x23,array,3
*dim,nodenum,array,50
*dim,yloc,array,50
*dim,sz,array,50
*dim,sxz,array,50
*dim,syz,array,50
*dim,famatrixct,array,10
*dim,famatrixshear,array,10
*dim,fatempcheck,array,10
! Adjust the dimension of the following arrays if more than 25 cycles are expected:
*dim,faglassunis,array,25
*dim,facarbonunis,array,25
*dim,Frcarbonunis,array,25
*dim,s1check,array,50
*dim,cyclearray,array,25
*dim,eeff,array,25
*dim,wmax,array,25
*dim,plystatus,array,10,4,2
!
! Laminate 1 = top flange, sublam 1, Laminate 2 = top flange, sublam 2, Laminate 3 =
bottom flange, sublam 2, Laminate 4 = bottom subflange
firstply(1)=1,1,2,3
secondply(1)=1,1,17,4
! fibertype(laminate,ply#): 1 = carbon, 2 = glass, 3 = CSM
fibertype(1,1)=1,2,2,2
fibertype(1,2)=1,2,2,3
!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!! INPUT !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
! INITIAL MATERIAL PROPERTIES:
```

!
! Unidirectional carbon fiber:
ex(1)=16.71E+06
ey(1)=1.11E+06
ez(1)=1.11E+06
prxy(1)=0.2136
pryz(1)=0.3015
prxz(1)=0.21360
gxy(1)=0.45E+06
gyz(1)=0.43E+06
gxz(1)=0.45E+06
alphax(1)=-0.44E-07
alphay(1)=0.14575E-04
alphaz(1)=0.14575E-04
!
! unidirectional glass fiber:
ex(2)=4.98E+06
ey(2)=1.08E+06
ez(2)=1.08E+06
prxy(2)=0.2306
pryz(2)=0.254
prxz(2)=0.2306
gxy(2)=0.45E+06
gyz(2)=0.43E+06
gxz(2)=0.45E+06
alphax(2)=0.42686E-05
alphay(2)=0.183008E-04
alphaz(2)=0.183008E-04
!
! CSM glass fiber mat:
ex(3)=1.47E+06
ey(3)=1.47E+06
ez(3)=1.47E+06
prxy(3)=0.2804
pryz(3)=0.2804
prxz(3)=0.2804
gxy(3)=0.58e+6
gyz(3)=0.58e+6
gxz(3)=0.58e+6
alphax(3)=0.1045670E-04
alphay(3)=0.1045670E-04
alphaz(3)=0.1045670E-04
!
!
! MATERIAL STRENGTH PARAMETERS FOR USE IN HASHIN AND QUADRATIC FAILURE CRITERIA:

```
!
! unidirectional carbon/vinyl ester, Vf = 55%:
X1c(1)=-75.146e3
X12s(1)=6e3
X3(1)=168
X13(1)=4670
X23(1)=4670
!
! unidirectional glass/vinyl ester, Vf = 45%:
X1c(2)=-130e3
X12s(2)=7.9437e3
X2t(2)=5.973e3
X3(2)=265
X13(2)=5430
X23(2)=5430
!
! CSM glass/vinyl ester, Vf = 25% (could degrade CSM plies if strength values were
known)
X1t(3)=
X2t(3)=
X12s(3)=
!
!
!!!!!!!!!!!!!!!!!!!!!!!!!! PREPROCESSING !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
! Initialize material property arrays:
!
*do,i,1,10                          ! iterate through zones
        *do,j,3,4                   ! iterate through laminates
                *do,k,1,2           ! iterate through plies: 1 = 90 deg, 2 = +-45/CSM
                                    !                        (depends on lam #)
                        *if,k,eq,1,then             ! (90 plies in flange, sublam 2)
                                exzone(i,j,k)=ex(2)
                                eyzone(i,j,k)=ey(2)
                                ezzone(i,j,k)=ez(2)
                                gxyzone(i,j,k)=gxy(2)
                                gyzzone(i,j,k)=gyz(2)
                                gxzzone(i,j,k)=gxz(2)
                                prxyzone(i,j,k)=prxy(2)
                                pryzzone(i,j,k)=pryz(2)
                                prxzzone(i,j,k)=prxz(2)
                                alphaxzone(i,j,k)=alphax(2)
                                alphayzone(i,j,k)=alphay(2)
                                alphazzone(i,j,k)=alphaz(2)
                        *elseif,k,eq,2,and,j,eq,3           ! 45 plies in flange, sublam 2
                                exzone(i,j,k)=ex(2)
```

```
                    eyzone(i,j,k)=ey(2)
                    ezzone(i,j,k)=ez(2)
                    gxyzone(i,j,k)=gxy(2)
                    gyzzone(i,j,k)=gyz(2)
                    gxzzone(i,j,k)=gxz(2)
                    prxyzone(i,j,k)=prxy(2)
                    pryzzone(i,j,k)=pryz(2)
                    prxzzone(i,j,k)=prxz(2)
                    alphaxzone(i,j,k)=alphax(2)
                    alphayzone(i,j,k)=alphay(2)
                    alphazzone(i,j,k)=alphaz(2)

                *elseif,k,eq,2,and,j,eq,3          ! CSM plies in subflange
                    exzone(i,j,k)=ex(3)
                    eyzone(i,j,k)=ey(3)
                    ezzone(i,j,k)=ez(3)
                    gxyzone(i,j,k)=gxy(3)
                    gyzzone(i,j,k)=gyz(3)
                    gxzzone(i,j,k)=gxz(3)
                    prxyzone(i,j,k)=prxy(3)
                    pryzzone(i,j,k)=pryz(3)
                    prxzzone(i,j,k)=prxz(3)
                    alphaxzone(i,j,k)=alphax(3)
                    alphayzone(i,j,k)=alphay(3)
                    alphazzone(i,j,k)=alphaz(3)
                *endif
            *enddo
        *enddo
*enddo
!
!
! ASSIGN INITIAL MATERIAL PROPERTIES:
! all walls except BOTTOM FLANGE/SUBLAM 2 & BOTTOM SUBFLANGE:
/prep7
MPTEMP
MPTEMP,1,,
MPDATA,EX,1,1,ex(1),
MPTEMP
MPTEMP,1,,
MPDATA,EY,1,1,ey(1),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,1,1,ez(1),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,1,1,gxy(1),
```

```
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,1,1,gyz(1),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,1,1,gxz(1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,1,1,alphax(1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,1,1,alphay(1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,1,1,alphaz(1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,1,1,prxy(1),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,1,1,pryz(1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,1,1,prxz(1),
!
MPTEMP
MPTEMP,1,,
MPDATA,EX,2,1,ex(2),
MPTEMP
MPTEMP,1,,
MPDATA,EY,2,1,ey(2),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,2,1,ez(2),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,2,1,gxy(2),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,2,1,gyz(2),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,2,1,gxz(2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,2,1,alphax(2),
```

```
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,2,1,alphay(2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,2,1,alphaz(2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,2,1,prxy(2),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,2,1,pryz(2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,2,1,prxz(2),
!
MPTEMP
MPTEMP,1,,
MPDATA,EX,3,1,ex(3),
MPTEMP
MPTEMP,1,,
MPDATA,EY,3,1,ey(3),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,3,1,ez(3),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,3,1,gxy(3),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,3,1,gyz(3),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,3,1,gxz(3),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,3,1,alphax(3),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,3,1,alphay(3),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,3,1,alphaz(3),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,3,1,prxy(3),
```

```
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,3,1,pryz(3),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,3,1,prxz(3),
!
MPTEMP
MPTEMP,1,,
MPDATA,EX,4,1,0.2900000E+08,
MPTEMP
MPTEMP,1,,
MPDATA,NUXY,4,1,0.2946430E+00,
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,4,1,0.6500000E-05,
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,4,1,0.2946430E+00,
!
MPTEMP
MPTEMP,1,,
MPDATA,EX,5,1,0.1500000E+03,
MPTEMP
MPTEMP,1,,
MPDATA,NUXY,5,1,0.4999000E+00,
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,5,1,0.9000000E-04,
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,5,1,0.4999000E+00,
!
MPTEMP
MPTEMP,1,,
MPDATA,EX,6,1,0.2657100E+04,
MPTEMP
MPTEMP,1,,
MPDATA,NUXY,6,1,0.3046180E+00,
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,6,1,0.1173230E-04,
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,6,1,0.3046180E+00,
!
```

```
MPTEMP
MPTEMP,1,,
MPDATA,EX,7,1,0.2657100E+07,
MPTEMP
MPTEMP,1,,
MPDATA,NUXY,7,1,0.2614174E+00,
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,7,1,0.7857240E-05,
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,7,1,0.2614174E+00,
!
!
! Assign material properies to bottom flangesublam 2 and bottom subflange in each zone:
!
*do,m,1,9                ! iterate through zones
!
! BOTTOM FLANGE, SUBLAM 2 (UNIFORM ACROSS ALL ZONES INITIALLY)
!
! 90 DEGREE GLASS:
MPTEMP
MPTEMP,1,,
MPDATA,EX,90+m,1,exzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,EY,90+m,1,eyzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,90+m,1,ezzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,90+m,1,gxyzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,90+m,1,gyzzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,90+m,1,gxzzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,90+m,1,alphaxzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,90+m,1,alphayzone(m,3,1),
MPTEMP
```

```
MPTEMP,1,,
MPDATA,ALPZ,90+m,1,alphazzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,90+m,1,prxyzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,90+m,1,pryzzone(m,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,90+m,1,prxzzone(m,3,1),
!
!+-45 DEGREE GLASS:
MPTEMP
MPTEMP,1,,
MPDATA,EX,80+m,1,exzone(m,3,2)
MPTEMP
MPTEMP,1,,
MPDATA,EY,80+m,1,eyzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,80+m,1,ezzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,80+m,1,gxyzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,80+m,1,gyzzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,80+m,1,gxzzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,80+m,1,alphaxzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,80+m,1,alphayzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,80+m,1,alphazzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,80+m,1,prxyzone(m,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,80+m,1,pryzzone(m,3,2),
```

```
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,80+m,1,prxzzone(m,3,2),

!
! BOTTOM SUBFLANGE (UNIFORM ACROSS ALL ZONES INITIALLY)
! 90 DEGREE GLASS:
MPTEMP
MPTEMP,1,,
MPDATA,EX,100+m,1,exzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,EY,100+m,1,eyzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,100+m,1,ezzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,100+m,1,gxyzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,100+m,1,gyzzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,100+m,1,gxzzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,100+m,1,alphaxzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,100+m,1,alphayzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,100+m,1,alphazzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,100+m,1,prxyzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,100+m,1,pryzzone(m,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,100+m,1,prxzzone(m,4,1),
!
! CSM GLASS PLIES:
MPTEMP
```

```
MPTEMP,1,,
MPDATA,EX,110+m,1,exzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,EY,110+m,1,eyzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,110+m,1,ezzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,110+m,1,gxyzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,110+m,1,gyzzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,110+m,1,gxzzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,110+m,1,alphaxzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,110+m,1,alphayzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,110+m,1,alphazzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,110+m,1,prxyzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,110+m,1,pryzzone(m,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,110+m,1,prxzzone(m,4,2),
*enddo
!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Repeat for 10th zone:
! BOTTOM FLANGE, SUBLAM 2 (UNIFORM ACROSS ALL ZONES INITIALLY)
!
! 90 DEGREE GLASS:
MPTEMP
MPTEMP,1,,
MPDATA,EX,90,1,exzone(10,3,1),
MPTEMP
```

```
MPTEMP,1,,
MPDATA,EY,90,1,eyzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,90,1,ezzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,90,1,gxyzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,90,1,gyzzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,90,1,gxzzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,90,1,alphaxzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,90,1,alphayzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,90,1,alphazzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,90,1,prxyzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,90,1,pryzzone(10,3,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,90,1,prxzzone(10,3,1),
!
!+-45 DEGREE GLASS:
MPTEMP
MPTEMP,1,,
MPDATA,EX,80,1,exzone(10,3,2)
MPTEMP
MPTEMP,1,,
MPDATA,EY,80,1,eyzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,80,1,ezzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,80,1,gxyzone(10,3,2),
```

```
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,80,1,gyzzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,80,1,gxzzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,80,1,alphaxzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,80,1,alphayzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,80,1,alphazzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,80,1,prxyzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,80,1,pryzzone(10,3,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,80,1,prxzzone(10,3,2),

!
! BOTTOM SUBFLANGE (UNIFORM ACROSS ALL ZONES INITIALLY)
! 90 DEGREE GLASS:
MPTEMP
MPTEMP,1,,
MPDATA,EX,100,1,exzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,EY,100,1,eyzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,100,1,ezzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,100,1,gxyzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,100,1,gyzzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,100,1,gxzzone(10,4,1),
```

```
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,100,1,alphaxzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,100,1,alphayzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,ALPZ,100,1,alphazzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,100,1,prxyzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,100,1,pryzzone(10,4,1),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,100,1,prxzzone (10,4,1),
!
! CSM GLASS PLIES:
MPTEMP
MPTEMP,1,,
MPDATA,EX,110,1,exzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,EY,110,1,eyzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,EZ,110,1,ezzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,GXY,110,1,gxyzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,GYZ,110,1,gyzzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,GXZ,110,1,gxzzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPX,110,1,alphaxzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,ALPY,110,1,alphayzone(10,4,2),
MPTEMP
MPTEMP,1,,
```

```
MPDATA,ALPZ,110,1,alphazzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXY,110,1,prxyzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRYZ,110,1,pryzzone(10,4,2),
MPTEMP
MPTEMP,1,,
MPDATA,PRXZ,110,1,prxzzone(10,4,2),
!
!
! Input ply thickness for BOTTOM FLANGE SUBLAM 2 & BOTTOM SUBFLANGE:
!
! The ply thicknesses for the bottom subflange 2 are:
flangethick(38)=0.0178223684210526,0.0178223684210526,0.0169736842105263
flangethick(41)=0.0166907894736842,0.0166907894736842,0.0166907894736842,0.016
6907894736842,0.0178223684210526,0.0178223684210526,0.0169736842105263,0.017
8223684210526,0.0178223684210526,0.0169736842105263
flangethick(51)=0.0166907894736842,0.0166907894736842,0.0166907894736842,0.016
6907894736842,0.0178223684210526,0.0178223684210526,0.0169736842105263
!
! The ply thicknesses for the bottom subflange are:
subflangethick(1)=0.019,0.018,0.018,0.027,0.018,0.018,0.027,0.019,0.019,0.027
subflangethick(11)=0.018,0.018,0.027,0.018,0.018,0.019
!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
! INITIALIZE REAL CONSTANTS IN EACH ZONE:
!
*do,m,1,9
! Bottom flange sublaminate (2):
        R,80+m,20,0,0,0,0
        RMORE,0,0,0,0,0,0
        RMORE,2,0,flangethick(38),90+m,90,flangethick(39)
        RMORE,3,0,flangethick(40),80+m,-45,flangethick(41)
        RMORE,80+m,45,flangethick(42),80+m,-45,flangethick(43)
        RMORE,80+m,45,flangethick(44),2,0,flangethick(45)
        RMORE,90+m,90,flangethick(46),3,0,flangethick(47)
        RMORE,2,0,flangethick(48),90+m,90,flangethick(49)
        RMORE,3,0,flangethick(50),80+m,-45,flangethick(51)
        RMORE,80+m,45,flangethick(52),80+m,-45,flangethick(53)
        RMORE,80+m,45,flangethick(54),2,0,flangethick(55)
        RMORE,90+m,90,flangethick(56),3,0,flangethick(57)
!
! Bottom subflange:
```

```
        R,90+m,16,0,0,0,0
        RMORE,0,0,0,0,0,0
        RMORE,90+m,0,subflangethick(1),2,0,subflangethick(2)
        RMORE,90+m,90,subflangethick(3),90+m,0,subflangethick(4)
        RMORE,2,0,subflangethick(5),90+m,90,subflangethick(6)
        RMORE,90+m,0,subflangethick(7),90+m,0,subflangethick(8)
        RMORE,90+m,0,subflangethick(9),90+m,0,subflangethick(10)
        RMORE,90+m,90,subflangethick(11),2,0,subflangethick(12)
        RMORE,90+m,0,subflangethick(13),90+m,90,subflangethick(14)
        RMORE,2,0,subflangethick(15),90+m,0,subflangethick(16)
*enddo
!
! Repeat for 10th zone:
!
! Bottom flange sublaminate (2):
        R,80,20,0,0,0,0
        RMORE,0,0,0,0,0,0
        RMORE,2,0,flangethick(38),90,90,flangethick(39)
        RMORE,3,0,flangethick(40),80,-45,flangethick(41)
        RMORE,80,45,flangethick(42),80,-45,flangethick(43)
        RMORE,80,45,flangethick(44),2,0,flangethick(45)
        RMORE,90,90,flangethick(46),3,0,flangethick(47)
        RMORE,2,0,flangethick(48),90,90,flangethick(49)
        RMORE,3,0,flangethick(50),80,-45,flangethick(51)
        RMORE,80,45,flangethick(52),80,-45,flangethick(53)
        RMORE,80,45,flangethick(54),2,0,flangethick(55)
        RMORE,90,90,flangethick(56),3,0,flangethick(57)
!
! Bottom subflange:
        R,90,16,0,0,0,0
        RMORE,0,0,0,0,0,0
        RMORE,90,0,subflangethick(1),2,0,subflangethick(2)
        RMORE,90,90,subflangethick(3),90,0,subflangethick(4)
        RMORE,2,0,subflangethick(5),90,90,subflangethick(6)
        RMORE,90,0,subflangethick(7),90,0,subflangethick(8)
        RMORE,90,0,subflangethick(9),90,0,subflangethick(10)
        RMORE,90,90,subflangethick(11),2,0,subflangethick(12)
        RMORE,90,0,subflangethick(13),90,90,subflangethick(14)
        RMORE,2,0,subflangethick(15),90,0,subflangethick(16)
!
!
! SPECIFY ELEMENTS TO USE AS CRITICAL ELEMENTS AND FOR
DETERMINING FA IN TENSILE PLIES:
! (I used subscripts 3 and 4 instead of 8 and 9 for the sublam 2 and subflange since a 3-D
! array over 7 cannot be viewed in this version of ANSYS.  Furthermore, having only 4
! planes will require less memory than 9.)
```

```
!
! bottom flange, sublam2:
numzoneelems(1,3)=10,5,5,5,5,5,5,5,6,48
zoneelems(1,1,3)=4977,4978,4979,4980,4981,4982,4983,4984,4985,4986
zoneelems(1,2,3)=4987,4988,4989,4990,4991
zoneelems(1,3,3)=4992,4993,4994,4995,4996
zoneelems(1,4,3)=4997,4998,4999,5000,5001
zoneelems(1,5,3)=5002,5003,5004,5005,5006
zoneelems(1,6,3)=5007,5008,5009,5010,5011
zoneelems(1,7,3)=5012,5013,5014,5015,5016
zoneelems(1,8,3)=5017,5018,5019,5020,5021
zoneelems(1,9,3)=5022,5023,5024,5025,5026,8897
zoneelems(1,10,3)=4855,4856,4857,4858,4859,4860,4861,4862,4863,4864
zoneelems(11,10,3)=4865,4866,4867,4868,4869,4870,4871,4872,4873,4874
zoneelems(21,10,3)=4875,4876,5771,5772,5773,5774,5775,5776,5777,5778
zoneelems(31,10,3)=5779,7071,7072,7073,7074,7075,7076,7077,7078,7079
zoneelems(41,10,3)=8898,8899,8900,8901,8902,8903,8904,8905
!
! bottom subflange:
numzoneelems(1,4)=10,5,5,5,5,5,5,5,6,48
zoneelems(1,1,4)=8065,8069,8073,8077,8081,8085,8089,8093,8097,8101
zoneelems(1,2,4)=8105,8109,8113,8117,8121
zoneelems(1,3,4)=8125,8129,8133,8137,8141
zoneelems(1,4,4)=8145,8149,8153,8157,8161
zoneelems(1,5,4)=8165,8169,8173,8177,8181
zoneelems(1,6,4)=8185,8189,8193,8197,8201
zoneelems(1,7,4)=8205,8209,8213,8217,8221
zoneelems(1,8,4)=8225,8229,8233,8237,8241
zoneelems(1,9,4)=8245,8249,8253,8257,8261,9133
zoneelems(1,10,4)=6007,6011,6015,6019,6023,6027,6031,6035,6039,6673
zoneelems(11,10,4)=6677,6681,6685,6689,6693,6697,6701,6705,6709,6713
zoneelems(21,10,4)=6717,6721,6725,6729,6733,6737,6741,6745,6749,6753
zoneelems(31,10,4)=6757,7306,7310,7314,7318,7322,7326,7330,7334,7338
zoneelems(41,10,4)=9137,9141,9145,9149,9153,9157,9161,9165
!
! top flange, sublam 1 (zone 10 only):
numzoneelems(10,1)=48
zoneelems(1,10,1)=4306,4309,4312,4315,4318,4321,4324,4327,4330,4333
zoneelems(11,10,1)=4336,4339,4342,4345,4348,4351,4354,4357,4360,4363
zoneelems(21,10,1)=4366,4369,9773,9776,9779,9782,9785,9788,9791,9794
zoneelems(31,10,1)=9797,11608,11611,11614,11617,11620,11623,11626,11629,11632
zoneelems(41,10,1)=11701,11704,11707,11710,11713,11716,11719,11722
!
! top flange, sublam 2 (zone 10 only):
numzoneelems(10,2)=48
zoneelems(1,10,2)=9619,9622,9625,9628,9631,9634,9637,9640,11810,11813
```

```
zoneelems(11,10,2)=11816,11819,11822,11825,11828,11831,11834,11837,11840,11843
zoneelems(21,10,2)=11846,11849,11852,11855,11858,11861,11864,11867,11870,11873
zoneelems(31,10,2)=12229,12232,12235,12238,12241,12244,12247,12250,12253,12409
zoneelems(41,10,2)=12412,12415,12418,12421,12424,12427,12430,12433,
!
finish
parsav,all
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
! START FATIGUE LOOP HERE:
!
failstatus=0            ! 0 = not failed, 1 = failed
load=60000              ! applied load per actuator (lbs)
La=13.5*12              ! shear span in inches (from end of beam to middle of load patch)
deltaT=75-280           ! temperature change from stress-free state
maxcount=12             ! number of cycle increments
!
! Input cycle increments to perform calculations at:
!cyclearray(1)=1,500,1000,5000,1e4,1e5,2e5,5e5,1e6,2e6,4e6,4.3e6          ! 30 kips
cyclearray(1)=1,10,100,200,500,1000,2000,5000,1e4,2e4,32000,32120      ! 60 kips
!
! Initialize remaining strengths parameters:
frsum1=0
frsum2=0
Frcarbonunis(1)=1
! Guess life to be used in stiffness reductions:
Nfassumed=32120
!
! Begin cycle iterations:
*do,n,1,maxcount
cycle=cyclearray(n)

*if,n,eq,1,then
        deltacycles=1
*else
        deltacycles=cyclearray(n)-cyclearray(n-1)
*endif
parsav,all
!
!!!!!!!!!!!!!!!!!!!!! STRESS ANALYSIS !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
!******************  GLOBAL MODEL ****************************
*if,n,gt,1,then
        resume,DWB_taper_global_LP_stresses_new,db
!       eplot,all
```

```
        parres,new
! initialize faglobal to avoid summing old values
!       *dim,faglobal,array,10,4,2
        *do,i,1,10
                *do,j,1,4
                        *do,k,1,2
                                faglobal(i,j,k)=0.0
                        *enddo
                *enddo
        *enddo
*endif
!
! Update material models in preprocessor:
!
/prep7
        *do,i,1,9                                       !iterate through each zone
! bottom flange, sublam 2, 90 deg ply:
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EX,90+i,1,exzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EY,90+i,1,eyzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EZ,90+i,1,ezzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXY,90+i,1,gxyzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GYZ,90+i,1,gyzzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXZ,90+i,1,gxzzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPX,90+i,1,alphaxzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPY,90+i,1,alphayzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPZ,90+i,1,alphazzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
```

```
                                MPDATA,PRXY,90+i,1,prxyzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRYZ,90+i,1,pryzzone(i,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXZ,90+i,1,prxzzone(i,3,1),
!
! bottom flange, sublam 2, 45 deg ply:
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EX,80+i,1,exzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EY,80+i,1,eyzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EZ,80+i,1,ezzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXY,80+i,1,gxyzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GYZ,80+i,1,gyzzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXZ,80+i,1,gxzzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPX,80+i,1,alphaxzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPY,80+i,1,alphayzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPZ,80+i,1,alphazzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXY,80+i,1,prxyzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRYZ,80+i,1,pryzzone(i,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXZ,80+i,1,prxzzone(i,3,2),
!
```

```
! subflange, 90 deg ply:
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,EX,100+i,1,exzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,EY,100+i,1,eyzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,EZ,100+i,1,ezzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,GXY,100+i,1,gxyzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,GYZ,100+i,1,gyzzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,GXZ,100+i,1,gxzzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,ALPX,100+i,1,alphaxzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,ALPY,100+i,1,alphayzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,ALPZ,100+i,1,alphazzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,PRXY,100+i,1,prxyzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,PRYZ,100+i,1,pryzzone(i,4,1),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,PRXZ,100+i,1,prxzzone(i,4,1),
!
! subflange, CSM ply:
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,EX,110+i,1,exzone(i,4,2),
                        MPTEMP
                        MPTEMP,1,,
                        MPDATA,EY,110+i,1,eyzone(i,4,2),
                        MPTEMP
```

```
                                MPTEMP,1,,
                                MPDATA,EZ,110+i,1,ezzone(i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXY,110+i,1,gxyzone(i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GYZ,110+i,1,gyzzone(i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXZ,110+i,1,gxzzone (i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPX,110+i,1,alphaxzone(i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPY,1100+i,1,alphayzone(i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPZ,110+i,1,alphazzone(i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXY,110+i,1,prxyzone(i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRYZ,110+i,1,pryzzone(i,4,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXZ,110+i,1,prxzzone(i,4,2),
        *enddo
!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Repeat for 10th zone:
! bottom flange, sublam 2, 90 deg ply:
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EX,90,1,exzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EY,90,1,eyzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EZ,90,1,ezzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXY,90,1,gxyzone(10,3,1),
```

```
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GYZ,90,1,gyzzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXZ,90,1,gxzzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPX,90,1,alphaxzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPY,90,1,alphayzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPZ,90,1,alphazzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXY,90,1,prxyzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRYZ,90,1,pryzzone(10,3,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXZ,90,1,prxzzone(10,3,1),
!
! bottom flange, sublam 2, 45 deg ply:
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EX,80,1,exzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EY,80,1,eyzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EZ,80,1,ezzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXY,80,1,gxyzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GYZ,80,1,gyzzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXZ,80,1,gxzzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
```

```
                                MPDATA,ALPX,80,1,alphaxzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPY,80,1,alphayzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPZ,80,1,alphazzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXY,80,1,prxyzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRYZ,80,1,pryzzone(10,3,2),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,PRXZ,80,1,prxzzone(10,3,2),
!
! subflange, 90 deg ply:
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EX,100,1,exzone(10,4,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EY,100,1,eyzone(10,4,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,EZ,100,1,ezzone(10,4,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXY,100,1,gxyzone(10,4,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GYZ,100,1,gyzzone(10,4,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,GXZ,100,1,gxzzone(10,4,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPX,100,1,alphaxzone(10,4,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPY,100,1,alphayzone(10,4,1),
                                MPTEMP
                                MPTEMP,1,,
                                MPDATA,ALPZ,100,1,alphazzone(10,4,1),
                                MPTEMP
```

```
                    MPTEMP,1,,
                    MPDATA,PRXY,100,1,prxyzone(10,4,1),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,PRYZ,100,1,pryzzone(10,4,1),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,PRXZ,100,1,prxzzone(10,4,1),
!
! subflange, CSM ply:
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,EX,110,1,exzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,EY,110,1,eyzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,EZ,110,1,ezzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,GXY,110,1,gxyzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,GYZ,110,1,gyzzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,GXZ,110,1,gxzzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,ALPX,110,1,alphaxzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,ALPY,1100,1,alphayzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,ALPZ,110,1,alphazzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,PRXY,110,1,prxyzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,PRYZ,110,1,pryzzone(10,4,2),
                    MPTEMP
                    MPTEMP,1,,
                    MPDATA,PRXZ,110,1,prxzzone(10,4,2),
```

```
finish
!
/solu
! Apply pressure loading to plate:
SFA,31,1,press,(load/(18*9))
SFA,146,1,press,(load/(18*9))
SFA,221,1,press,(load/(18*9))
SFA,335,1,press,(load/(18*9))
SFA,350,1,press,(load/(18*9))
SFA,366,1,press,(load/(18*9))
SFA,372,1,press,(load/(18*9))
SFA,410,1,press,(load/(18*9))
SFA,418,1,press,(load/(18*9))
SFA,424,1,press,(load/(18*9))
SFA,431,1,press,(load/(18*9))
SFA,466,1,press,(load/(18*9))
SFA,477,1,press,(load/(18*9))
!
! Apply thermal load:
TREF,280
TUNIF,280+deltaT
solve
*if,n,eq,2,then
!       save,DWB_global_%cycle%,db
*endif
/post1
!
! Calculate max deflection on bottom flange:
esel,s,elem,,4854
layer,1
etable,uzmax,u,z
*get,wmax(n),elem,4854,etab,uzmax
!
!
! Read stresses/strains in top flange, sublam 1 representative 0 degree CARBON ply (#1)
! and in top flange, sublam 2 representative 0 degree GLASS ply (#1)  (ZONE 10 only):
!
! First select only the appropriate elements:
esel,all
esel,s,elem,,zoneelems(1,1,3)
! bottom flange
        *do,i,1,10
                *do,j,3,4
                        *do,m,1,numzoneelems(i,j)
                                esel,a,elem,,zoneelems(m,i,j)
                        *enddo
```

```
                *enddo
        *enddo
!
! top flange
        *do,j,1,2
                *do,m,1,numzoneelems(10,j)
                        esel,a,elem,,zoneelems(m,10,j)
                *enddo
        *enddo
!
RSYS,SOLU  ! (Causes layer results to be output in the local layer coordinate system)
layer,1
etable,s1,s,x                           !Write stresses to ETABLE
etable,s2,s,y
etable,s12,s,xy
famax=0
*do,j,1,2                                       !iterate through each (top flange)
sublaminate
        *do,m,1,numzoneelems(10,j)              !iterate through each element
                *get,s1,elem,zoneelems(m,10,j),etab,s1
                *get,s2,elem,zoneelems(m,10,j),etab,s2
                *get,s12,elem,zoneelems(m,10,j),etab,s12
! Calc fa in each elem: compressive fiber mode:
                fatemp1=(s1/x1c(fibertype(j,1)))**2+(s12/x12s(fibertype(j,1)))**2
! Calc fa in each elem (COMPRESSIVE MATRIX mode):
fatemp2=(s2/(2*X23s(fibertype(j,1))))**2+((x2c(fibertype(j,1))/(2*X23s(fibertype(j,1))))
**2-1)*(s2/abs(X2c(fibertype(j,1))))+(s12/X12s(fibertype(j,1)))**2
                fatemp=SQRT(fatemp1>fatemp2)
!
! For each cycle (n), determine the max fa's for both the carbon and glass layers out of all
! the elements in zone 10:
                *if,j,eq,1,and,fatemp,gt,facarbonunis(n),then
                        facarbonunis(n)=fatemp
                *elseif,j,eq,2,and,fatemp,gt,faglassunis(n)
                        faglassunis(n)=fatemp
                *endif
! Compute Fa of in-plane critical elements and check for compression failure
                *if,facarbon,ge,1,then
                        *MSG,ui,cycle
                        Compression failure of carbon undirectional plies at %8I cycles.
                        failstatus=1
                *elseif,faglass,ge,1,then
                        *MSG,ui,cycle
                        Compression failure of glass unidirectional plies at %8I cycles.
                        failstatus=1
                *endif
```

```
        *enddo
!       *if,failstatus,eq,1,then
!               *exit
!       *endif
*enddo
!
!
! Read stresses/strains in bottom flange, sublam 2 representative 90 plies (#2) and +-45
plies (#17), and
! in bottom subflange representative 90 plies (#3) and CSM plies (#4)
!
!*if,failstatus,ne,1,then
        *do,i,1,10              !iterate through each zone
!iterate through each laminate (3=bot flange, sub 2; 4 = bot subflange):
                *do,j,3,4
!iterate through each ply (1 = 90 degrees, 2 = +-45/CSM , depending on laminate #):
                        *do,k,1,2
                                *if,k,eq,1,then
                                        layer,firstply(j)
                                *else
                                        layer,secondply(j)
                                *endif
                                etable,s1,s,x                   !Write stresses to ETABLE
                                etable,s2,s,y
                                etable,s12,s,xy
                                *do,m,1,numzoneelems(i,j)    !iterate through each element
                                        *get,s1,elem,zoneelems(m,i,j),etab,s1
                                        *get,s2,elem,zoneelems(m,i,j),etab,s2
                                        *get,s12,elem,zoneelems(m,i,j),etab,s12
!
! Apply Hashin's strength criteria for 1) matrix tension and 2) matrix compression:
!
! 1)    fatemp1=(s2/x2t(fibertype(j,k)))**2+(s12/x12s(fibertype(j,k)))**2
! 2)
        fatemp2=(s2/(2*X23s(fibertype(j,k))))**2+((x2c(fibertype(j,1))/(2*X23s(fibertyp
e(j,k))))**2-1)*(s2/X2c(fibertype(j,k)))+(s12/X12s(fibertype(j,k)))**2
!
! Alternately, apply the max stress failure criterion:
!
                                        *if,s2,gt,0,then
                                                fatemp1=s2/x2t(fibertype(j,k))
        ! tensile s2
                                        *elseif,s2,lt,0
                                                fatemp1=s2/x2c(fibertype(j,k))
        ! compressive s2
                                        *endif
```

```
                                        fatemp2=abs(s12/X12s(fibertype(j,k)))
        ! shear
!
                                        fatemp=fatemp1>fatemp2
! if using Hashin:                     faglobal(i,j,k)=faglobal(i,j,k)+sqrt(abs(fatemp))
        ! add up all fa's in a given zone and ply
! if using max stress:
                                        faglobal(i,j,k)=faglobal(i,j,k)+fatemp

                                *enddo
                                faglobal(i,j,k)=faglobal(i,j,k)/numzoneelems(i,j)
        ! calc average fa in the given zone and ply
                                *if,faglobal(i,j,k),ge,1,then
                                        plystatus(i,j,k)=1
        ! check for failure in each ply/zone
                                *endif
!
! For last element in zone, capture each Fa calc:
! (currently set for bottom flange, 90 deg ply)
*if,j,eq,3,and,k,eq,1,then
famatrixct(i)=fatemp1
famatrixshear(i)=fatemp2
fatempcheck(i)=faglobal(i,j,k)
*endif
                        *enddo
                *enddo
        *enddo
!*endif
!
layer,0
finish
parsav,all
!
!!*********************************************************************
!* POST-PROCESSING:
!
! Calculate cycles to failure for top flange unidirectional fiber critical elements:
!
        Ncarbonfail=10**(((Facarbonunis(n)-1.348493)/(-0.32866))**(1/0.593794))
                        ! Verghese (R=-1, full-reversed)
!       Nglassfail=(-1/142.86*log((Faglassunis(n)-0.69202)/(-0.55922)))**(1/(-0.61808))
                ! Phifer (R=0.1, tension-tension)
        Nglassfail=10**((Faglassunis(n)-1)/(-0.1060376214))
                ! Andersen et al. (R=10, compress-compress)
!
! Calculate remaining strength, Fr, in critical elements:
```

```
        *if,n,gt,1,then
                noi=(((1-Frcarbonunis(n-1))/(1-Facarbonunis(n)))**(1/1.2))*Ncarbonfail
                Frcarbonunis(n)=Frcarbonunis(n-1)-(1-
Facarbonunis(n))*(((noi+deltacycles)/Ncarbonfail)**1.2-(noi/Ncarbonfail)**1.2)
! assume glass Fr = 1, for now:
                Frglassunis=1
        *elseif,n,eq,1
                Frcarbonunis(1)=1
                Frglassunis=1
        *endif
!
! Assume that Fr of taper region is same as Frcarbonunis:
        Frtaper=Frcarbonunis
!
! Check for failure in critical elements:
!
        *if,Facarbonunis(n),ge,Frcarbonunis(n),then
                failstatus=1
                failtype='carbon unis'
        *elseif,Faglassunis(n),ge,Frglassunis
                failstatus-1
                failtype='glass unis'
        *endif
!
! Write Fa and Fr for all critical elements to file:
!
*CFOPEN, fatigue_output,txt,,APPEND
*VLEN,1
*vwrite,cycle,Facarbonunis(n),Frcarbonunis(n),wmax(n)
(f8.0,2x,f8.4,2x,f8.4,2x,f16.12)
*cfclos
!
!If any critical elements have failed, stop program:
        *if,failstatus,eq,1,then
                *MSG,ui,failtype,cycle
                Failure of %c at %8I cycles.
                *exit
        *endif
!
!*********************************************************************
! DEGRADE PROPERTIES FOR NEXT CYCLE:
!
        *do,i,1,10                                      !iterate through each zone
                *do,j,3,4                               !iterate through each laminate
                        *do,k,1,2                       !iterate through each ply
                                *if,plystatus(i,j,k),eq,1,then
```

```
! If off-axis plies in laminate 3 or 4 have failed, reduce off-axis properties to negligible
! values (assumes that only matrix damage occurs):
                                    eyzone(i,j,k)=eyzone(i,j,k)*1e-4
                                    ezzone(i,j,k)=ezzone(i,j,k)*1e-4
                                    gxyzone(i,j,k)=gxyzone(i,j,k)*1e-4
                                    gyzzone(i,j,k)=gyzzone(i,j,k)*1e-4
                                    gxzzone(i,j,k)=gxzzone(i,j,k)*1e-4
                                    prxyzone(i,j,k)=prxyzone(i,j,k)*1e-4
                                    pryzzone(i,j,k)=pryzzone(i,j,k)*1e-4
                                    prxzzone(i,j,k)=prxzzone(i,j,k)*1e-4
                                    alphayzone(i,j,k)=alphayzone(i,j,k)*1e-4
                                    alphazzone(i,j,k)=alphazzone(i,j,k)*1e-4
!
! Otherwise, degrade stiffnesses according to Fa:
                            *elseif,plystatus(i,j,k),ne,1
                                    *if,k,eq,1,then                 ! 90 degree plies
                                            Fachoose=0.2622*faglobal(i,j,k)
                                    *elseif,k,eq,2,and,j,eq,3       ! 45 degree plies
                                            Fachoose=0.552417*faglobal(i,j,k)
                                    *elseif,k,eq,2,and,j,eq,4       ! CSM plies
                                            Fachoose=0.803172*faglobal(i,j,k)
                                    *endif
! Calculate reduced Ex, then reduce all props by same percentage:
! (Reductions are based on extrapolations from Nathan Post's data from quasi-isotropic
! laminates containing a core of CSM)
!
                                    E2bar=-1.2386*Fachoose**2-0.2924*Fachoose+1
                                    n1=(8.4157814e-5)*exp(23.552271*Fachoose)
                                    n2=1.52708
                                    m1=0.37
                                    m2=5.6432
                                    Ereduced=(1-E2bar)*exp(-
(cycle/Nfassumed/n1)**m1)+E2bar*exp(-(cycle/Nfassumed/n2)**m2)
                                    redux=ereduced
                                    eyzone(i,j,k)=ey(2)*redux
                                    ezzone(i,j,k)=ez(2)*redux
                                    gxyzone(i,j,k)=gxy(2)*redux
                                    gyzzone(i,j,k)=gyz(2)*redux
                                    gxzzone(i,j,k)=gxz(2)*redux
                                    prxyzone(i,j,k)=prxy(2)*redux
                                    pryzzone(i,j,k)=pryz(2)*redux
                                    prxzzone(i,j,k)=prxz(2)*redux
                                    alphayzone(i,j,k)=alphay(2)*redux
                                    alphazzone(i,j,k)=alphaz(2)*redux
                            *endif
                    *enddo
```

```
          *enddo
     *enddo
!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
! Index the cycle count forward so the new value will be saved in the PARSAV file:
parsav,all,DWB_%cyclearray(n)%,parm
n=n+1
!cycle=cyclearray(n)
!
parsav,all
!parsav,all,DWB_%cyclearray(n-1)%,parm

!
*enddo
!
*if,failstatus,ne,1,then
*MSG,ui
Iterations are complete.
*endif
```