Advanced Dynamic Analysis Using MSC Nastran

NAS102B Workbook

September 2013

MSC Software®
Simulating Reality, Delivering Certainty™

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CONTENTS

Workshop

WORKSHOP 1

Model Checks

- **Workshop Objectives**
  - Edit a sample file to add model check commands
  - Review the f06 file to become familiar with the output
- **Software Version**
  - MSC Nastran 2013
- **Files Required**
  - beam_sol103_10modes_template.bdf
- **Problem Description**
  - Simple bar model

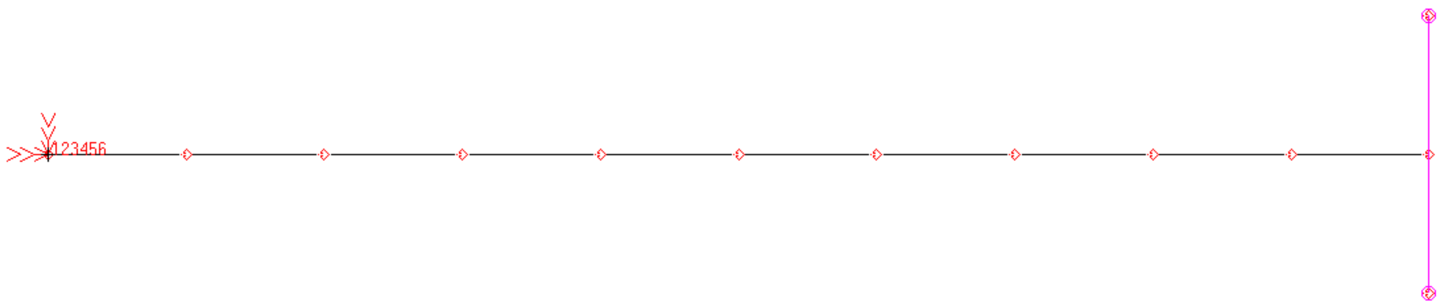
- **Suggested Steps**

1. Copy and edit the template file (beam_sol103_10modes_template.bdf) to add various model checkout commands
   - Grounding Checks
   - Weight Checks
   - Modal Effective Mass
   - Grid Point Kinetic Energy
   - Element Strain Energy

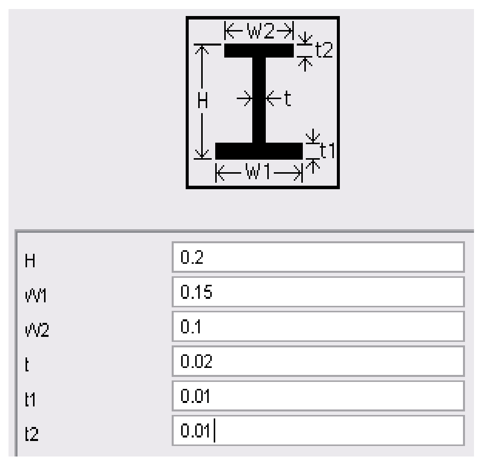
2. Review the output in the f06 file

3. If there is time, try some additional checks
   - Run free-free modes
   - Run to a higher frequency cutoff to see if the total modal mass improves

Model Description



L=10in
E=30E6
Nu=.3
Rho=7.4E-4
cross section as shown



WORKSHOP 2

Complex Eigenvalue Analysis

- **Workshop Objectives**
  - Learn how to set up a complex eigenvalue problem using
    - HESS method
    - CLAN method
  - Learn to perform both the direct and modal methods

- **Software Version**
  - MSC Nastran 2013

- **Files Required**
  - real-eigen.dat

- **Problem Description**
  - Simple bar model with a viscous damper

- **Suggested Steps**

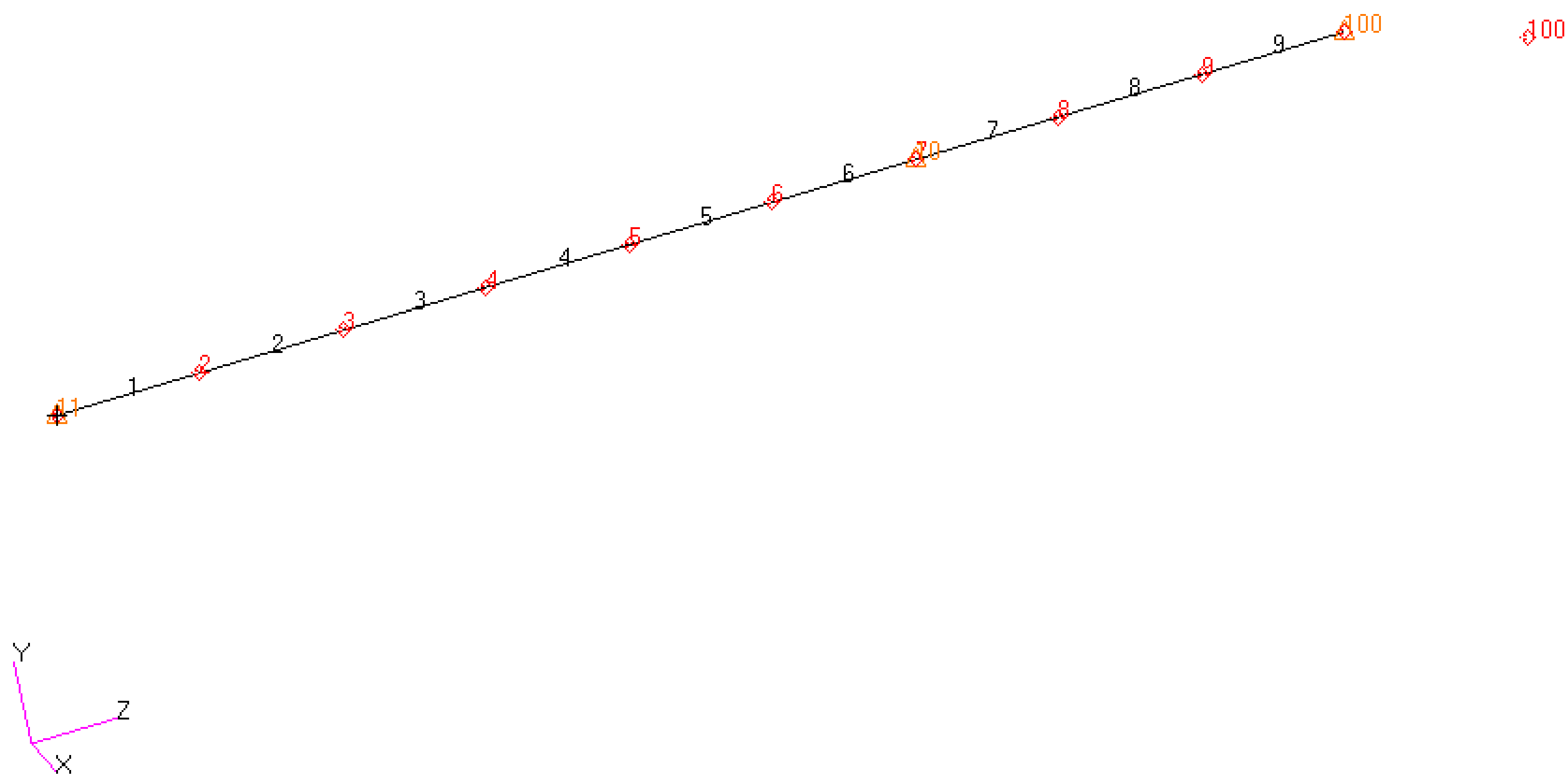
1. Run real-eigen.dat to calculate the real eigenvalues

2. Make a copy of real-eigen.dat and modify it to perform a complex eigenvalue analysis
   a) Remove the “$” sign from the PBUSH entry to add the viscous damping (B=2.0 in DOF 1 and 2)
   b) Perform a direct complex eigenvalue analysis
      i. use SOL 107
      ii. Set up the appropriate CMETHOD Case Control
      iii. Set up the appropriate EIGC entry
   c) Use the HESS method and request 8 roots

3. Repeat step 2 using the CLAN method

4. Repeat step 3 performing a modal complex eigenvalue analysis

Model Description



SOLUTION FOR WORKSHOP # 2

Output From Real Eigensolution

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	2.831001E+03	5.320715E+01	8.468182E+00	1.000000E+00	2.831001E+03
2	2	3.170371E+03	5.630605E+01	8.961386E+00	1.000000E+00	3.170371E+03
3	3	6.950095E+04	2.636303E+02	4.195807E+01	1.000000E+00	6.950095E+04
4	4	6.950645E+04	2.636407E+02	4.195973E+01	1.000000E+00	6.950645E+04
5	5	7.069150E+06	2.658787E+03	4.231591E+02	1.000000E+00	7.069150E+06
6	6	1.278354E+09	3.575408E+04	5.690438E+03	1.000000E+00	1.278354E+09
7	7	2.509200E+09	5.009191E+04	7.972375E+03	1.000000E+00	2.509200E+09
8	8	8.987462E+09	9.480223E+04	1.508824E+04	1.000000E+00	8.987462E+09

Input File – comp-eigen-hess_viscous-damping.dat

```
SOL 107
CEND
TITLE = A RIGID DISK ON A SHAFT
SUBTI = NEARLY MASSLESS SHAFT WITH DAMPING - viscous damping - b=2
LABEL =
$
    CMETHOD      = 1
    DISP(PHASE)  = ALL
$
BEGIN BULK
$ Tension load on shaft
FORCE   1       10              100.    0.      0.      1.
$ PARAMETERS
PARAM   COUPMASS1
PARAM   GRDPNT  10
PARAM   POST    0
$ GEOMETRY
GRID    1               0.      0.      0.              6
.
GRID    10              0.      0.      90.             6
$ SHAFT CONNECTIVITY SPECIFICATION
CBAR    1       1       1       2       100
.
GRID    100             10.     0.      100.            123456
$ SHAFT PROPERTIES
PBAR    1       1       10.     1.6477061.647706
MAT1    1       1000000.        .3      1.E-09
$ BOUNDARY CONDITIONS
CBUSH   10      10      7                                       0
PBUSH   10      K       1.+3    1.+3
                B       2.0     2.0
CBUSH   11      11      1                                       0
PBUSH   11      K       1.+8    1.+8    1.+8    1.+9
$ MASS SPECIFICATIONS
CONM2   100     10              157.0-4
        2.45            2.45                    4.9
$ CEIGENVALUE EXTRACTION
EIGC    1       HESS    MAX                             8
ENDDATA
```

Typical Output - comp-eigen-hess_viscous-damping.f06

- **Complex Eigenvalue Table**

C O M P L E X   E I G E N V A L U E   S U M M A R Y

ROOT NO.	EXTRACTION ORDER	EIGENVALUE (REAL)	EIGENVALUE (IMAG)	FREQUENCY (CYCLES)	DAMPING COEFFICIENT
1	1	-2.613201E-01	-5.323201E+01	8.472136E+00	9.818156E-03
2	2	-2.613201E-01	5.323201E+01	8.472136E+00	9.818156E-03
3	3	-4.415390E-01	-5.634652E+01	8.967828E+00	1.567227E-02
4	4	-4.415390E-01	5.634652E+01	8.967828E+00	1.567227E-02
5	5	-1.420432E+01	-2.679704E+02	4.264881E+01	1.060141E-01
6	6	-1.420432E+01	2.679704E+02	4.264881E+01	1.060141E-01
7	7	-1.373118E+01	-2.683933E+02	4.271612E+01	1.023214E-01
8	8	-1.373118E+01	2.683933E+02	4.271612E+01	1.023214E-01

Typical Output - comp-eigen-hess_viscous-damping.f06

- **Complex Eigenvectors**

COMPLEX EIGENVALUE = -2.613201E-01, -5.323201E+01

C O M P L E X   E I G E N V E C T O R   NO.   1

(MAGNITUDE/PHASE)

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	2.657258E-07	0.0	0.0	0.0	8.505533E-03	0.0
		179.3607	0.0	0.0	0.0	178.5133	0.0
2	G	8.236807E-02	0.0	0.0	0.0	7.699281E-03	0.0
		178.4856	0.0	0.0	0.0	178.4245	0.0
3	G	1.486109E-01	0.0	0.0	0.0	5.280700E-03	0.0
		178.3907	0.0	0.0	0.0	177.9957	0.0
4	G	1.826058E-01	0.0	0.0	0.0	1.253778E-03	0.0
		178.1765	0.0	0.0	0.0	173.6025	0.0
5	G	1.682383E-01	0.0	0.0	0.0	4.398794E-03	0.0
		177.6468	0.0	0.0	0.0	0.9994	0.0
6	G	8.947263E-02	0.0	0.0	0.0	1.165481E-02	0.0
		175.3297	0.0	0.0	0.0	359.9791	0.0
7	G	7.069932E-02	0.0	0.0	0.0	2.052435E-02	0.0
		5.4890	0.0	0.0	0.0	359.7118	0.0
8	G	3.195368E-01	0.0	0.0	0.0	2.885036E-02	0.0
		0.9387	0.0	0.0	0.0	359.6069	0.0
9	G	6.383753E-01	0.0	0.0	0.0	3.447632E-02	0.0
		0.2596	0.0	0.0	0.0	359.5577	0.0
10	G	1.000000E+00	0.0	0.0	0.0	3.740222E-02	0.0
		0.0	0.0	0.0	0.0	359.5284	0.0
100	G	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0

Typical Output - comp-eigen-hess_viscous-damping.f06

- **Complex Eigenvectors**

```
COMPLEX EIGENVALUE = -2.613201E-01,  5.323201E+01
                                C O M P L E X   E I G E N V E C T O R   NO.          2
                                                (MAGNITUDE/PHASE)

POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
     1       G      2.657258E-07   0.0            0.0            0.0            8.505533E-03   0.0
                    180.6393         0.0            0.0            0.0          181.4867         0.0
     2       G      8.236807E-02   0.0            0.0            0.0            7.699281E-03   0.0
                    181.5144         0.0            0.0            0.0          181.5755         0.0
     3       G      1.486109E-01   0.0            0.0            0.0            5.280700E-03   0.0
                    181.6093         0.0            0.0            0.0          182.0043         0.0
     4       G      1.826058E-01   0.0            0.0            0.0            1.253778E-03   0.0
                    181.8235         0.0            0.0            0.0          186.3975         0.0
     5       G      1.682383E-01   0.0            0.0            0.0            4.398794E-03   0.0
                    182.3532         0.0            0.0            0.0          359.0006         0.0
     6       G      8.947263E-02   0.0            0.0            0.0            1.165481E-02   0.0
                    184.6703         0.0            0.0            0.0            0.0209         0.0
     7       G      7.069932E-02   0.0            0.0            0.0            2.052435E-02   0.0
                    354.5110         0.0            0.0            0.0            0.2882         0.0
     8       G      3.195368E-01   0.0            0.0            0.0            2.885036E-02   0.0
                    359.0613         0.0            0.0            0.0            0.3931         0.0
     9       G      6.383753E-01   0.0            0.0            0.0            3.447632E-02   0.0
                    359.7404         0.0            0.0            0.0            0.4423         0.0
    10       G      1.000000E+00   0.0            0.0            0.0            3.740222E-02   0.0
                      0.0            0.0            0.0            0.0            0.4716         0.0
   100       G      0.0            0.0            0.0            0.0            0.0            0.0
                      0.0            0.0            0.0            0.0            0.0            0.0
```

Input File – comp-eigen-clan_viscous-damping.dat

```
SOL 107
CEND
TITLE = A RIGID DISK ON A SHAFT
SUBTI = NEARLY MASSLESS SHAFT WITH DAMPING - viscous damping - b=2
LABEL =
$
  CMETHOD     = 1
  DISP(PHASE) = ALL
$
BEGIN BULK
$ Tension load on shaft
FORCE   1       10              100.    0.      0.      1.
$ PARAMETERS
PARAM   COUPMASS1
PARAM   GRDPNT  10
PARAM   POST    0
$ GEOMETRY
GRID    1               0.      0.      0.              6
.
GRID    10              0.      0.      90.             6
$ SHAFT CONNECTIVITY SPECIFICATION
CBAR    1       1       1       2       100
.
GRID    100             10.     0.      100.            123456
$ SHAFT PROPERTIES
PBAR    1       1       10.     1.6477061.647706
MAT1    1       1000000.        .3      1.E-09
$ BOUNDARY CONDITIONS
CBUSH   10      10      7                                       0
PBUSH   10      K       1.+3    1.+3
                B       2.0     2.0
CBUSH   11      11      1                                       0
PBUSH   11      K       1.+8    1.+8    1.+8    1.+9
$ MASS SPECIFICATIONS
CONM2   100     10              157.0-4
        2.45            2.45                    4.9
$ CEIGENVALUE EXTRACTION
EIGC    1       CLAN    MAX                             8
ENDDATA
```

Typical Output - comp-eigen-clan_viscous-damping.f06

- **Complex Eigenvalue Table**

C O M P L E X   E I G E N V A L U E   S U M M A R Y

ROOT NO.	EXTRACTION ORDER	EIGENVALUE (REAL)	EIGENVALUE (IMAG)	FREQUENCY (CYCLES)	DAMPING COEFFICIENT
1	1	-2.613201E-01	-5.323201E+01	8.472136E+00	9.818156E-03
2	2	-2.613201E-01	5.323201E+01	8.472136E+00	9.818156E-03
3	3	-4.415390E-01	-5.634652E+01	8.967828E+00	1.567227E-02
4	4	-4.415390E-01	5.634652E+01	8.967828E+00	1.567227E-02
5	5	-1.420432E+01	-2.679704E+02	4.264881E+01	1.060141E-01
6	6	-1.420432E+01	2.679704E+02	4.264881E+01	1.060141E-01
7	7	-1.373118E+01	-2.683933E+02	4.271612E+01	1.023214E-01
8	8	-1.373118E+01	2.683933E+02	4.271612E+01	1.023214E-01

Typical Output - comp-eigen-clan_viscous-damping.f06

- **Complex Eigenvectors**

```
COMPLEX EIGENVALUE = -2.613201E-01, -5.323201E+01
                                C O M P L E X   E I G E N V E C T O R   NO.          1
                                                   (MAGNITUDE/PHASE)

POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
       1      G      2.657258E-07   0.0            0.0            0.0            8.505533E-03   0.0
                     179.3607         0.0            0.0            0.0          178.5133         0.0
       2      G      8.236807E-02   0.0            0.0            0.0            7.699281E-03   0.0
                     178.4856         0.0            0.0            0.0          178.4245         0.0
       3      G      1.486109E-01   0.0            0.0            0.0            5.280700E-03   0.0
                     178.3907         0.0            0.0            0.0          177.9957         0.0
       4      G      1.826058E-01   0.0            0.0            0.0            1.253778E-03   0.0
                     178.1765         0.0            0.0            0.0          173.6025         0.0
       5      G      1.682383E-01   0.0            0.0            0.0            4.398794E-03   0.0
                     177.6468         0.0            0.0            0.0            0.9994         0.0
       6      G      8.947263E-02   0.0            0.0            0.0            1.165481E-02   0.0
                     175.3297         0.0            0.0            0.0          359.9791         0.0
       7      G      7.069932E-02   0.0            0.0            0.0            2.052435E-02   0.0
                       5.4890         0.0            0.0            0.0          359.7118         0.0
       8      G      3.195368E-01   0.0            0.0            0.0            2.885036E-02   0.0
                       0.9387         0.0            0.0            0.0          359.6069         0.0
       9      G      6.383753E-01   0.0            0.0            0.0            3.447632E-02   0.0
                       0.2596         0.0            0.0            0.0          359.5577         0.0
      10      G      1.000000E+00   0.0            0.0            0.0            3.740222E-02   0.0
                       0.0            0.0            0.0            0.0          359.5284         0.0
     100      G      0.0            0.0            0.0            0.0            0.0            0.0
                       0.0            0.0            0.0            0.0            0.0            0.0
```

Input File – comp-eigen-clan-modal_viscous-damping.dat

```
SOL 107
CEND
TITLE = A RIGID DISK ON A SHAFT
SUBTI = NEARLY MASSLESS SHAFT WITH DAMPING - viscous damping - b=2
LABEL =
$
  METHOD=100
  CMETHOD      = 1
  DISP(PHASE)  = ALL
$
BEGIN BULK
$ Tension load on shaft
FORCE   1       10              100.    0.      0.      1.
$ PARAMETERS
PARAM   COUPMASS1
PARAM   GRDPNT  10
PARAM   POST    0
$ GEOMETRY
GRID    1               0.      0.      0.              6
.
GRID    10              0.      0.      90.             6
$ SHAFT CONNECTIVITY SPECIFICATION
CBAR    1       1       1       2       100
.
GRID    100             10.     0.      100.            123456
$ SHAFT PROPERTIES
PBAR    1       1       10.     1.6477061.647706
MAT1    1       1000000.        .3      1.E-09
$ BOUNDARY CONDITIONS
CBUSH   10      10      7                                       0
PBUSH   10      K       1.+3    1.+3
                B       2.0     2.0
CBUSH   11      11      1                                       0
PBUSH   11      K       1.+8    1.+8    1.+8    1.+9
$ MASS SPECIFICATIONS
CONM2   100     10              157.0-4
        2.45            2.45                    4.9
$ CEIGENVALUE EXTRACTION
EIGC    1       CLAN    MAX                             8
eigrl   100                     10
ENDDATA
```

Typical Output - comp-eigen-clan-modal_viscous-damping.f06

- **Real Eigenvalue Table**

R E A L   E I G E N V A L U E S
(BEFORE AUGMENTATION OF RESIDUAL VECTORS)

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	2.831001E+03	5.320715E+01	8.468182E+00	1.000000E+00	2.831001E+03
2	2	3.170371E+03	5.630605E+01	8.961386E+00	1.000000E+00	3.170371E+03
3	3	6.950095E+04	2.636303E+02	4.195807E+01	1.000000E+00	6.950095E+04
4	4	6.950645E+04	2.636407E+02	4.195973E+01	1.000000E+00	6.950645E+04
5	5	7.069150E+06	2.658787E+03	4.231591E+02	1.000000E+00	7.069150E+06
6	6	1.278354E+09	3.575408E+04	5.690438E+03	1.000000E+00	1.278354E+09
7	7	2.509200E+09	5.009191E+04	7.972375E+03	1.000000E+00	2.509200E+09
8	8	8.987462E+09	9.480223E+04	1.508824E+04	1.000000E+00	8.987462E+09
9	9	1.216498E+10	1.102950E+05	1.755399E+04	1.000000E+00	1.216498E+10
10	10	2.805201E+10	1.674874E+05	2.665644E+04	1.000000E+00	2.805201E+10

- **Complex Eigenvalue Table**

C O M P L E X   E I G E N V A L U E   S U M M A R Y

ROOT NO.	EXTRACTION ORDER	EIGENVALUE (REAL)	EIGENVALUE (IMAG)	FREQUENCY (CYCLES)	DAMPING COEFFICIENT
1	1	-2.613201E-01	-5.323201E+01	8.472136E+00	9.818156E-03
2	2	-2.613201E-01	5.323201E+01	8.472136E+00	9.818156E-03
3	3	-4.415390E-01	-5.634652E+01	8.967828E+00	1.567227E-02
4	4	-4.415390E-01	5.634652E+01	8.967828E+00	1.567227E-02
5	5	-1.420432E+01	-2.679704E+02	4.264881E+01	1.060141E-01
6	6	-1.420432E+01	2.679704E+02	4.264881E+01	1.060141E-01
7	7	-1.373118E+01	-2.683933E+02	4.271612E+01	1.023214E-01
8	8	-1.373118E+01	2.683933E+02	4.271612E+01	1.023214E-01

Typical Output - comp-eigen-clan-modal_viscous-damping.f06

- **Complex Eigenvectors**

COMPLEX EIGENVALUE = -2.613201E-01, -5.323201E+01

C O M P L E X   E I G E N V E C T O R   NO. 1

(MAGNITUDE/PHASE)

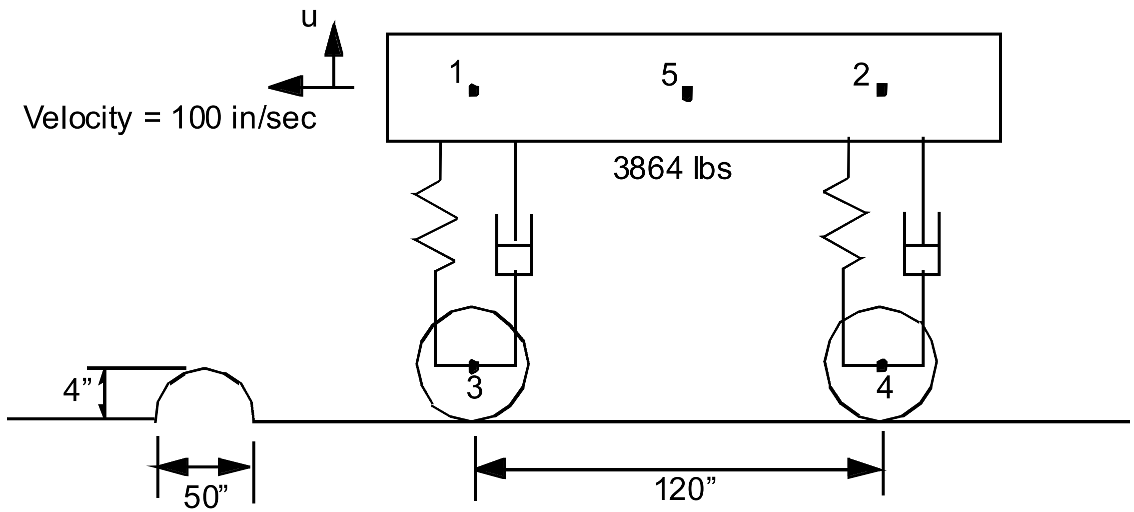
POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	1.921353E-06	2.131583E-16	1.483640E-15	5.549002E-17	6.149998E-02	0.0
		359.4451	95.3198	275.2921	275.4592	358.5977	0.0
2	G	5.955693E-01	1.011693E-14	1.413540E-13	6.737606E-14	5.567029E-02	0.0
		358.5700	252.8028	275.2921	94.7226	358.5089	0.0
3	G	1.074544E+00	8.678078E-14	1.886815E-13	9.978229E-15	3.818255E-02	0.0
		358.4751	102.7822	275.2921	279.3996	358.0801	0.0
4	G	1.320347E+00	3.765685E-14	1.026013E-13	1.288148E-13	9.065544E-03	0.0
		358.2609	250.0099	275.2921	275.3523	353.6869	0.0
5	G	1.216461E+00	1.999791E-13	7.368972E-14	1.469226E-13	3.180585E-02	0.0
		357.7312	271.8707	95.2922	95.7089	181.0838	0.0
6	G	6.469394E-01	2.945727E-13	2.344984E-13	6.225547E-14	8.427110E-02	0.0
		355.4141	93.8573	95.2921	272.6246	180.0635	0.0
7	G	5.111973E-01	2.383632E-13	2.940711E-13	6.947912E-14	1.484030E-01	0.0
		185.5734	286.9326	95.2921	270.8755	179.7963	0.0
8	G	2.310438E+00	1.256037E-13	2.364988E-13	1.156255E-13	2.086049E-01	0.0
		181.0231	29.9850	95.2921	99.1223	179.6913	0.0
9	G	4.615826E+00	2.461013E-13	1.169581E-13	6.719806E-14	2.492840E-01	0.0
		180.3440	40.9533	95.2922	267.3264	179.6421	0.0
10	G	7.230584E+00	3.027030E-13	1.287817E-14	1.028163E-14	2.704399E-01	0.0
		180.0844	15.6691	275.2919	195.5642	179.6129	0.0
100	G	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0

WORKSHOP 3

Linear Transient Analysis Using NOLINs

Workshop 3 - Car Traveling Over A Bump

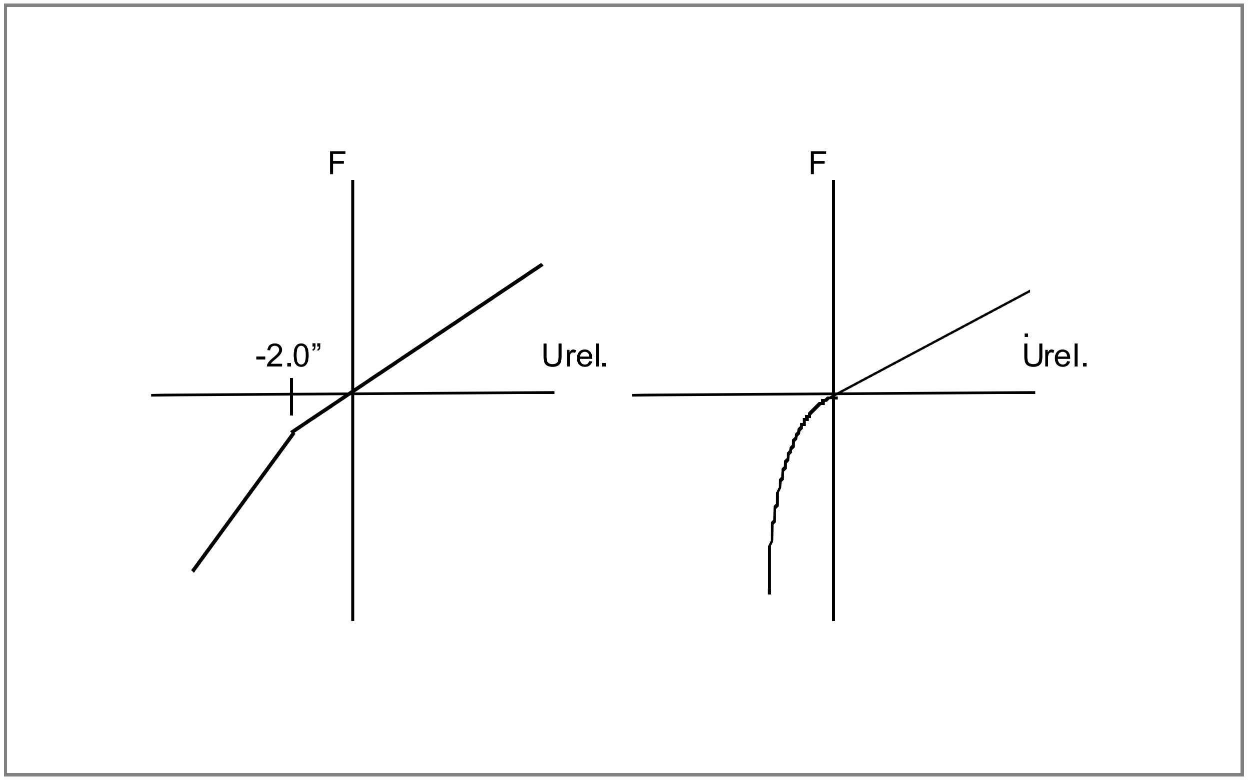
- **Simulate the following car model travelling over a bump using the NOLIN element.**



$$k: \begin{cases} u \geq -2.0\text{in} & \textbf{197.4 lb/in} \\ u < -2.0\text{in} & \textbf{394.8 lb/in} \end{cases}$$

$$c: \begin{cases} \dot{u} \geq 0 & \textbf{1.88 lb/(in/sec)} \\ \dot{u} \leq 0 & \textbf{1.88 lb/(in/sec) + 0.3 lb/(in/sec)}^2 \end{cases}$$

Workshop 3 - Car Traveling Over A Bump (cont.)



Workshop 3 – Input File

- **Use the following partial input file as a starting point**

```
$
$    wkshp3.dat
$
$ case control, add :  nolin callout
$                      plot nonlin forces
$
$ bulk data,    add :  transfer function to monitor relative displacements
$                      nolin for springs and dampers
$                      apply appropriate enforced displacement
$
ID NAS102, WORKSHOP13
SOL 109
TIME 100
CEND
TITLE= SIMPLE CAR MODEL WITH NOLINEAR
SUBTITLE= SPRINGS AND DAMPERS RUNNING OVER A BUMP
LABEL= SOL 109, CONSTANT DELTA TIME
SPC= 100
TFL= 100
NONLINEAR = 100
DLOAD = 100
TSTEP = 100
DISPLACEMENT(PLOT)= ALL
NLLOAD(PLOT)= ALL
$
```

Workshop 3 – Input File (cont.)

```
OUTPUT(XYPLOT)
CSCALE=1.3
XAXIS= YES
YAXIS= YES
XGRID LINES= YES
YGRID LINES= YES
XTITLE= TIME (SEC)
YTITLE= VERTICAL DISPLACEMENT OF POINT 1
XYPLOT DISP/1(T2)
YTITLE= VERTICAL DISPLACEMENT OF POINT 2
XYPLOT DISP/2(T2)
YTITLE= VERTICAL DISPLACEMENT OF POINT 3
XYPLOT DISP/3(T2)
YTITLE= VERTICAL DISPLACEMENT OF POINT 4
XYPLOT DISP/4(T2)
YTITLE= VERTICAL DISPLACEMENT OF POINT 5
XYPLOT DISP/5(T2)
YTITLE= NONLINEAR FORCES AT POINT 1
XYPLOT NONLINEAR/1(T2)
YTITLE= NONLINEAR FORCES AT POINT 2
XYPLOT NONLINEAR/2(T2)
$
BEGIN BULK
PARAM,POST,-1
$
$ CARRIAGE POINTS
$
GRID, 1, , 0., 0., 0.
GRID, 2, , 120., 0., 0.
GRID, 5, , 60., 0., 0.
$
$ WHEEL POINTS
$
GRID, 3, , 0., -10., 0.
GRID, 4, , 120., -10., 0.
$
```

```
$
$ CAR CARRIAGE
$
CBAR, 5, 11, 1, 5, 0., 1., 0.
CBAR, 6, 11, 5, 2, 0., 1., 0.
PBAR, 11, 12, 10., 10., 10.
MAT1, 12, 3.0E+7, , .33
$
$ CONSTRAINTS TO ELIMINATE RIGID-BODY MODES
$
SPC1, 100, 1345, 1, 2, 5
SPC1, 100, 13456, 3, 4
$
$ SYSTEM WILL HAVE A NATURAL FREQUENCY OF 1 HZ
$ WITH CRITICAL DAMPING OF 1 PERCENT
$
CONM2, 10, 1, ,2.5
CONM2, 15, 2, ,2.5
CONM2, 20, 5, ,5.
$
CELAS2, 30, 197.4, 1, 2, 3, 2
CELAS2, 40, 197.4, 2, 2, 4, 2
$
CDAMP2, 50, 1.88, 1, 2, 3, 2
CDAMP2, 60, 1.88, 2, 2, 4, 2
$
$ INTEGRATION INFORMATION
TSTEP, 100, 200, .05, 1
$
$***********************
$ insert the EPOINT's, TF's, NOLIN's TLOAD2, SPCD, etc here
$***********************
$
ENDDATA
```

Solution For Workshop 3

```
SOL 109
CEND
TITLE= SIMPLE CAR MODEL WITH NOLINEAR
SUBTITLE= SPRINGS AND DAMPERS RUNNING OVER A
BUMP
LABEL= SOL 109, CONSTANT DELTA TIME
SEALL= ALL
SPC= 100
TFL= 100
NONLINEAR = 100
DLOAD = 100
TSTEP = 100
DISPLACEMENT(PLOT)= ALL
NLLOAD(PLOT)= ALL
$
OUTPUT(XYPLOT)
CSCALE=1.3
XAXIS= YES
YAXIS= YES
XGRID LINES= YES
YGRID LINES= YES
XTITLE= TIME (SEC)
YTITLE= VERTICAL DISPLACEMENT OF POINT 1
XYPLOT DISP/1(T2)
YTITLE= VERTICAL DISPLACEMENT OF POINT 2
XYPLOT DISP/2(T2)
YTITLE= VERTICAL DISPLACEMENT OF POINT 3
XYPLOT DISP/3(T2)
```

```
YTITLE= VERTICAL DISPLACEMENT OF POINT 4
XYPLOT DISP/4(T2)
YTITLE= VERTICAL DISPLACEMENT OF POINT 5
XYPLOT DISP/5(T2)
YTITLE= NONLINEAR FORCES AT POINT 1
XYPLOT NONLINEAR/1(T2)
YTITLE= NONLINEAR FORCES AT POINT 2
XYPLOT NONLINEAR/2(T2)
$
BEGIN BULK
PARAM,POST,-1
$
$ CARRIAGE POINTS
$
GRID, 1, , 0., 0., 0.
GRID, 2, , 120., 0., 0.
GRID, 5, , 60., 0., 0.
$

$WHEEL POINTS
$
GRID, 3, , 0., -10., 0.
GRID, 4, , 120., -10., 0.
$
$ CAR CARRIAGE
$
CBAR, 5, 11, 1, 5, 0., 1., 0.
CBAR, 6, 11, 5, 2, 0., 1., 0.
PBAR, 11, 12, 10., 10., 10.
MAT1, 12, 3.0E+7, , .33
$
```

Solution For Workshop 3 (cont.)

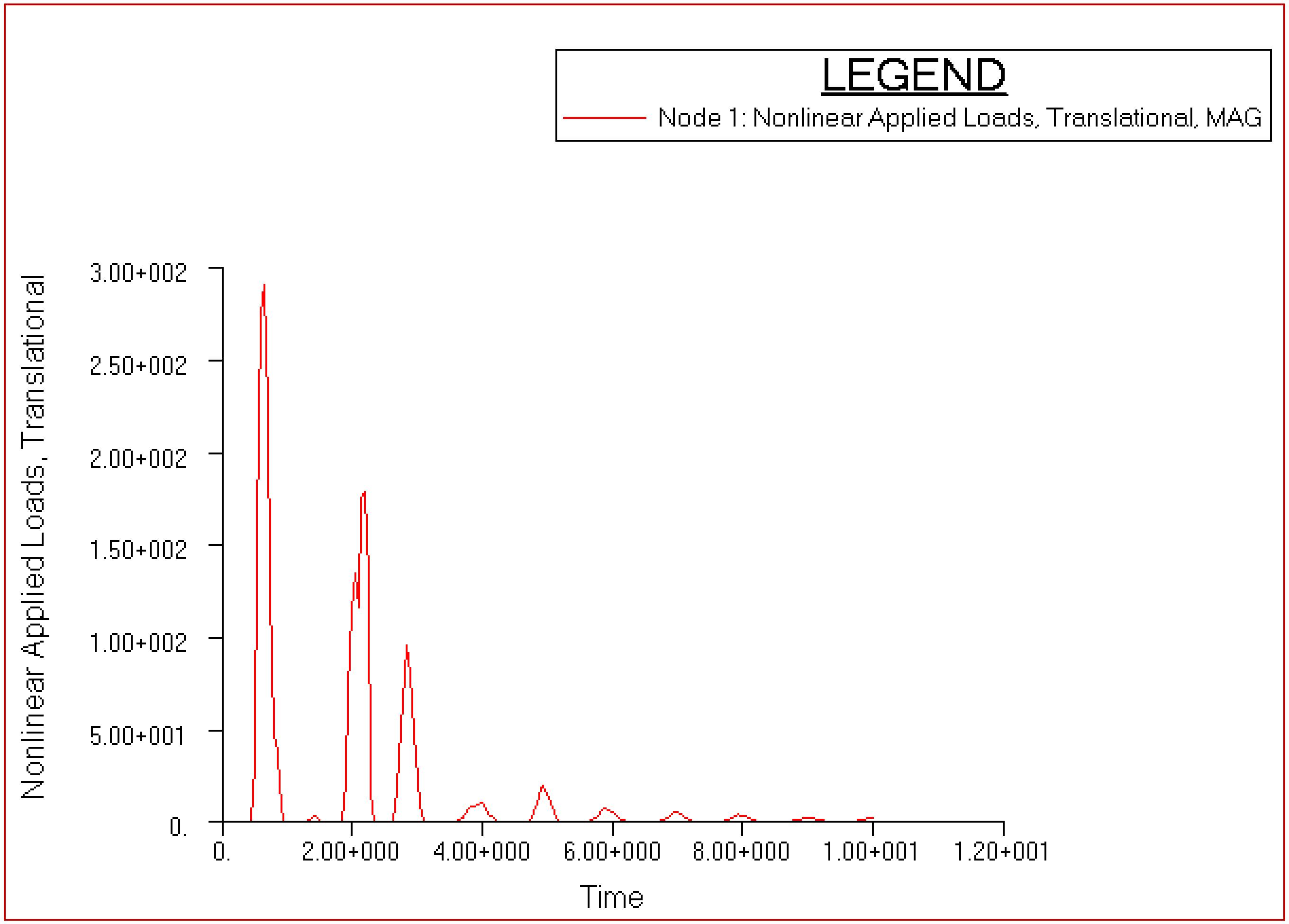
```
$
$ CONSTRAINTS TO ELIMINATE RIGID-BODY MODES
$
SPC1, 100, 1345, 1, 2, 5
SPC1, 100, 13456, 3, 4
$
$ SYSTEM WILL HAVE A NATURAL FREQUENCY OF 1 HZ
$ WITH CRITICAL DAMPING OF 1 PERCENT
$
CONM2, 10, 1, ,2.5
CONM2, 15, 2, ,2.5
CONM2, 20, 5, ,5.
$
CELAS2, 30, 197.4, 1, 2, 3, 2
CELAS2, 40, 197.4, 2, 2, 4, 2
$
CDAMP2, 50, 1.88, 1, 2, 3, 2
CDAMP2, 60, 1.88, 2, 2, 4, 2
$
$ INTEGRATION INFORMATION
TSTEP, 100, 200, .05, 1
$
$ DEFINE EXTRA POINTS TO HOLD DIFFERENCES
$ BETWEEN WHEELS AND CARRIAGE
$
EPOINT, 101, 102
$
```

```
$ USE TRANSFER FUNCTIONS TO TRACK DIFFERENCES
$ 101= V1 - V3
$ 102= V2 - V4
$
TF, 100, 101, 0, 1., 0., 0.,
, 1, 2, -1., 0., 0.,
, 3, 2, 1., 0., 0.
$
TF, 100, 102, 0, 1., 0., 0.,
, 2, 2, -1., 0., 0.,
, 4, 2, 1., 0., 0.
$
$ ADD NONLINEAR PORTION OF SPRINGS

NOLIN1, 100, 1, 2, 197.4, 101, 0, 111
NOLIN1, 100, 2, 2, 197.4, 102, 0, 111
TABLED2, 111, -2.0,
, -1., 1., 0., 0., 1., 0.,ENDT
$
$ ADD NONLINEAR PORTION OF DAMPERS
$
NOLIN4, 100, 1, 2, -0.3, 101, 10, 2.
NOLIN4, 100, 2, 2, -0.3, 102, 10, 2.
$
$ MOVE WHEELS OVER BUMP
$
TLOAD2, 100, 222, 333, D, 0., 0.5, 1., -90.
SPCD, 222, 3, 2, 4.
SPCD, 222, 4, 2, 4.
SPC1,100,2,3,4

DELAY, 333, 4, 2, 1.2
$
ENDDATA
```

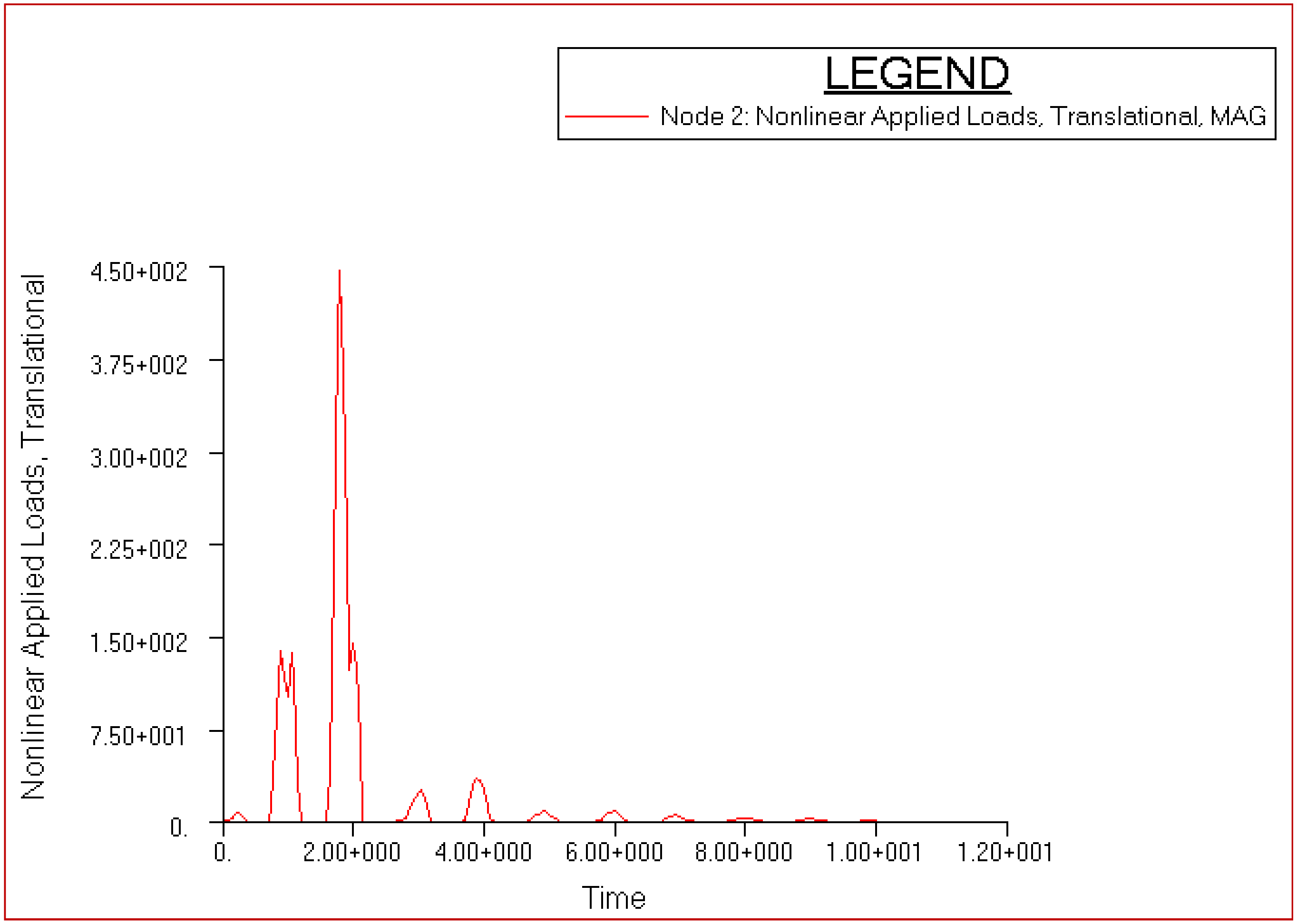
Partial Output File For Workshop 3

```
0                             X Y - O U T P U T  S U M M A R Y  ( R E S P O N S E )
0 SUBCASE  CURVE FRAME    CURVE ID./          XMIN-FRAME/    XMAX-FRAME/    YMIN-FRAME/     X FOR        YMAX-FRAME/     X FOR
     ID     TYPE   NO.  PANEL  : GRID ID        ALL DATA       ALL DATA       ALL DATA        YMIN         ALL DATA        YMAX
0        1  NONLIN   1          1(   4)      0.000000E+00   1.000000E+01   0.000000E+00   0.000000E+00   2.898043E+02   6.500000E-01
                                             0.000000E+00   1.000000E+01   0.000000E+00   0.000000E+00   2.898043E+02   6.500000E-01
0        1  NONLIN   2          2(   4)      0.000000E+00   1.000000E+01   0.000000E+00   0.000000E+00   4.457731E+02   1.800000E+00
                                             0.000000E+00   1.000000E+01   0.000000E+00   0.000000E+00   4.457731E+02   1.800000E+00
1     SIMPLE CAR MODEL WITH NOLINEAR                                   DECEMBER  19, 2011  MSC.NASTRAN 11/25/11    PAGE    10
       SPRINGS AND DAMPERS RUNNING OVER A BUMP
0      SOL 109, CONSTANT DELTA TIME
0                             X Y - O U T P U T  S U M M A R Y  ( R E S P O N S E )
0 SUBCASE  CURVE FRAME    CURVE ID./          XMIN-FRAME/    XMAX-FRAME/    YMIN-FRAME/     X FOR        YMAX-FRAME/     X FOR
     ID     TYPE   NO.  PANEL  : GRID ID        ALL DATA       ALL DATA       ALL DATA        YMIN         ALL DATA        YMAX
0        1  DISP     3          1(   4)      0.000000E+00   1.000000E+01  -2.850177E+00   2.200000E+00   5.836246E+00   4.500000E-01
                                             0.000000E+00   1.000000E+01  -2.850177E+00   2.200000E+00   5.836246E+00   4.500000E-01
0        1  DISP     4          2(   4)      0.000000E+00   1.000000E+01  -2.635520E+00   2.050000E+00   7.577414E+00   1.600000E+00
                                             0.000000E+00   1.000000E+01  -2.635520E+00   2.050000E+00   7.577414E+00   1.600000E+00
0        1  DISP     5          3(   4)      0.000000E+00   1.000000E+01   0.000000E+00   5.000000E-01   4.000000E+00   2.500000E-01
                                             0.000000E+00   1.000000E+01   0.000000E+00   5.000000E-01   4.000000E+00   2.500000E-01
0        1  DISP     6          4(   4)      0.000000E+00   1.000000E+01   0.000000E+00   0.000000E+00   4.000000E+00   1.450000E+00
                                             0.000000E+00   1.000000E+01   0.000000E+00   0.000000E+00   4.000000E+00   1.450000E+00
0        1  DISP     7          5(   4)      0.000000E+00   1.000000E+01  -2.208439E+00   2.150000E+00   4.005989E+00   1.600000E+00
                                             0.000000E+00   1.000000E+01  -2.208439E+00   2.150000E+00   4.005989E+00   1.600000E+00
```

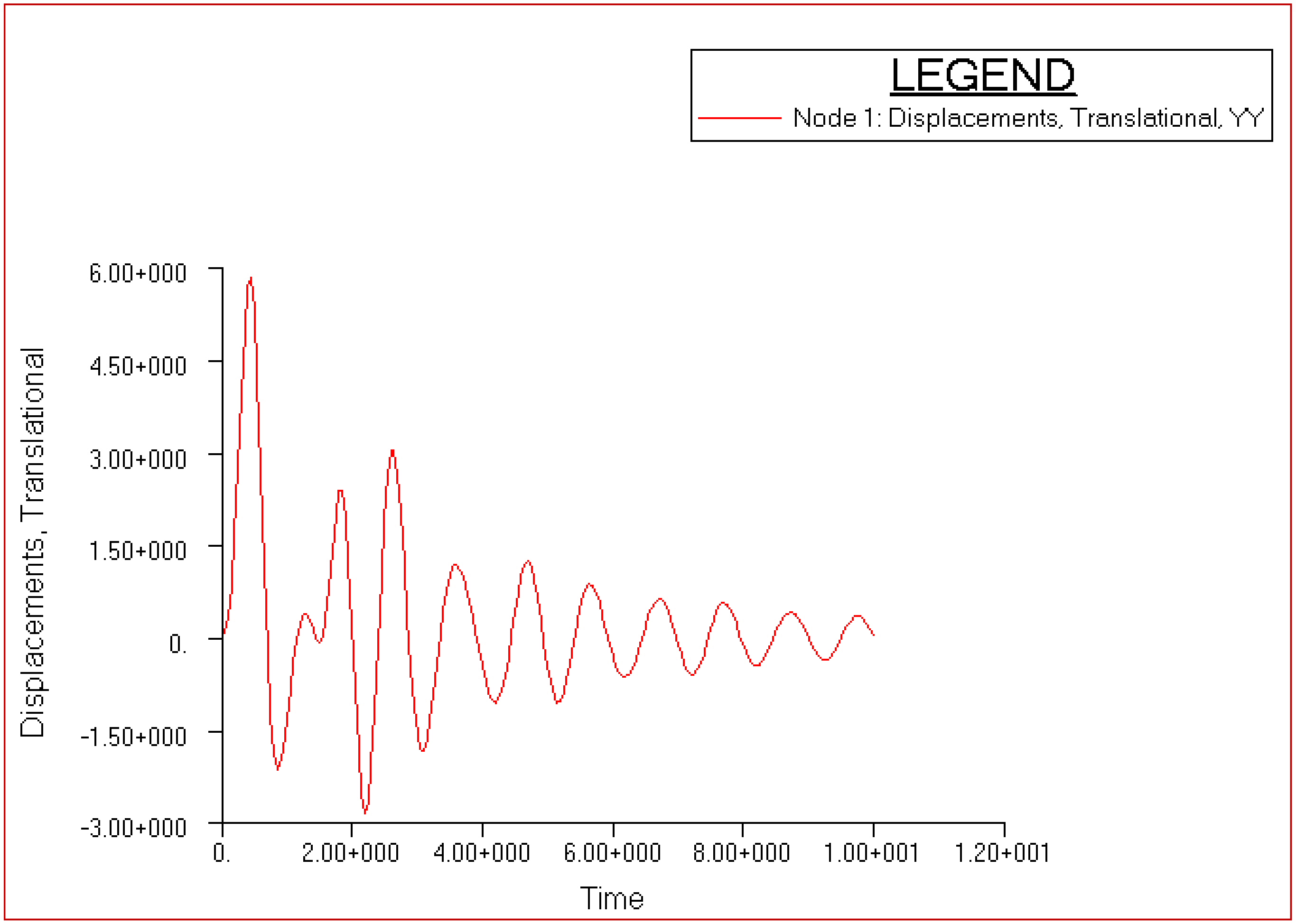
Partial Output For Workshop 3 (cont.)



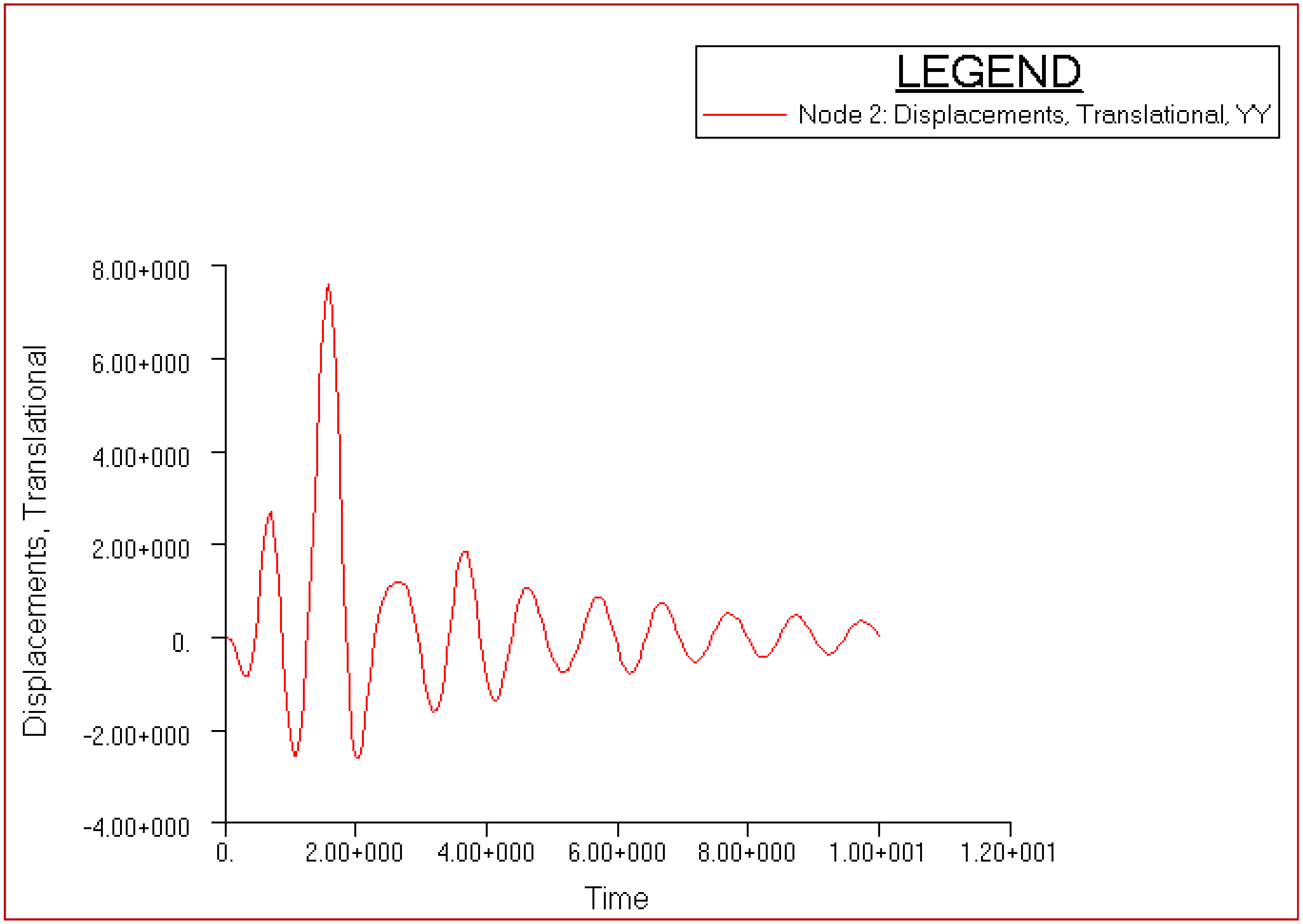
Partial Output For Workshop 3 (cont.)



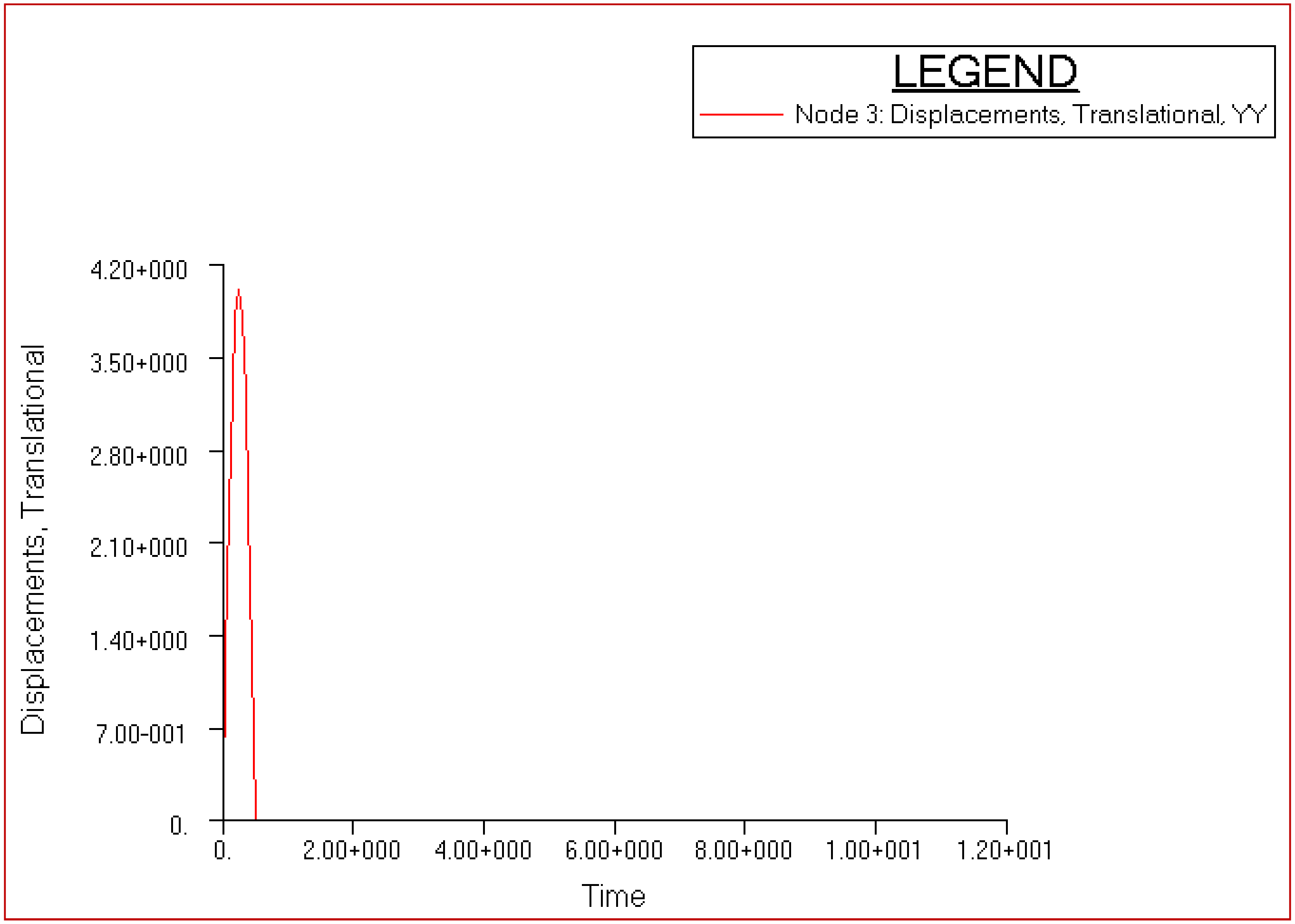
Partial Output For Workshop 3 (cont.)



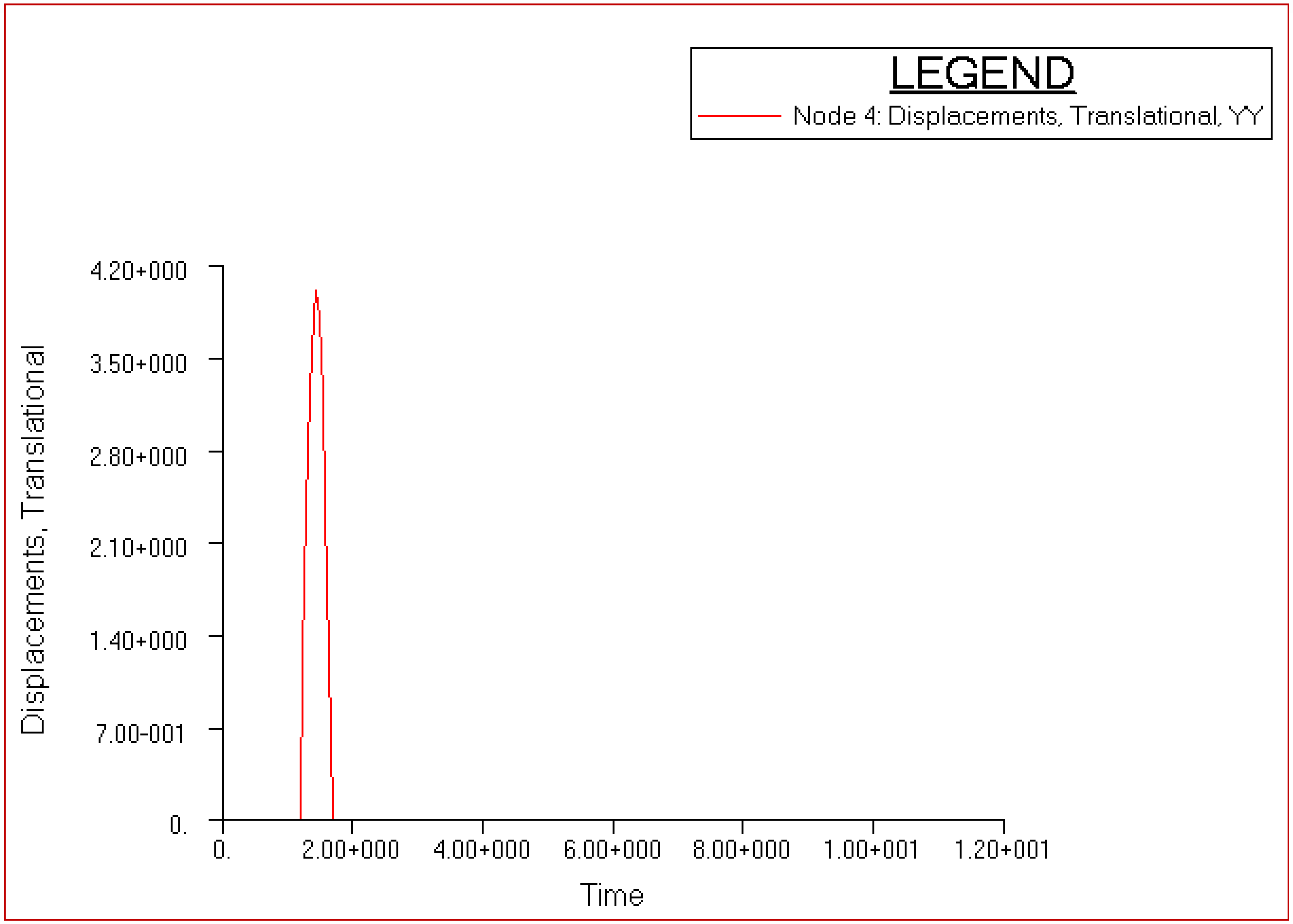
Partial Output For Workshop 3 (cont.)



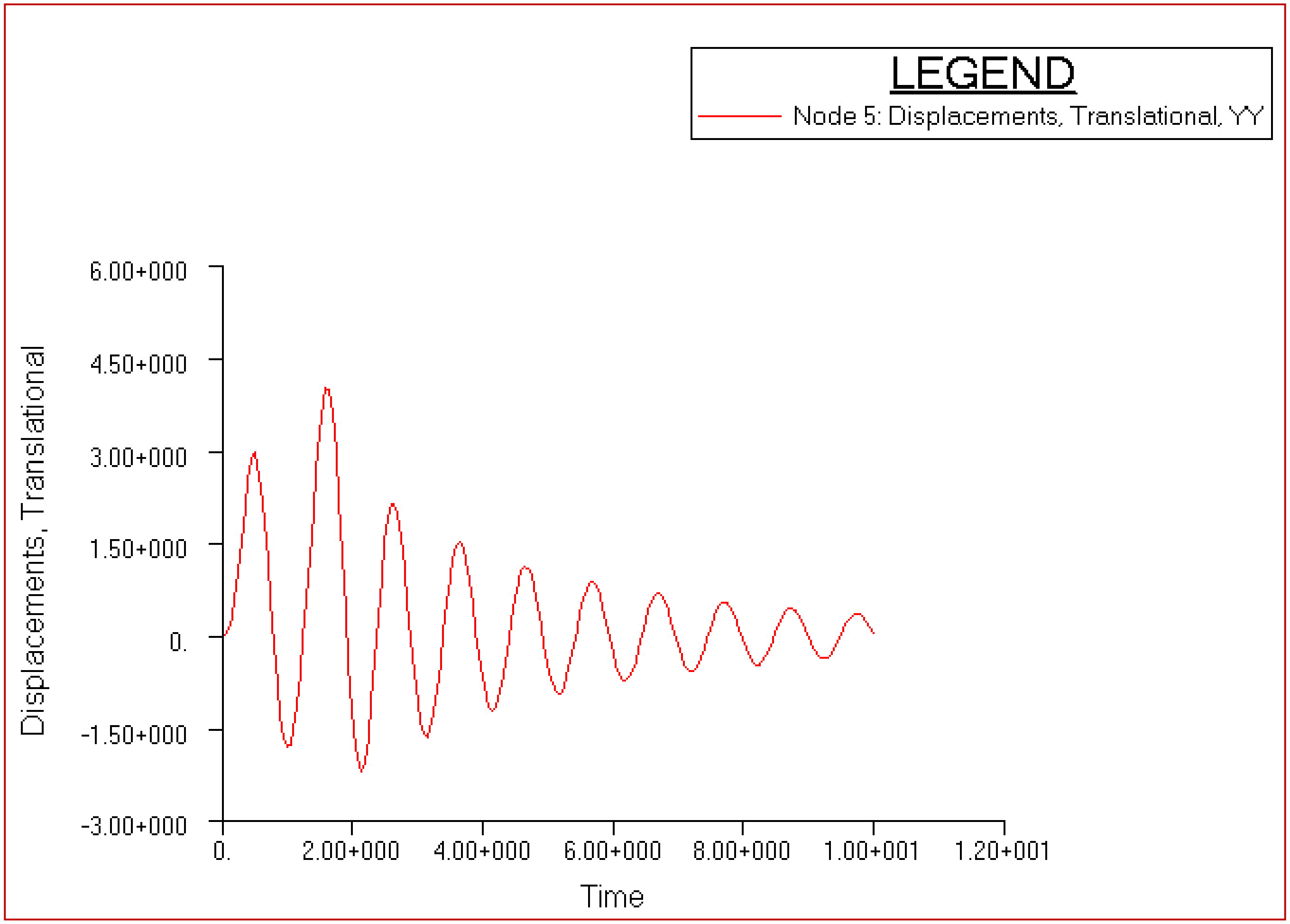
Partial Output For Workshop 3 (cont.)



Partial Output For Workshop 3 (cont.)



Partial Output For Workshop 3 (cont.)



WORKSHOP 4

Test Analysis Correlation

- **Workshop Objectives**
  - Learn how to set up a test – analysis correlation run
  - Make an ASET selection and evaluate the results
  - Based on the results seen, select a new ASET and evaluate
  - Using the final ASET, perform a test-analysis correlation run
- **Software Version**
  - MSC Nastran 2013
- **Files Required**
  - ws04_step1_punch_full_model.dat
  - ws04_step2_premac_first-try.dat
  - ws04_step3_postmac.dat
  - test_eigenvectors.pch
- **Problem Description**
  - Simple bar model

- **Suggested Steps**

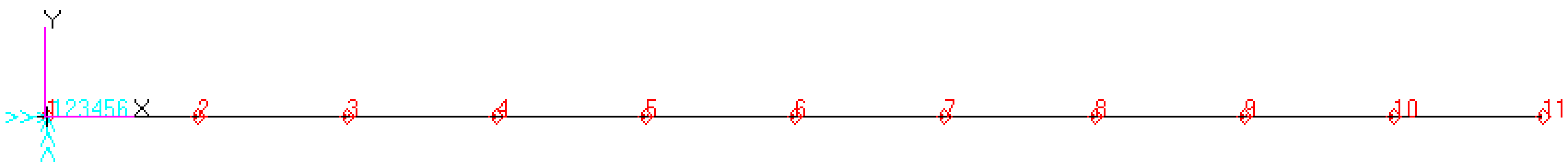
1. Run ws04_step1_punch_full_model.dat to export the full FEM eigenvectors

2. Edit ws04_step2_premac_first-try.dat to identify the desired ASET grids
   a) As a starting set, try grids 2, 3, 4 and 5
   b) Look at the MAC and XORTHO results

3. Copy ws04_step2_premac_first-try.dat to ws04_step2_premac_second-try.dat and repeat step 2 using grids 3, 5, 7, 9 and 11
   a) Look at the MAC and XORTHO results

4. Edit ws04_step3_postmac.dat to do test – analysis correlation with the second ASET selection punch file
   a) Look at the MAC and XORTHO results

Model Description



SOLUTION FOR WORKSHOP 4

Output From Step 1

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	7.636173E+05	8.738520E+02	1.390779E+02	1.000000E+00	7.636173E+05
2	2	9.593501E+06	3.097338E+03	4.929566E+02	1.000000E+00	9.593501E+06
3	3	2.932654E+07	5.415398E+03	8.618873E+02	1.000000E+00	2.932654E+07
4	4	8.492998E+07	9.215746E+03	1.466731E+03	1.000000E+00	8.492998E+07
5	5	2.253432E+08	1.501144E+04	2.389144E+03	1.000000E+00	2.253432E+08
6	6	2.282285E+08	1.510723E+04	2.404391E+03	1.000000E+00	2.282285E+08

R E A L   E I G E N V A L U E S

Input File – ws04_step2_premac_first-try.dat

```
$ Test-Analysis, Step 2
$ compare the ASET selected DOF against
$ the full FEM eigenvectors
$
SOL 103
diag 8,15
$
$  INCLUDE ALTER FOR CROSS-ORTHOGONALITY CHECKS
$
INCLUDE 'SSSALTERDIR:premaca.alt'
$
CEND
ECHO=NONE
TITLE = TEST-ANALYSIS:  ANALYSIS ASET Checkout
SUBTITLE = REDUCED MODEL
LABEL = 4 POINTS
DISP =  ALL
SPC=1
METHOD=100
BEGIN BULK
$
$  READ PCH FILE OF FULL MODEL
$  INCLUDE PUNCHED DISPLS. FROM Step 1, FULL RUN
INCLUDE 'ws04_step1_punch_full_model.pch'
$
PARAM   POST    0
PARAM   AUTOSPC YES
GRDSET, , , , , , ,345
BAROR, , , , , 0., 1., 0.
```

```
GRID    1               0.0     0.0     0.0
GRID    2               10.     0.0     0.0
GRID    3               20.     0.0     0.0
GRID    4               30.     0.0     0.0
GRID    5               40.     0.0     0.0
GRID    6               50.     0.0     0.0
GRID    7               60.     0.0     0.0
GRID    8               70.     0.0     0.0
GRID    9               80.     0.0     0.0
GRID    10              90.     0.0     0.0
GRID    11              100.    0.0     0.0
CBAR    1       1       1       2
CBAR    2       1       2       3
CBAR    3       1       3       4
CBAR    4       1       4       5
CBAR    5       1       5       6
CBAR    6       1       6       7
CBAR    7       1       7       8
CBAR    8       1       8       9
CBAR    9       1       9       10
CBAR    10      1       10      11
$  REDUCE TO TEST DOF
ASET1, 12, 2, 3, 4, 5
SPC     1       1       123456  0.0
PBAR    1       1       1.0     160.0   160.0
MAT1    1       3.+7            .3      7.7E-4
EIGRL   100     0.0     10000.  6
ENDDATA
```

Output from First Try

- **Note the frequencies do not match well with the Full FEM results**

- **ASET based modes:**

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	8.868048E+05	9.417031E+02	1.498767E+02	1.000000E+00	8.868048E+05
2	2	1.312384E+07	3.622684E+03	5.765681E+02	1.000000E+00	1.312384E+07
3	3	9.803955E+07	9.901492E+03	1.575871E+03	1.000000E+00	9.803955E+07
4	4	2.544989E+08	1.595302E+04	2.539002E+03	1.000000E+00	2.544989E+08
5	5	7.950909E+08	2.819736E+04	4.487749E+03	1.000000E+00	7.950909E+08
6	6	1.334889E+09	3.653613E+04	5.814905E+03	1.000000E+00	1.334889E+09

- **Full FEM modes:**

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	7.636173E+05	8.738520E+02	1.390779E+02	1.000000E+00	7.636173E+05
2	2	9.593501E+06	3.097338E+03	4.929566E+02	1.000000E+00	9.593501E+06
3	3	2.932654E+07	5.415398E+03	8.618873E+02	1.000000E+00	2.932654E+07
4	4	8.492998E+07	9.215746E+03	1.466731E+03	1.000000E+00	8.492998E+07
5	5	2.253432E+08	1.501144E+04	2.389144E+03	1.000000E+00	2.253432E+08
6	6	2.282285E+08	1.510723E+04	2.404391E+03	1.000000E+00	2.282285E+08

Output from First Try (cont.)

- **Note the MAC does not indicate good reduction**
  - Significant off-diagonal terms and not 1.0 on all diagonals

```
^^^MODAL ASSURANCE CRITERIA FOR RESIDUAL STRUCTURE A-SET
^^^
^^^MODAL ASSURANCE CALCULATION IS PERFORMED FOR    6         CALCULATED MODES AND    6          INPUT MODES
^^^
^^^ ANALYTICAL MODE    1          COMPARED TO INPUT MODE 1         - MAC =    9.999995E-01
^^^ ANALYTICAL MODE    1          COMPARED TO INPUT MODE 2         - MAC =    1.083155E-36
^^^ ANALYTICAL MODE    1          COMPARED TO INPUT MODE 3         - MAC =    9.761190E-01
^^^ ANALYTICAL MODE    1          COMPARED TO INPUT MODE 4         - MAC =    3.891217E-30
^^^ ANALYTICAL MODE    1          COMPARED TO INPUT MODE 5         - MAC =    7.573141E-01
^^^ ANALYTICAL MODE    1          COMPARED TO INPUT MODE 6         - MAC =    8.040386E-26
^^^ ANALYTICAL MODE    2          COMPARED TO INPUT MODE 1         - MAC =    6.898552E-32
^^^ ANALYTICAL MODE    2          COMPARED TO INPUT MODE 2         - MAC =    9.999390E-01
^^^ ANALYTICAL MODE    2          COMPARED TO INPUT MODE 3         - MAC =    2.227334E-31
^^^ ANALYTICAL MODE    2          COMPARED TO INPUT MODE 4         - MAC =    9.618793E-01
^^^ ANALYTICAL MODE    2          COMPARED TO INPUT MODE 5         - MAC =    2.832677E-26
^^^ ANALYTICAL MODE    2          COMPARED TO INPUT MODE 6         - MAC =    4.160402E-01
^^^ ANALYTICAL MODE    3          COMPARED TO INPUT MODE 1         - MAC =    8.364609E-01
^^^ ANALYTICAL MODE    3          COMPARED TO INPUT MODE 2         - MAC =    3.722513E-33
^^^ ANALYTICAL MODE    3          COMPARED TO INPUT MODE 3         - MAC =    9.336467E-01
^^^ ANALYTICAL MODE    3          COMPARED TO INPUT MODE 4         - MAC =    3.858437E-30
^^^ ANALYTICAL MODE    3          COMPARED TO INPUT MODE 5         - MAC =    9.896603E-01
^^^ ANALYTICAL MODE    3          COMPARED TO INPUT MODE 6         - MAC =    1.053125E-25
^^^ ANALYTICAL MODE    4          COMPARED TO INPUT MODE 1         - MAC =    5.279402E-33
^^^ ANALYTICAL MODE    4          COMPARED TO INPUT MODE 2         - MAC =    2.657365E-01
^^^ ANALYTICAL MODE    4          COMPARED TO INPUT MODE 3         - MAC =    5.613560E-32
^^^ ANALYTICAL MODE    4          COMPARED TO INPUT MODE 4         - MAC =    4.585466E-01
^^^ ANALYTICAL MODE    4          COMPARED TO INPUT MODE 5         - MAC =    6.500995E-26
^^^ ANALYTICAL MODE    4          COMPARED TO INPUT MODE 6         - MAC =    9.767579E-01
^^^ ANALYTICAL MODE    5          COMPARED TO INPUT MODE 1         - MAC =    2.978526E-34
^^^ ANALYTICAL MODE    5          COMPARED TO INPUT MODE 2         - MAC =    5.080408E-02
^^^ ANALYTICAL MODE    5          COMPARED TO INPUT MODE 3         - MAC =    2.795144E-33
^^^ ANALYTICAL MODE    5          COMPARED TO INPUT MODE 4         - MAC =    4.326751E-02
^^^ ANALYTICAL MODE    5          COMPARED TO INPUT MODE 5         - MAC =    5.987992E-29
^^^ ANALYTICAL MODE    5          COMPARED TO INPUT MODE 6         - MAC =    3.902807E-04
^^^ ANALYTICAL MODE    6          COMPARED TO INPUT MODE 1         - MAC =    1.457861E-35
^^^ ANALYTICAL MODE    6          COMPARED TO INPUT MODE 2         - MAC =    8.894073E-03
^^^ ANALYTICAL MODE    6          COMPARED TO INPUT MODE 3         - MAC =    5.946561E-34
^^^ ANALYTICAL MODE    6          COMPARED TO INPUT MODE 4         - MAC =    6.734312E-03
^^^ ANALYTICAL MODE    6          COMPARED TO INPUT MODE 5         - MAC =    1.508191E-30
^^^ ANALYTICAL MODE    6          COMPARED TO INPUT MODE 6         - MAC =    1.783772E-05
^^^
```

Output from First Try (cont.)

- **Note the Self XORTHO is very poor (Large off-diagonal terms)**

```
0       MATRIX CHECKIT   (GINO NAME 101 ) IS A DB  PREC            6 COLUMN X            6 ROW SYMMETRC MATRIX.
0COLUMN        1       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)    1.0000D+00 -3.2532D-17 -9.8900D-01 -3.9863D-15 -5.4868D-01 -3.0511D-13
0COLUMN        2       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)   -3.2532D-17  1.0000D+00  1.4249D-16 -9.8845D-01  5.3797D-14 -3.2658D-01
0COLUMN        3       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)   -9.8900D-01  1.4249D-16  1.0000D+00  3.8986D-15  4.1906D-01  2.3502D-13
0COLUMN        4       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)   -3.9863D-15 -9.8845D-01  3.8986D-15  1.0000D+00 -7.3664D-14  4.6546D-01
0COLUMN        5       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)   -5.4868D-01  5.3797D-14  4.1906D-01 -7.3664D-14  1.0000D+00  3.8736D-13
0COLUMN        6       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)   -3.0511D-13 -3.2658D-01  2.3502D-13  4.6546D-01  3.8736D-13  1.0000D+00
```

- **Note the XORTHO is very poor (Large off-diagonal terms, non 1.0 diagonal)**

```
0       MATRIX ORTHOA   (GINO NAME 101 ) IS A DB  PREC            6 COLUMN X            6 ROW SQUARE   MATRIX.
0COLUMN        1       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)   -1.0000D+00  3.5515D-17 -4.1908D-04 -7.1704D-18 -4.9527D-19  3.5920D-19
0COLUMN        2       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)   -2.9927D-18 -9.9999D-01  1.0787D-16 -5.0122D-03  6.9988D-04  1.7442D-04
0COLUMN        3       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)    9.8906D-01 -1.6150D-16 -1.4750D-01  3.8807D-17 -1.2140D-18 -4.8491D-19
0COLUMN        4       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)    4.0228D-15  9.8921D-01 -5.7835D-16 -1.4565D-01  1.5576D-02  3.7209D-03
0COLUMN        5       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)    5.4833D-01 -5.4450D-14  8.3595D-01  1.4729D-13 -4.3642D-15 -6.3178D-16
0COLUMN        6       ROWS         1 THRU         6     --------------------------------------------------
    ROW
       1)    3.0494D-13  3.3132D-01  4.5091D-13 -9.4331D-01  1.9578D-02  4.2168D-03
```

Input File – ws04_step2_premac_second-try.dat

```
$ Test-Analysis, Step 2
$ compare the ASET selected DOF against
$ the full FEM eigenvectors
$
SOL 103
diag 8,15
$
$  INCLUDE ALTER FOR CROSS-ORTHOGONALITY CHECKS
$
INCLUDE 'SSSALTERDIR:premaca.alt'
$
CEND
ECHO=NONE
TITLE = TEST-ANALYSIS:  ANALYSIS ASET Checkout
SUBTITLE = REDUCED MODEL
LABEL = 5 POINTS
DISP =  ALL
SPC=1
METHOD=100
BEGIN BULK
$
$  READ PCH FILE OF FULL MODEL
$  INCLUDE PUNCHED DISPLS. FROM Step 1, FULL RUN
INCLUDE 'ws04_step1_punch_full_model.pch'
$
PARAM   POST    0
PARAM   AUTOSPC YES
GRDSET, , , , , , ,345
BAROR, , , , , 0., 1., 0.
```

```
GRID    1               0.0     0.0     0.0
GRID    2               10.     0.0     0.0
GRID    3               20.     0.0     0.0
GRID    4               30.     0.0     0.0
GRID    5               40.     0.0     0.0
GRID    6               50.     0.0     0.0
GRID    7               60.     0.0     0.0
GRID    8               70.     0.0     0.0
GRID    9               80.     0.0     0.0
GRID    10              90.     0.0     0.0
GRID    11              100.    0.0     0.0
CBAR    1       1       1       2
CBAR    2       1       2       3
CBAR    3       1       3       4
CBAR    4       1       4       5
CBAR    5       1       5       6
CBAR    6       1       6       7
CBAR    7       1       7       8
CBAR    8       1       8       9
CBAR    9       1       9       10
CBAR    10      1       10      11
$  REDUCE TO TEST DOF
ASET1, 12, 3, 5, 7, 9, 11
SPC     1       1       123456  0.0
PBAR    1       1       1.0     160.0   160.0
MAT1    1       3.+7            .3      7.7E-4
EIGRL   100     0.0     10000.  6
ENDDATA
```

Output from Second Try

- **Note the frequencies match much more closely**

- **ASET based modes:**

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
			R E A L	E I G E N V A L U E S		
1	1	7.636484E+05	8.738698E+02	1.390807E+02	1.000000E+00	7.636484E+05
2	2	9.652552E+06	3.106856E+03	4.944714E+02	1.000000E+00	9.652552E+06
3	3	2.936994E+07	5.419404E+03	8.625249E+02	1.000000E+00	2.936994E+07
4	4	8.952774E+07	9.461910E+03	1.505910E+03	1.000000E+00	8.952774E+07
5	5	2.280674E+08	1.510190E+04	2.403542E+03	1.000000E+00	2.280674E+08
6	6	2.597403E+08	1.611646E+04	2.565014E+03	1.000000E+00	2.597403E+08

- **Full FEM modes:**

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
			R E A L	E I G E N V A L U E S		
1	1	7.636173E+05	8.738520E+02	1.390779E+02	1.000000E+00	7.636173E+05
2	2	9.593501E+06	3.097338E+03	4.929566E+02	1.000000E+00	9.593501E+06
3	3	2.932654E+07	5.415398E+03	8.618873E+02	1.000000E+00	2.932654E+07
4	4	8.492998E+07	9.215746E+03	1.466731E+03	1.000000E+00	8.492998E+07
5	5	2.253432E+08	1.501144E+04	2.389144E+03	1.000000E+00	2.253432E+08
6	6	2.282285E+08	1.510723E+04	2.404391E+03	1.000000E+00	2.282285E+08

Output from Second Try (cont.)

- **Note the MAC indicates good reduction**
  - Near 1.0 on the diagonal, < .1 on off-diagonal

```
^^^MODAL ASSURANCE CRITERIA FOR RESIDUAL STRUCTURE A-SET
^^^
^^^MODAL ASSURANCE CALCULATION IS PERFORMED FOR     6          CALCULATED MODES AND    6          INPUT MODES
^^^
^^^ ANALYTICAL MODE     1          COMPARED TO INPUT MODE 1         - MAC =     1.000000E+00
^^^ ANALYTICAL MODE     1          COMPARED TO INPUT MODE 2         - MAC =     9.331833E-33
^^^ ANALYTICAL MODE     1          COMPARED TO INPUT MODE 3         - MAC =     9.598562E-02
^^^ ANALYTICAL MODE     1          COMPARED TO INPUT MODE 4         - MAC =     2.399516E-30
^^^ ANALYTICAL MODE     1          COMPARED TO INPUT MODE 5         - MAC =     1.005941E-01
^^^ ANALYTICAL MODE     1          COMPARED TO INPUT MODE 6         - MAC =     1.222282E-26
^^^ ANALYTICAL MODE     2          COMPARED TO INPUT MODE 1         - MAC =     4.126525E-32
^^^ ANALYTICAL MODE     2          COMPARED TO INPUT MODE 2         - MAC =     9.999999E-01
^^^ ANALYTICAL MODE     2          COMPARED TO INPUT MODE 3         - MAC =     1.429794E-32
^^^ ANALYTICAL MODE     2          COMPARED TO INPUT MODE 4         - MAC =     2.777777E-02
^^^ ANALYTICAL MODE     2          COMPARED TO INPUT MODE 5         - MAC =     1.876482E-27
^^^ ANALYTICAL MODE     2          COMPARED TO INPUT MODE 6         - MAC =     2.777777E-02
^^^ ANALYTICAL MODE     3          COMPARED TO INPUT MODE 1         - MAC =     9.622484E-02
^^^ ANALYTICAL MODE     3          COMPARED TO INPUT MODE 2         - MAC =     1.240105E-33
^^^ ANALYTICAL MODE     3          COMPARED TO INPUT MODE 3         - MAC =     9.999998E-01
^^^ ANALYTICAL MODE     3          COMPARED TO INPUT MODE 4         - MAC =     1.241349E-29
^^^ ANALYTICAL MODE     3          COMPARED TO INPUT MODE 5         - MAC =     1.059392E-01
^^^ ANALYTICAL MODE     3          COMPARED TO INPUT MODE 6         - MAC =     1.283692E-26
^^^ ANALYTICAL MODE     4          COMPARED TO INPUT MODE 1         - MAC =     8.047325E-32
^^^ ANALYTICAL MODE     4          COMPARED TO INPUT MODE 2         - MAC =     2.777777E-02
^^^ ANALYTICAL MODE     4          COMPARED TO INPUT MODE 3         - MAC =     7.488634E-34
^^^ ANALYTICAL MODE     4          COMPARED TO INPUT MODE 4         - MAC =     1.000000E+00
^^^ ANALYTICAL MODE     4          COMPARED TO INPUT MODE 5         - MAC =     1.695138E-27
^^^ ANALYTICAL MODE     4          COMPARED TO INPUT MODE 6         - MAC =     2.777777E-02
^^^ ANALYTICAL MODE     5          COMPARED TO INPUT MODE 1         - MAC =     1.016641E-01
^^^ ANALYTICAL MODE     5          COMPARED TO INPUT MODE 2         - MAC =     9.179594E-31
^^^ ANALYTICAL MODE     5          COMPARED TO INPUT MODE 3         - MAC =     1.071091E-01
^^^ ANALYTICAL MODE     5          COMPARED TO INPUT MODE 4         - MAC =     3.917640E-30
^^^ ANALYTICAL MODE     5          COMPARED TO INPUT MODE 5         - MAC =     9.999937E-01
^^^ ANALYTICAL MODE     5          COMPARED TO INPUT MODE 6         - MAC =     1.064844E-25
^^^ ANALYTICAL MODE     6          COMPARED TO INPUT MODE 1         - MAC =     2.792243E-30
^^^ ANALYTICAL MODE     6          COMPARED TO INPUT MODE 2         - MAC =     2.777778E-02
^^^ ANALYTICAL MODE     6          COMPARED TO INPUT MODE 3         - MAC =     2.929205E-30
^^^ ANALYTICAL MODE     6          COMPARED TO INPUT MODE 4         - MAC =     2.777778E-02
^^^ ANALYTICAL MODE     6          COMPARED TO INPUT MODE 5         - MAC =     6.187933E-26
^^^ ANALYTICAL MODE     6          COMPARED TO INPUT MODE 6         - MAC =     1.000000E+00
```

Output from Second Try (cont.)

- **Note the Self XORTHO is very good**

```
0       MATRIX CHECKIT   (GINO NAME 101 ) IS A DB  PREC            6 COLUMN X           6 ROW SYMMETRC MATRIX.
0COLUMN        1       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)   1.0000D+00 -1.8113D-17 -4.3685D-04  5.3943D-16 -1.3560D-03  4.4012D-15
0COLUMN        2       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)  -1.8113D-17  1.0000D+00  5.1067D-18  5.4149D-11  1.7657D-15 -3.4196D-11
0COLUMN        3       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)  -4.3685D-04  5.1067D-18  1.0000D+00  2.8619D-15 -1.5855D-03  4.2993D-15
0COLUMN        4       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)   5.3943D-16  5.4149D-11  2.8619D-15  1.0000D+00 -1.4999D-15 -3.5885D-11
0COLUMN        5       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)  -1.3560D-03  1.7657D-15 -1.5855D-03 -1.4999D-15  1.0000D+00  8.5594D-14
0COLUMN        6       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)   4.4012D-15 -3.4196D-11  4.2993D-15 -3.5885D-11  8.5594D-14  1.0000D+00
```

- **Note the XORTHO is very good**

```
0       MATRIX ORTHOA    (GINO NAME 101 ) IS A DB  PREC            6 COLUMN X           6 ROW SQUARE   MATRIX.
0COLUMN        1       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)  -1.0000D+00  8.2392D-17  2.9384D-07 -2.2544D-17  1.3846D-08 -2.1394D-18
0COLUMN        2       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)   1.0050D-16  1.0000D+00  1.0516D-17 -4.9004D-12 -2.0489D-16  3.4195D-11
0COLUMN        3       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)   4.3714D-04 -5.4494D-18  1.0000D+00  2.9321D-16  2.4651D-05  1.8671D-17
0COLUMN        4       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)  -5.1688D-16  4.9249D-11  3.1554D-15 -1.0000D+00 -4.9618D-16  3.5885D-11
0COLUMN        5       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)   1.3560D-03  1.9704D-15 -1.6108D-03  9.9811D-16  1.0000D+00  2.4438D-13
0COLUMN        6       ROWS         1 THRU         6      --------------------------------------------------
    ROW
        1)  -4.3991D-15 -5.5511D-16  4.3118D-15  8.3267D-16  3.2998D-13 -1.0000D+00
```

Input File – ws04_step3_postmac.dat

```
$  TEST-ANALYSIS, POST TEST Correlation
SOL 100
diag 8, 15
$
$  INCLUDE ALTER FOR CROSS-ORTHOGONALITY CHECKS
$
INCLUDE 'SSSALTERDIR:postmaca.alt'
$
CEND
TITLE = TEST-ANALYSIS:  POST  POSTMAC1
SUBTITLE = CORRELATE TEST AND ANALYSIS MODES
LABEL = 5 POINTS
BEGIN BULK
$
$  READ PCH FILE OF ANALYSIS MODEL
$  FROM PRE-TEST RUN (ASET)
$
INCLUDE 'ws04_step2_premac_second-try.pch'
$
$
$  READ PCH FILE OF TEST DATA
$  FROM EXTERNAL FILE
$
INCLUDE 'test_eigenvectors.pch'
$
$  DEFINE GRIDS FOR TEST-ANALYSIS
$  The position doesn't matter, just the ID's
$
GRID    3
GRID    5
GRID    7
GRID    9
GRID    11
$
ENDDATA
```

Output From Correlation Run

- **Output from Step 3**
  - MAC results of the Full FEM Model and the Test modes

Note that mode 5 and mode 6 are swapped between the test modes and the analysis modes… this is identified by the ‘near 1.0’ term being off the diagonal.

```
^^^MODAL ASSURANCE CALCULATION IS PERFORMED FOR     6        FULL MODEL MODES AND    6         TEST MODES
^^^ FULL MODEL MODE     1           COMPARED TO TEST MODE  1          - MAC =    9.993510E-01
^^^ FULL MODEL MODE     1           COMPARED TO TEST MODE  2          - MAC =    2.215651E-33
^^^ FULL MODEL MODE     1           COMPARED TO TEST MODE  3          - MAC =    2.091196E-01
^^^ FULL MODEL MODE     1           COMPARED TO TEST MODE  4          - MAC =    1.056176E-33
^^^ FULL MODEL MODE     1           COMPARED TO TEST MODE  5          - MAC =    1.284397E-34
^^^ FULL MODEL MODE     1           COMPARED TO TEST MODE  6          - MAC =    1.062026E-01
^^^ FULL MODEL MODE     2           COMPARED TO TEST MODE  1          - MAC =    2.755091E-36
^^^ FULL MODEL MODE     2           COMPARED TO TEST MODE  2          - MAC =    9.998970E-01
^^^ FULL MODEL MODE     2           COMPARED TO TEST MODE  3          - MAC =    1.010103E-36
^^^ FULL MODEL MODE     2           COMPARED TO TEST MODE  4          - MAC =    3.038901E-02
^^^ FULL MODEL MODE     2           COMPARED TO TEST MODE  5          - MAC =    2.777778E-02
^^^ FULL MODEL MODE     2           COMPARED TO TEST MODE  6          - MAC =    3.480348E-37
^^^ FULL MODEL MODE     3           COMPARED TO TEST MODE  1          - MAC =    9.629782E-02
^^^ FULL MODEL MODE     3           COMPARED TO TEST MODE  2          - MAC =    1.929121E-33
^^^ FULL MODEL MODE     3           COMPARED TO TEST MODE  3          - MAC =    9.081355E-01
^^^ FULL MODEL MODE     3           COMPARED TO TEST MODE  4          - MAC =    2.298510E-32
^^^ FULL MODEL MODE     3           COMPARED TO TEST MODE  5          - MAC =    3.656624E-36
^^^ FULL MODEL MODE     3           COMPARED TO TEST MODE  6          - MAC =    9.552094E-02
^^^ FULL MODEL MODE     4           COMPARED TO TEST MODE  1          - MAC =    1.552570E-30
^^^ FULL MODEL MODE     4           COMPARED TO TEST MODE  2          - MAC =    2.760769E-02
^^^ FULL MODEL MODE     4           COMPARED TO TEST MODE  3          - MAC =    4.221343E-30
^^^ FULL MODEL MODE     4           COMPARED TO TEST MODE  4          - MAC =    9.998970E-01
^^^ FULL MODEL MODE     4           COMPARED TO TEST MODE  5          - MAC =    2.777778E-02
^^^ FULL MODEL MODE     4           COMPARED TO TEST MODE  6          - MAC =    1.732344E-31
^^^ FULL MODEL MODE     5           COMPARED TO TEST MODE  1          - MAC =    1.092327E-01
^^^ FULL MODEL MODE     5           COMPARED TO TEST MODE  2          - MAC =    1.656170E-27
^^^ FULL MODEL MODE     5           COMPARED TO TEST MODE  3          - MAC =    4.396997E-02
^^^ FULL MODEL MODE     5           COMPARED TO TEST MODE  4          - MAC =    1.538004E-27
^^^ FULL MODEL MODE     5           COMPARED TO TEST MODE  5          - MAC =    6.274038E-26
^^^ FULL MODEL MODE     5           COMPARED TO TEST MODE  6          - MAC =    9.995029E-01
^^^ FULL MODEL MODE     6           COMPARED TO TEST MODE  1          - MAC =    1.165788E-26
^^^ FULL MODEL MODE     6           COMPARED TO TEST MODE  2          - MAC =    2.784739E-02
^^^ FULL MODEL MODE     6           COMPARED TO TEST MODE  3          - MAC =    5.084902E-27
^^^ FULL MODEL MODE     6           COMPARED TO TEST MODE  4          - MAC =    2.784739E-02
^^^ FULL MODEL MODE     6           COMPARED TO TEST MODE  5          - MAC =    1.000000E+00
^^^ FULL MODEL MODE     6           COMPARED TO TEST MODE  6          - MAC =    1.051063E-25
^^^
```

Output From Correlation Run (cont.)

- **Additional output from Step 3**
  - MAC results of the ASET FEM Model and the Test modes
    - Again, we see that mode 5 and mode 6 are swapped between the test modes and the analysis modes

```
^^^MODAL ASSURANCE CALCULATION IS PERFORMED FOR     6           ANALYSIS MODES AND 6          REDUCED MODEL MODES
^^^ ANALYTICAL MODE     1          COMPARED TO TEST MODE   1           - MAC =     9.993510E-01
^^^ ANALYTICAL MODE     1          COMPARED TO TEST MODE   2           - MAC =     4.279361E-34
^^^ ANALYTICAL MODE     1          COMPARED TO TEST MODE   3           - MAC =     2.091194E-01
^^^ ANALYTICAL MODE     1          COMPARED TO TEST MODE   4           - MAC =     3.849048E-35
^^^ ANALYTICAL MODE     1          COMPARED TO TEST MODE   5           - MAC =     2.365835E-35
^^^ ANALYTICAL MODE     1          COMPARED TO TEST MODE   6           - MAC =     1.062026E-01
^^^ ANALYTICAL MODE     2          COMPARED TO TEST MODE   1           - MAC =     2.333624E-34
^^^ ANALYTICAL MODE     2          COMPARED TO TEST MODE   2           - MAC =     9.998971E-01
^^^ ANALYTICAL MODE     2          COMPARED TO TEST MODE   3           - MAC =     2.315568E-33
^^^ ANALYTICAL MODE     2          COMPARED TO TEST MODE   4           - MAC =     3.038901E-02
^^^ ANALYTICAL MODE     2          COMPARED TO TEST MODE   5           - MAC =     2.777778E-02
^^^ ANALYTICAL MODE     2          COMPARED TO TEST MODE   6           - MAC =     3.315157E-33
^^^ ANALYTICAL MODE     3          COMPARED TO TEST MODE   1           - MAC =     9.653700E-02
^^^ ANALYTICAL MODE     3          COMPARED TO TEST MODE   2           - MAC =     7.443814E-34
^^^ ANALYTICAL MODE     3          COMPARED TO TEST MODE   3           - MAC =     9.082690E-01
^^^ ANALYTICAL MODE     3          COMPARED TO TEST MODE   4           - MAC =     5.214750E-33
^^^ ANALYTICAL MODE     3          COMPARED TO TEST MODE   5           - MAC =     8.916561E-34
^^^ ANALYTICAL MODE     3          COMPARED TO TEST MODE   6           - MAC =     9.556985E-02
^^^ ANALYTICAL MODE     4          COMPARED TO TEST MODE   1           - MAC =     5.781594E-33
^^^ ANALYTICAL MODE     4          COMPARED TO TEST MODE   2           - MAC =     2.760769E-02
^^^ ANALYTICAL MODE     4          COMPARED TO TEST MODE   3           - MAC =     1.164472E-32
^^^ ANALYTICAL MODE     4          COMPARED TO TEST MODE   4           - MAC =     9.998971E-01
^^^ ANALYTICAL MODE     4          COMPARED TO TEST MODE   5           - MAC =     2.777778E-02
^^^ ANALYTICAL MODE     4          COMPARED TO TEST MODE   6           - MAC =     2.711909E-32
^^^ ANALYTICAL MODE     5          COMPARED TO TEST MODE   1           - MAC =     1.103399E-01
^^^ ANALYTICAL MODE     5          COMPARED TO TEST MODE   2           - MAC =     5.666964E-32
^^^ ANALYTICAL MODE     5          COMPARED TO TEST MODE   3           - MAC =     4.480625E-02
^^^ ANALYTICAL MODE     5          COMPARED TO TEST MODE   4           - MAC =     3.756292E-32
^^^ ANALYTICAL MODE     5          COMPARED TO TEST MODE   5           - MAC =     2.610863E-30
^^^ ANALYTICAL MODE     5          COMPARED TO TEST MODE   6           - MAC =     9.994664E-01
^^^ ANALYTICAL MODE     6          COMPARED TO TEST MODE   1           - MAC =     1.938919E-31
^^^ ANALYTICAL MODE     6          COMPARED TO TEST MODE   2           - MAC =     2.784740E-02
^^^ ANALYTICAL MODE     6          COMPARED TO TEST MODE   3           - MAC =     7.675702E-32
^^^ ANALYTICAL MODE     6          COMPARED TO TEST MODE   4           - MAC =     2.784740E-02
^^^ ANALYTICAL MODE     6          COMPARED TO TEST MODE   5           - MAC =     1.000000E+00
^^^ ANALYTICAL MODE     6          COMPARED TO TEST MODE   6           - MAC =     2.168827E-30
```

Output From Correlation Run (cont.)

- **Additional output from Step 3 (cont.)**
  - CHECKIT
    - This represents $(\Phi_{test})^T * M_{ASET} * \Phi_{test}$ and is to check the quality of the test modes
    - It should have 1.0 on the diagonal and less than .1 on the off diagonal
      - As can be seen, the diagonal is very good, but the off-diagonal has some higher than desired values

```
0       MATRIX CHECKIT   (GINO NAME 101 ) IS A DB  PREC          6 COLUMN X             6 ROW SQUARE   MATRIX.
0COLUMN        1       ROWS         1 THRU       6      --------------------------------------------------
    ROW
       1)   1.0000D+00  0.0000D+00  2.4999D-01  0.0000D+00  0.0000D+00  2.7419D-02
0COLUMN        2       ROWS         2 THRU       5      --------------------------------------------------
    ROW
       2)   1.0000D+00  0.0000D+00  8.5251D-03  3.0224D-11
0COLUMN        3       ROWS         1 THRU       6      --------------------------------------------------
    ROW
       1)   2.4999D-01  0.0000D+00  1.0000D+00  0.0000D+00  0.0000D+00 -1.2581D-01
0COLUMN        4       ROWS         2 THRU       5      --------------------------------------------------
    ROW
       2)   8.5251D-03  0.0000D+00  1.0000D+00  3.1716D-11
0COLUMN        5       ROWS         2 THRU       5      --------------------------------------------------
    ROW
       2)   3.0224D-11  0.0000D+00  3.1716D-11  1.0000D+00
0COLUMN        6       ROWS         1 THRU       6      --------------------------------------------------
    ROW
       1)   2.7419D-02  0.0000D+00 -1.2581D-01  0.0000D+00  0.0000D+00  1.0000D+00
```

Output From Correlation Run (cont.)

- **Additional output from Step 3 (cont.)**
  - ORTHO2
    - This represents $(\Phi_{test})^T * M_{ASET} * \Phi_{FEM}$ and is to compare the test mode shapes with the FULL FEM mode shapes partitioned to the ASET DOF
    - It should have >.95 on the diagonal and <.1 on the off diagonal
      - The criteria for what is appropriate for the diagonal and off diagonal is set by each organization, .95/.10 is commonly used… since this is comparing the FULL FEM to the test, the results will be worse
      - As can be seen, the diagonal is pretty good, but the off-diagonal has a higher than desired value
      - The swapped modes are also evident in the XORTHO output, as seen previously in the MAC

```
 ^^^RESULTS OF CROSS-ORTHOGONALITY TEST
 ^^^EACH ROW REPRESENTS ONE FULL MODEL MODE, EACH COLUMN REPRESENTS AN INPUT MODE
0      MATRIX ORTHO2    (GINO NAME 101 ) IS A DB  PREC            6 COLUMN X            6 ROW SQUARE   MATRIX.
0COLUMN         1       ROWS         1 THRU        6     --------------------------------------------------
    ROW
       1)  -9.9962D-01 -1.4401D-18  6.0394D-03  2.1261D-15 -1.1755D-02 -3.4128D-15
0COLUMN         2       ROWS         1 THRU        6     --------------------------------------------------
    ROW
       1)   6.1428D-17 -9.9383D-01  2.4584D-17  7.7971D-04  6.6532D-16  2.6177D-11
0COLUMN         3       ROWS         1 THRU        6     --------------------------------------------------
    ROW
       1)  -2.5888D-01 -6.3331D-19 -9.4030D-01 -2.1756D-15  1.0828D-01  2.8097D-14
0COLUMN         4       ROWS         1 THRU        6     --------------------------------------------------
    ROW
       1)  -3.9951D-17 -9.3253D-03  1.5905D-16 -9.4702D-01  2.5009D-15  2.7468D-11
0COLUMN         5       ROWS         1 THRU        6     --------------------------------------------------
    ROW
       1)  -1.2604D-17 -6.3978D-11 -2.6892D-17 -6.3978D-11 -2.4342D-13  8.6603D-01
0COLUMN         6       ROWS         1 THRU        6     --------------------------------------------------
    ROW
       1)  -1.4139D-02  1.1662D-22  2.3332D-02 -5.5994D-17 -9.8756D-01 -2.8514D-13
```

Output From Correlation Run (cont.)

- **Additional output from Step 3 (cont.)**
  - ORTHOA
    - This represents $(\Phi_{test})^T * M_{ASET} * \Phi_{ASET}$ and is to compare the test mode shapes with the ASET FEM mode shapes
    - It should have >.95 on the diagonal and <.1 on the off diagonal
      - The criteria for what is appropriate for the diagonal and off diagonal is set by each organization, .95/.10 is commonly used… this will often be better then the FULL FEM comparison, as it more closely represents the test data acquisition
      - As can be seen, the diagonal is very good and again, the off-diagonal has one out-of-bound term
      - The swapped modes are also evident in the XORTHO output, as seen previously in the MAC

```
 ^^^RESULTS OF CROSS-ORTHOGONALITY TEST
 ^^^EACH ROW REPRESENTS ONE ANALYTICAL MODE, EACH COLUMN REPRESENTS AN INPUT MODE
0      MATRIX ORTHOA    (GINO NAME 101 ) IS A DB  PREC           6 COLUMN X          6 ROW SQUARE    MATRIX.
0COLUMN        1       ROWS         1 THRU        6    ------------------------------------------------
    ROW
       1)    9.9966D-01   2.0417D-17   5.6116D-03   3.4999D-19  -1.3249D-02   1.3340D-17
0COLUMN        2       ROWS         1 THRU        6    ------------------------------------------------
    ROW
       1)    2.1600D-17  -9.9996D-01  -5.1634D-17  -8.2329D-04   7.4215D-17  -3.0223D-11
0COLUMN        3       ROWS         1 THRU        6    ------------------------------------------------
    ROW
       1)    2.5890D-01   6.1310D-17  -9.4181D-01   5.3178D-17   1.0785D-01  -1.5260D-16
0COLUMN        4       ROWS         1 THRU        6    ------------------------------------------------
    ROW
       1)    2.6658D-18  -9.3829D-03   7.6269D-17   9.9994D-01   1.2649D-16  -3.1716D-11
0COLUMN        5       ROWS         1 THRU        6    ------------------------------------------------
    ROW
       1)    9.0713D-19  -6.4163D-11   2.0926D-17   3.1668D-11  -1.5600D-15  -1.0000D+00
0COLUMN        6       ROWS         1 THRU        6    ------------------------------------------------
    ROW
       1)    1.4140D-02  -7.6485D-17   2.3385D-02   1.2233D-16  -9.9962D-01   1.5615D-15
```

WORKSHOP 5

FRF

- **Workshop Objectives**
  - Learn how to generate FRF components
  - Learn how to assemble FRF components
  - Look at the results from the FRF runs and compared that with a single shot frequency response run

- **Software Version**
  - MSC Nastran 2013

- **Files Required**
  - part10.dat
  - part20.dat
  - part30.dat
  - frf_2a.dat

- **Problem Description**
  - 3 components—one for each FRF run
  - Assemble FRF components

- **Suggested Steps**

  – First, do Component 10

1. Create FRF for component 10. The model information is contained in part10.dat
2. Apply unit load at grid point 35, component 3 and grid point 93, component 3 using the FRFXIT and FRFXIT1 entries (one for each loaded grid)
3. Define connection points at grid points 13 and 23
4. Use the output2 format
5. Request displacement, velocity, and acceleration output at grid points 13, 23, 93, and 98
6. Request stress output for element 33
7. A template to run this job is contained in frf_2a.dat

- **Suggested Steps (cont.)**

  – Next, do Component 20

1. Create FRF for component 20. The model information is contained in part20.dat
2. Copy the frf_2a.dat file to frf_2b.dat as a starting point, and edit this new file
3. Apply unit load at grid point 42, component 3 and grid point 104, component 3 using the FRFXIT and FRFXIT1 entries (again, use one form for each grid)
4. Define connection points at grid points 14 and 24
5. Use the output2 format
6. Request displacement, velocity, and acceleration output at grid points 14, 24, 99, and 104
7. Request stress output for element 44

- **Suggested Steps (cont.)**

  – Next, do Component 30

1. Create FRF for component 30. The model information is contained in part30.dat
2. Copy the frf_2b.dat file to frf_2c.dat as a starting point, and edit this new file
3. Apply unit load at grid point 7, component 3 and grid point 8, component 3 using the FRFXIT and FRFXIT1 entries (again, use one form for each grid)
4. Define connection points at grid points 13, 14, 23,and 24
5. Use the output2 format
6. Request displacement, velocity, and acceleration output at grid points 13,14, 23, and 24
7. Request stress output for element 44

- **Suggested Steps (cont.)**

  – Next, do the assembly

1. Start with frf_assembly.dat as a template for creating the assembly run
2. Read the proper op2 file via the “ASSIGN INPUTT2” command
3. In the assembly run, bring in the three .asm files generated from the 3 generation runs

- **Suggested Steps (cont.)**

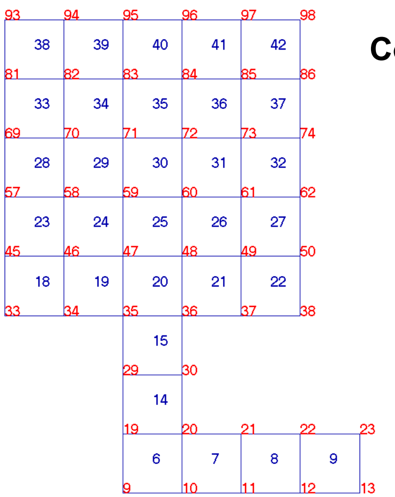
  – Next, run the baseline file for comparison

1. Run the same job using a single shot run, use the provide file: frf-full.dat which uses the double-headed.bdf include file
2. Compare the results at 20 hertz
3. Compare the results with the FRF run and one-shot run
   - Loading at grid point 13 and response at grid point 13
   - Loading at grid point 7 and response at grid point 23

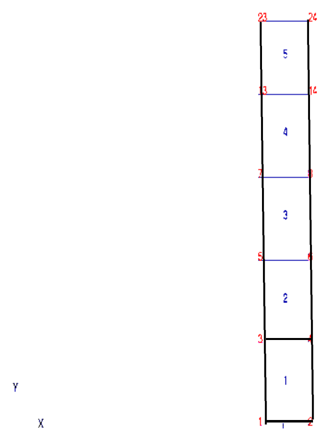
Model Description

- **3 Components**

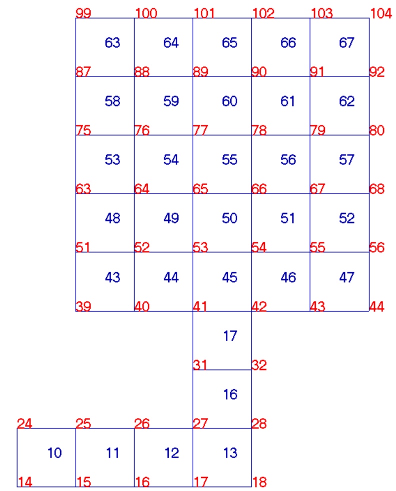
Component 10



Component 30

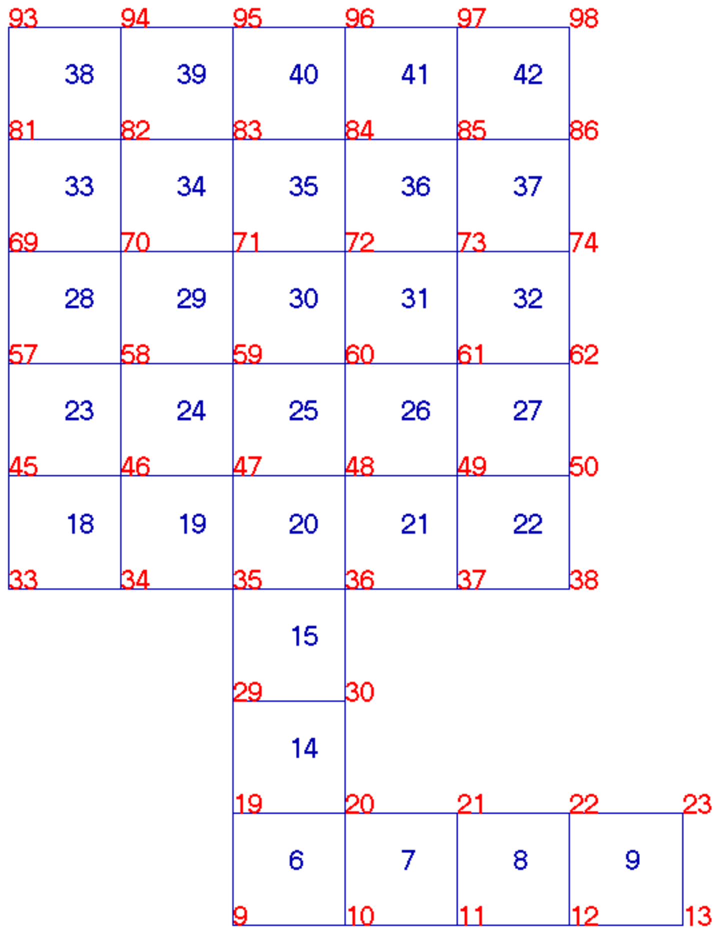


Component 20



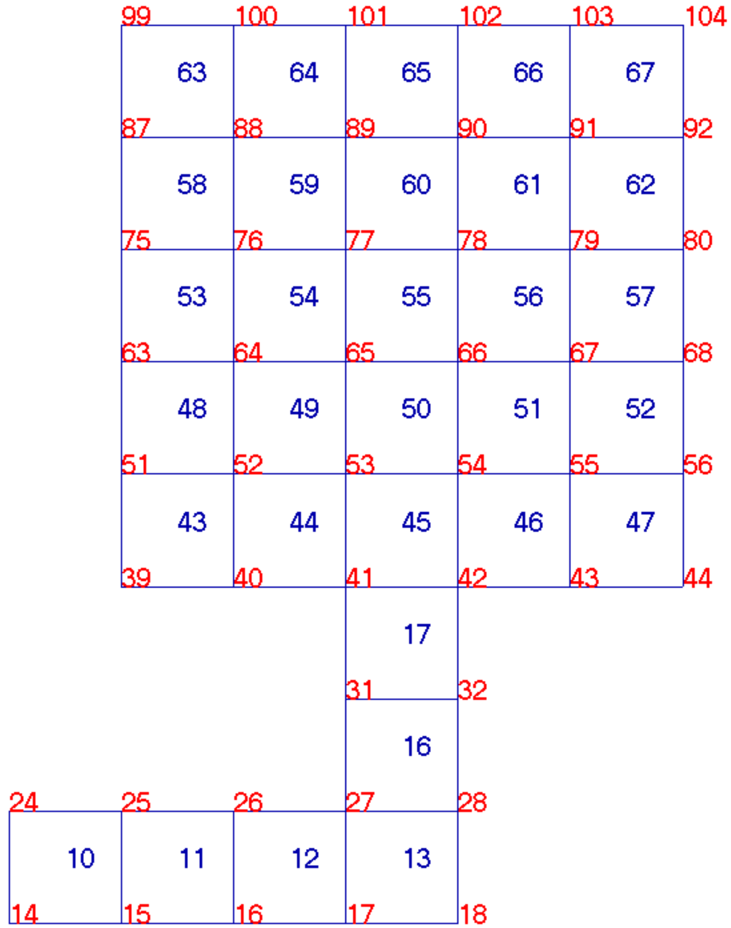
Model Description (cont.)

- **Component 10**



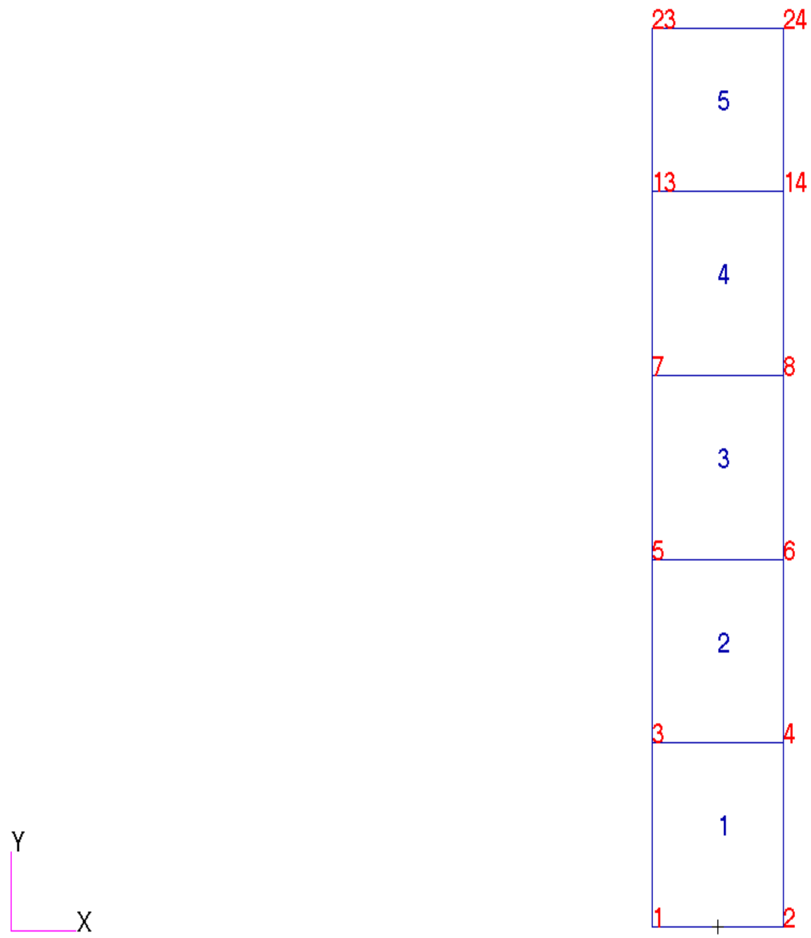
Model Description (cont.)

- **Component 20**



Model Description (cont.)

- **Component 30**



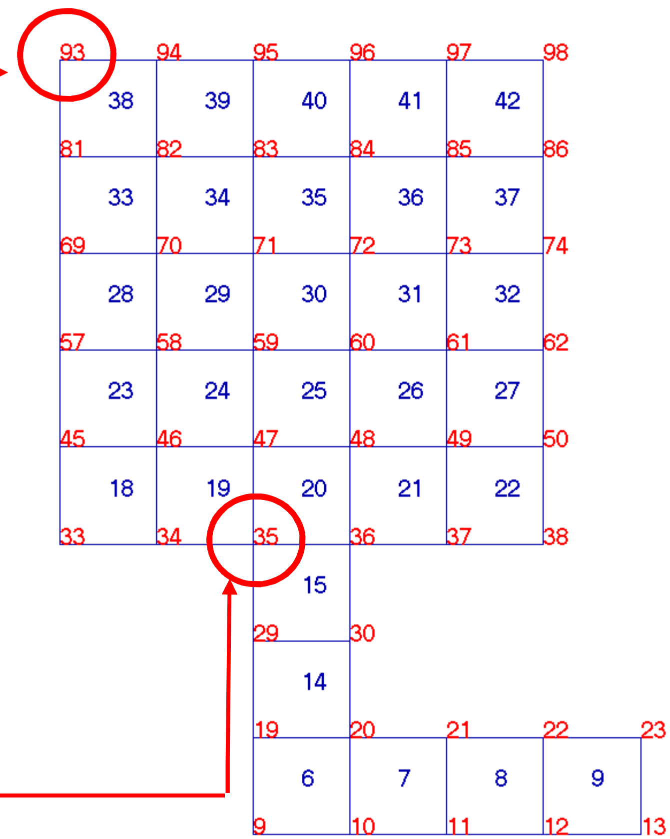
SOLUTION FOR WORKSHOP # 5

Component 10 Generation Run

- **Generation run for component 10**
- **Unit load at grid point 35 and 93**

Component 10

```
$
$  frf_2a.dat
$  frf for comp 10 using op2 option
$
assign output2='frf_2a_op2',unit=31,delete
SOL     108
DIAG 8,15
CEND
TITLE = generate frf for comp 10 using op2 option
SUBTITLE = FRF GENERATION FOR COMPONENT NO. 10
SET 1000 = 13,23
SET 2000 = 13,23,93,98
SET 3000 = 33
FRF(COMPID=10 compname=comp10 CONNPTS=1000,op2=31)
FREQ = 5000
DISP(phase) = 2000
velo(phase) = 2000
acce(phase) = 2000
OLOAD=ALL
STRE = 3000
BEGIN BULK
PARAM,G,0.01
FREQ,5000,10.0,20.0,30.0
FRFXIT1,3,93
frfxit     35          3          $ unit load applied at grid point 35 direction 3
$
INCLUDE 'part10.dat'
$
ENDDATA
```



MSC Software

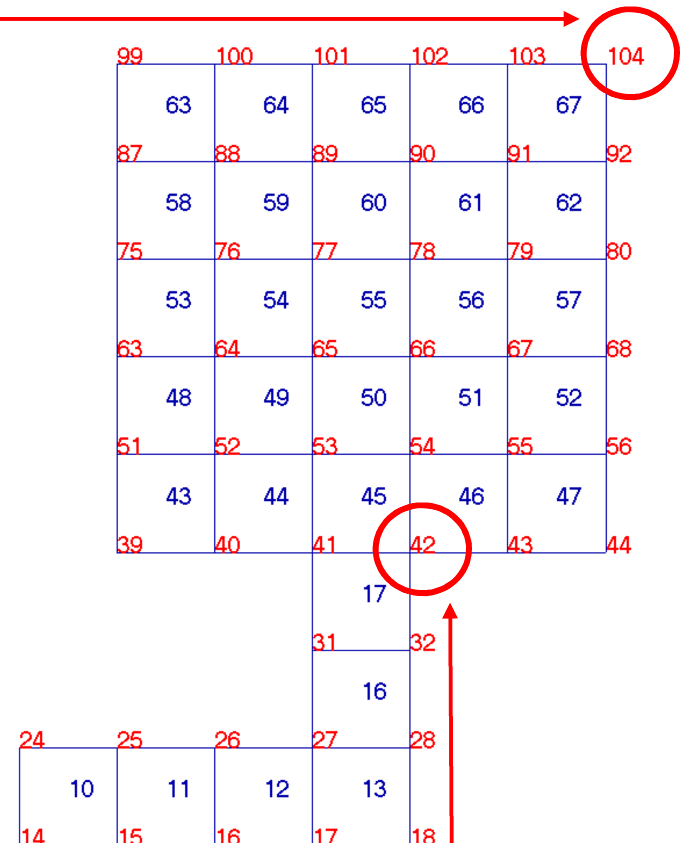
Component 20 Generation Run

- **Generation run for component 20**
- **Unit load at grid point 42 and 104**

Component 20

```
$
$  frf_2b.dat
$  frf for comp 20 using op2 option
$
assign output2='frf_2b_op2',unit=32,delete
SOL     108
DIAG 8,15
CEND
TITLE = generate frf for comp 20 using op2 option
SUBTITLE = FRF GENERATION FOR COMPONENT NO. 20
SET 1000 = 14,24
SET 2000 = 14,24,99,104
SET 3000 = 44
FRF(COMPID=20 compname=comp20 CONNPTS=1000 op2=32)
FREQ = 5000
DISP(phase) = 2000
velo(phase) = 2000
acce(phase) = 2000
OLOAD=ALL
STRE = 3000
BEGIN BULK
PARAM,G,0.01
FREQ,5000,10.0,20.0,30.0
FRFXIT1,3,104
frfxit     42              3
$
INCLUDE 'part20.dat'
$
ENDDATA
```

$ unit load applied at grid point 42 direction 3

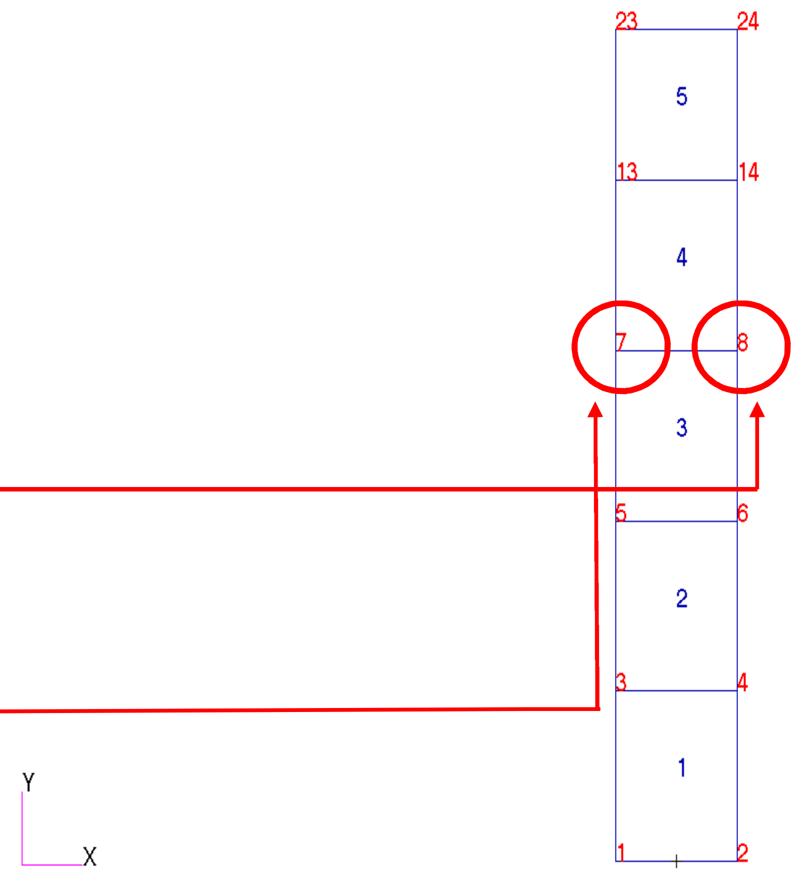


Component 30 Generation Run

- **Generation run for component 30**
- **Unit load at grid point 7 and 8**

Component 30

```
$
$  frf_2c.dat
$  frf for comp 30 using op2 option
$
assign output2='frf_2c_op2',unit=33,delete
SOL     108
DIAG 8,15
CEND
TITLE = generate frf for comp 30 using op2 option
SUBTITLE = FRF GENERATION FOR COMPONENT NO. 30
spc = 100
SET 1000 = 13,14,23,24
SET 3000 = 5
FRF(COMPID=30 compname=comp30 CONNPTS=1000,op2=33)
FREQ = 5000
DISP(phase) = 1000
velo(phase) = 1000
acce(phase) = 1000
OLOAD=ALL
STRE = 3000
BEGIN BULK
spc1,100,123456,1,2
PARAM,G,0.01
FREQ,5000,10.0,20.0,30.0
FRFXIT1,3,7
frfxit      8                3              $ unit load applied at grid point 8 direction 3
$
INCLUDE 'part30.dat'
$
ENDDATA
```



Assembly Run

Assemby Run

```
$
$   frf_assembly.dat
$
assign inputt2='frf_2a_op2',unit=31
assign inputt2='frf_2b_op2',unit=32
assign inputt2='frf_2c_op2',unit=33
$
SOL     108
DIAG 8,15
CEND
TITLE = sol 108 - bring in comp 10, 20, 30 using op2 option
SUBTITLE = FRF BASED ASSEMBLY (FBA) USING THE ASM OPTION
FRF(ASM XITOUT=unitall)
DISP(phase) = ALL
STRE(phase) = ALL
BEGIN BULK
include 'frf_2a.asm'
include 'frf_2b.asm'
include 'frf_2c.asm'
ENDDATA
```

These output2 files were generated from the previous 3 generation runs

ASM describer denotes assembly (default is GEN, for generation)

These ASM files were generated from the previous 3 generation runs

Results Comparison

Load at grid point 13 (T3) – Response at grid 13 (T3) at 20 Hz

- **FRF Run**

```
1     SOL 108 - BRING IN COMP 10, 20, 30 USING OP2 OPTION                  DECEMBER  19, 2011  MSC.NASTRAN 11/25/11   PAGE    35
       FRF BASED ASSEMBLY (FBA) USING THE ASM OPTION                             FBA OUTPUT FOR FRF COMPONENT        10 (COMP10   )
0     UNIT LOAD ON GRID        13/3 (FRF COMP.        10 / COMP10   )                                         FBA SUBCASE          9
       FREQUENCY =   2.000000E+01
                                              C O M P L E X   D I S P L A C E M E N T   V E C T O R
                                                                (MAGNITUDE/PHASE)

       POINT ID.    TYPE          T1              T2              T3              R1              R2              R3
0          13        G       0.0             0.0             1.497421E-02    1.163808E-03    2.151397E-03    0.0
                               0.0             0.0           359.1704        358.1897        359.0002          0.0
0          23        G       0.0             0.0             1.537547E-02    7.744131E-05    6.716002E-04    0.0
                               0.0             0.0           359.1049        196.9581        358.0282          0.0
0          35        G       0.0             0.0             4.846601E-04    9.209557E-03    1.308926E-03    0.0
                               0.0             0.0           337.9925        179.4995        180.4884          0.0
```

- **One-shot Run**

```
0                                                                                                              SUBCASE 2
      FREQUENCY =   2.000000E+01
                                              C O M P L E X   D I S P L A C E M E N T   V E C T O R
                                                                (MAGNITUDE/PHASE)

      POINT ID.    TYPE          T1              T2              T3              R1              R2              R3
0            7       G       0.0             0.0             1.198668E-02    5.066612E-03    1.972500E-03    0.0
                               0.0             0.0           359.2179        359.1330        359.1010          0.0
0            8       G       0.0             0.0             1.071159E-02    4.287366E-03    1.186601E-03    0.0
                               0.0             0.0           359.2431        359.1408        358.8354          0.0
0           13       G       0.0             0.0             1.497421E-02    1.163808E-03    2.151397E-03    0.0
                               0.0             0.0           359.1704        358.1897        359.0002          0.0
0           14       G       0.0             0.0             1.342347E-02    1.366029E-03    1.676386E-03    0.0
                               0.0             0.0           359.1930        358.4375        358.9254          0.0
0           23       G       0.0             0.0             1.537547E-02    7.744131E-05    6.716002E-04    0.0
                               0.0             0.0           359.1049        196.9581        358.0282          0.0
```

Results Comparison

Load at grid point 7 (T3) – Response at grid 23 (T3) at 30 Hz

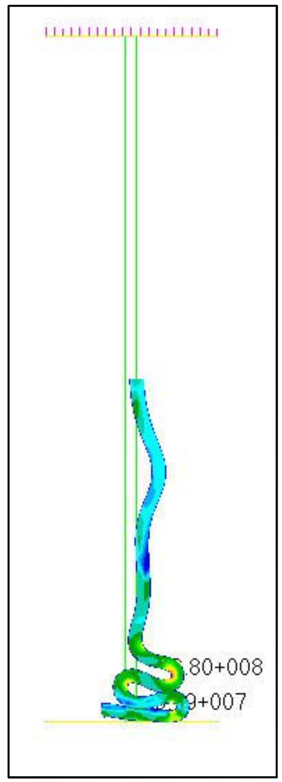
- **FRF Run**

```
1     SOL 108 - BRING IN COMP 10, 20, 30 USING OP2 OPTION                DECEMBER  19, 2011  MSC.NASTRAN 11/25/11    PAGE    24
       FRF BASED ASSEMBLY (FBA) USING THE ASM OPTION                          FBA OUTPUT FOR FRF COMPONENT        10 (COMP10  )
0     UNIT LOAD ON GRID        7/3 (FRF COMP.       30 / COMP30  )                                         FBA SUBCASE         5
       FREQUENCY =  3.000000E+01
                                          C O M P L E X   D I S P L A C E M E N T   V E C T O R
                                                        (MAGNITUDE/PHASE)

       POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
0          13       G      0.0            0.0            1.778913E-02   1.055151E-03   7.140101E-03   0.0
                             0.0            0.0          358.5667       358.4153       355.3266         0.0
0          23       G      0.0            0.0            1.809506E-02   2.436631E-04   5.582085E-03   0.0
                             0.0            0.0          358.6122       169.2204       354.6796         0.0
0          35       G      0.0            0.0            2.314667E-02   1.286235E-02   9.387693E-03   0.0
                             0.0            0.0          355.6430       176.5634       353.6531         0.0
0          69       G      0.0            0.0            5.118722E-03   1.433360E-02   9.596031E-03   0.0
                             0.0            0.0          343.5486       176.5258       353.5502         0.0
```

- **One-shot Run**

```
0                                                                                                          SUBCASE 1
      FREQUENCY =   3.000000E+01
                                          C O M P L E X   D I S P L A C E M E N T   V E C T O R
                                                        (MAGNITUDE/PHASE)

      POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
0          7       G      0.0            0.0            1.482456E-02   5.504564E-03   6.244773E-03   0.0
                            0.0            0.0          358.6264       358.2880       355.7595         0.0
0          8       G      0.0            0.0            1.015295E-02   3.529959E-03   5.443347E-03   0.0
                            0.0            0.0            0.0576         0.4435       355.2194         0.0
0         13       G      0.0            0.0            1.778913E-02   1.055151E-03   7.140101E-03   0.0
                            0.0            0.0          358.5667       358.4153       355.3266         0.0
0         14       G      0.0            0.0            1.236494E-02   1.420344E-03   6.479627E-03   0.0
                            0.0            0.0            0.0588       358.9908       354.9695         0.0
0         23       G      0.0            0.0            1.809506E-02   2.436631E-04   5.582085E-03   0.0
                            0.0            0.0          358.6122       169.2204       354.6796         0.0
```

WORKSHOP 6
Dynamic Collapse of a Cylinder



- **Workshop Objectives**
  - Nonlinear Transient Dynamic Analysis
  - Large Deformation and Large Strain
  - Contact analysis using rigid-deformable contact
  - Elastic-plastic material

- **Software Version**
  - MSC Nastran 2013

- **Files Required**
  - Cylinder.bdf

- **Problem Description**
  - In this Exercise we analyze the dynamic collapse of a cylinder.
  - The 0.08 meter long cylinder (radius = 0.02 m ; thickness = 0.0131 m) is compressed axially by two rigid bodies, one of which is fixed, and the other moving with a velocity of 50 m/s.
  - The purpose of the analysis is to examine the stresses and deformations.
  - The cylinder is made of an elasto-plastic material with linear work hardening. We model the cylinder here with a 100X3 mesh of 4-noded, 2D solid axisymmetric (CQUADX) elements.

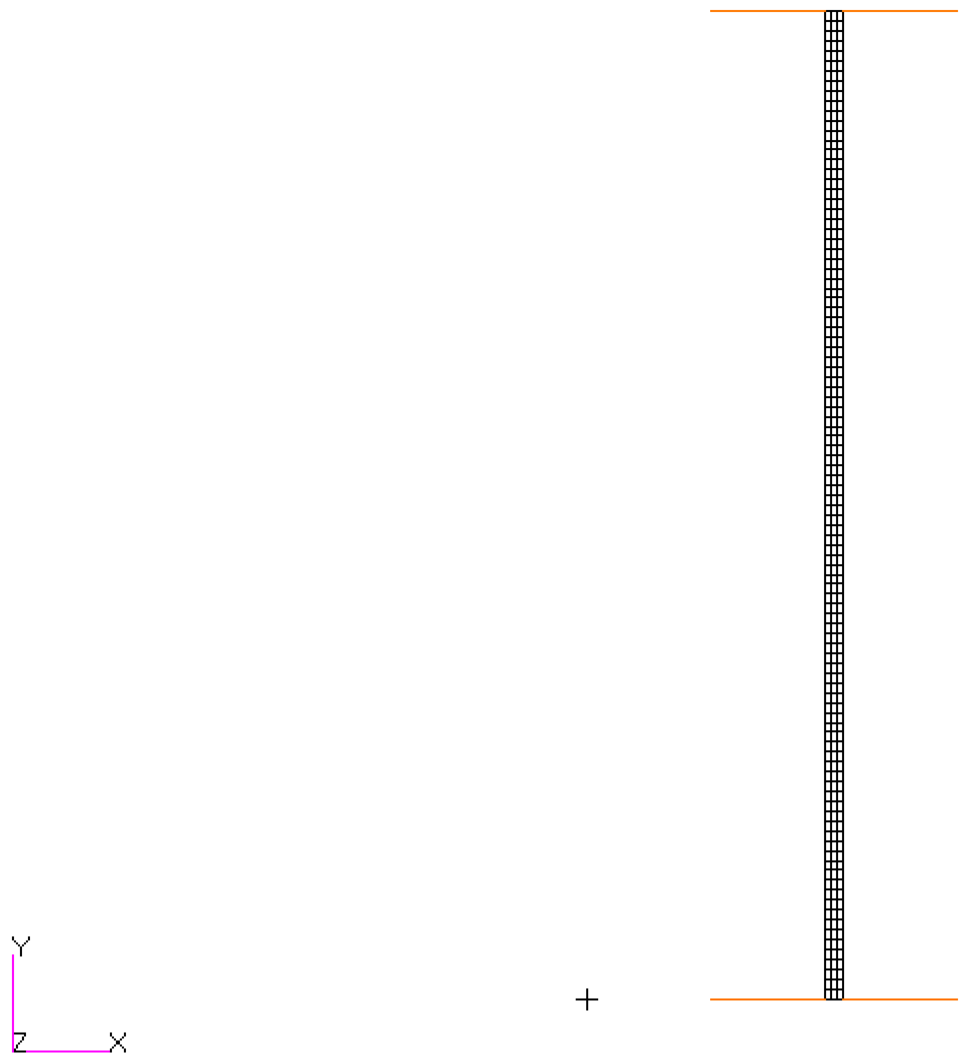
- **Suggested Steps**

1. Edit the file cylinder.bdf to add:
   - Appropriate ANALYSIS case control callout for Nonlinear Transient
   - Appropriate TSTEPNL case control callout
   - TSTEPNL bulk data entry
     - Use an integration step size of 1.0e-6
     - Integrate for .0008 seconds
     - Use Pure Full Newton stiffness update method
     - Force the stiffness update for the start of every increment (hint- see the KSTEP remarks in the QRG)
     - Use Displacement and Vector Component for the Convergence criteria
     - Use .01 for the displacement convergence error tolerance

2. Run the job and review the f06 file for any error messages

3. Load the XDB into Patran to look at results

Model Description



SOLUTION FOR WORKSHOP # 6

Input File

```
NASTRAN SYSTEM(316)=19
SOL 400
CEND
TITLE = Nonlinear Transient Analysis
SUBCASE 1
 STEP 1
   SUBTITLE=Trans_Dynamic
   ANALYSIS = NLTRAN
   TSTEPNL = 1
   BCONTACT = ALLBODY
   DISPLACEMENT(PLOT,SORT1,REAL)=ALL
   SPCFORCES(PLOT,SORT1,REAL)=ALL
   STRAIN(PLOT,SORT1,REAL,VONMISES,STRCUR,BILIN)=ALL
   STRESS(PLOT,SORT1,REAL,VONMISES,BILIN)=ALL
   NLSTRESS(PLOT,SORT1)=ALL
   BOUTPUT(PLOT,SORT1,REAL)=ALL
BEGIN BULK
PARAM    POST    0
PARAM   PRTMAXIM YES
BCPARA   0       NLGLUE  1       NBODIES 3       FTYPE   6
PARAM    LGDISP  1
TSTEPNL  1       400     2.-6            PFNT    -1              UV
        .01
$ Elements and Element Properties for region : cylinder
PLPLANE  1       1
PSHLN2   1       1
         C4      AXSOLID L
$ Pset: "cylinder" will be imported as: "plplane.1"
CQUADX   1       1       1       2       6       5
CQUADX   2       1       2       3       7       6
.
.
.
ENDDATA
```

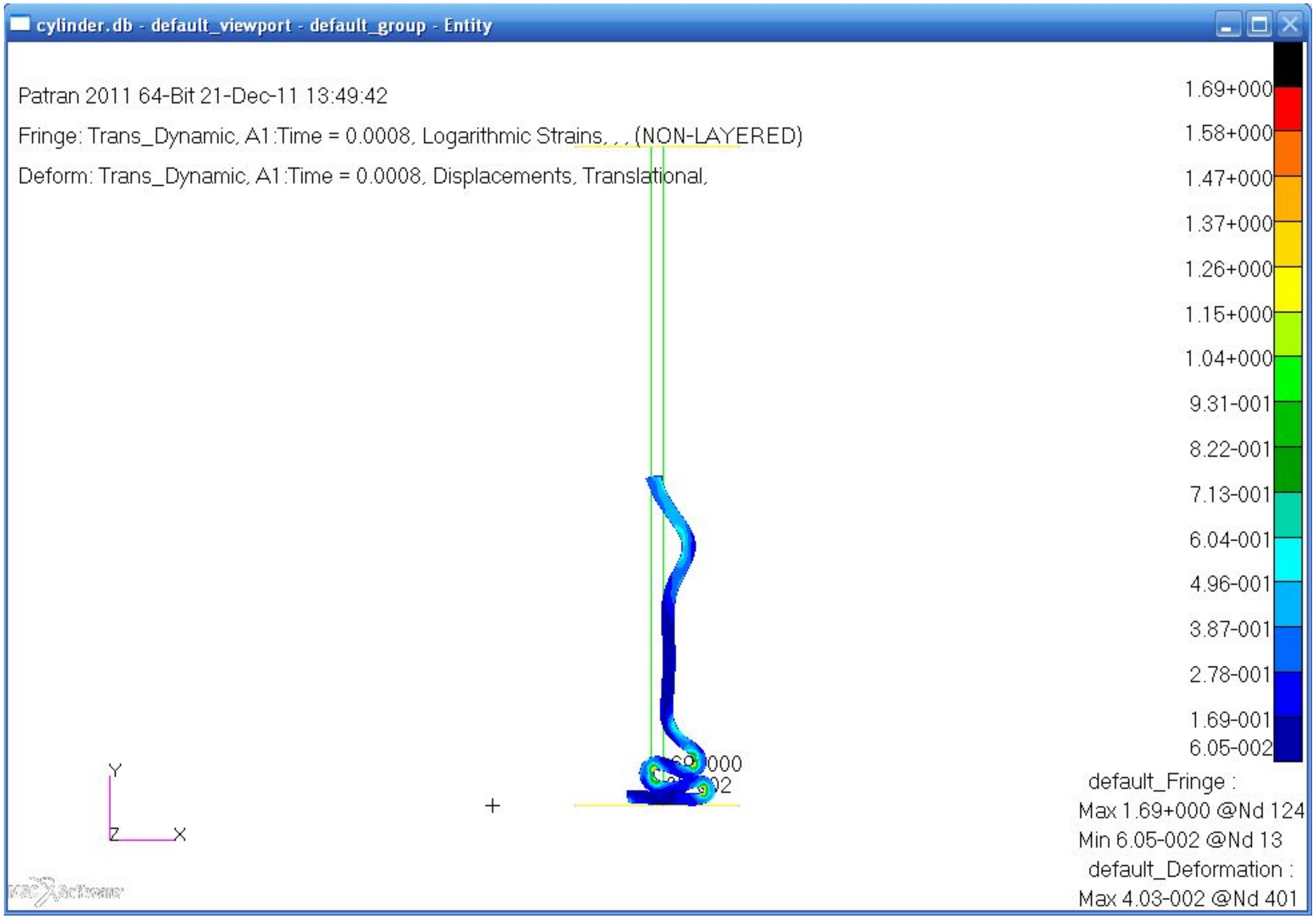
STS Output File

```
information summary of job:   ./cylinder
version: MSC Nastran 2012.1.0, Built on Nov 25, 2011
date:     Dec 21, 2011; Day Time: 13:26:38

  subcase       inc  cycl  sepa cut      cycl    split    separ    cut  rmesh time step    total time   wall time    cpu time     max resp. type
  /step #        #     #    #    #         #        #        #       #     #      of           of
         1         |--of the inc--|-----------of the analysis-----------|   the inc       the job
         1         0     0    0    0         0        0        0      0     0 0.0000E+00  0.0000E+00       3.00        0.77   0.0000E+00 disp
         1         1    11    0    0        11        0        0      0     0 2.0000E-06  2.0000E-06       4.00        1.64  -1.0000E-04 disp
         1         2     5    0    0        16        0        0      0     0 2.0000E-06  4.0000E-06       5.00        2.08  -2.0000E-04 disp
         1         3     2    0    0        18        0        0      0     0 5.0000E-07  4.5000E-06       5.00        2.27  -2.2500E-04 disp
         1         4     2    0    0        20        0        0      0     0 5.0000E-07  5.0000E-06       5.00        2.45  -2.5000E-04 disp
         1         5     2    0    0        22        0        0      0     0 5.0000E-07  5.5000E-06       5.00        2.62  -2.7500E-04 disp


         1       264     3    1    0       598        0       50      0     0 2.0000E-06  5.2200E-04     106.00       60.39  -2.6288E-02 disp
         1       265     2    0    1       600        0       50      1     0 4.2355E-07  5.2242E-04     107.00       60.66  -2.6309E-02 disp
         1       266    16    0    0       616        0       50      1     0 1.5765E-06  5.2400E-04     114.00       62.27  -2.6388E-02 disp
         1       267     9    1    1       625        0       51      2     0 4.6994E-07  5.2447E-04     116.00       63.22  -2.6411E-02 disp
         1       268     3    0    1       628        0       51      3     0 3.9984E-08  5.2451E-04     117.00       63.59  -2.6413E-02 disp
         1       269     9    0    1       637        0       51      4     0 5.2365E-07  5.2503E-04     120.00       64.53  -2.6439E-02 disp
         1       270     7    0    0       644        0       51      4     0 9.6642E-07  5.2600E-04     123.00       65.23  -2.6488E-02 disp
         1       271     5    0    0       649        0       51      4     0 2.0000E-06  5.2800E-04     124.00       65.70  -2.6588E-02 disp
         1       272     5    1    0       654        0       52      4     0 2.0000E-06  5.3000E-04     126.00       66.19  -2.6688E-02 disp
         1       273     4    1    0       658        0       53      4     0 2.0000E-06  5.3200E-04     127.00       66.59  -2.6789E-02 disp
         1       274     4    1    1       662        0       54      5     0 4.0508E-08  5.3204E-04     127.00       67.03  -2.6791E-02 disp
         1       275     4    1    1       666        0       55      6     0 4.5462E-08  5.3209E-04     128.00       67.48  -2.6793E-02 disp
         1       276     4    1    1       670        0       56      7     0 4.5354E-08  5.3213E-04     130.00       67.91  -2.6795E-02 disp
         1       277     5    1    0       675        0       57      7     0 1.8687E-06  5.3400E-04     132.00       68.38  -2.6890E-02 disp
         1       278     4    1    0       679        0       58      7     0 2.0000E-06  5.3600E-04     134.00       68.77  -2.6992E-02 disp
         1       279    17    0    0       696        0       58      7     0 2.0000E-06  5.3800E-04     139.00       70.38  -2.7094E-02 disp
         1       280     4    1    1       700        0       59      8     0 5.7880E-08  5.3806E-04     142.00       70.84  -2.7097E-02 disp
         1       281     6    1    0       706        0       60      8     0 1.9421E-06  5.4000E-04     143.00       71.44  -2.7196E-02 disp
         1       282    10    2    0       716        0       62      8     0 2.0000E-06  5.4200E-04     147.00       72.41  -2.7297E-02 disp
         1       283     6    1    0       722        0       63      8     0 2.0000E-06  5.4400E-04     147.00       73.00  -2.7397E-02 disp
         1       284     3    0    0       725        0       63      8     0 2.0000E-06  5.4600E-04     148.00       73.30  -2.7496E-02 disp


         1       408     4    1    0      1086        0      123      9     0 2.0000E-06  7.9200E-04     214.00      110.70  -3.9899E-02 disp
         1       409     5    1    0      1091        0      124      9     0 2.0000E-06  7.9400E-04     215.00      111.23  -4.0000E-02 disp
         1       410     3    0    0      1094        0      124      9     0 2.0000E-06  7.9600E-04     216.00      111.53  -4.0100E-02 disp
         1       411     4    2    0      1098        0      126      9     0 2.0000E-06  7.9800E-04     217.00      111.95  -4.0201E-02 disp
         1       412     4    1    0      1102        0      127      9     0 2.0000E-06  8.0000E-04     218.00      112.38  -4.0302E-02 disp
 Job ends with exit number :          0
            total wall time:           219.00
            total cpu  time:           113.12

            exit DEFINITION -----
            = 0   job terminates normally
            = 1   job terminates abnormally (check Fatal Error Message in F06)
```

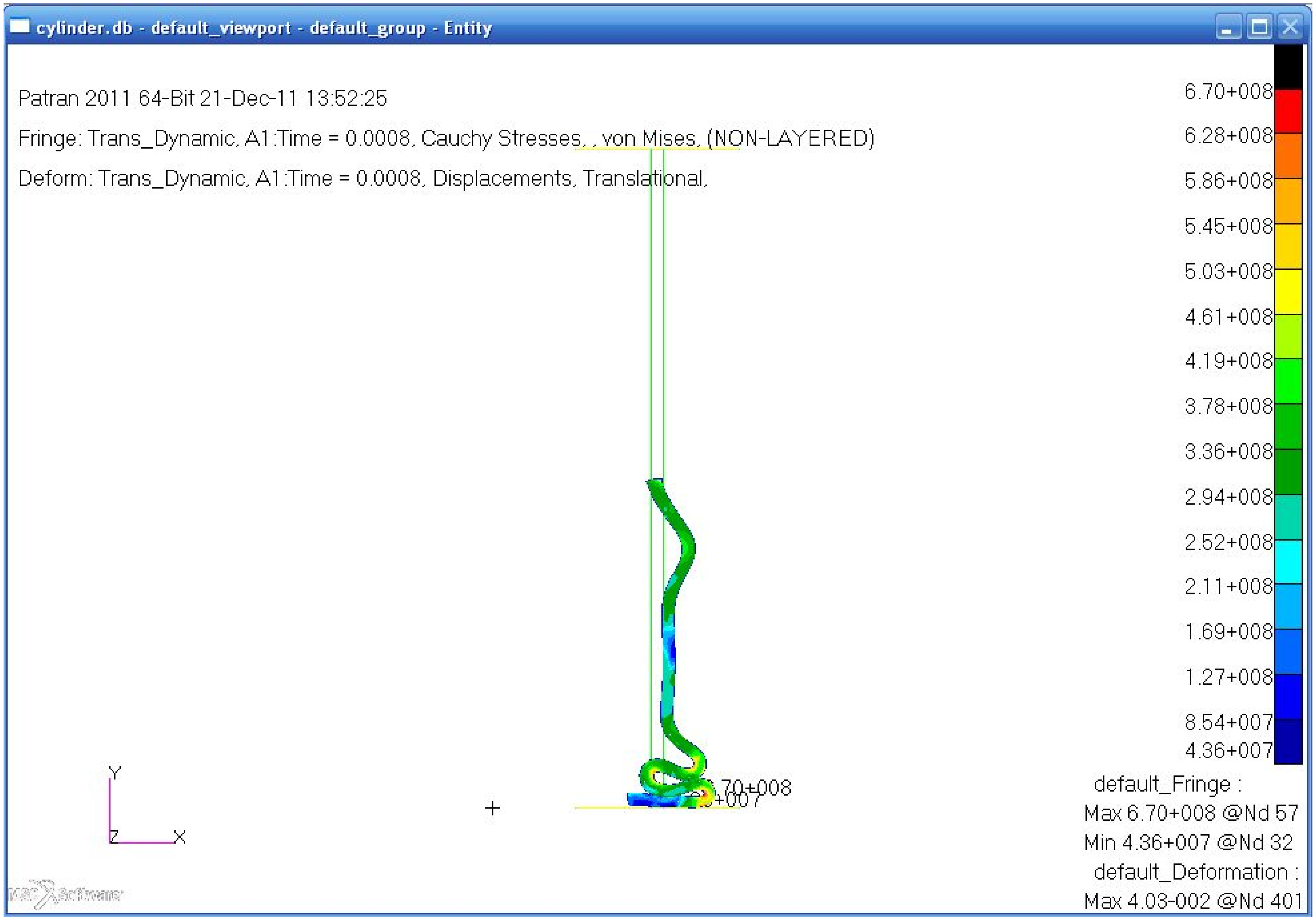
F06 Output File, example output

```
                    N O N - L I N E A R   I T E R A T I O N   S O L U T I O N   C O N T R O L   P A R A M E T E R S

     LOOP CONTROLS FOR :    SUBCASE         1,          STEP         1,          SUBSTEP         0


     SOLUTION CONTROL PARAMETERS FROM : TSTEPNL                     ID :           1

          Number of Time Steps (NDT) ..............          400
          Time Increment (DT) .....................     2.00E-06
          Time Step Interval for Output (NO) ......            1
          Matrix Update Option (METHOD) ...........         PFNT
          Matrix Update Increment (KSTEP) .........            1
          Maximum Number of Iterations (MAXITER) ..           25
          Convergence Options (CONV) ..............     U   V
                     - Displacement     (EPSU) ......     1.00E-02
          Tolerance  - Residual Force (EPSP) ......     1.00E-02
                     - Work             (EPSW) ......    -1.00E-02
          Divergence Limit (MAXDIV) ...............            2
          Maximum Quasi-Newton Vectors (MAXQN) ....            0
          Maximum Line Searches (MAXLS) ...........            0
          Error Tolerance in YF (FSTRESS) .........     2.00E-01

          Maximum Number of Bisection (MAXBIS) ....            5
          Time Step Skip Factor (ADJUST) ..........            5
          Number of Steps for Dominant Resp.(MSTEP)            0
          Bounds of Time Stepping (RB) ............     6.00E-01
          Maximum Ratio of Adjusted Step (MAXR) ...     3.20E+01
          Tolerance on Disp or Temp (UTOL) ........     1.00E-01
          Maximum Incremental Rotation (RTOLB) ....     2.00E+01
          Minimum Number of Iterations (MINITER) ..            0

0                                                                                             SUBCASE 1          STEP 1
0                        N O N - L I N E A R   I T E R A T I O N   M O D U L E   O U T P U T

     STIFFNESS UPDATE TIME          0.01 SECONDS                                        SUBCASE        1          STEP        1
            ITERATION TIME          0.05 SECONDS

                   - TIME STEP -        - - ERROR FACTORS - -       CONV ITR MAT   AVG      TOTL        - - - - - - DISP - - - - - - -  NO.  TOT  TOT
    TIME        NO.  BIS ADJUST ITR  DISP      LOAD      WORK       RATE DIV DIV R_FORCE    WORK        AVG         MAX      AT GRID C QNV  KUD  ITR

%2.00000E-06     1   0 1.0000   1 1.00E+00 6.35E-01 1.00E+00  1.00   0    1  1.6E+02-1.054E+01 1.64E-06 -1.000E-04      401  2  0    0    1
%2.00000E-06     1   0 1.0000   2 3.29E-01 1.01E+00 7.48E+00  0.86   0    1  3.6E+01-1.072E+01 7.59E-07 -1.000E-04      401  2  0    1    2
%2.00000E-06     1   0 1.0000   3 2.11E-01 7.17E-01 8.93E-01  0.80   0    1  1.6E+01-1.076E+01 5.02E-07 -1.000E-04      401  2  0    2    3
%2.00000E-06     1   0 1.0000   4 1.50E-01 3.02E-01 4.16E-01  0.59   0    1  8.1E+00-1.076E+01 4.35E-07 -1.000E-04      401  2  0    3    4
%2.00000E-06     1   0 1.0000   5 7.99E-02 1.53E-01 1.50E-01  0.45   0    1  5.4E+00-1.076E+01 4.19E-07 -1.000E-04      401  2  0    4    5
%2.00000E-06     1   0 1.0000   6 4.39E-02 1.22E-01 5.49E-02  0.60   0    1  3.9E+00-1.075E+01 4.15E-07 -1.000E-04      401  2  0    5    6
%2.00000E-06     1   0 1.0000   7 2.74E-02 1.04E-01 2.53E-02  0.78   0    1  3.0E+00-1.075E+01 4.14E-07 -1.000E-04      401  2  0    6    7
%2.00000E-06     1   0 1.0000   8 1.93E-02 7.79E-02 1.35E-02  0.78   0    1  2.3E+00-1.075E+01 4.14E-07 -1.000E-04      401  2  0    7    8
%2.00000E-06     1   0 1.0000   9 1.45E-02 6.82E-02 9.26E-03  0.78   0    1  1.9E+00-1.075E+01 4.15E-07 -1.000E-04      401  2  0    8    9
%2.00000E-06     1   0 1.0000  10 1.16E-02 5.93E-02 6.10E-03  0.79   0    1  1.8E+00-1.075E+01 4.15E-07 -1.000E-04      401  2  0    9   10
%2.00000E-06     1   0 1.0000  11 9.63E-03 5.21E-02 4.44E-03  0.79   0    1  1.7E+00-1.075E+01 4.15E-07 -1.000E-04      401  2  0   10   11
%4.00000E-06     2   0 1.0000   1 1.00E+00 1.83E+00 1.00E+00  1.00   2    1  6.2E+01-1.839E+01 1.18E-06 -2.000E-04      404  2  0   11   12
%4.00000E-06     2   0 1.0000   2 1.89E-02 4.16E-01 2.65E+01  0.23   0    1  4.3E+00-1.842E+01 1.03E-06 -2.000E-04      404  2  0   12   13
%4.00000E-06     2   0 1.0000   3 1.98E-02 1.49E-01 6.37E-03  0.25   0    1  1.4E+00-1.842E+01 1.03E-06 -2.000E-04      404  2  0   13   14
%4.00000E-06     2   0 1.0000   4 1.11E-02 8.87E-02 7.45E-03  0.42   0    1  9.4E-01-1.842E+01 1.03E-06 -2.000E-04      404  2  0   14   15
```

Results, Strain and Deformation (True Scale)



Results, Stress and Deformation (True Scale)



Results, deformation at Various Times

WORKSHOP 7

Normal Modes Using Parts Superelements

- **Workshop Objectives**
  - Learn how to set up a Parts Superelement Input File
  - Compare the results against a baseline non-se run
- **Software Version**
  - MSC Nastran 2013
- **Files Required**
  - ws07_part-se_template.dat
  - plot1.blk
  - prop1.blk
  - se1.blk, se2.blk, se3.blk, se4.blk, se5.blk, se6.blk, se7.blk
  - ws07_no-se.dat

- **Suggested Steps**

1. Run the baseline no-SE file (ws07_no-se.dat)

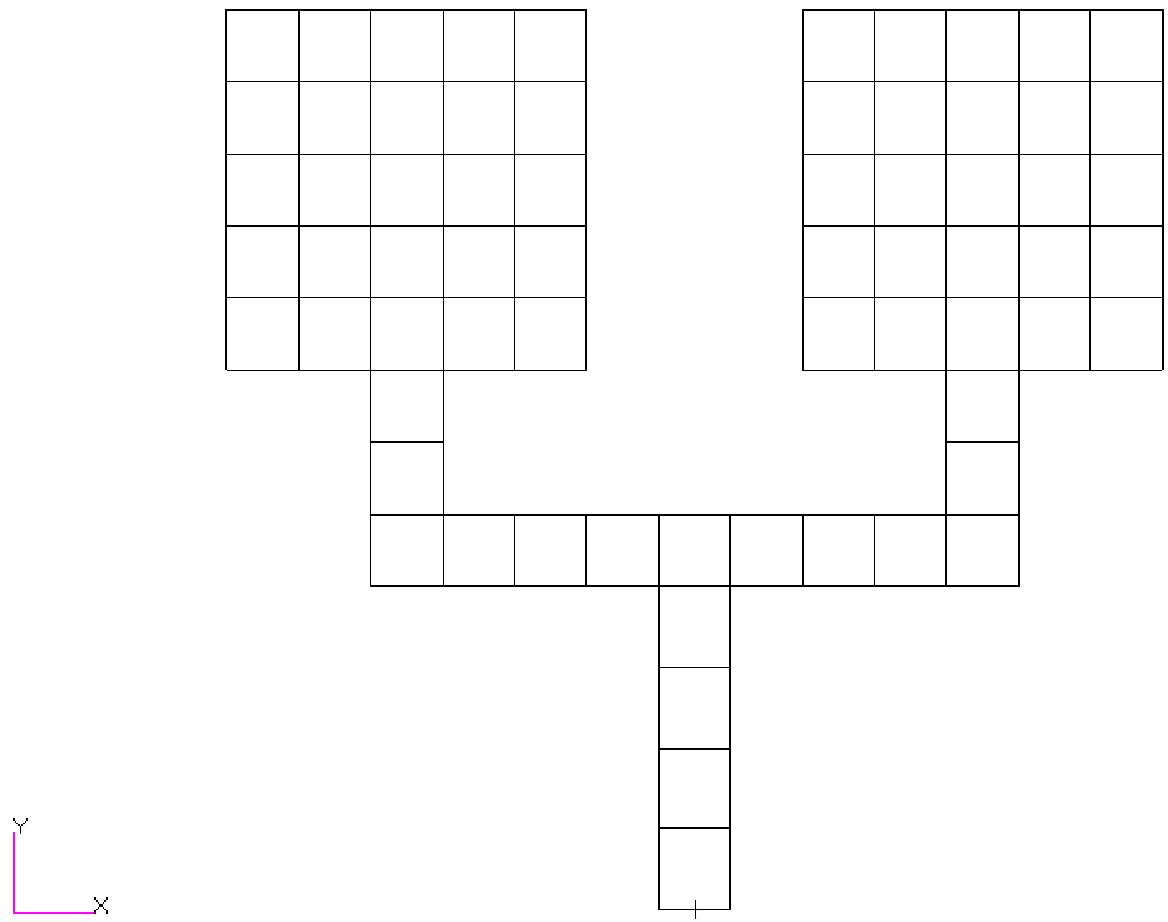
2. Edit ws07_part-se_template.dat to set up the SE run (rename to new file)
   a) Add the appropriate SUPER/METHOD entries in the case control
   b) For SE 7, remember to add the SPC case control callout
   c) Add the appropriate EIGRL, SPOINT and QSET1 entries within each BEGIN SUPER section in the bulk data… for example:

```
eigrl,1,,,10
spoint,101,thru,116
qset1,0,101,thru,116
```

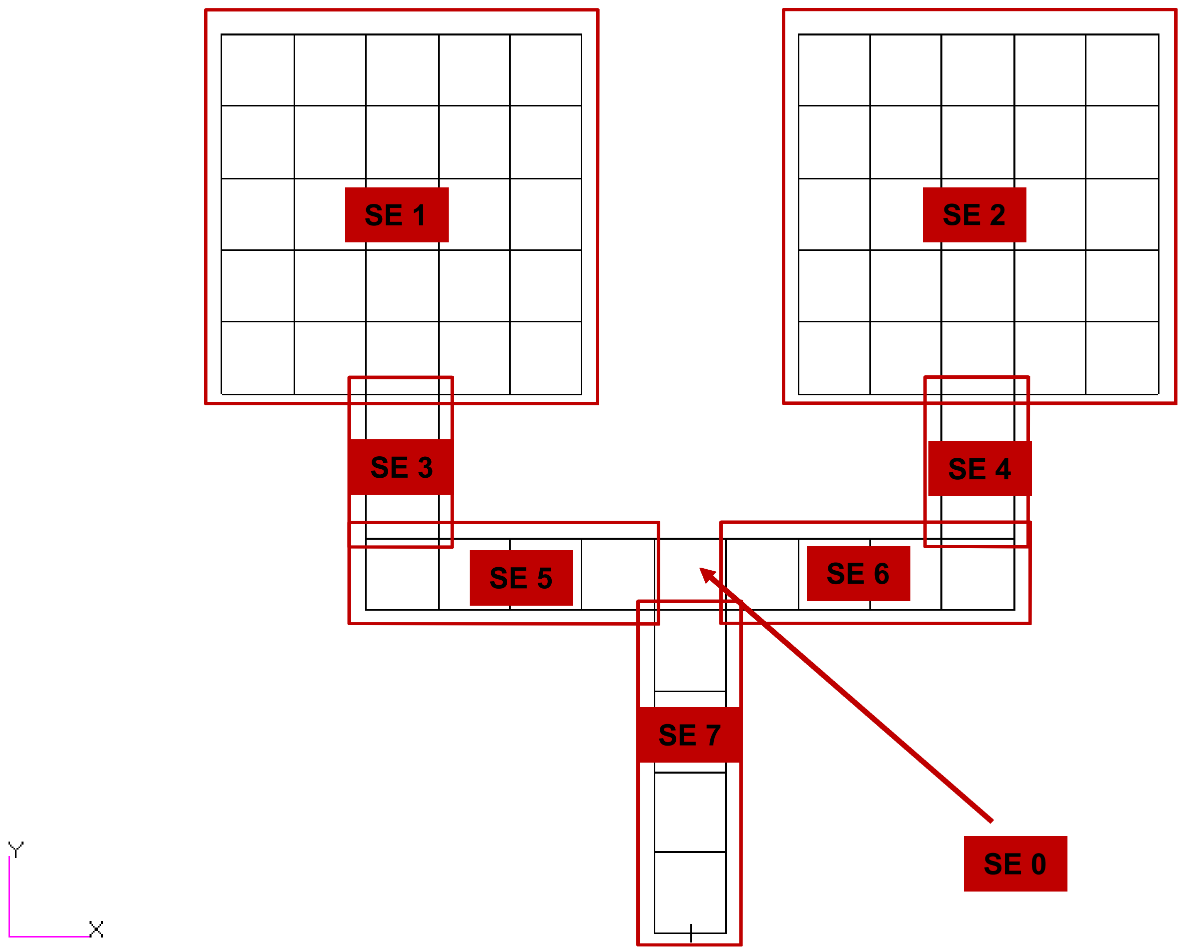
3. Run the edited file and review the results.

4. Compare the baseline normal modes to the residual normal modes from the SE run

Model Description



Model Description (cont.)



SOLUTION FOR WORKSHOP 7

Output From Baseline Modes Run

```
0      RESIDUAL MODES                                                                                    SUBCASE 100

                                              R E A L   E I G E N V A L U E S
   MODE    EXTRACTION      EIGENVALUE            RADIANS             CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                       MASS              STIFFNESS
        1         1        1.170368E+03        3.421065E+01        5.444794E+00        1.000000E+00        1.170368E+03
        2         2        3.453109E+03        5.876316E+01        9.352447E+00        1.000000E+00        3.453109E+03
        3         3        3.977881E+04        1.994463E+02        3.174286E+01        1.000000E+00        3.977881E+04
        4         4        6.090933E+04        2.467982E+02        3.927914E+01        1.000000E+00        6.090933E+04
        5         5        1.185066E+05        3.442478E+02        5.478874E+01        1.000000E+00        1.185066E+05
        6         6        2.228255E+05        4.720440E+02        7.512813E+01        1.000000E+00        2.228255E+05
        7         7        2.300895E+05        4.796765E+02        7.634288E+01        1.000000E+00        2.300895E+05
        8         8        1.284227E+06        1.133237E+03        1.803603E+02        1.000000E+00        1.284227E+06
        9         9        1.328736E+06        1.152708E+03        1.834592E+02        1.000000E+00        1.328736E+06
       10        10        2.355170E+06        1.534656E+03        2.442481E+02        1.000000E+00        2.355170E+06
```

Output From Parts SE Run

```
0      NORMAL MODES                                                                                 SUPERELEMENT 1
       SE1 CMS                                                                                          SUBCASE 1

                                             R E A L   E I G E N V A L U E S
                                     (AFTER AUGMENTATION OF RESIDUAL VECTORS)
   MODE    EXTRACTION      EIGENVALUE            RADIANS             CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                        MASS              STIFFNESS
        1         1        2.614156E+05        5.112882E+02        8.137404E+01        1.000000E+00        2.614156E+05
        2         2        1.080109E+06        1.039283E+03        1.654070E+02        1.000000E+00        1.080109E+06
        3         3        6.900456E+06        2.626872E+03        4.180796E+02        1.000000E+00        6.900456E+06
        4         4        1.217278E+07        3.488952E+03        5.552839E+02        1.000000E+00        1.217278E+07
        5         5        2.004629E+07        4.477308E+03        7.125857E+02        1.000000E+00        2.004629E+07
        6         6        2.737869E+07        5.232465E+03        8.327726E+02        1.000000E+00        2.737869E+07
        7         7        4.412288E+07        6.642505E+03        1.057188E+03        1.000000E+00        4.412288E+07
        8         8        7.973088E+07        8.929215E+03        1.421129E+03        1.000000E+00        7.973088E+07
        9         9        8.158190E+07        9.032270E+03        1.437530E+03        1.000000E+00        8.158190E+07
       10        10        1.013638E+08        1.006796E+04        1.602365E+03        1.000000E+00        1.013638E+08
       11        11        1.200425E+08        1.095639E+04        1.743763E+03        1.000000E+00        1.200425E+08
       12        12        2.174532E+08        1.474629E+04        2.346946E+03        1.000000E+00        2.174532E+08
       13        13        2.800076E+08        1.673343E+04        2.663208E+03        1.000000E+00        2.800076E+08
       14        14        2.711912E+09        5.207602E+04        8.288156E+03        1.000000E+00        2.711912E+09
       15        15        5.883924E+09        7.670674E+04        1.220826E+04        1.000000E+00        5.883924E+09
       16        16        1.949152E+10        1.396120E+05        2.221994E+04        1.000000E+00        1.949152E+10
```

```
0      NORMAL MODES                                                                                 SUPERELEMENT 2
       SE2 CMS                                                                                          SUBCASE 2

                                             R E A L   E I G E N V A L U E S
                                     (AFTER AUGMENTATION OF RESIDUAL VECTORS)
   MODE    EXTRACTION      EIGENVALUE            RADIANS             CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                        MASS              STIFFNESS
        1         1        2.614156E+05        5.112882E+02        8.137404E+01        1.000000E+00        2.614156E+05
        2         2        1.080109E+06        1.039283E+03        1.654070E+02        1.000000E+00        1.080109E+06
        3         3        6.900456E+06        2.626872E+03        4.180796E+02        1.000000E+00        6.900456E+06
        4         4        1.217278E+07        3.488952E+03        5.552839E+02        1.000000E+00        1.217278E+07
        5         5        2.004629E+07        4.477308E+03        7.125857E+02        1.000000E+00        2.004629E+07
        6         6        2.737869E+07        5.232465E+03        8.327726E+02        1.000000E+00        2.737869E+07
        7         7        4.412288E+07        6.642505E+03        1.057188E+03        1.000000E+00        4.412288E+07
        8         8        7.973088E+07        8.929215E+03        1.421129E+03        1.000000E+00        7.973088E+07
        9         9        8.158190E+07        9.032270E+03        1.437530E+03        1.000000E+00        8.158190E+07
       10        10        1.013638E+08        1.006796E+04        1.602365E+03        1.000000E+00        1.013638E+08
       11        11        1.200425E+08        1.095639E+04        1.743763E+03        1.000000E+00        1.200425E+08
       12        12        2.174532E+08        1.474629E+04        2.346946E+03        1.000000E+00        2.174532E+08
       13        13        2.800076E+08        1.673343E+04        2.663208E+03        1.000000E+00        2.800076E+08
       14        14        2.711912E+09        5.207602E+04        8.288156E+03        1.000000E+00        2.711912E+09
       15        15        5.883924E+09        7.670674E+04        1.220826E+04        1.000000E+00        5.883924E+09
       16        16        1.949152E+10        1.396120E+05        2.221994E+04        1.000000E+00        1.949152E+10
```

Output From Parts SE Run (cont.)

0 NORMAL MODES SE3 CMS

SUPERELEMENT 3
SUBCASE 3

R E A L   E I G E N V A L U E S
(BEFORE AUGMENTATION OF RESIDUAL VECTORS)

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	5.417837E+08	2.327625E+04	3.704530E+03	1.000000E+00	5.417837E+08
2	2	4.830148E+09	6.949927E+04	1.106115E+04	1.000000E+00	4.830148E+09
3	3	4.919888E+10	2.218082E+05	3.530187E+04	1.000000E+00	4.919888E+10
4	4	9.182872E+10	3.030325E+05	4.822912E+04	1.000000E+00	9.182872E+10
5	5	1.405542E+11	3.749055E+05	5.966807E+04	1.000000E+00	1.405542E+11
6	6	1.831938E+11	4.280115E+05	6.812014E+04	1.000000E+00	1.831938E+11

0 NORMAL MODES SE4 CMS

SUPERELEMENT 4
SUBCASE 4

R E A L   E I G E N V A L U E S
(BEFORE AUGMENTATION OF RESIDUAL VECTORS)

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	5.417837E+08	2.327625E+04	3.704530E+03	1.000000E+00	5.417837E+08
2	2	4.830148E+09	6.949927E+04	1.106115E+04	1.000000E+00	4.830148E+09
3	3	4.919888E+10	2.218082E+05	3.530187E+04	1.000000E+00	4.919888E+10
4	4	9.182872E+10	3.030325E+05	4.822912E+04	1.000000E+00	9.182872E+10
5	5	1.405542E+11	3.749055E+05	5.966807E+04	1.000000E+00	1.405542E+11
6	6	1.831938E+11	4.280115E+05	6.812014E+04	1.000000E+00	1.831938E+11

0 NORMAL MODES SE5 CMS

SUPERELEMENT 5
SUBCASE 5

R E A L   E I G E N V A L U E S
(AFTER AUGMENTATION OF RESIDUAL VECTORS)

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	7.189294E+07	8.478971E+03	1.349470E+03	1.000000E+00	7.189294E+07
2	2	1.379721E+08	1.174615E+04	1.869458E+03	1.000000E+00	1.379721E+08
3	3	2.180079E+08	1.476509E+04	2.349937E+03	1.000000E+00	2.180079E+08
4	4	4.007080E+08	2.001769E+04	3.185915E+03	1.000000E+00	4.007080E+08
5	5	7.714247E+08	2.777453E+04	4.420454E+03	1.000000E+00	7.714247E+08
6	6	3.849240E+09	6.204224E+04	9.874329E+03	1.000000E+00	3.849240E+09
7	7	1.134085E+10	1.064934E+05	1.694895E+04	1.000000E+00	1.134085E+10
8	8	3.075428E+10	1.753690E+05	2.791084E+04	1.000000E+00	3.075428E+10
9	9	5.480160E+10	2.340974E+05	3.725776E+04	1.000000E+00	5.480160E+10
10	10	6.619594E+10	2.572857E+05	4.094829E+04	1.000000E+00	6.619594E+10
11	11	9.055923E+10	3.009306E+05	4.789459E+04	1.000000E+00	9.055923E+10
12	12	1.360746E+11	3.688829E+05	5.870953E+04	1.000000E+00	1.360746E+11
13	13	1.607295E+11	4.009108E+05	6.380694E+04	1.000000E+00	1.607295E+11

Output From Parts SE Run (cont.)

```
0       NORMAL MODES                                                                                       SUPERELEMENT 6
        SE6 CMS                                                                                               SUBCASE 6
```

R E A L   E I G E N V A L U E S
(AFTER AUGMENTATION OF RESIDUAL VECTORS)

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	7.189294E+07	8.478971E+03	1.349470E+03	1.000000E+00	7.189294E+07
2	2	1.379721E+08	1.174615E+04	1.869458E+03	1.000000E+00	1.379721E+08
3	3	2.180079E+08	1.476509E+04	2.349937E+03	1.000000E+00	2.180079E+08
4	4	4.007080E+08	2.001769E+04	3.185915E+03	1.000000E+00	4.007080E+08
5	5	7.714247E+08	2.777453E+04	4.420454E+03	1.000000E+00	7.714247E+08
6	6	3.849240E+09	6.204224E+04	9.874329E+03	1.000000E+00	3.849240E+09
7	7	1.134085E+10	1.064934E+05	1.694895E+04	1.000000E+00	1.134085E+10
8	8	3.075428E+10	1.753690E+05	2.791084E+04	1.000000E+00	3.075428E+10
9	9	5.480160E+10	2.340974E+05	3.725776E+04	1.000000E+00	5.480160E+10
10	10	6.619594E+10	2.572857E+05	4.094829E+04	1.000000E+00	6.619594E+10
11	11	9.055923E+10	3.009306E+05	4.789459E+04	1.000000E+00	9.055923E+10
12	12	1.360746E+11	3.688829E+05	5.870953E+04	1.000000E+00	1.360746E+11
13	13	1.607295E+11	4.009108E+05	6.380694E+04	1.000000E+00	1.607295E+11

```
0       NORMAL MODES                                                                                       SUPERELEMENT 7
        SE7 CMS                                                                                               SUBCASE 7
```

R E A L   E I G E N V A L U E S
(AFTER AUGMENTATION OF RESIDUAL VECTORS)

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	2.685150E+07	5.181844E+03	8.247160E+02	1.000000E+00	2.685150E+07
2	2	7.641080E+07	8.741327E+03	1.391225E+03	1.000000E+00	7.641080E+07
3	3	1.930735E+08	1.389509E+04	2.211472E+03	1.000000E+00	1.930735E+08
4	4	3.536554E+08	1.880573E+04	2.993025E+03	1.000000E+00	3.536554E+08
5	5	5.233405E+08	2.287664E+04	3.640930E+03	1.000000E+00	5.233405E+08
6	6	4.607559E+09	6.787900E+04	1.080328E+04	1.000000E+00	4.607559E+09
7	7	5.744142E+09	7.579012E+04	1.206237E+04	1.000000E+00	5.744142E+09
8	8	2.249862E+10	1.499954E+05	2.387251E+04	1.000000E+00	2.249862E+10
9	9	3.019818E+10	1.737762E+05	2.765735E+04	1.000000E+00	3.019818E+10
10	10	5.431832E+10	2.330629E+05	3.709311E+04	1.000000E+00	5.431832E+10
11	11	7.878803E+10	2.806921E+05	4.467353E+04	1.000000E+00	7.878803E+10
12	12	1.017002E+11	3.189047E+05	5.075526E+04	1.000000E+00	1.017002E+11
13	13	1.704683E+11	4.128781E+05	6.571159E+04	1.000000E+00	1.704683E+11

Output From Parts SE Run (cont.)

Residual Modes from Part SE run:

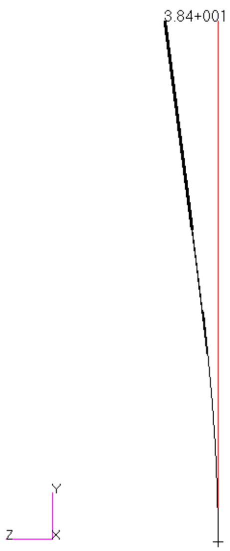
```
      NORMAL MODES                                                                                   SUPERELEMENT 0
0     RESIDUAL MODES                                                                                    SUBCASE 100

                                               R E A L   E I G E N V A L U E S
   MODE    EXTRACTION       EIGENVALUE            RADIANS             CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                         MASS              STIFFNESS
        1         1        1.170368E+03        3.421065E+01        5.444794E+00        1.000000E+00        1.170368E+03
        2         2        3.453109E+03        5.876316E+01        9.352447E+00        1.000000E+00        3.453109E+03
        3         3        3.977881E+04        1.994463E+02        3.174286E+01        1.000000E+00        3.977881E+04
        4         4        6.090933E+04        2.467982E+02        3.927914E+01        1.000000E+00        6.090933E+04
        5         5        1.185066E+05        3.442478E+02        5.478874E+01        1.000000E+00        1.185066E+05
        6         6        2.228255E+05        4.720440E+02        7.512813E+01        1.000000E+00        2.228255E+05
        7         7        2.300895E+05        4.796765E+02        7.634288E+01        1.000000E+00        2.300895E+05
        8         8        1.284227E+06        1.133237E+03        1.803603E+02        1.000000E+00        1.284227E+06
        9         9        1.328736E+06        1.152708E+03        1.834592E+02        1.000000E+00        1.328736E+06
       10        10        2.355170E+06        1.534656E+03        2.442481E+02        1.000000E+00        2.355170E+06
```

Assembly Modes from non-SE run:

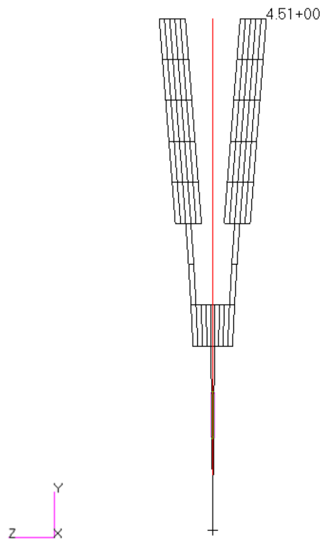
```
0     RESIDUAL MODES                                                                                    SUBCASE 100

                                               R E A L   E I G E N V A L U E S
   MODE    EXTRACTION       EIGENVALUE            RADIANS             CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                         MASS              STIFFNESS
        1         1        1.170368E+03        3.421065E+01        5.444794E+00        1.000000E+00        1.170368E+03
        2         2        3.453109E+03        5.876316E+01        9.352447E+00        1.000000E+00        3.453109E+03
        3         3        3.977881E+04        1.994463E+02        3.174286E+01        1.000000E+00        3.977881E+04
        4         4        6.090933E+04        2.467982E+02        3.927914E+01        1.000000E+00        6.090933E+04
        5         5        1.185066E+05        3.442478E+02        5.478874E+01        1.000000E+00        1.185066E+05
        6         6        2.228255E+05        4.720440E+02        7.512813E+01        1.000000E+00        2.228255E+05
        7         7        2.300895E+05        4.796765E+02        7.634288E+01        1.000000E+00        2.300895E+05
        8         8        1.284227E+06        1.133237E+03        1.803603E+02        1.000000E+00        1.284227E+06
        9         9        1.328736E+06        1.152708E+03        1.834592E+02        1.000000E+00        1.328736E+06
       10        10        2.355170E+06        1.534656E+03        2.442481E+02        1.000000E+00        2.355170E+06
```

Output From Parts SE Run (cont.)

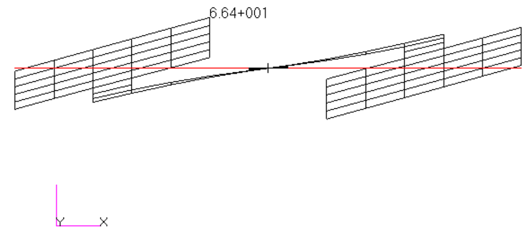
Mode 1



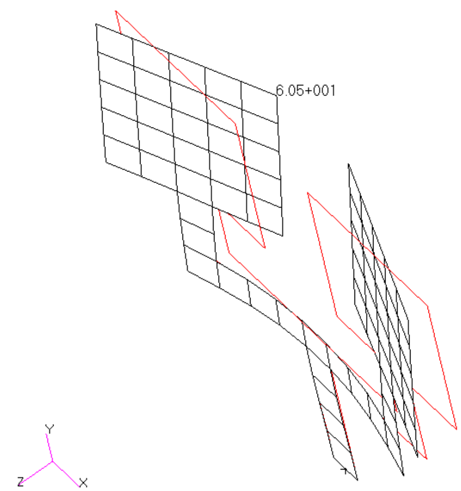
Mode 2



Mode 3



Mode 3



WORKSHOP 8

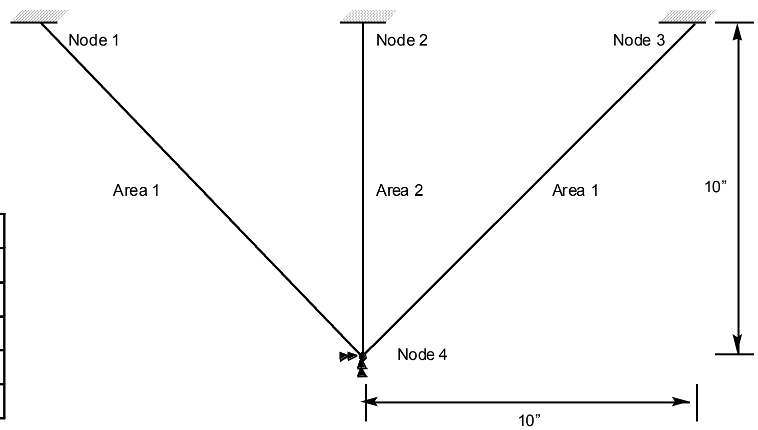
OPTIMIZATION USING NORMAL MODES

Workshop 8 – Optimization Using Normal Modes

Minimize the weight of the following three bar truss problem. The first mode must be between 1500-1550 Hz. The structure must remain symmetric.

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

Elastic Modulus:	10E6
Poisson's Ratio	0.33
Density:	0.1
Wt.-Mass Conversion	0.00259
Area 1:	1.0
Area 2:	2.0



Workshop 8 - Optimization Statement

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

Workshop 8 – Input File Starting Point

- **Use the following partial input file (ws10_modes_template.dat) as a starting point and edit it as needed.**

```
$
$  ws8_modes_template.dat
$
$   executive control,   add :  optimization solution sequence
$
$   case control,        add :  type of analysis
$                               appropriate case control callout
$
$   bulk data,           add :  design variable
$                               objective function
$                               constraints
$                               relate design variable to property
$
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
$
$ ***** add design objective and constraint callouts
$
$
SUBCASE 1
$
$ ***** add analysis method callout
$
  METHOD= 10
$
$
BEGIN BULK
$
```

Workshop 8 – Input File Starting Point (cont.)

```
$
$------------------------------------------------------------------------
$ ANALYSIS MODEL
$------------------------------------------------------------------------
$
EIGRL, 10, , , 2
PARAM, POST, -1
$
$ 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
$
$ ***** add other 2 DESVAR entries
$
$
$...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
$
$ ***** add last DVPREL1 entry
$
$
$...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
```

Solution for Workshop 8

```
$ Workshop 8, Design Optimization using Modes
$
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
```

Solution for Workshop 8 (cont.)

```
$
$--------------------------------------------------------------------
$ 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
$
ENDDATA
```

Solution for Workshop 8 (cont.)

```
1     SYMMETRIC THREE BAR TRUSS DESIGN OPTIMIZATION - VARIATION OF D200      DECEMBER  21, 2011  MSC.NASTRAN 11/25/11    PAGE    32
       GOAL IS TO MIN WT WHILE KEEPING THE 1ST MODE BETWEEN 1500-1550
0                                                                                                          SUBCASE 1
                                   ***************************************************************
                                   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          12
                                       NUMBER OF OPTIMIZATIONS W.R.T. APPROXIMATE MODELS    11

                                              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	2.838825E+00	2.839155E+00	-1.162217E-04	3.184454E-01
2	1.660545E+00	1.660677E+00	-7.960795E-05	4.225225E-01
3	1.495517E+00	1.495508E+00	6.058081E-06	1.847232E-01
4	1.181010E+00	1.181111E+00	-8.528571E-05	1.250616E-01
5	8.858725E-01	8.858328E-01	4.474556E-05	1.250616E-01
6	8.533267E-01	8.533446E-01	-2.102433E-05	2.190769E-02
7	7.466428E-01	7.466765E-01	-4.510203E-05	2.190769E-02
8	6.533338E-01	6.533419E-01	-1.249856E-05	2.190769E-02
9	5.716476E-01	5.716742E-01	-4.650143E-05	2.190769E-02
10	5.839298E-01	5.839311E-01	-2.347720E-06	4.574802E-04
11	5.839311E-01	5.839311E-01	0.000000E+00	4.574802E-04

Solution for Workshop 8 (cont.)

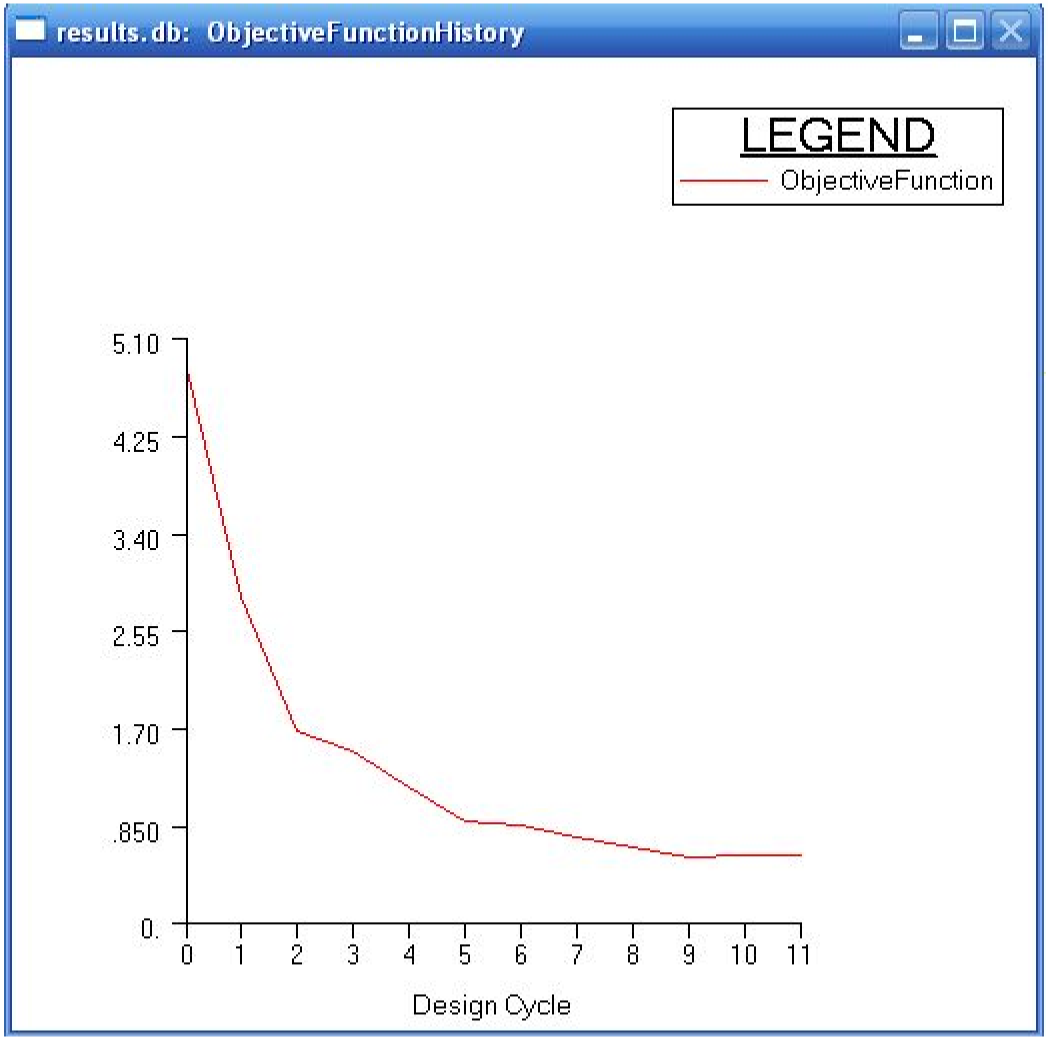
1 SYMMETRIC THREE BAR TRUSS DESIGN OPTIMIZATION - VARIATION OF D200 DECEMBER 21, 2011 MSC.NASTRAN 11/25/11 PAGE 33
GOAL IS TO MIN WT WHILE KEEPING THE 1ST MODE BETWEEN 1500-1550
0 SUBCASE 1

DESIGN VARIABLE HISTORY

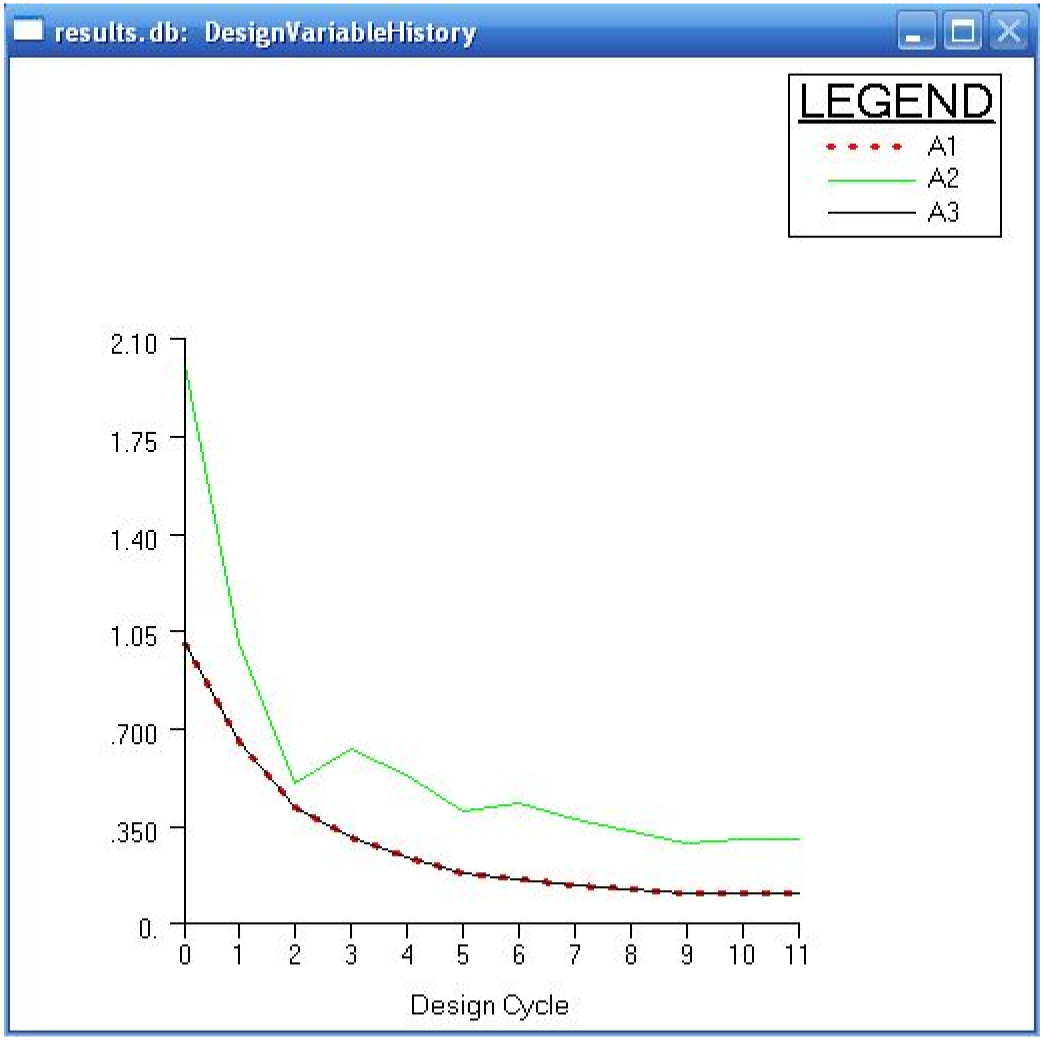
INTERNAL DV. ID.	EXTERNAL DV. ID.	LABEL	INITIAL	1	2	3	4	5
1	1	A1	1.0000E+00	6.5024E-01	4.1036E-01	3.0777E-01	2.3083E-01	1.7312E-01
2	2	A2	2.0000E+00	1.0000E+00	5.0000E-01	6.2500E-01	5.2823E-01	3.9617E-01
3	3	A3	1.0000E+00	6.5024E-01	4.1036E-01	3.0777E-01	2.3083E-01	1.7312E-01

INTERNAL DV. ID.	EXTERNAL DV. ID.	LABEL	6	7	8	9	10	11
1	1	A1	1.5148E-01	1.3255E-01	1.1598E-01	1.0148E-01	1.0148E-01	1.0148E-01
2	2	A2	4.2489E-01	3.7178E-01	3.2531E-01	2.8464E-01	2.9690E-01	2.9690E-01
3	3	A3	1.5148E-01	1.3255E-01	1.1598E-01	1.0148E-01	1.0148E-01	1.0148E-01

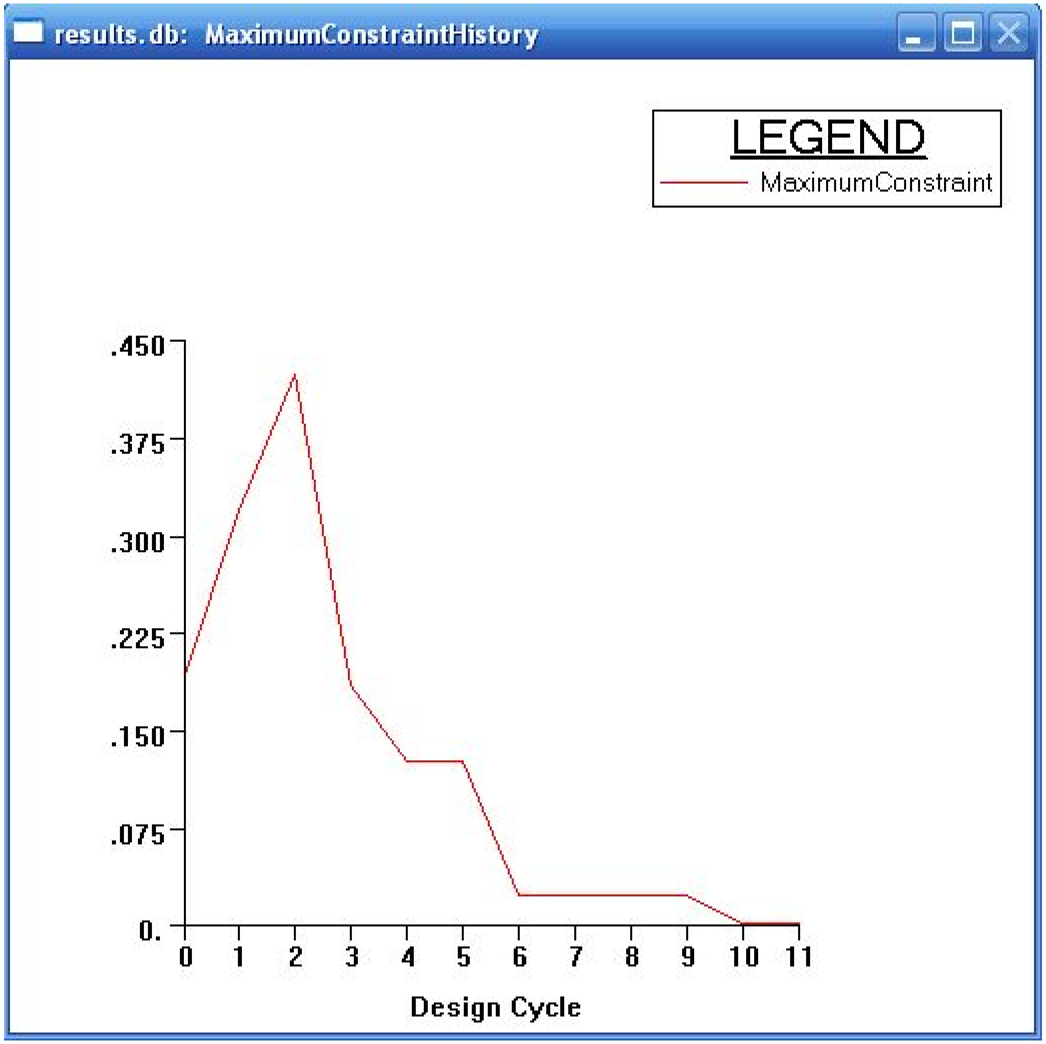
Solution for Workshop 8 (cont.)



Solution for Workshop 8 (cont.)



Solution for Workshop 8 (cont.)

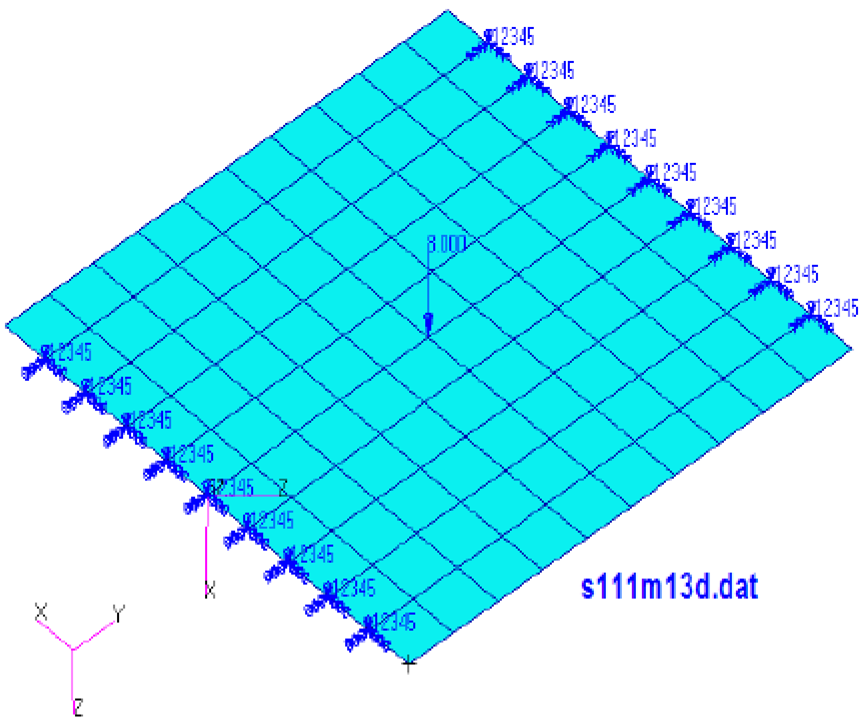


WORKSHOP 9

Monitor Points

Problem Definition

- **Example problem s111m13.dat is a modal frequency response model that contains MONPNT1, MONPNT3, and MONDSP1 entries. There are two subcases for a central load. The 1st subcase is shown in Figure below.**
- **Run the file and review the results**



User Input File - Case Control Section

```
and 15k form $nastran f04=6
$ DEC/CMS
$ *1    15-JUN-1990 17:05:27 CMSMGR "66B PLUS/G 66B/ Initial installation
     of TPL test problems"
$ DEC/CMS REPLACEMENT HISTORY, Element BST10A.DAT
NASTRAN PREFOPT=2,SYSTEM(20)=0
$ id msc, s111m13d.dat $ mdr4 10-Feb-2009 ehj
$id msc, mondsp1.dat $ ehj/klk v2006 22-Jul-2006
$ Modified 16-Aug-2007 v2007 ehj
$id msc, q9292981.dat $ v2005 klk 1-Mar-2005
$ id msc, q9292981.dat $ v2005 klk 1-Mar-2005
$id msc, q8610951.dat $ v2005 tin 28-Jan-2005
DIAG     8,15,56 $
SOL      111
$
$$
CEND
TITLE = Frequency response TEST OF SQUARE SURFACE with monitor point
SUBTITLE = 10 X 10 MESH
SPC = 12
sdamping=12
$DISP = ALL
set 999 = 110902
disp(sort2) = 999
$acce(sort2)=all
method = 1
ECHO = unSORT
MONITOR = ALL
$STRESS=ALL
freq = 10
subcase 1
label = static load
dload = 14
$DISP = ALL
$STRESS=ALL
subcase 3
label = gravity load
dload = 20
$DISP = ALL
$STRESS=ALL
```

User Input File - Bulk Data Section

```
BEGIN BULK
tabdmp1        12
      0.0       .05            100000.        0.05           endt
$AERO,     0, 34000.,   4000., 1.21E-12
eigrl,1,,,10
rload1,14,14,,,101
rload1,20,20,,,101
tabled1,101
,0.,1.,10000.,1.,endt
freq1,10,100.,100.,3
$ TURN OFF RESEQUENCER
PARAM   NEWSEQ  -1
$
CORD1R  52      1       2       3
GRID    110000                                          6
GRID    110010          20.                             6
GRID    111010          20.     20.                     6
GRID    111000                  20.                     6
GRIDG   11              6       10      110000  110010  111010
      +GR1
+GR1    10      111000
FORCE   13      110505          4.                      1.
FORCE   14      110505          8.                      1.
FORCE   20      110505          16.                     1.
SPCG    12      11      12345   0000    0010
SPCG    12      11      12345   1000    1010
MAT1    1001    3.0+7   11.538+6         .1
param,wtmass,.00259
PSHELL  101     1001    1.0     1001
CGEN    QUAD4   1100001 101     11
MONPNT1 MPT11   This is the first MONPNT1
        123456  PLATE1  52      1.      2.      3.0
MONPNT1 MPT12   This is the second MONPNT1
        123456  PLATE2          20.     20.     0.0
AECOMP  PLATE1  SET1    1       2
AECOMP  PLATE2  SET1    1
SET1    1       110000  110010  111010  111000
SET1    2       110505
MONDSP1 DISP2   This is a displacement monitor point
        123456  PLATE3  52      1.      2.      3.
$
MONDSP1 DISPref This should match grid 110902
        123456  point1          4.      18.      0.            123456
aecomp  point1   set1    110902
set1    110902  110902
```

```
$
$MONDSP1 DISP1   This is a displacement monitor point
$       123456  PLATE4          0.      0.      0.
AECOMP  PLATE3  SET1    3       4
$AECOMP  PLATE4  SET1    3       4
SET1    3       110901  110902  110903  110904  110905
SET1    4       110801  110802  110803
$MONPNT2 MPT22   This is a STRESS-MONPT2  monitor point
$       STRESS  QUAD4   SY1     1100082
$MONPNT2 MP2TST5 This is the fifth test of the monpnt2 card
$       STRESS  QUAD4   SX1     1100097
$MONPNT2 MP2TST6 This is the sixth test of the monpnt2 card
$       STRESS  QUAD4   SZ1     1100100
MONPNT3 MPT31   This is the first MONPT3
        123456  5       6               1.      2.      3.
MONPNT3 MPT41   This is the second MONPT3
        123456  3       4               1.      2.      3.
SET1    5       110901  119992  110903  110904  110905
SET1    6       1100081 9999980
GRID    1               10.
GRID    2                       10.
GRID    3                               10.
ENDDATA
```

Partial Output File - F06

```
STATIC LOAD                                                                                         SUBCASE 1

                              S T R U C T U R A L   M O N I T O R   P O I N T   D I S P L A C E M E N T S
                                                      (REAL/IMAGINARY)

       MONITOR POINT NAME = DISP2             COMPONENT = 123456        GENERAL            SUBCASE NO.        1
       LABEL = THIS IS A DISPLACEMENT MONITOR POINT
         CP =          52          X = 1.000000E+00           Y = 2.000000E+00           Z = 3.000000E+00         CD =          52

         FREQUENCY       T1             T2             T3             R1             R2             R3
         ------------   ------------   ------------   ------------   ------------   ------------   ------------
         1.000000E+02   9.331630E-06   7.714264E-06   1.142239E-06   3.345541E-07  -4.731310E-07   4.621815E-07
                       -5.560066E-08  -4.663981E-08  -6.488654E-09  -1.900483E-09   2.687689E-09  -3.033787E-09
         2.000000E+02   9.721770E-06   8.044613E-06   1.186316E-06   3.474638E-07  -4.913880E-07   4.847471E-07
                       -1.203002E-07  -1.010250E-07  -1.398631E-08  -4.096495E-09   5.793319E-09  -6.610803E-09
         3.000000E+02   1.044643E-05   8.658742E-06   1.267942E-06   3.713716E-07  -5.251988E-07   5.268791E-07
                       -2.072620E-07  -1.743763E-07  -2.394549E-08  -7.013472E-09   9.918547E-09  -1.152342E-08
         4.000000E+02   1.165478E-05   9.684080E-06   1.403449E-06   4.110607E-07  -5.813276E-07   5.976722E-07
                       -3.416177E-07  -2.881529E-07  -3.912291E-08  -1.145883E-08   1.620524E-08  -1.929935E-08
```

Partial Output File - F06 (cont.)

```
STATIC LOAD                                                                                          SUBCASE 1

                               S T R U C T U R A L   M O N I T O R   P O I N T   D I S P L A C E M E N T S
                                                          (REAL/IMAGINARY)

        MONITOR POINT NAME = DISPREF           COMPONENT = 123456        GENERAL            SUBCASE NO.        1
        LABEL = THIS SHOULD MATCH GRID 110902
          CP =         0          X = 4.000000E+00          Y = 1.800000E+01          Z = 0.000000E+00         CD =         0

 FREQUENCY       T1             T2             T3             R1             R2             R3
         ------------   ------------   ------------   ------------   ------------   ------------   ------------
         1.000000E+02  -2.266899E-16   6.340627E-17   6.134659E-07  -5.654550E-07  -5.357583E-08   0.000000E+00
                       -7.858230E-19   6.725395E-20  -3.891078E-09   3.566681E-09   9.811468E-11   0.000000E+00
         2.000000E+02  -2.254382E-16   6.326737E-17   6.417602E-07  -5.912814E-07  -5.318035E-08   0.000000E+00
                       -1.576553E-18   1.350999E-19  -8.452305E-09   7.744707E-09   1.722514E-10   0.000000E+00
         3.000000E+02  -2.233463E-16   6.303516E-17   6.944417E-07  -6.393656E-07  -5.225575E-08   0.000000E+00
                       -2.377141E-18   2.041351E-19  -1.465663E-08   1.342171E-08   1.820249E-10   0.000000E+00
         4.000000E+02  -2.204056E-16   6.270858E-17   7.825979E-07  -7.198230E-07  -5.024258E-08   0.000000E+00
                       -3.192622E-18   2.749670E-19  -2.436954E-08   2.229969E-08   3.726731E-11   0.000000E+00
```

Partial Output File - F06 (cont.)

```
STATIC LOAD                                                                                                SUBCASE 1

                              S T R U C T U R A L   M O N I T O R   P O I N T   I N T E G R A T E D   L O A D S (MONPNT1)
                                                             (REAL/IMAGINARY)

        MONITOR POINT NAME = MPT11                 COMPONENT =  CX           GENERAL              SUBCASE NO.        1
        LABEL = THIS IS THE FIRST MONPNT1
          CP =         52           X = 1.000000E+00          Y = 2.000000E+00          Z = 3.000000E+00          CD =       52

          FREQUENCY       INERTIAL        EXTERNAL        FLEXIBLE        GUST            TOTAL           TOTAL
                                                          INCREMENT                       AERO
          ------------    ------------    ------------    ------------    ------------    ------------    ------------
          1.000000E+02   -2.227723E-05    6.531973E+00                                    0.000000E+00    6.531950E+00
                          1.155847E-07    0.000000E+00                                    0.000000E+00    1.155847E-07
          2.000000E+02   -9.175640E-05    6.531973E+00                                    0.000000E+00    6.531881E+00
                          9.786321E-07    0.000000E+00                                    0.000000E+00    9.786321E-07
          3.000000E+02   -2.172930E-04    6.531973E+00                                    0.000000E+00    6.531755E+00
                          3.654058E-06    0.000000E+00                                    0.000000E+00    3.654058E-06
          4.000000E+02   -4.174524E-04    6.531973E+00                                    0.000000E+00    6.531556E+00
                          1.014130E-05    0.000000E+00                                    0.000000E+00    1.014130E-05
```

Partial Output File - F06 (cont.)

```
STATIC LOAD                                                                                         SUBCASE 1

                              S T R U C T U R A L   M O N I T O R   P O I N T   I N T E G R A T E D   L O A D S (MONPNT1)
                                                         (REAL/IMAGINARY)

        MONITOR POINT NAME = MPT11                COMPONENT =  CMX          GENERAL              SUBCASE NO.        1
        LABEL = THIS IS THE FIRST MONPNT1
          CP =         52          X = 1.000000E+00          Y = 2.000000E+00          Z = 3.000000E+00          CD =       52

          FREQUENCY       INERTIAL       EXTERNAL       FLEXIBLE       GUST           TOTAL          TOTAL
                                                        INCREMENT                     AERO
          ------------   ------------   ------------   ------------   ------------   ------------   ------------
          1.000000E+02   2.869013E-04  -1.880346E+01                                 0.000000E+00  -1.880317E+01
                        -1.488579E-06   0.000000E+00                                 0.000000E+00  -1.488579E-06
          2.000000E+02   1.181701E-03  -1.880346E+01                                 0.000000E+00  -1.880227E+01
                        -1.260349E-05   0.000000E+00                                 0.000000E+00  -1.260349E-05
          3.000000E+02   2.798447E-03  -1.880346E+01                                 0.000000E+00  -1.880066E+01
                        -4.705944E-05   0.000000E+00                                 0.000000E+00  -4.705944E-05
          4.000000E+02   5.376236E-03  -1.880346E+01                                 0.000000E+00  -1.879808E+01
                        -1.306065E-04   0.000000E+00                                 0.000000E+00  -1.306065E-04
```

Partial Output File - F06 (cont.)

```
STATIC LOAD                                                                                                 SUBCASE 1

                              S T R U C T U R A L   M O N I T O R   P O I N T   I N T E G R A T E D   L O A D S (MONPNT1)
                                                                 (REAL/IMAGINARY)

        MONITOR POINT NAME = MPT12                COMPONENT =  CX           GENERAL            SUBCASE NO.        1
        LABEL = THIS IS THE SECOND MONPNT1
          CP =         0          X = 2.000000E+01          Y = 2.000000E+01          Z = 0.000000E+00          CD =         0

 FREQUENCY      INERTIAL       EXTERNAL       FLEXIBLE       GUST           TOTAL          TOTAL
                                                       INCREMENT                     AERO
          ------------   ------------   ------------   ------------   ------------   ------------   ------------
          1.000000E+02  -8.893522E-15   0.000000E+00                                 0.000000E+00  -8.893522E-15
                         9.754059E-18   0.000000E+00                                 0.000000E+00   9.754059E-18
          2.000000E+02  -3.564941E-14   0.000000E+00                                 0.000000E+00  -3.564941E-14
                         7.841858E-17   0.000000E+00                                 0.000000E+00   7.841858E-17
          3.000000E+02  -8.049498E-14   0.000000E+00                                 0.000000E+00  -8.049498E-14
                         2.668470E-16   0.000000E+00                                 0.000000E+00   2.668470E-16
          4.000000E+02  -1.438134E-13   0.000000E+00                                 0.000000E+00  -1.438134E-13
                         6.398367E-16   0.000000E+00                                 0.000000E+00   6.398367E-16
```

Partial Output File - F06 (cont.)

```
STATIC LOAD                                                                                                   SUBCASE 1

                              S T R U C T U R A L   M O N I T O R   P O I N T   I N T E G R A T E D   L O A D S (MONPNT1)
                                                                 (REAL/IMAGINARY)

        MONITOR POINT NAME = MPT12                COMPONENT =   CMX          GENERAL              SUBCASE NO.         1
        LABEL = THIS IS THE SECOND MONPNT1
          CP =          0           X = 2.000000E+01          Y = 2.000000E+01          Z = 0.000000E+00          CD =         0

          FREQUENCY       INERTIAL       EXTERNAL       FLEXIBLE       GUST           TOTAL          TOTAL
                                                        INCREMENT                     AERO
          ------------   ------------   ------------   ------------   ------------   ------------   ------------
          1.000000E+02   0.000000E+00   0.000000E+00                                 0.000000E+00   0.000000E+00
                         0.000000E+00   0.000000E+00                                 0.000000E+00   0.000000E+00
          2.000000E+02   0.000000E+00   0.000000E+00                                 0.000000E+00   0.000000E+00
                         0.000000E+00   0.000000E+00                                 0.000000E+00   0.000000E+00
          3.000000E+02   0.000000E+00   0.000000E+00                                 0.000000E+00   0.000000E+00
                         0.000000E+00   0.000000E+00                                 0.000000E+00   0.000000E+00
          4.000000E+02   0.000000E+00   0.000000E+00                                 0.000000E+00   0.000000E+00
                         0.000000E+00   0.000000E+00                                 0.000000E+00   0.000000E+00
```

Partial Output File - F06 (cont.)

```
STATIC LOAD                                                                                                   SUBCASE 1

                S T R U C T U R A L   I N T E G R A T E D   F R E E   B O D Y   M O N I T O R   P O I N T   L O A D S
(MONPNT3)
                                                        (REAL/IMAGINARY)

        MONITOR POINT NAME = MPT31            COMPONENT =  CX                                            SUBCASE NO.         1
        LABEL = THIS IS THE FIRST MONPT3
          CP =        0          X = 1.000000E+00          Y = 2.000000E+00          Z = 3.000000E+00

          FREQUENCY      RESULTANT

          ------------   ------------
          1.000000E+02  -9.437375E-09
                        -2.202706E-11
          2.000000E+02  -9.402346E-09
                        -4.418799E-11
          3.000000E+02  -9.343811E-09
                        -6.661769E-11
          4.000000E+02  -9.261545E-09
                        -8.945327E-11
```

Partial Output File - F06 (cont.)

```
STATIC LOAD                                                                                    SUBCASE 1

            S T R U C T U R A L   I N T E G R A T E D   F R E E   B O D Y   M O N I T O R   P O I N T   L O A D S
(MONPNT3)
                                                 (REAL/IMAGINARY)

      MONITOR POINT NAME = MPT31              COMPONENT =   CMX                                 SUBCASE NO.        1
      LABEL = THIS IS THE FIRST MONPT3
        CP =          0          X = 1.000000E+00          Y = 2.000000E+00          Z = 3.000000E+00

        FREQUENCY      RESULTANT

        ------------   ------------
        1.000000E+02   4.460948E+00
                      -2.557972E-02
        2.000000E+02   4.733721E+00
                      -5.800123E-02
        3.000000E+02   5.244946E+00
                      -1.072007E-01
        4.000000E+02   6.108082E+00
                      -1.922249E-01
```