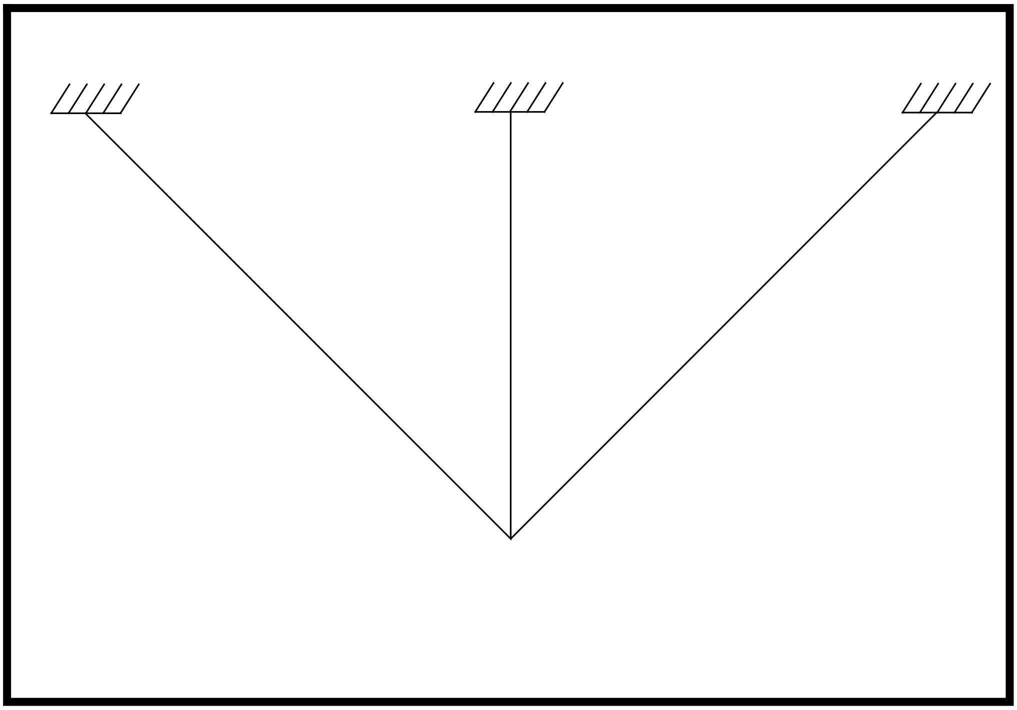
WORKSHOP PROBLEM 15

Weight Minimization of a Three Bar Truss



Objectives:

- Minimize the weight of the truss.
- First mode must be between 1500-1550 Hz.
- Submit the file for analysis in MSC/NASTRAN.
- Recover the desired objective while satisfying the frequency requirement.

Model Description:

You must minimize the weight of the following three bar truss problem. The first mode must be between 1500-1550 hz. The model will have different areas for the inside and outside beams. The structure must remain symetric.

Below is a Geometric representation of the truss. It also contains the loads and boundary constraints.

Figure 15.1-Loads and Boundary Conditions

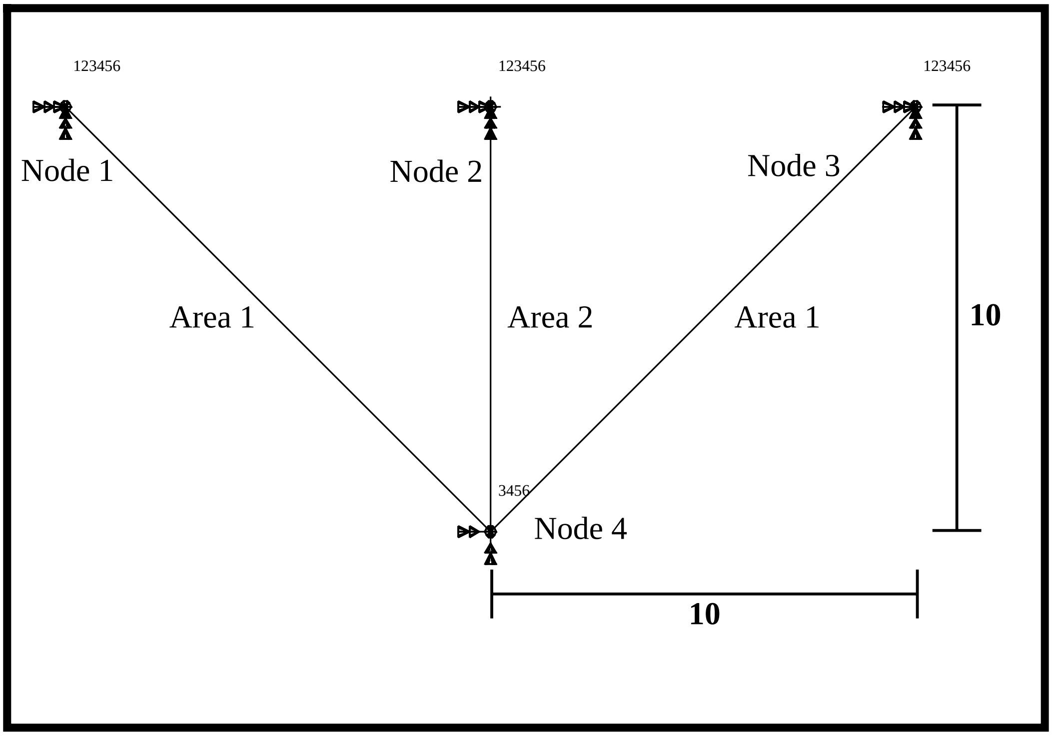


Table 15.1

Elastic Modulus	**10E6**
Poisson's Ratio	**.33**
Density	**.1**
Wt.-Mass Conversion	**.00259**
Area 1	**1.0**
Area 2	**2.0**

Optimization Statement

- **Design Variables**
  - These are the areas of the three rod elements (A1, A2, A3).
- **Objective**
  - Minimize the weight of the truss.
- **Subject to the follow constraints**
  - The first mode must be between 1500-1550 Hz.
  - A1=A3 to impose symmetry.

Suggested Exercise Steps:

- Generate the analysis model. The nodes (GRID) and element connectivities (CROD) should be defined manually.
- Define material (MAT1) and element (PROD) properties.
- Apply fixed boundary constraints (SPC1) to the upper nodes.
- Create the appropriate design optimization model.
- Define the disign variables (DESVAR).
- Relate one design variable to another design variable (DLINK).
- Define design variable to analysis model parameter relations (DVPREL).
- Specify design sensitivity response quantities (DRESP1).
- Define constraints (DCONSTR).
- Define optimization control parameters (DOPTPRM).
- Prepare the model for linear static analysis and normal modes analysis using Lanczos Method.
    - PARAM, WTMASS, 0.00259
- Generate an input file and submit it to MSC/NASTRAN for structural optimization analysis.
- Review the results, specifically the eigenvalues and the design variable history.

ID SEMINAR,PROB5

CEND

BEGIN BULK

1	2	3	4	5	6	7	8	9	10

1	2	3	4	5	6	7	8	9	10

ENDDATA

Generating an input file for MSC/NASTRAN Users:

MSC/NASTRAN users can generate an input file using the data from page 15-3 (Model Description). The result should be similar to the output below.

1. MSC/NASTRAN input file: **prob15.dat**

```
ASSIGN OUTPUT2='prob15.op2', UNIT=12
ID NAS102, WORKSHOP 15
TIME 10
SOL 200            $ OPTIMIZATION
CEND
TITLE= SYMMETRIC THREE BAR TRUSS DESIGN OPTIMIZATION - VARIATION OF D200X1
SUBTITLE= GOAL IS TO MIN WT WHILE KEEPING THE 1ST MODE BETWEEN 1500-1550 HZ
ECHO= SORT
SPC= 100
DISP(PLOT) ALL
DESOBJ(MIN)= 100   $ (DESIGN OBJECTIVE = DRESP ID)
DESSUB= 200        $  DEFINE CONSTRAINT SET FOR BOTH SUBCASES
SUBCASE 1
  ANALYSIS= MODES
  METHOD= 10
BEGIN BULK
$
$-----------------------------------------------------------------------
$ ANALYSIS MODEL
$-----------------------------------------------------------------------
$
EIGRL, 10, , , 2
PARAM, POST, -1
PARAM, PATVER, 3.0
$
$ GRID DATA
$      2        3        4      5       6       7      8       9       10
GRID,   1,       ,      -10.0,    0.0,  0.0
GRID,   2,       ,        0.0,    0.0,  0.0
GRID,   3,       ,       10.0,    0.0,  0.0
GRID,   4,       ,        0.0,  -10.0,  0.0
$ SUPPORT DATA
SPC,    100,    1,      123456,  ,      2,      123456
SPC,    100,    3,      123456,  ,      4,      3456
$ ELEMENT DATA
CROD,   1,      11,     1,       4
CROD,   2,      12,     2,       4
```

```
CROD,   3,      13,     3,       4
$ PROPERTY DATA
PROD,   11,     1,      1.0
PROD,   12,     1,      2.0
PROD,   13,     1,      1.0
MAT1,   1,      1.0E+7, ,       0.33,   0.1
$
PARAM, WTMASS, .00259
$
$-----------------------------------------------------------------------
$ DESIGN MODEL
$-----------------------------------------------------------------------
$
$...DESIGN VARIABLE DEFINITION
$
$DESVAR,ID,     LABEL,  XINIT,  XLB,    XUB,    DELXV(OPTIONAL)
DESVAR, 1,      A1,     1.0,    0.1,    100.0
DESVAR, 2,      A2,     2.0,    0.1,    100.0
DESVAR, 3,      A3,     1.0,    0.1,    100.0
$
$...IMPOSE X3=X1 (LEADS TO A3=A1)
$
$DLINK, ID,     DDVID,  CO,     CMULT,  IDV1,   C1,     IDV2,   C2,     +
$+,     IDV3,   C3,     ...
DLINK,  1,      3,      0.0,    1.0,    1       1.00
$
$...DEFINITION OF DESIGN VARIABLE TO ANALYSIS MODEL PARAMETER RELATIONS
$
$DVPREL1,ID,    TYPE,   PID,    FID,    PMIN,   PMAX,   CO,     ,       +
$+,     DVID1,  COEF1,  DVID2,  COEF2,  ...
DVPREL1, 10,    PROD,   11,     4,      ,       ,       ,       ,       +DP1
+DP1,   1,      1.0
DVPREL1, 20,    PROD,   12,     4,      ,       ,       ,       ,       +DP2
+DP2,   2,      1.0
DVPREL1, 30,    PROD,   13,     4,      ,       ,       ,       ,       +DP3
+DP3,   3,      1.0
$
$...STRUCTURAL RESPONSE INDENTIFICATION
$
$DRESP1 ID      LABEL   RTYPE   PTYPE   REGION  ATTA    ATTB    ATT1    +
$+      ATT2    ...
DRESP1  100     W       WEIGHT
DRESP1  210     MODE1   EIGN                    1
$
$...CONSTRAINTS
```

```
$
$DCONSTR,DCID,  RID,    LALLOW, UALLOW
DCONSTR, 200,   210,    8.883E7, 9.485E7
$
$...OPTIMIZATION CONTROL
$
DOPTPRM, DESMAX, 30
$
$.......2.......3.......4.......5.......6.......7.......8.......9.......0
ENDDATA
```

Submitting the input file for analysis:

2. 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 prob15 scr=yes**. Monitor the run using the UNIX **ps** command.

3. When the run is completed, edit the **prob15.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.

4. While still editing **prob15.f06**, search for the word:

   DESIGN VARIABLE HISTORY

Design Variable	Initial Value	Optimization Value	Iteration Value
1	________	____________	__________
2	________	____________	__________
3	________	____________	__________

Comparison of Results

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

****
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 13
NUMBER OF OPTIMIZATIONS W.R.T. APPROXIMATE MODELS 12

OBJECTIVE AND MAXIMUM CONSTRAINT HISTORY

CYCLE NUMBER	OBJECTIVE FROM APPROXIMATE OPTIMIZATION	OBJECTIVE FROM EXACT ANALYSIS	FRACTIONAL ERROR OF APPROXIMATION	MAXIMUM VALUE OF CONSTRAINT
INITIAL		4.828427E+00	1.922634E-01	
1	4.623621E+00	4.623881E+00	-5.620305E-05	-3.995783E-03
2	3.699294E+00	3.699106E+00	5.104681E-05	-3.995698E-03
3	2.958779E+00	2.959009E+00	-7.783429E-05	-4.092440E-03
4	2.367016E+00	2.367207E+00	-8.087595E-05	-4.092440E-03
5	1.892135E+00	1.892194E+00	-3.087028E-05	-4.955952E-03
6	1.514454E+00	1.514385E+00	4.518410E-05	-4.523099E-03
7	1.210997E+00	1.210911E+00	7.078262E-05	-5.035487E-03
8	9.690463E-01	9.690970E-01	-5.227955E-05	-4.640506E-03
9	7.749816E-01	7.748774E-01	1.344586E-04	-4.126600E-03
10	6.199054E-01	6.199020E-01	5.480649E-06	-4.126516E-03
11	5.758885E-01	5.758446E-01	7.618205E-05	-2.931787E-04
12	5.758446E-01	5.758446E-01	0.000000E+00	-2.931787E-04

DESIGN VARIABLE HISTORY

INTERNAL DV. ID. :	EXTERNAL DV. ID.	LABEL	INITIAL	1	2	3	4	5
1	1	A1	1.0000E+00	8.0000E-01	6.4000E-01	5.1190E-01	4.0952E-01	3.2706E-01
2	2	A1	2.0000E+00	2.3611E+00	1.8889E+00	1.5111E+00	1.2089E+00	9.6712E-01
3	3	A1	1.0000E+00	8.0000E-01	6.4000E-01	5.1190E-01	4.0952E-01	3.2706E-01

INTERNAL DV. ID.	EXTERNAL DV. ID.	LABEL	6	7	8	9	10	11
1	1	A1	2.6187E-01	2.0929E-01	1.6756E-01	1.3405E-01	1.0724E-01	1.0000E-01
2	2	A1	7.7370E-01	6.1896E-01	4.9517E-01	3.9573E-01	3.1659E-01	2.9300E-01
3	3	A1	2.6187E-01	2.0929E-01	1.6756E-01	1.3405E-01	1.0724E-01	1.0000E-01

INTERNAL DV. ID.	EXTERNAL DV. ID.	LABEL	12	13	14	15	16	17
1	1	A1	1.0000E-01					
2	2	A1	2.9300E-01					
3	3	A1	1.0000E-01					