WORKSHOP 8

Objectives:

- Design a structure with strength and buckling limits
- Impose three buckling conditions

  (a) The MSC.Nastran buckling analysis

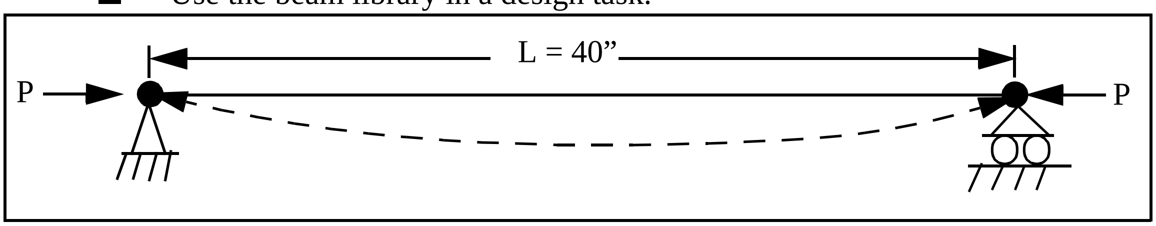
  (b) Euler Buckling Equation Limit

$$\sigma \geq \sigma_{cr}^{Eul} = \frac{-\pi^2 E}{(L'/\rho)^2}$$

  (c) Johnson Short Columns Design Formula

$$\sigma \geq \sigma_{cr}^{John} = -\sigma_{co}\left[1.0 - \frac{\sigma_{co}(L'/\rho)^2}{4\pi^2 E}\right]$$

- Use the beam library in a design task.



For the pinned-pinned condition and a rod cross section type:

L’ = L

$$\rho = \frac{r}{2}$$ (ρ = radius of gyration)

Assume σ_{co} = +80,000. (σ_{co} is an empiracally determined column yield stress)

Model Description:

- Subject to:
  - Static load of -200,000 at grid point 6
  - pins at points 1 and 6
  - Buckling Analysis
- Objective Funcations: Minimize the Weight
- Design variable: Radius of rod
- Constraints:

  Static Case:

  - $-80,000 \leq \sigma \leq 100,000$
  - $\sigma \geq \sigma_{cr}^{EUL}$
  - when $-\sigma > \dfrac{\sigma_{co}}{2}$ *

    $\sigma \geq \sigma_{cr}^{John}$

  Buckling Subcase:

  $$\lambda \geq 1.0$$

*The Johnson Condition is the critical design condition only if the magnitude at the compressive stress is greater than $\sigma_{co}/2$. This can be implemented in MSC.Nastran by multiplying the response by a factor that is the maximum of 0.0 and $(-\sigma - \sigma_{co}/2)$. When the maximum is 0.0, the Johnson condition is ignored.

Generating an input file for MSC.Nastran Users:

1. Generate an input file using the data from pages 8-1 through 8-3. Use the following input file as a starting point.

```
ID MSC, wkshp8a
TIME  130     $
SOL 200       $  OPTIMIZATION
CEND
TITLE    = buckling test case
SUBTITLE = johnson/euler buckling case
ECHO   = SORT
spc    = 100
DESOBJ = 20
SUBCASE 1
   DESSUB = 1
   LABEL  = LOAD CONDITION 1
   LOAD   = 300
   ANALYSIS = STATICS
   DISP   = ALL
   STRESS = ALL
SUBCASE 2
   DESSUB = 2
   ANALYSIS = BUCK
   METHOD    = 1
   DISP      = ALL
   LABEL     = BUCKLING FACTORS
$
BEGIN BULK
param,post,-1
$-----------------------------------------------------------------------
$ ANALYSIS MODEL
$-----------------------------------------------------------------------
$
$ GRID DATA
$       2       3       4       5       6       7       8       9       10
GRDSET                                                  345
grid         1        0.0      0.0    0.0
grid         2        8.0      0.0     0.0
grid         3        16.0     0.0     0.0
grid         4        24.0     0.0     0.0
grid         5        32.0     0.0     0.0
grid         6        40.0     0.0     0.0
grid         10       0.0      0.0     100.0        123456
$
$ ELEMENT AND MATERIAL DATA
cbar         1            10           1            2            10
cbar         2            10           2            3            10
cbar         3            10           3            4            10
cbar         4            10           4            5            10
cbar         5            10           5            6            10
MAT1         1            3.0e7                     0.33         0.1
$ PROPERTY DATA
PbarL   10      1       mscbml0rod
             1.0
$ BOUNDARY CONDITION DATA
spc1         100          1            1
spc1         100          2            1            6
$ EXTERNAL LOADS DATA
FORCE        300          6                         -2.0e5  1.0
```

```
$ BUCKLING ANALYSIS DATA
EIGRL        1            .05                          4
$
$------------------------------------------------------------------------
$ DESIGN MODEL
$------------------------------------------------------------------------
$
$ Beginning of Design Modeling Exercise for the Bulk Data Section
$
     .
     .
     .
$
ENDDATA
```

2. The completed MSC.Nastran input file is shown below:

```
ID MSC, soln8a
TIME  130     $
SOL 200       $  OPTIMIZATION
CEND
TITLE    = buckling test case
SUBTITLE = johnson/euler buckling case
ECHO   = SORT
spc    = 100
DESOBJ = 20
SUBCASE 1
   DESSUB = 1
   LABEL  = LOAD CONDITION 1
   LOAD   = 300
   ANALYSIS = STATICS
   DISP   = ALL
   STRESS = ALL
SUBCASE 2
   DESSUB = 2
   ANALYSIS = BUCK
   METHOD    = 1
   DISP      = ALL
   LABEL     = BUCKLING FACTORS
$
BEGIN BULK
param,post,-1
$-----------------------------------------------------------------------
$ ANALYSIS MODEL
$-----------------------------------------------------------------------
$
$ GRID DATA
$       2       3       4       5       6       7       8       9       10
GRDSET                                                  345
grid  1                 0.0    0.0      0.0
grid  2           8.0   0.0    0.0
grid  3           16.0  0.0    0.0
grid  4           24.0  0.0    0.0
grid  5           32.0  0.0    0.0
grid  6           40.0  0.0    0.0
grid  10          0.0   0.0    100.0      123456
$
$ ELEMENT AND MATERIAL DATA
cbar  1   10     1     2     10
cbar  2   10     2     3     10
cbar  3   10     3     4     10
cbar  4   10     4     5     10
cbar  5   10     5     6     10
MAT1    1   3.0e7           0.33    0.1
$ PROPERTY DATA
PbarL   10      1       mscbml0rod
      1.0
$ BOUNDARY CONDITION DATA
spc1  100  1       1
spc1  100  2       1      6
$ EXTERNAL LOADS DATA
FORCE  300    6               -2.0e5  1.0
$ BUCKLING ANALYSIS DATA
EIGRL   1       .05             4
$
$-----------------------------------------------------------------------
```

```
$ DESIGN MODEL
$------------------------------------------------------------------------
$
DESVAR  1       rg1.0      0.01          10.0
DOPTPRM p2    15      DESMAX  20      DELP    0.5     GMAX    0.01
        CONVDV  0.01    CONVPR  0.02    p1    1
DRESP1  20      W       WEIGHT
DRESP1  23      S1      STRESS  Pbar            7               10
DRESP1  24      S1      STRESS  Pbar            8               10
DRESP1  25      S1      sTRESS  Pbar            6               10
dresp2       31            EUL           31
      DESVAR               1
      DTABLE               L             E
      DRESP1               25
$  EULER CONSTRAINT CONDITION
deqatn       31            rgyra(r,l,e,sigma) = r / 2.0;
                euler = - sigma * ( L / rGYRA ) **2 / (PI(1)**2 * E)
dresp2       32            JOHNSON       32
      DESVAR               1
      DTABLE               L     E       SIGMAC
      DRESP1               25
$
$ JOHNSON CONSTRAINT CONDITION THAT IS ONLY ACTIVE WHEN FAC IS NONZERO
$
deqatn       32            LORHO2(r,l,e,SIGMAC,sigma) = (2.0 * L / R ) ** 2;
                fac = max((-sigma - sigmac/2.0), 0.0);
                JOHNSON = - FAC * sigma / ((-sigma - sigmac/2.0) *
                            SIGMAc * ( 1.0 - SIGMAC * LORHO2/
                            (4.0 * PI(1)**2 * E) ) )
DCONSTR      1    23              100000.
dconstr      1    24       -80000.
dconstr      1    31              1.0
dconstr      1    32              1.0
dtable       e    30.0e6          l      40.0    sigmac           8.0e4
DVPREL1      10   pbarl           1012
      1      1.0
$
$  DESIGN FOR BUCKLING EIGENVALUE
DRESP1  1       BUCK1   LAMA                    1
dconstr      2   1       1.0
param  dsnokd     1.0
$
ENDDATA
```

3. Submit the input file to MSC.Nastran for analysis.

   To submit the MSC.Nastran **.dat** file, find an available UNIX shell window and at the command prompt enter **nastran wkshp8 scr=yes**. Monitor the run using the UNIX **ps** command.

4. When the run is completed, edit the **wkshp8.f06** file and search for the word **FATAL**. If no matches exist, search for the word **WARNING**. Determine whether existing WARNING messages indicate modeling errors.

   4a. While still editing **wkshp8.f06**, search for the word:

   H I S T O R Y

Comparison of Results:

5. Compare the results obtained in the **.f06** file with the following:

```
G0                                                                                                                          SUBCASE 2
                                              ***************************************************************
                                              S U M M A R Y   O F   D E S I G N   C Y C L E   H I S T O R Y
                                              ***************************************************************

                                                                 (HARD CONVERGENCE ACHIEVED)

                                                                 (SOFT CONVERGENCE ACHIEVED)

                                                  NUMBER OF FINITE ELEMENT ANALYSES COMPLETED           3
                                                  NUMBER OF OPTIMIZATIONS W.R.T. APPROXIMATE MODELS     2

                                                        OBJECTIVE AND MAXIMUM CONSTRAINT HISTORY
            ---------------------------------------------------------------------------------------------------------------
                                OBJECTIVE FROM            OBJECTIVE FROM          FRACTIONAL ERROR          MAXIMUM VALUE
              CYCLE              APPROXIMATE                  EXACT                      OF                      OF
              NUMBER            OPTIMIZATION                ANALYSIS               APPROXIMATION             CONSTRAINT
            ---------------------------------------------------------------------------------------------------------------

              INITIAL                                     1.256637E+01                                    4.017613E-01

                    1            1.539844E+01             1.539775E+01            4.471775E-05            3.485799E-03

                    2            1.540468E+01             1.540468E+01            1.238162E-07            2.788901E-03
            ---------------------------------------------------------------------------------------------------------------
1    BUCKLING TEST CASE                                                         NOVEMBER  10, 1999  MSC.NASTRAN 10/11/99   PAGE    71
      JOHNSON/EULER BUCKLING CASE
0                                                                                                                        SUBCASE 2
                                                                  DESIGN VARIABLE HISTORY
 -----------------------------------------------------------------------------------------------------------------------------------
  INTERNAL |   EXTERNAL   |              |
   DV. ID. |    DV. ID.   |    LABEL     |   INITIAL    :      1       :      2       :      3       :      4       :      5       :
 -----------------------------------------------------------------------------------------------------------------------------------
         1 |          1   |  RG          |   1.0000E+00 :   1.1069E+00 :   1.1072E+00 :
 *** USER INFORMATION MESSAGE 6464 (DOM12E)
     RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER =        2.
```

6. Use the output produced by DOPTPRM parameter p2 = 15 to determine the critical desgn case in the **.f06** file, search for **FINAL**. Then search again for **DESIGN CONSTRAINTS**. This will lead to a table like:

----- DESIGN CONSTRAINTS ON RESPONSES -----

(MAXIMUM RESPONSE CONSTRAINTS MARKED WITH **)

INTERNAL ID	DCONSTR ID	INTERNAL RESPONSE ID	RESPONSE TYPE	L/U FLAG	INTERNAL REGION ID	SUBCASE ID	VALUE
1	1	2	STRESS	LOWER	1	1	-3.5085E-01
2	1	3	STRESS	LOWER	1	1	-3.5085E-01
3	1	4	STRESS	LOWER	1	1	-3.5085E-01
4	1	5	STRESS	LOWER	1	1	-3.5085E-01
5	1	6	STRESS	LOWER	1	1	-3.5085E-01
6	1	1	EQUA	UPPER	31	1	-8.4299E-02
7	1	2	EQUA	UPPER	31	1	-8.4299E-02
8	1	3	EQUA	UPPER	31	1	-8.4299E-02
9	1	4	EQUA	UPPER	31	1	-8.4299E-02
10	1	5	EQUA	UPPER	31	1	-8.4299E-02
11	1	6	EQUA	UPPER	32	1	2.7889E-03**
12	1	7	EQUA	UPPER	32	1	2.7889E-03**
13	1	8	EQUA	UPPER	32	1	2.7889E-03**
14	1	9	EQUA	UPPER	32	1	2.7889E-03**
15	1	10	EQUA	UPPER	32	1	2.7889E-03**
16	2	12	LAMA	LOWER	0	2	-8.6330E-02

----- CONSTRAINTS ON DESIGNED PROPERTIES -----

This indicates that five constraints are tied at the maximum value and that they are associated with an EQUA response type and have internal ID’s 6 thru 10.

Search for RETAINED DRESP2. This leads to a table like:

---- RETAINED DRESP2 RESPONSES ----

INTERNAL ID	DRESP2 ID	RESPONSE LABEL	EQUATION ID	LOWER BOUND	VALUE	UPPER BOUND
1	31	EUL	31	N/A	9.1570E-01	1.0000E+00
2	31	EUL	31	N/A	9.1570E-01	1.0000E+00
3	31	EUL	31	N/A	9.1570E-01	1.0000E+00
4	31	EUL	31	N/A	9.1570E-01	1.0000E+00
5	31	EUL	31	N/A	9.1570E-01	1.0000E+00
6	32	JOHNSON	32	N/A	1.0028E+00	1.0000E+00
7	32	JOHNSON	32	N/A	1.0028E+00	1.0000E+00
8	32	JOHNSON	32	N/A	1.0028E+00	1.0000E+00
9	32	JOHNSON	32	N/A	1.0028E+00	1.0000E+00
10	32	JOHNSON	32	N/A	1.0028E+00	1.0000E+00

It is seen that the maximum constraints are associated with the Johnson condition.

7. Repeat the workshop problem with L = 60. How do the answers change and what is the critical design condition?