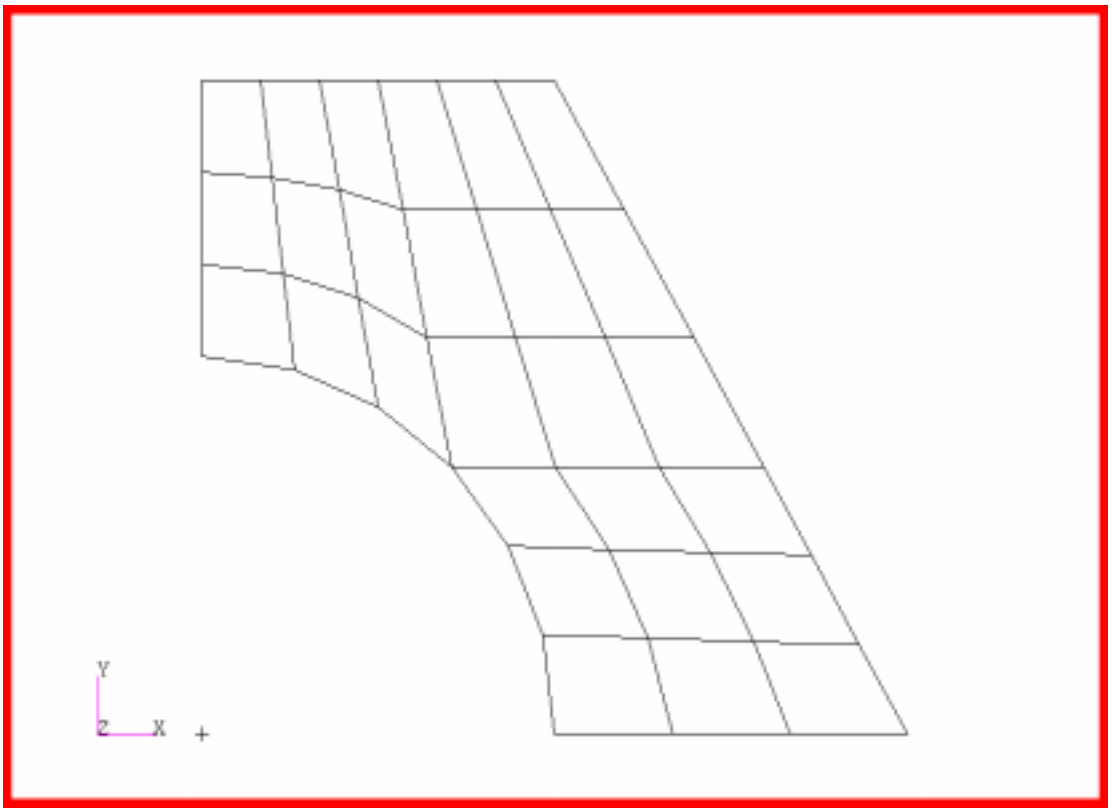
WORKSHOP 6

Objectives:

- Perform shape optimization of the planar culvert model using the analytical boundary shape method. See seminar notes for further detailed description of the model.



Model Description:

- Objective Function: Volume Minimization.
- Constraints: Von Mises Stresses < 31,000 psi

Hints:

1. Create an auxiliary model by putting CBAR elements around he outside edge of the culvert model.
2. For the auxiliary model, fix the right and top edges similar to the direct input of shape method .
3. Apply the appropriate boundary conditions at the left (symmetric b.c.) and bottom edges (fixed b.c.).
4. Apply enforced displacements around the hole by creating seven subcases -- one at each grid point around the hole.
5. Include the proper BNDGRIDs and DVBSHAPs -- one DVBSHAP for each design variable.
6. If a smoother shape is desired, reduce the size of the fractional change in the design variable at the expense of more iterations .

Generating an input file for MSC.Nastran Users:

7. Generate an input file using the data from pages 6-1 through 6-3. Use the following input file as a starting point.

```
$
$    wkshp6.dat
$
nastran q4skew=10.,q4taper=100.
$
$   culvert problem using the analytical boundary shape
$
SOL    200  $
TIME   100
CEND
TITLE=CULVERT EXAMPLE USING EXTERNAL AUXILIARY STRUCTURE
SUBTITLE=THE PRIMARY STRUCTURE
ANALYSIS = STATICS
SPC=25
 LOAD=1
 DISP=ALL
 STRESS=all
$
$  call out objective function
$
  desobj=...
$
$  call out design constraint
$
  dessub=...
$
$  ------------------------------------------------------------
$
$  START OF AUXILIARY MODEL SUBCASE
$
AUXCASE
 AUXMODEL = 1
 TITLE = AUXILIARY MODEL
 DISP=ALL
$
$  add auxiliary model subcases--one for each loading condition
$
SUBCASE..
 LOAD=..
 SPC =..
$
     .
     .
$
BEGIN BULK
$
$  ------------------------------------------------------------
$
$    ANALYTICAL MODEL
$
PARAM,POST,-1
PARAM,CDIF,NO
PARAM,NEWSEQ,-1
GRID,  1,, 3.00000, 0.00000,.00
GRID,  2,, 4.00000, 0.00000,.00
GRID,  3,, 5.00000, 0.00000,.00
GRID,  4,, 6.00000, 0.00000,.00
GRID,  5,, 2.89464, 0.78478,.00
GRID,  6,, 3.79369, 0.75885,.00
GRID,  7,, 4.69274, 0.73293,.00
GRID,  8,, 5.59178, 0.70700,.00
GRID,  9,, 2.60164, 1.49178,.00
GRID, 10,, 3.46229, 1.46585,.00
GRID, 11,, 4.32293, 1.43993,.00
GRID, 12,, 5.18357, 1.41400,.00
GRID, 13,, 0.00000, 3.00000,.00
```

```
GRID, 14,, 0.78478, 2.89464,.00
GRID, 15,, 1.49178, 2.60164,.00
GRID, 16,, 2.12100, 2.12100,.00
GRID, 17,, 3.00578, 2.12100,.00
GRID, 18,, 3.89057, 2.12100,.00
GRID, 19,, 4.77535, 2.12100,.00
GRID, 20,, 0.00000, 3.73200,.00
GRID, 21,, 0.68985, 3.66176,.00
GRID, 22,, 1.32785, 3.46643,.00
GRID, 23,, 1.91400, 3.14600,.00
GRID, 24,, 2.67052, 3.14600,.00
GRID, 25,, 3.42704, 3.14600,.00
GRID, 26,, 4.18357, 3.14600,.00
GRID, 27,, 0.00000, 4.46400,.00
GRID, 28,, 0.59493, 4.42888,.00
GRID, 29,, 1.16393, 4.33122,.00
GRID, 30,, 1.70700, 4.17100,.00
GRID, 31,, 2.33526, 4.17100,.00
GRID, 32,, 2.96352, 4.17100,.00
GRID, 33,, 3.59178, 4.17100,.00
GRID, 34,, 0.00000, 5.19600,.00
GRID, 35,, 0.50000, 5.19600,.00
GRID, 36,, 1.00000, 5.19600,.00
GRID, 37,, 1.50000, 5.19600,.00
GRID, 38,, 2.00000, 5.19600,.00
GRID, 39,, 2.50000, 5.19600,.00
GRID, 40,, 3.00000, 5.19600,.00
CQUAD4,     1,101,     1,     2,     6,     5
CQUAD4,     2,101,     2,     3,     7,     6
CQUAD4,     3,101,     3,     4,     8,     7
CQUAD4,     4,101,     5,     6,    10,     9
CQUAD4,     5,101,     6,     7,    11,    10
CQUAD4,     6,101,     7,     8,    12,    11
CQUAD4,     7,101,     9,    10,    17,    16
CQUAD4,     8,101,    10,    11,    18,    17
CQUAD4,     9,101,    11,    12,    19,    18
CQUAD4,    10,101,    13,    14,    21,    20
CQUAD4,    11,101,    14,    15,    22,    21
CQUAD4,    12,101,    15,    16,    23,    22
CQUAD4,    13,101,    20,    21,    28,    27
CQUAD4,    14,101,    21,    22,    29,    28
CQUAD4,    15,101,    22,    23,    30,    29
CQUAD4,    16,101,    27,    28,    35,    34
CQUAD4,    17,101,    28,    29,    36,    35
CQUAD4,    18,101,    29,    30,    37,    36
CQUAD4,    19,101,    16,    17,    24,    23
CQUAD4,    20,101,    17,    18,    25,    24
CQUAD4,    21,101,    18,    19,    26,    25
CQUAD4,    22,101,    23,    24,    31,    30
CQUAD4,    23,101,    24,    25,    32,    31
CQUAD4,    24,101,    25,    26,    33,    32
CQUAD4,    25,101,    30,    31,    38,    37
CQUAD4,    26,101,    31,    32,    39,    38
CQUAD4,    27,101,    32,    33,    40,    39
FORCE   1       34      0       1250.           -1.
FORCE   1       35      0       2500.           -1.
FORCE   1       36      0       2500.           -1.
FORCE   1       37      0       2500.           -1.
FORCE   1       38      0       2500.           -1.
FORCE   1       39      0       2500.00         -1.
FORCE   1       40      0       1250.           -1.
PSHELL,101,102,.44
MAT1,102,2.+7,,.3,0.731-3
SPC1,25,345,1,THRU,40
SPC1,25,126,1,THRU,4
spc1,25,6,6,7,10,11
spc1,25,6,17,18
spc1,25,6,21,thru,25
spc1,25,6,28,thru,32
SPC1,25,1,13,20,27,34
$
```

```
$-------------------------------------------------------------
$
$   DESIGN MODEL
$
bndgrid,...
       .
       .
$
desvar,....
       .
       .
$
dvbshap,...
       .
       .
$
dresp1  5       volume  volume
dresp1  2       von-mis stress  pshell          9               101
DCONSTR 10      2       -3.100e43.100e4
doptprm DESMAX  25      APRCOD  1
param,nasprt,1
$
BEGIN BULK AUXMODEL = 1
$
$   ----------------------------------------------------------$
$    AUXILIARY MODEL
$
CBAR    1       1       1       2       1.      1.
CBAR    2       1       2       3       1.      1.
CBAR    3       1       3       4       1.      1.
$
CBAR    11      1       4       8       1.      1.
CBAR    12      1       8       12      1.      1.
CBAR    13      1       12      19      1.      1.
CBAR    14      1       19      26      1.      1.
CBAR    15      1       26      33      1.      1.
CBAR    16      1       33      40      1.      1.
$
CBAR    21      1       34      35      1.      1.
CBAR    22      1       35      36      1.      1.
CBAR    23      1       36      37      1.      1.
CBAR    24      1       37      38      1.      1.
CBAR    25      1       38      39      1.      1.
CBAR    26      1       39      40      1.      1.
$
CBAR    31      1       1       5       1.      1.
CBAR    32      1       5       9       1.      1.
CBAR    33      1       9       16      1.      1.
CBAR    34      1       16      15      1.      1.
CBAR    35      1       15      14      1.      1.
CBAR    36      1       14      13      1.      1.
$
CBAR    41      1       13      20      1.      1.
CBAR    42      1       20      27      1.      1.
CBAR    43      1       27      34      1.      1.
$
PBAR    1       102     20.0    1.0     1.0
MAT1,102,2.+7,,.3,0.731-3
$
$   ADD AUXILIARY MODEL LOADING
$   USE ENFORCED DISPLACEMENT
$
      .
      .
      .
$
ENDDATA
```

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

```
$
$    soln6.dat
$
nastran q4skew=10.,q4taper=100.
$
$   culvert problem using the analytical boundary shape
$
SOL    200  $
TIME   100
CEND
TITLE=CULVERT EXAMPLE USING EXTERNAL AUXILIARY STRUCTURE       D200CS
SUBTITLE=THE PRIMARY STRUCTURE
ANALYSIS = STATICS
SPC=25
 LOAD=1
 DISP=ALL
 STRESS=all
 DESSUB = 10
 desobj = 5
$
AUXCASE
 AUXMODEL = 1
 TITLE = AUXILIARY MODEL
$ SPC = 250
 DISP=ALL
$
SUBCASE 1
 LOAD=100
 spc = 100
SUBCASE 2
 LOAD=101
 spc = 101
SUBCASE 3
 LOAD=102
 spc = 102
SUBCASE 4
 LOAD=103
 spc = 103
SUBCASE 5
 LOAD=104
 spc = 104
SUBCASE 6
 LOAD=105
 spc = 105
SUBCASE 7
 LOAD=106
 spc = 106
$
BEGIN BULK
$
$    ANALYTICAL MODEL
$
PARAM,POST,-1
PARAM,CDIF,NO
PARAM,NEWSEQ,-1
GRID,  1,, 3.00000, 0.00000,.00
GRID,  2,, 4.00000, 0.00000,.00
GRID,  3,, 5.00000, 0.00000,.00
GRID,  4,, 6.00000, 0.00000,.00
GRID,  5,, 2.89464, 0.78478,.00
GRID,  6,, 3.79369, 0.75885,.00
GRID,  7,, 4.69274, 0.73293,.00
GRID,  8,, 5.59178, 0.70700,.00
GRID,  9,, 2.60164, 1.49178,.00
GRID, 10,, 3.46229, 1.46585,.00
GRID, 11,, 4.32293, 1.43993,.00
GRID, 12,, 5.18357, 1.41400,.00
GRID, 13,, 0.00000, 3.00000,.00
```

```
GRID, 14,, 0.78478, 2.89464,.00
GRID, 15,, 1.49178, 2.60164,.00
GRID, 16,, 2.12100, 2.12100,.00
GRID, 17,, 3.00578, 2.12100,.00
GRID, 18,, 3.89057, 2.12100,.00
GRID, 19,, 4.77535, 2.12100,.00
GRID, 20,, 0.00000, 3.73200,.00
GRID, 21,, 0.68985, 3.66176,.00
GRID, 22,, 1.32785, 3.46643,.00
GRID, 23,, 1.91400, 3.14600,.00
GRID, 24,, 2.67052, 3.14600,.00
GRID, 25,, 3.42704, 3.14600,.00
GRID, 26,, 4.18357, 3.14600,.00
GRID, 27,, 0.00000, 4.46400,.00
GRID, 28,, 0.59493, 4.42888,.00
GRID, 29,, 1.16393, 4.33122,.00
GRID, 30,, 1.70700, 4.17100,.00
GRID, 31,, 2.33526, 4.17100,.00
GRID, 32,, 2.96352, 4.17100,.00
GRID, 33,, 3.59178, 4.17100,.00
GRID, 34,, 0.00000, 5.19600,.00
GRID, 35,, 0.50000, 5.19600,.00
GRID, 36,, 1.00000, 5.19600,.00
GRID, 37,, 1.50000, 5.19600,.00
GRID, 38,, 2.00000, 5.19600,.00
GRID, 39,, 2.50000, 5.19600,.00
GRID, 40,, 3.00000, 5.19600,.00
CQUAD4,    1,101,    1,    2,    6,    5
CQUAD4,    2,101,    2,    3,    7,    6
CQUAD4,    3,101,    3,    4,    8,    7
CQUAD4,    4,101,    5,    6,   10,    9
CQUAD4,    5,101,    6,    7,   11,   10
CQUAD4,    6,101,    7,    8,   12,   11
CQUAD4,    7,101,    9,   10,   17,   16
CQUAD4,    8,101,   10,   11,   18,   17
CQUAD4,    9,101,   11,   12,   19,   18
CQUAD4,   10,101,   13,   14,   21,   20
CQUAD4,   11,101,   14,   15,   22,   21
CQUAD4,   12,101,   15,   16,   23,   22
CQUAD4,   13,101,   20,   21,   28,   27
CQUAD4,   14,101,   21,   22,   29,   28
CQUAD4,   15,101,   22,   23,   30,   29
CQUAD4,   16,101,   27,   28,   35,   34
CQUAD4,   17,101,   28,   29,   36,   35
CQUAD4,   18,101,   29,   30,   37,   36
CQUAD4,   19,101,   16,   17,   24,   23
CQUAD4,   20,101,   17,   18,   25,   24
CQUAD4,   21,101,   18,   19,   26,   25
CQUAD4,   22,101,   23,   24,   31,   30
CQUAD4,   23,101,   24,   25,   32,   31
CQUAD4,   24,101,   25,   26,   33,   32
CQUAD4,   25,101,   30,   31,   38,   37
CQUAD4,   26,101,   31,   32,   39,   38
CQUAD4,   27,101,   32,   33,   40,   39
FORCE   1       34      0       1250.           -1.
FORCE   1       35      0       2500.           -1.
FORCE   1       36      0       2500.           -1.
FORCE   1       37      0       2500.           -1.
FORCE   1       38      0       2500.           -1.
FORCE   1       39      0       2500.00         -1.
FORCE   1       40      0       1250.           -1.
PSHELL,101,102,.44
MAT1,102,2.+7,,.3,0.731-3
SPC1,25,345,1,THRU,40
SPC1,25,126,1,THRU,4
spc1,25,6,6,7,10,11
spc1,25,6,17,18
spc1,25,6,21,thru,25
spc1,25,6,28,thru,32
SPC1,25,1,13,20,27,34
$
$ design model
$
bndgrid 123456  34      thru    40
```

```
bndgrid 123456  4       8       12      19      26      33
bndgrid 345     1       thru    40
bndgrid 2       2       3
bndgrid 1       20      27
bndgrid 12      1       5       9
bndgrid 12      13      thru    16
$
desvar  1       b1      3.      -1.e6   1.e6
desvar  2       b2      3.      -1.e6   1.e6
desvar  3       b3      3.      -1.e6   1.e6
desvar  4       b4      3.      -1.e6   1.e6
desvar  5       b5      3.      -1.e6   1.e6
desvar  6       b6      3.      -1.e6   1.e6
desvar  7       b7      3.      -1.e6   1.e6
$
dvbshap 1       1       1       .01
dvbshap 2       1       2       .01
dvbshap 3       1       3       .01
dvbshap 4       1       4       .01
dvbshap 5       1       5       .01
dvbshap 6       1       6       .01
dvbshap 7       1       7       .01
$
dresp1  5       volume  volume
dresp1  2       von-mis stress  pshell          9               101
DCONSTR 10      2       -3.100e43.100e4
doptprm DESMAX  25      APRCOD  1
param,nasprt,1
$
BEGIN BULK AUXMODEL = 1
$
CBAR    1       1       1       2       1.      1.
CBAR    2       1       2       3       1.      1.
CBAR    3       1       3       4       1.      1.
$
CBAR    11      1       4       8       1.      1.
CBAR    12      1       8       12      1.      1.
CBAR    13      1       12      19      1.      1.
CBAR    14      1       19      26      1.      1.
CBAR    15      1       26      33      1.      1.
CBAR    16      1       33      40      1.      1.
$
CBAR    21      1       34      35      1.      1.
CBAR    22      1       35      36      1.      1.
CBAR    23      1       36      37      1.      1.
CBAR    24      1       37      38      1.      1.
CBAR    25      1       38      39      1.      1.
CBAR    26      1       39      40      1.      1.
$
CBAR    31      1       1       5       1.      1.
CBAR    32      1       5       9       1.      1.
CBAR    33      1       9       16      1.      1.
CBAR    34      1       16      15      1.      1.
CBAR    35      1       15      14      1.      1.
CBAR    36      1       14      13      1.      1.
$
CBAR    41      1       13      20      1.      1.
CBAR    42      1       20      27      1.      1.
CBAR    43      1       27      34      1.      1.
$
PBAR    1       102     20.0    1.0     1.0
MAT1,102,2.+7,,.3,0.731-3
$
spcadd,100,200,250
spcadd,101,201,250
spcadd,102,202,250
spcadd,103,203,250
spcadd,104,204,250
spcadd,105,205,250
spcadd,106,206,250
$
SPC1,250,345,1,THRU,40
```

```
SPC1,250,123456,34,THRU,40
SPC1,250,123456,4,8,12,19,26,33
SPC1,250,1,13,20,27
SPC1,250,2,1,THRU,4
$
spc,200,13,2
spc,201,14,12
spc,202,15,12
spc,203,16,12
spc,204,9,12
spc,205,5,12
spc,206,1,1
$
spcd,100,13,2,1.
spcd,101,14,1,.259,14,2,.9659
spcd,102,15,1,.5,15,2,.866
spcd,103,16,1,.707,16,2,.707
spcd,104,9,1,.866,9,2,.5
spcd,105,5,1,.9659,5,2,.259
spcd,106,1,1,1.
$
ENDDATA
```

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

   To submit the MSC.Nastran **.dat** file, find an available UNIX shell window and enter **nastran wkshp6 scr=yes** at the command prompt. Monitor the run using the UNIX **ps** command.

10. When the run is completed, edit the **wkshp6.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.

    10a. While still editing **wkshp6.f06**, search for the word:

    H I S T O R Y

Comparison of Results:

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

```
        *****************************************************************
        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           9
            NUMBER OF OPTIMIZATIONS W.R.T. APPROXIMATE MODELS     8
```

OBJECTIVE AND MAXIMUM CONSTRAINT HISTORY

CYCLE NUMBER	OBJECTIVE FROM APPROXIMATE OPTIMIZATION	OBJECTIVE FROM EXACT ANALYSIS	FRACTIONAL ERROR OF APPROXIMATION	MAXIMUM VALUE OF CONSTRAINT
INITIAL		7.214704E+00		-1.390531E-01
1	7.070451E+00	7.068990E+00	2.066814E-04	-8.626418E-02
2	6.809552E+00	6.804862E+00	6.892382E-04	6.404297E-03
3	6.572814E+00	6.570068E+00	4.179721E-04	-1.326991E-03
4	6.158632E+00	6.152329E+00	1.024385E-03	1.462399E-02
5	5.788686E+00	5.796309E+00	-1.315181E-03	7.971597E-02
6	5.799503E+00	5.802665E+00	-5.449061E-04	1.459627E-02
7	5.813872E+00	5.813963E+00	-1.574704E-05	4.446195E-04
8	5.813963E+00	5.813963E+00	0.000000E+00	4.446195E-04

1 AUXILIARY MODEL FEBRUARY 4, 1998 MSC/NASTRAN 7/17/97 PAGE 341

0

DESIGN VARIABLE HISTORY

INTERNAL DV. ID.	EXTERNAL DV. ID.	LABEL	INITIAL	1	2	3	4	5
1	1	B1	3.0000E+00	6.0000E+00	1.2000E+01	2.4000E+01	4.8000E+01	9.2578E+01
2	2	B2	3.0000E+00	6.0000E+00	1.2000E+01	2.4000E+01	4.8000E+01	8.7852E+01
3	3	B3	3.0000E+00	6.0000E+00	1.2000E+01	2.4000E+01	3.5622E+01	0.0000E+00
4	4	B4	3.0000E+00	6.0000E+00	1.2000E+01	4.4726E+00	0.0000E+00	4.3272E-02
5	5	B5	3.0000E+00	6.0000E+00	8.1674E+00	0.0000E+00	-5.0000E-02	-6.3706E-03
6	6	B6	3.0000E+00	6.0000E+00	1.2000E+01	2.4000E+01	2.3699E+01	3.6471E+01
7	7	B7	3.0000E+00	6.0000E+00	1.2000E+01	2.4000E+01	4.7981E+01	8.3955E+01

INTERNAL DV. ID.	EXTERNAL DV. ID.	LABEL	6	7	8	9	10	11
1	1	B1	6.3561E+01	5.8000E+01	5.8000E+01			
2	2	B2	9.8300E+01	9.9934E+01	9.9934E+01			
3	3	B3	3.9013E-03	4.6733E-03	4.6733E-03			
4	4	B4	4.6902E-02	4.7506E-02	4.7506E-02			
5	5	B5	-5.9094E-03	-6.4221E-03	-6.4221E-03			
6	6	B6	3.4061E+01	3.2747E+01	3.2747E+01			
7	7	B7	8.4077E+01	8.4850E+01	8.4850E+01			

X-Y Plots of Design Results:

Figure 6.1 - Objective Function

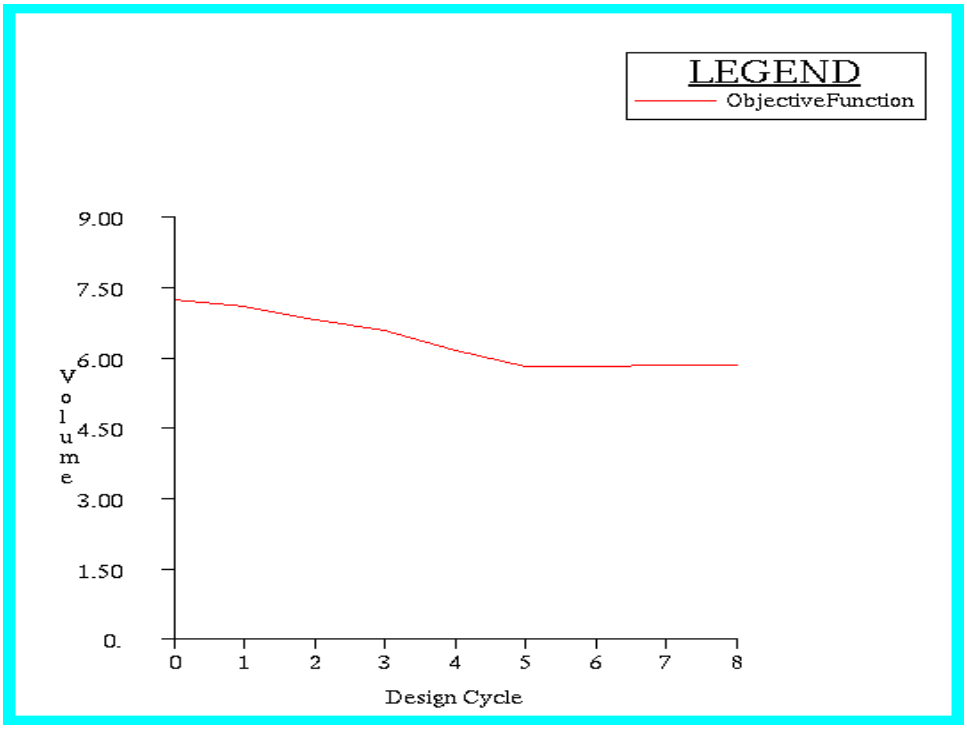


Figure 6.2 - Design Variables

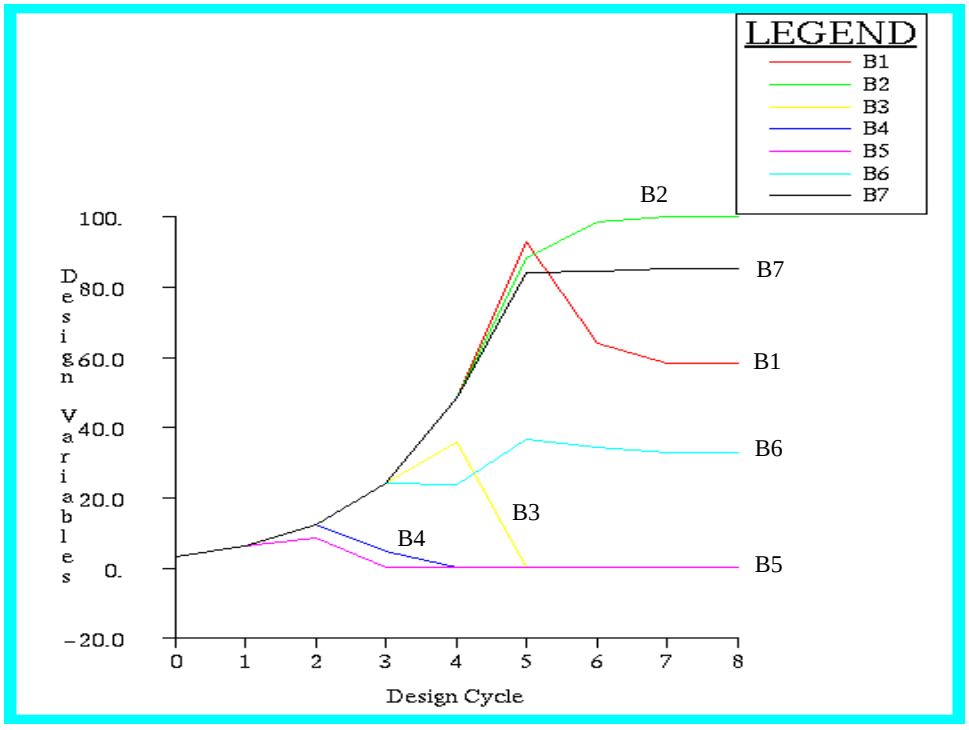


Figure 6.3 - Maximum Constraint