# THE UNIVERSITY OF MICHIGAN

# MSC/NASTRAN

# INTERACTIVE TRAINING PROGRAM

July 19, 1982

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   (courtesy MacNeal-Schwendler Corporation)



William J. Anderson

Problem 1. Plane Stress

Consider a thin sheet of metal under uniform tension in the x direction (Fig. 1). The sheet has a circular hole which causes a stress concentration.

The sheet has a planform of 1000 mm × 1000 mm (39.370 in. × 39.370 in.) and is 1 mm (0.0394 in.) thick. The hole is 300 mm (11.811 in.) in diameter.

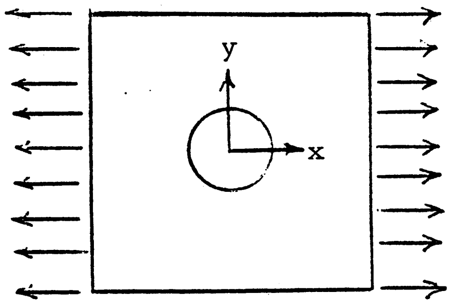


Fig. 1. Sheet metal under plane stress.

The material is aluminum, with

$E = 68950.$ mPa $(10.0 \times 10^6$ psi)

$G = 26520.$ mPa $(3.846 \times 10^6$ psi)

$\nu = 0.3$

A) Carry out a solution for stress, particularly in the vicinity of the hole. Reduce the size of the problem by using symmetry. Use isoparametric elements -- even two will suffice for a rough answer.

B) Compare your answer with that given in Popov, "Mechanics of Materials," Prentice-Hall, 2nd Ed., 1976, pp. 48-50. The maximum stress is at the upper edge of the hole on the y axis.

$$\sigma_{x_{max}} = K \sigma_{x_{average}}$$
$$= K\, P/A_{effective}$$

For this geometry, K = 2.28. Hence

$$\sigma_{x_{max}} = (2.28)\ (100000\ \mathrm{N})/(700\ \mathrm{mm}^2)$$
$$= 326.\ \mathrm{mPa}\ \ (47,200\ \mathrm{psi})$$

The value for stress concentration factor is therefore 3.26.

Problem 2. Beam.

A slender cantilever beam is 3000 mm (118.11 in.) long. It is loaded with two concentrated loads as shown in Fig. 1.

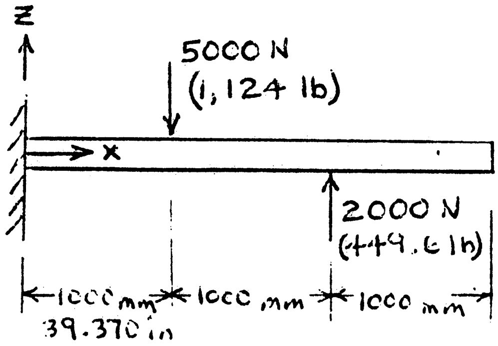


Fig. 1. Cantilever beam with concentrated loads.

The beam is made of steel, with properties

E = 206,840. mPa (30. $\times 10^6$ psi)

G = 79,550. mPa (11.54 $\times 10^6$ psi)

$\nu = 0.3$

The beam is solid, with rectangular cross section (Fig. 2). The moment of inertia about the yy axis is

$I_{yy} = 1.25 \times 10^7$ mm$^4$
(30.03 in$^4$).

and about the zz axis is:

$I_{zz} = 2.81 \times 10^7$ mm$^4$
(67.57 in$^4$)

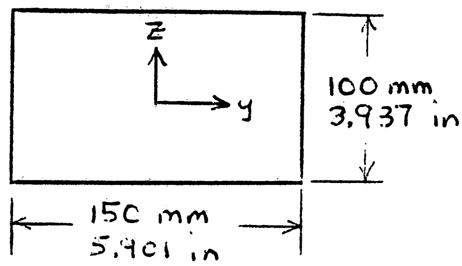


Fig. 2. Cross-section of beam. Free-end view.

A) Carry out a finite element solution for deflection and stress in the beam.

B) Compare the tip deflection and stress at the root with those obtained by Roark and Young in "Formulas for Stress and Strain," McGraw-Hill, 5th Ed., 1975, p.96.

$W_{tip}$ = + 1.031 mm (0.04061 in.) upward

$\sigma_{root}$ = 4.000 mPa (580.2 psi) tension in top fiber comp. in bottom fiber

Problem 3. Plate.

A uniform, elastic plate is fixed at a wall and supported by a piano hinge (drawn as a roller). Two vertical loads of 1000 N (224.8 lb.) are applied at the corners shown in Fig. 1. The plate is 10 mm (0.394 in.) thick aluminum with properties:

E = 68950. mPa  ($10.0 \times 10^6$ psi)

G = 26520. mPa  ($3.846 \times 10^6$ psi)

$\nu = 0.3$

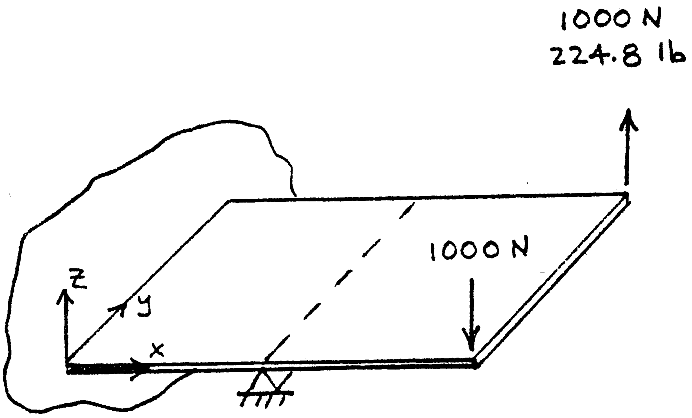


Fig. 1. Plate under concentrated loads.

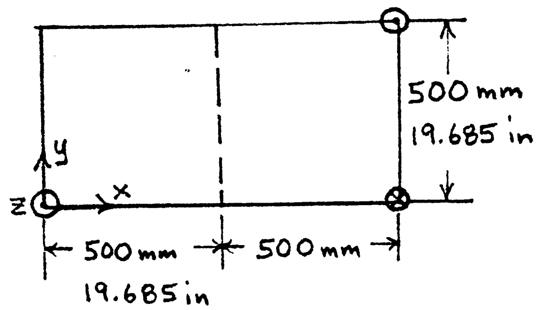


Fig. 2. Plane view of plate

The piano hinge constrains all motion except rotation about its axis. Conventional plate theories do not contain a degree of freedom in rotation about the z axis. The engineer must therefore constrain this degree of freedom in a finite element program.

Find the deflection under each of the loads.

Problem 4. Solid.

Consider a spur gear with "pitch circle" radius of 100 mm (3.937 in.) and with 20 teeth. A tooth on the gear is subjected to a line load by the mating tooth as contact is made (Fig. 1). This steady running load is modeled as a line load of 600 N/mm acting at the pitch circle radius. The load is assumed to act in the +y direction for simplicity.

The side view of the tooth is shown in more detail in Fig. 2. The tooth is "cylindrical," i.e., it can be swept out by straight line generators.

The gear is made of steel with properties:

$E = 206,840.$ mPa $(30.0 \times 10^6$ psi)

$G = 79,550.$ mPa $(11.5 \times 10^6$ psi)

$\nu = 0.3$

A) Find the maximum stress in the gear tooth for the case of uniform line load shown in Fig. 1.

B) Find the maximum stress in the gear tooth for the case of gear misalignment, where the full 6000 N (1,349 lb.) acts at one side of the tooth (Fig. 3).

C) Compare the two cases above to see how much conservation needs to be included in the design to prevent short term failure due to misalignment and before the gears "wear in."

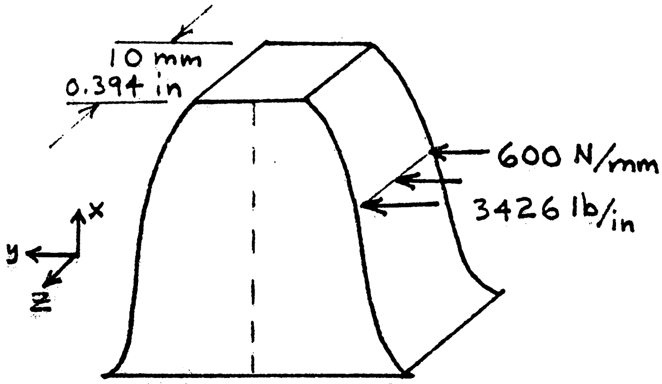


Fig. 1. Spur gear tooth under steady running load.

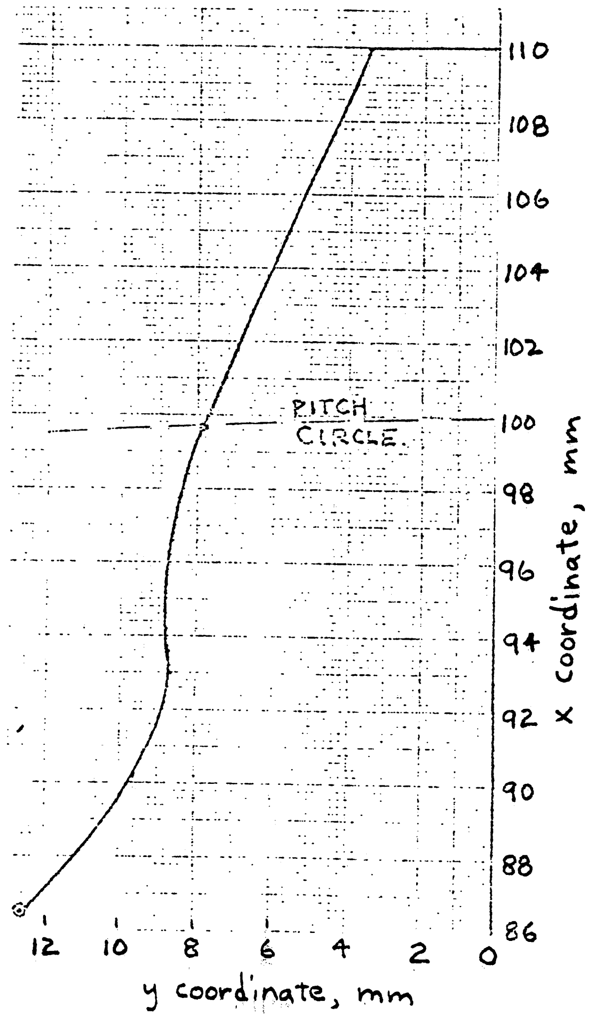


Fig. 2. Contour of spur gear tooth.

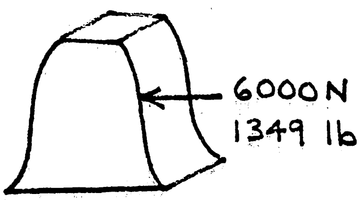


Fig. 3. Eccentric load.

SOLUTION TECHNIQUES

FOR

COMPUTER PROBLEM SET

FINITE ELEMENT METHODS

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September 11, 1981

Sample Problem #1

PLANE STRESS SOLUTION WITH QUAD8

## I. Problem Statement

Consider a thin sheet of metal with a circular hole, and under uniaxial tension (Fig. 1). This is considered a "plane stress" problem because both the structure and the loading on the structure lie in a 2-dimensional plane. Little of interest happens in the z direction, out of the plane.

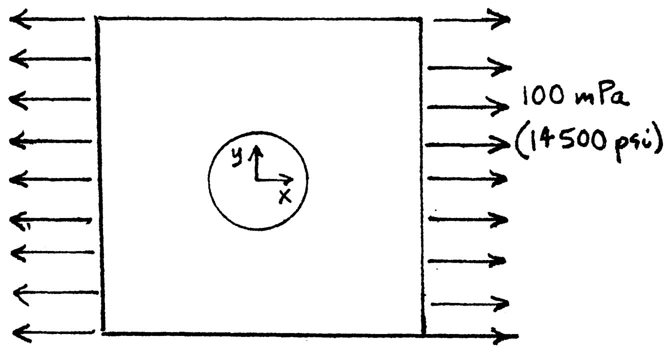



Fig. 1. Plane Stress Problem.

The sheet metal is aluminum with E = 68950 m Pa ($10^7$ psi) and $\nu = 0.3$. The sheet is 1.00 mm (0.0394 in) thick. The planform is 1000 mm by 1000 mm (39.370 in x 39.370 in). The hole is 300 mm (11.811 in) in diameter.

Carry out a solution for the stress in the vicinity of the hole. Use the CQUAD8 element, which is an 8-noded isoparametric element with both inplane (plane stress) and out of plane (bending) capability. We will suppress the out-of-plane behavior by constraining z displacements and all rotations. (Plane stress problems need no rotations at a node.)

## II. Symmetry

Students have a lot of trouble with symmetry, although it is not a hard concept. Here, solve a quarter of the problem, say the first quadrant. Note that the two cut surfaces each have a force and a displacement condition. Imposition of the displacement symmetry also removes the rigid body modes in this problem, but that it is an accidental side effect and does not always happen.

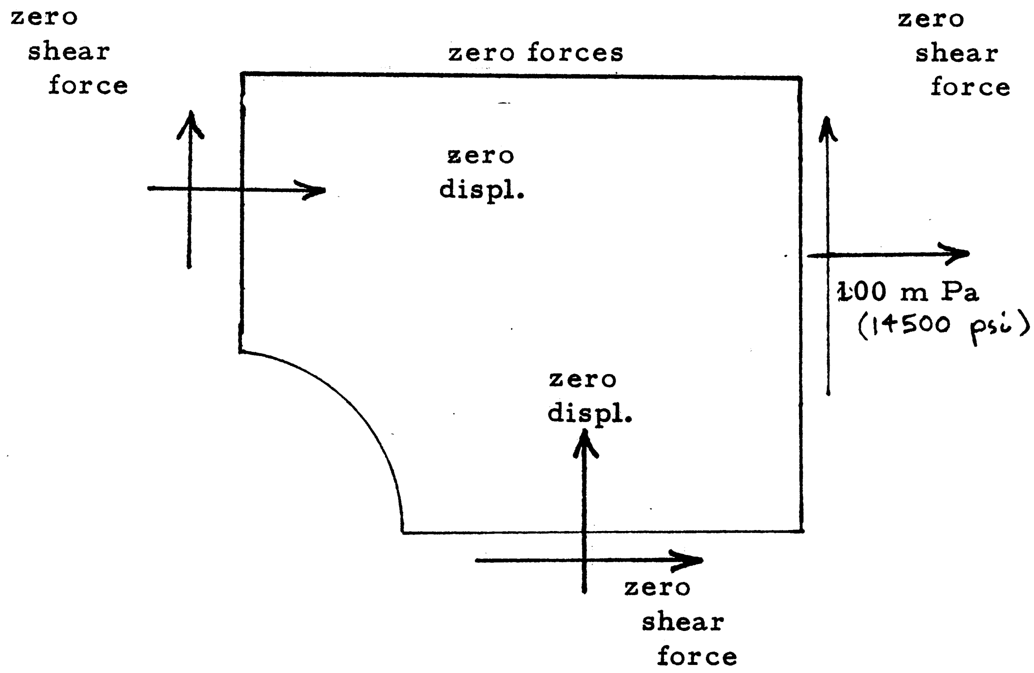



Figure 2. First Quadrant. Solved by Symmetry

III. Mesh

Let us use 2 CQUAD8 elements. A crude, 2-element mesh is chosen.

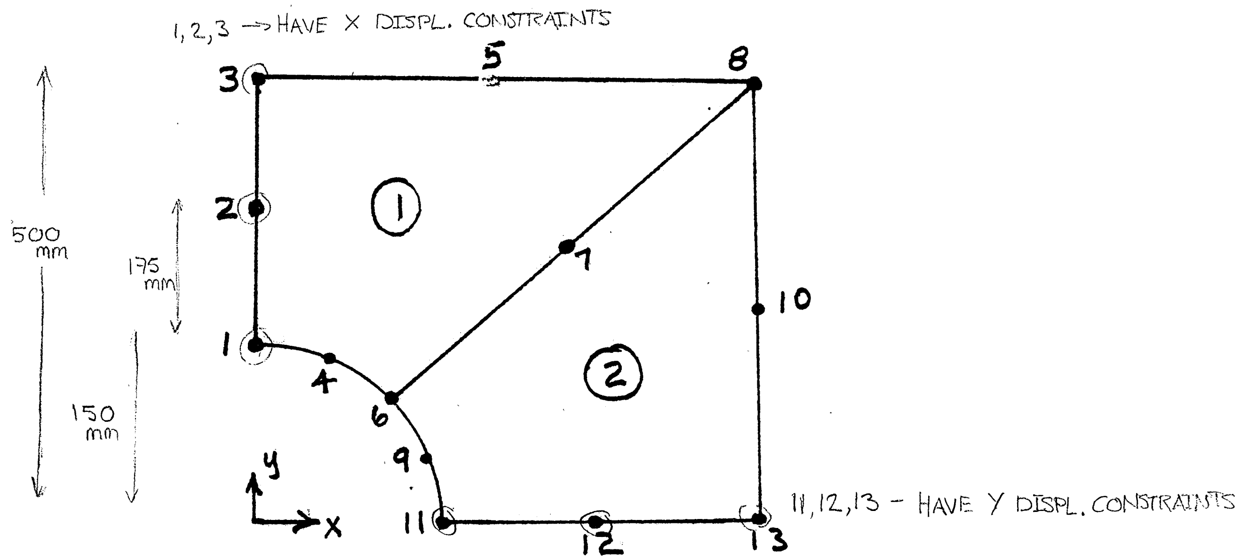



Figure 3. A Suggested Nodal Layout Chosen for Ease of Data Input

The x, y coordinates of the nodes are entered on "GRID" cards:

| | mm | | inches |
|---|---|---|---|
| 1) | 0., 150. | 1) | 0., 59.06 |
| 2) | 0., 325. | 2) | 0., 127.95 |
| 3) | 0., 500. | 3) | 0., 196.85 |
| 4) | 57.40, 138.60 | 4) | 22.60, 54.57 |
| 5) | 250., 500. | 5) | 98.43, 196.85 |
| 6) | 106.10, 106.10 | 6) | 41.77, 41.77 |
| 7) | 303., 303. | 7) | 119.29, 119.29 |
| 8) | 500., 500. | 8) | 196.85, 196.85 |
| 9) | 138.60, 57.40 | 9) | 54.57, 22.60 |
| 10) | 500., 250. | 10) | 196.85, 98.43 |
| 11) | 150., 0. | 11) | 59.06, 0. |
| 12) | 325., 0. | 12) | 127.95, 0. |
| 13) | 500., 0. | 13) | 196.85, 0. |

The connectivity of the elements is entered on CQUAD8 cards:

CQUAD8, 1, 1, 1, 6, 8, 3, 4, 7, 5, 2

connectivity (nodal points)

CQUAD8, 2, 1, 6, 11, 13, 8, 9, 12, 10, 7

IV. Constraints

We have two kinds of constraints in this problem:

a) The plane stress condition that makes z displacements ("3" direction) and all rotations ("4", "5", "6" directions) zero. Use the GRDSET card for this:

GRDSET, , 0, , , , 0, 3456

b) The symmetry conditions which cause some x displacements ("1" direction) and some y displacements ("2" direction) to be zero. Enter the constrained degree of freedom in the 8th field of the appropriate GRID card.

## V. Loads

Distributed loading on isoparametric elements calls for careful procedures in creating consistent equivalent nodal loads. This approach is beyond the grasp of the student at this time, therefore, a simpler "lumped" load method will be used. The lumped loads shown in Fig. 4 can be calculated based on the area exposed to pressure. This introduces a small error which will be discussed later.

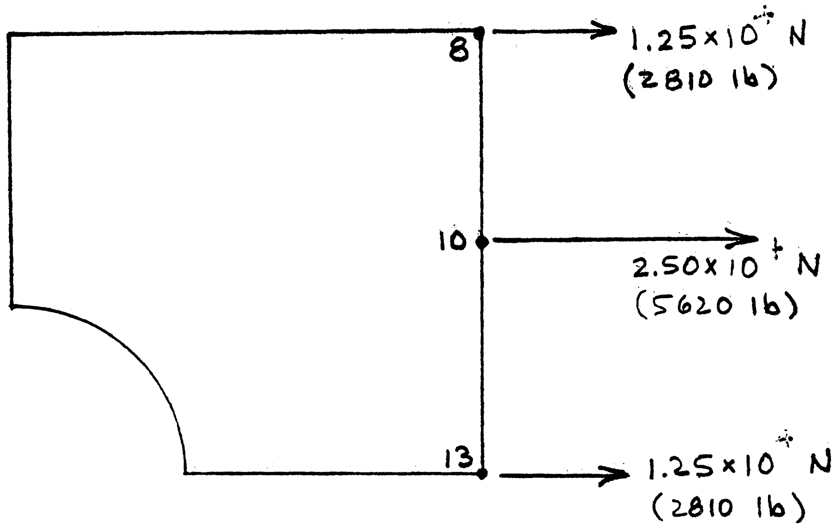



Figure 4. Lumped Loads

This loading is entered on FORCE cards:

FORCE, 1, 8, 0, 1., 125000., 0., 0.

FORCE, 1, 10, 0, 1., 250000., 0., 0.

FORCE, 1, 13, 0, 1., 125000. 0., 0.

## VI. Data File

The above description covers the generation of the bulk data deck. When one adds the executive and the case control cards (perhaps through using the preprocessor PRENASTRAN) one should have the data file shown on pages 9 and 10.

VII. Execution. Plotting.

Let us presume the input data for MSC/NASTRAN are in a permanent file named DATA and the output from the run is to be put in a temporary file named -OUTPUT. The run is executed by

$RUN AERO:NASTRAN SCARDS=DATA SPRINT=-OUTPUT

Plot instructions (if requested) will appear in a file -PLOT, automatically created for you.

A) To get a print of the tabular results, to be picked up at the Computing Center, North Campus (CCNC),

$COPY -OUTPUT *PRINT*

B) To view the plots on a Tektronix storage tube, and before signing off,

$RUN *PLOTSEE PAR=-PLOT

C) To get CALCOMP plots, to be picked up at CCNC,

$RENAME -PLOT PLOT

$RUN *CCQUEUE PAR=PLOT

D) The cost of this run will be $3.00 to $5.00 during the daytime (normal rates).

# TERMINAL SESSION USING PRENASTRAN FOR PROB. 1.

W.J.A.

```
`"xf
%Enter terminal type: LA36

  MTS Ann Arbor (LA36,LF26-CCOF,00362)
#SIG K4L7
#Enter user password.
?
#TERM,NORMAL,UNIV
#**LAST SIGNON WAS: 09:56:32
# USER "K4L7" SIGNED ON AT  10:07:03 ON SAT JUL 18/81
#RUN AERO:PRENASTRAN
#EXECUTION BEGINS
 NASTRAN Preprocessor by Ed Chmiel,Helen Buus and Bill Anderson
                ****** VERSION 4.2 *********
 Enter Y for introduction and instructions, anything else  to start.
 ? Y

 This preprocessor program allows the user to create a complete
 NASTRAN data file interactively which is suitable for input to
 AERO:NASTRAN or which can be puched on cards for execution on
 a system other than MTS.  Such a data file can be generated
 for one of four types of problems:
      1 - Plane Stress (using CQDMEM  or CQUAD8 elements)
      2 - Beam         (using CBAR elements)
      3 - Plate        (using CQUAD4 elements)
      4 - Solid        (using CHEXA elements)
 The program will prompt the user for information as required
 during file generation.  There are eight steps in generating
 a file:
      1) Executive Control Deck - user supplies problem
         identification
      2) Case Control Deck - user supplies title, subtitle, and
         number of subcases
      3) Grid Point Definitions - user supplies grid point id's
         and coordinates
      4) Grid Point Constraints - user supplies grid point id's
         and constraint codes
      5) Element Definitions - user supplies element id's
         property id's, and grid point connectivities
      6) Property Definitions - user supplies material id's
         and thicknesses or section properties, if required
      7) Material Definitions - user supplies Young's Modulus
         and Poisson's Ratio
      8) Load Definitions - user supplies grid point id's and
         Cartesian components of forces
```

Read program messages and prompts carefully before entering any information. References to the NASTRAN User's Manual, Vol 1 are enclosed in parentheses, eg (2.4-307). If a message is not fully understood, refer to the appropriate page.

If for some reason the program terminates before all eight steps of file generation have been completed, it can be re-run using the program's Restart capability. This allows the user to continue generating the file without having to re-enter data that has been successfully entered in the file. There is also a Rewrite capablility which allows the user to edit the file. It is extremely important that the type of problem, type of element, and the number of grid points and elements be the same in Restart or Rewrite mode as in Create mode.

```
Choose mode of operation:
     1 - Create
     2 - Restart
     3 - Rewrite
? 1

Executive Control Deck
Enter Problem Identification (2.2-1):
? ANDERSON,AERO510   $ JULY 18, 1981.  DATA IN K4L7:ESCDATA8.

Enter problem type(1=Plane Stress,2=Beam,3=Plate,4=Solid):
? 1
Choose element type for Plane Stress:
  1 - CQDMEM  (for stress contour plots)
  2 - CQUAD8  (for better accuracy with fewer elements)
? 2

Case Control Deck
Enter Title (2.3-137):
? ESC PROBLEM #1.
Enter Subtitle (2.3-117):
? PLANE STRESS. PLATE WITH HOLE.
From one to nine subcases may be requested to allow
application of different sets of loads to the model.
For each subcase, the user will be prompted for a
set of loads in Step 8 of file generation.
Enter desired number of subcases (2.3-55 and 2.3-111):
? 1

GRID Grid Point Definitions (2.4-205)
Define each grid point by entering its id number and
coordinates.  Repeat process for each grid point.  If an error
was made in defining a grid point, the same id and correct
coordinates may be re-entered thereby replacing the old
information in the data file.  When all grid points have been
defined, enter $ENDFILE or CTRL-C to stop.  The program will
then check if all grid points numbered from one to the user
defined maximum have been defined.  Enter maximum grid id:
? 13
Maximum grid id = 13, please confirm(Y or N):
? Y
```

```
For each grid point, enter ID,X,Y:
? 1,0.,150.
? 2,0.,325.
? 3,0.,500.
? 4,57.4,138.6
? 5,250.,500.
? 6,106.1,106.1
? 7,303.,303.
? 8,500.,500.
? 9,138.6,57.4
? 10,500.,250.
? 11,150.,0.
? 12,325.,0.
? 13,500.,0.
? $ENDFILE
Define the constraints for a grid point( GRID 2.4-205):
Enter grid number,constraints (any digits 1-6, no blanks).
Enter $ENDFILE or CTRL-C to stop.
? 1,13456
? 2,13456
? 3,13456
? 11,23456
? 12,23456
? 13,23456
? $ENDFILE

CQUAD8  Element Definitions (2.4-112c)
Define each element by entering its id number and grid id's
specifying the element's connectivity.  If an error was made
in defining an element, the same id and correct connectivity
may be re-entered thereby replacing the old information in
the data file.  When all elements have been defined, enter
$ENDFILE or CTRL-C to stop.  The program will then check if
all elements numbered from one to the user defined maximum
have been defined.  Enter maximum element id:
? 2
Maximum element id =  2, please confirm(Y or N):
? Y
For each element, enter EID,GID1,...,GID8 where
GID1 thru GID4 define element corners in counter-clockwise
order, and GID5 thru GID8 define midpoints of element edges
in counter-clockwise order
NOTE - Following definition of the first element there
       will be a prompt for property id number and an
       option will be given to either use the same property
       id for all elements or to enter a new id for each
       element
Enter element data:
? 1,1,6,8,3,4,7,5,2
Enter property id:
? 1
Is given property id to be used for all elements (Y or N)?
? Y
Enter element data:
? 2,6,11,13,8,9,12,10,7
? $ENDFILE
```

```
PSHELL  Property Definitions (2.4-326a)
Enter material id and thickness for property id  1:
? 1,1.

MAT1 Material Definitions (2.4-215)
Enter Young's Modulus, Poisson's Ratio for material  1:
? 68950.,.3

FORCE Load Definitions (2.4-179)
   1 load subcase(s) have been requested
Define loads for subcase 1
For each load, enter grid id defining point at which load
is to be applied, followed by X,Y,Z components of force,
ie. GID,FX,FY,FZ.  To delete a load, enter -GID,0,0,0.
Enter $ENDFILE or CTRL-C to stop for given subcase:
? 8,12500.,0.,0.
? 10,25000.,0.,0.
? 13,12500.,0.,0.
? $ENDFILE
Enter 1 to list datafile, or 0:
? 1
:$LIST DATA
.    10      ID ANDERSON,AERO510  $ JULY 18, 1981.  DATA IN K4L7:ESCDATA8.
>    11      TIME 1
>    12      SOL 24
>    13      DIAG 14
>    14      CEND
>   100      TITLE=ESC PROBLEM #1.
>   101      SUBTITLE= PLANE STRESS. PLATE WITH HOLE.
>   102      ECHO=BOTH
>   104      DISPLACEMENT=ALL
>   105      STRESS=ALL
>   106      ELFORCE=ALL
>   107      SPCFORCES=ALL
>   111      SUBCASE 1
>   111.5    LOAD=1
>   140      OUTPUT(PLOT)
>   141      PLOTTER NASTRAN
>   142      SET 1 INCLUDE ALL
>   153      AXES Z,X,Y
>   154      VIEW 0.,0.,0.
>   155      FIND
>   156      PLOT LABEL BOTH
>   157      PLOT STATIC DEFORMATION 0 SET 1
>   190      BEGIN BULK
>   191      PARAM   AUTOSPC   YES
>   192      GRDSET                                                      3456
>   201      GRID            1           0.0    150.000   0.0           13456
>   202      GRID            2           0.0    325.000   0.0           13456
>   203      GRID            3           0.0    500.000   0.0           13456
>   204      GRID            4        57.400 138.600   0.0
>   205      GRID            5       250.000 500.000   0.0
>   206      GRID            6       106.100 106.100   0.0
>   207      GRID            7       303.000 303.000   0.0
```

```
>   208     GRID            8             500.000 500.000   0.0
>   209     GRID            9             138.600  57.400   0.0
>   210     GRID           10             500.000 250.000   0.0
>   211     GRID           11             150.000   0.0     0.0                 23456
>   212     GRID           12             325.000   0.0     0.0                 23456
>   213     GRID           13             500.000   0.0     0.0 .               23456
>   301     CQUAD8          1       1       1       6       8       3       4       7+A1001
>   301.1   +A1001          5       2
>   302     CQUAD8          2       1       6      11      13       8       9      12+A1002
>   302.1   +A1002         10       7
>   401     PSHELL          1       1 1.0
>   501     MAT1           16.90E+04      0.30
>   708.1   FORCE           1       8       0   1.0     12500.      0.      0.
>   710.1   FORCE           1      10       0   1.0     25000.      0.      0.
>   713.1   FORCE           1      13       0   1.0     12500.      0.      0.
>  1000     ENDDATA
#END OF FILE
 Enter 1 to punch cards, or 0:
 ? 0
 Enter 1 to enter rewrite mode, or 0 to stop:
 ? 0
#EXECUTION TERMINATED
#RENAME DATA ESCDATA8
#FILE "DATA" IS TO BE RENAMED AS "ESCDATA8".  PLEASE CONFIRM
?OK
#DONE.
#SIG $
#K4L7 10:07:03-10:23:47 SAT JUL 18/81
#     $.55
# $286.23
```

## TERMINAL SESSION USING NASTRAN FOR PROBLEM 1.

```
#LIST ESCDATA8
>    10     ID ANDERSON,AERO510  $ JULY 18, 1981.  DATA IN K4L7:ESCDATA8.
>    11     TIME 1
>    12     SOL 24
>    13     DIAG 14
>    14     CEND
>   100     TITLE=ESC PROBLEM #1.
>   101     SUBTITLE= PLANE STRESS. PLATE WITH HOLE.
>   102     ECHO=BOTH
>   104     DISPLACEMENT=ALL
>   105     STRESS=ALL
>   106     ELFORCE=ALL
>   107     SPCFORCES=ALL
>   111     SUBCASE 1
>   111.5   LOAD=1
>   150     OUTPUT(PLOT)
>   151     PLOTTER NASTRAN
>   152     SET 1 INCLUDE ALL
>   153     AXES Z,X,Y
>   154     VIEW 0.,0.,0.
>   155     FIND
>   156     PLOT LABEL BOTH
>   157     PLOT STATIC DEFORMATION 0 SET 1
>   190     BEGIN BULK
>   191     PARAM   AUTOSPC   YES
>   192     GRDSET                                                  3456
>   201     GRID           1          0.0   150.000   0.0          13456
>   202     GRID           2          0.0   325.000   0.0          13456
>   203     GRID           3          0.0   500.000   0.0          13456
>   204     GRID           4       57.400   138.600   0.0
>   205     GRID           5      250.000   500.000   0.0
>   206     GRID           6      106.100   106.100   0.0
>   207     GRID           7      303.000   303.000   0.0
>   208     GRID           8      500.000   500.000   0.0
>   209     GRID           9      138.600    57.400   0.0
>   210     GRID          10      500.000   250.000   0.0
>   211     GRID          11      150.000     0.0     0.0          23456
>   212     GRID          12      325.000     0.0     0.0          23456
>   213     GRID          13      500.000     0.0     0.0          23456
>   301     CQUAD8         1      1       1       6       8       3       4       7+A1001
>   301.1   +A1001         5      2
>   302     CQUAD8         2      1       6      11      13       8       9      12+A1002
>   302.1   +A1002        10      7
```

```
>    401       PSHELL           1         1 1.0
>    501       MAT1             16.90E+04        0.30
>    708.1     FORCE            1         8        0    1.0    12500.      0.       0.
>    710.1     FORCE            1        10        0    1.0    25000.      0.       0.
>    713.1     FORCE            1        13        0    1.0    12500.      0.       0.
>  1000        ENDDATA
#END OF FILE
#   $.03,  $13.85T
```

To run data through Nastran program : results

Warning : non exist. file / device attached to unit ? Partitioned data set organization requires a file

$29.

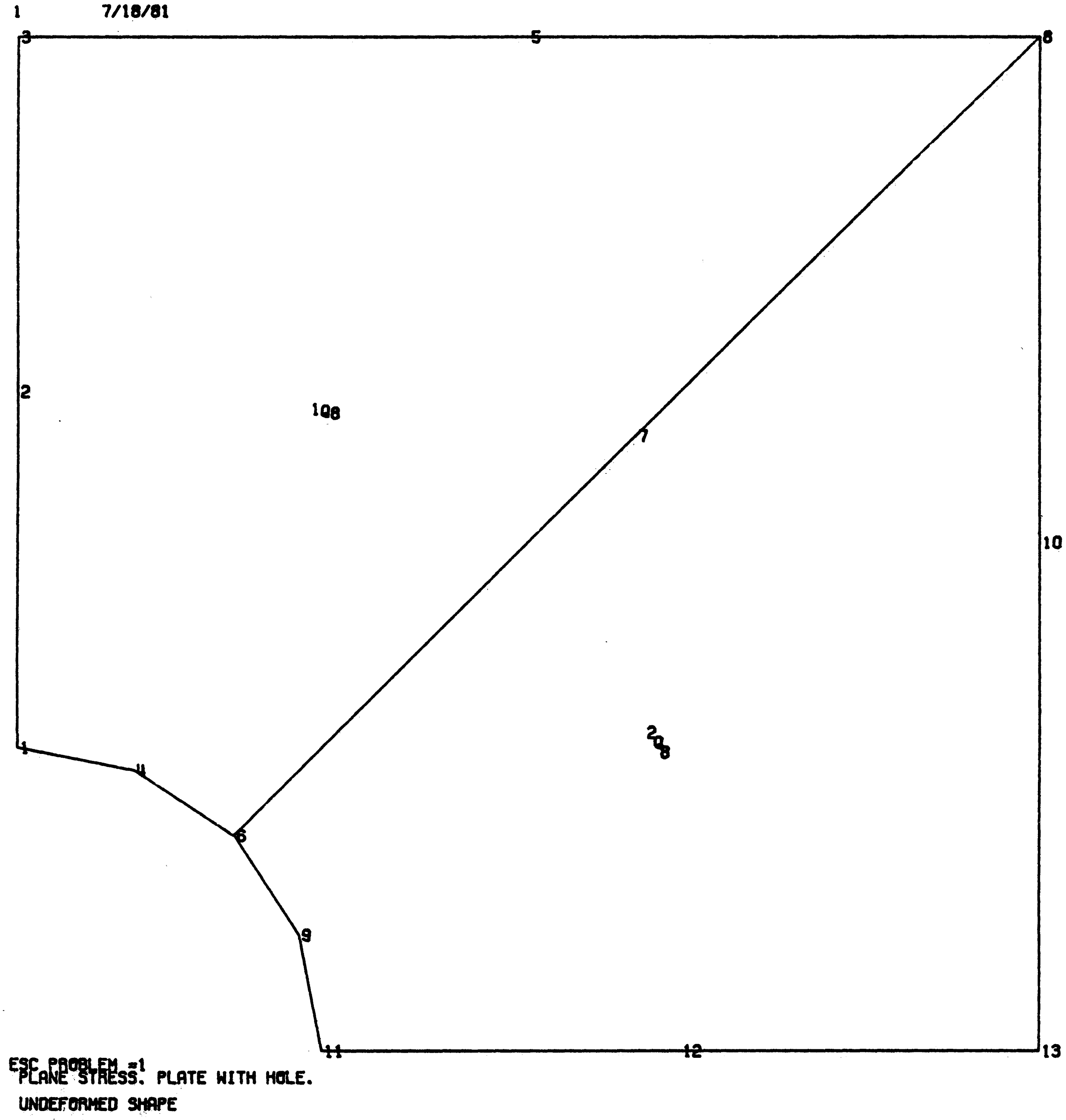
```
#RUN AERO:NASTRAN SCARDS=ESCDATA8  SPRINT=ESCRES8
#EXECUTION BEGINS
 EXECUTION BEGINS
#$CONTROL -##NO1 SIZE=1000P
#$CONTROL -##NO2 SIZE=1000P
#$CONTROL -##NO3 SIZE=1000P
#$CONTROL -##NO4 SIZE=1000P
 EXECUTION BEGINS
 NASTRAN LOADED AT LOCATION  700000
```

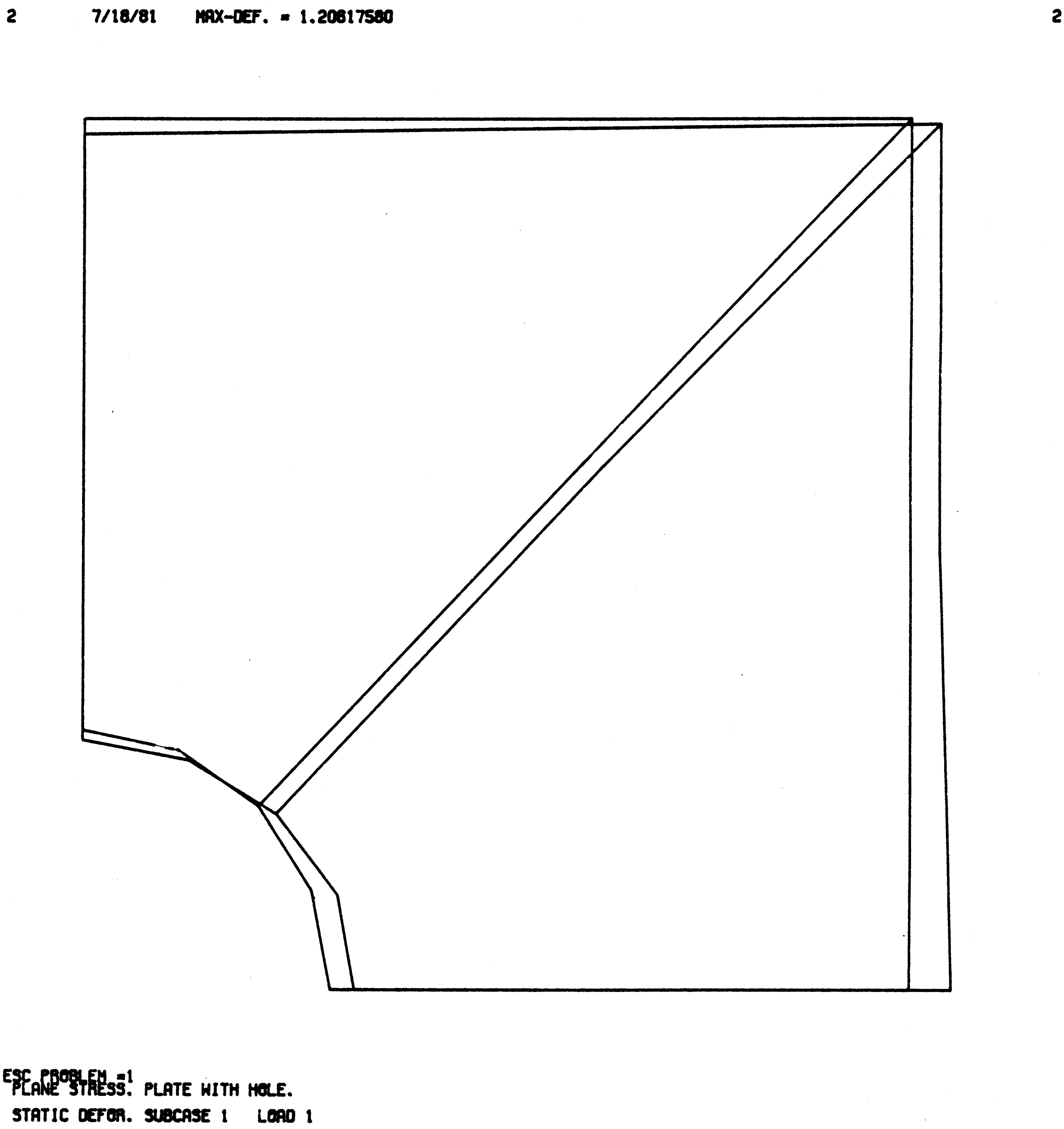
| CPU SEC | ELAP SEC | I/O SEC | EXCP COUNTS NASTRAN | TOTAL | TRACKS USED | | | |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | SEM1 | BEGN | |
| 0.133 | 6.0 | 0.5 | 11 | 0 | 16 | XSOR | | |
| 0.270 | 8.0 | 1.1 | 22 | 0 | 32 | IFP | | |
| 0.412 | 10.0 | 2.1 | 42 | 0 | 52 | XGPI | | |
| 1.093 | 16.0 | 3.2 | 64 | 0 | 60 | 9 | GP1 | BEGN |
| 1.175 | 18.0 | 3.9 | 79 | 0 | 76 | 11 | GP2 | BEGN |
| 1.228 | 20.0 | 4.2 | 84 | 0 | 76 | 15 | PLTHBDY | BEGN |
| 1.260 | 22.0 | 4.3 | 86 | 0 | 76 | 17 | PLTSET | BEGN |
| 1.331 | 25.0 | 4.9 | 99 | 0 | 92 | 19 | PRTMSG | BEGN |
| 1.356 | 26.0 | 5.0 | 101 | 0 | 92 | 22 | PLOT | BEGN |
| 1.895 | 30.0 | 5.6 | 112 | 0 | 92 | 23 | PRTMSG | BEGN |
| 1.928 | 31.0 | 5.7 | 114 | 0 | 92 | 26 | GP3 | BEGN |
| 2.000 | 34.0 | 6.3 | 126 | 0 | 92 | 28 | TA1 | BEGN |
| 2.191 | 38.0 | 7.3 | 147 | 0 | 92 | 31 | EMG | BEGN |
| 2.423 | 41.0 | 7.8 | 155 | 0 | 92 | 37 | EMA | BEGN |
| 2.840 | 46.0 | 8.7 | 174 | 0 | 92 | 97 | GP4 | BEGN |
| 2.921 | 47.0 | 9.4 | 188 | 0 | 96 | 99 | GPSP1 | BEGN |
| 2.987 | 49.0 | 9.8 | 197 | 0 | 96 | 110 | SCE1 | BEGN |
| 3.110 | 52.0 | 10.5 | 210 | 0 | 108 | 140 | RBMG2 | BEGN |
| 3.225 | 55.0 | 10.8 | 216 | 0 | 108 | 145 | SSG1 | BEGN |
| 3.338 | 57.0 | 11.4 | 229 | 0 | 108 | 148 | SSG2 | BEGN |
| 3.458 | 59.0 | 12.2 | 244 | 0 | 120 | 155 | SSG3 | BEGN |
| 3.605 | 62.0 | 12.9 | 258 | 0 | 120 | 160 | SDR1 | BEGN |
| 3.855 | 66.0 | 14.3 | 287 | 0 | 128 | 176 | SDR2 | BEGN |

```
   4.227     72.0    15.9     318       0    128     185    OFF      BEGN
   4.280     74.0    16.0     321       0    128     186    SDRX     BEGN
   4.326     76.0    16.3     327       0    128     188    OFF      BEGN
   4.452     80.0    16.5     331       0    128     189    GPFDR    BEGN
   4.551     82.0    16.8     335       0    128     190    OFF      BEGN
   4.577     83.0    16.8     336       0    128     193    OFF      BEGN
   4.698     87.0    17.0     341       0    128     205    PLTSET   BEGN
   4.772     89.0    17.7     354       0    128     206    PRTMSG   BEGN
   4.790     90.0    17.8     356       0    128     207    PLOT     BEGN
   5.420     95.0    18.4     369       0    128     208    PRTMSG   BEGN
   5.447     95.0    18.5     371       0    128     214    EXIT     BEGN
 IH0002I STOP       1
 VSSCMD238W NSTN04    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN03    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN02    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN01    - OPEN DSDEF BEING CLOSED


 PDS: PLOT DESCRIPTION GENERATION BEGINS.
#EXECUTION TERMINATED
#  $2.94,  $16.79T

#L ESCDATA8 *PRINT*
>*PRINT* ASSIGNED RECEIPT NUMBER 693264
#*PRINT* 693264 RELEASED TO CNTR, 3 PAGES.
#   $.08,  $16.87T
#C ESCRES8  *PRINT*
>*PRINT* ASSIGNED RECEIPT NUMBER 693265
#*PRINT* 693265 RELEASED TO CNTR, 17 PAGES.
#   $.25,  $17.12T
#RENAME -PLOT ESCPLOT8
#DONE.
#   $.01,  $17.14T
#RUN *CCQUEUE PAR=ESCPLOT8
#EXECUTION BEGINS
   2 PLOTS; PLOTTING REQUIRES    99 SEC. AND    24 IN.;     $.36
 PEN WAS UP  45% OF THE TIME.
 OK?
 OK
 'K4L7:ESCPLOT8    ' HAS BEEN PERMITTED 'R PKEY=*CCQUEUE'.
 PLOT ASSIGNED RECEIPT # 718840.
#EXECUTION TERMINATED
```

To get Calcomp plots, at CCNC

Don't destroy file before plot is complete!


7/18/81
ESC PROBLEM =1
PLANE STRESS. PLATE WITH HOLE.
UNDEFORMED SHAPE


2
7/18/81
MAX-DEF. = 1.20817580
2
ESC PROBLEM =1
PLANE STRESS. PLATE WITH HOLE.
STATIC DEFOR. SUBCASE 1
LOAD 1

MSC/NASTRAN PROBLEM SET

Sample Problem 1

PLANE STRESS SOLUTION WITH QDMEM

I. Procedure

Let us solve the plane stress problem with the QDMEM element. Although giving less accuracy than the "in-plane" solution from the QUAD8 element, this element allows the generation of contour plots in MSC/NASTRAN.*

Use the nodal coordinates:

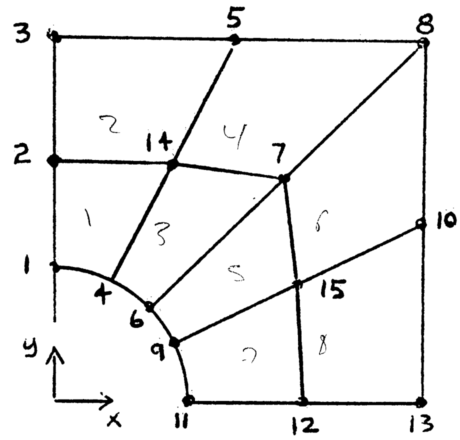



Fig. 1. Plane stress problem solved with 8 QDMEM elements.

| | | | |
|---|---|---|---|
| GRID | 1 | 0.0 | 150.000 |
| GRID | 2 | 0.0 | 325.000 |
| GRID | 3 | 0.0 | 500.000 |
| GRID | 4 | 57.400 | 138.600 |
| GRID | 5 | 250.000 | 500.000 |
| GRID | 6 | 106.100 | 106.100 |
| GRID | 7 | 303.000 | 303.000 |
| GRID | 8 | 500.000 | 500.000 |
| GRID | 9 | 138.600 | 57.400 |
| GRID | 10 | 500.000 | 250.000 |
| GRID | 11 | 150.000 | 0.0 |
| GRID | 12 | 325.000 | 0.0 |
| GRID | 13 | 500.000 | 0.0 |
| GRID | 14 | 191.200 | 325.000 |
| GRID | 15 | 325.000 | 191.200 |

* In MSC/NASTRAN Version 61, contour plots are not available for many of the more advanced, isoparametric elements.

## II. Results

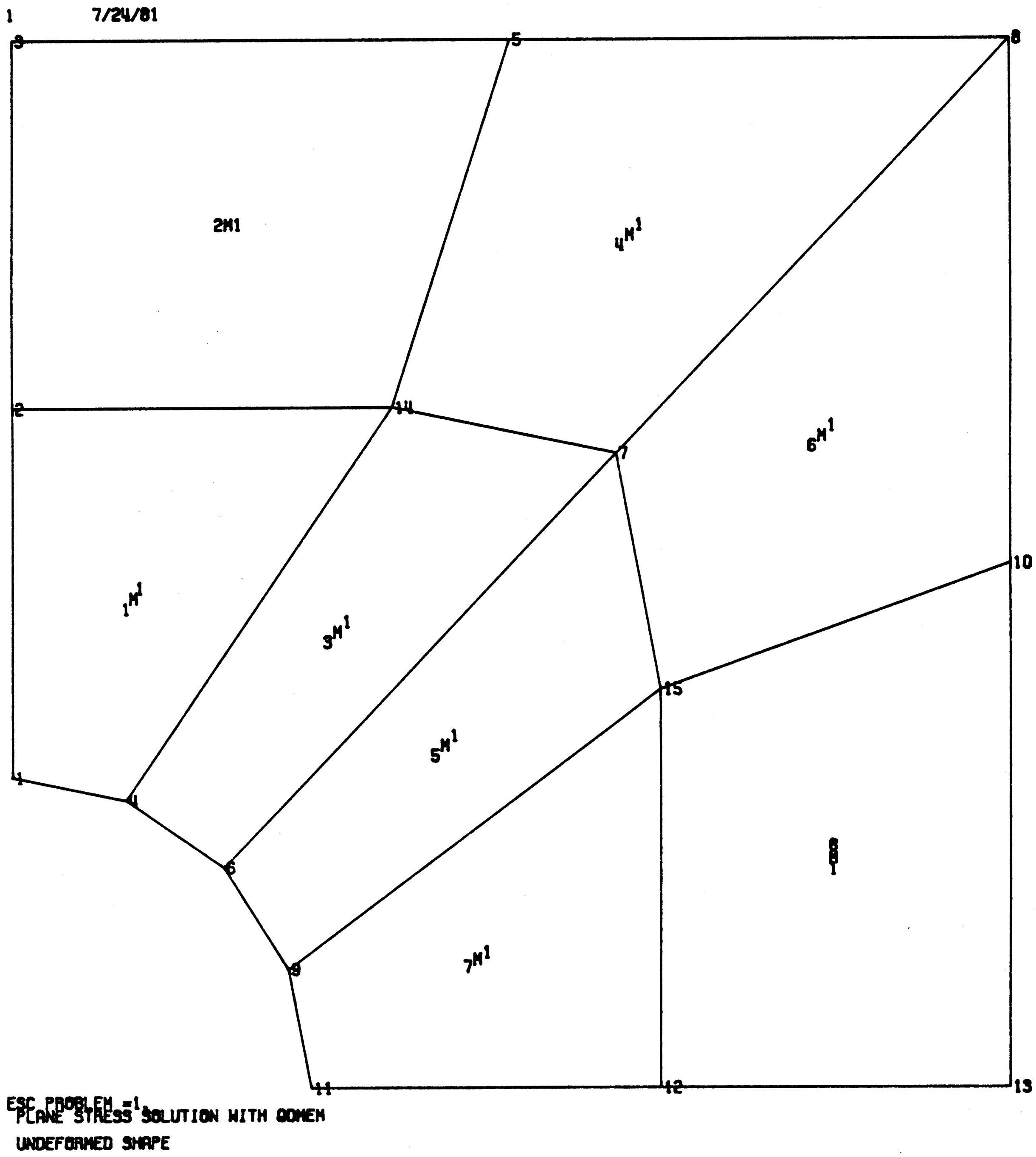
A) What is the stress at node 1, where the stress concentration occurs? (This may cause you some problem in interpretation. Melosh once said that for elements yielding only one stress, it is improper to interpolate that stress to the boundaries.)

B) Compare your answer with that of the QUAD8 element and with the recommended solution. What do you conclude about accuracy of "straight-sided" versus isoparametric elements?

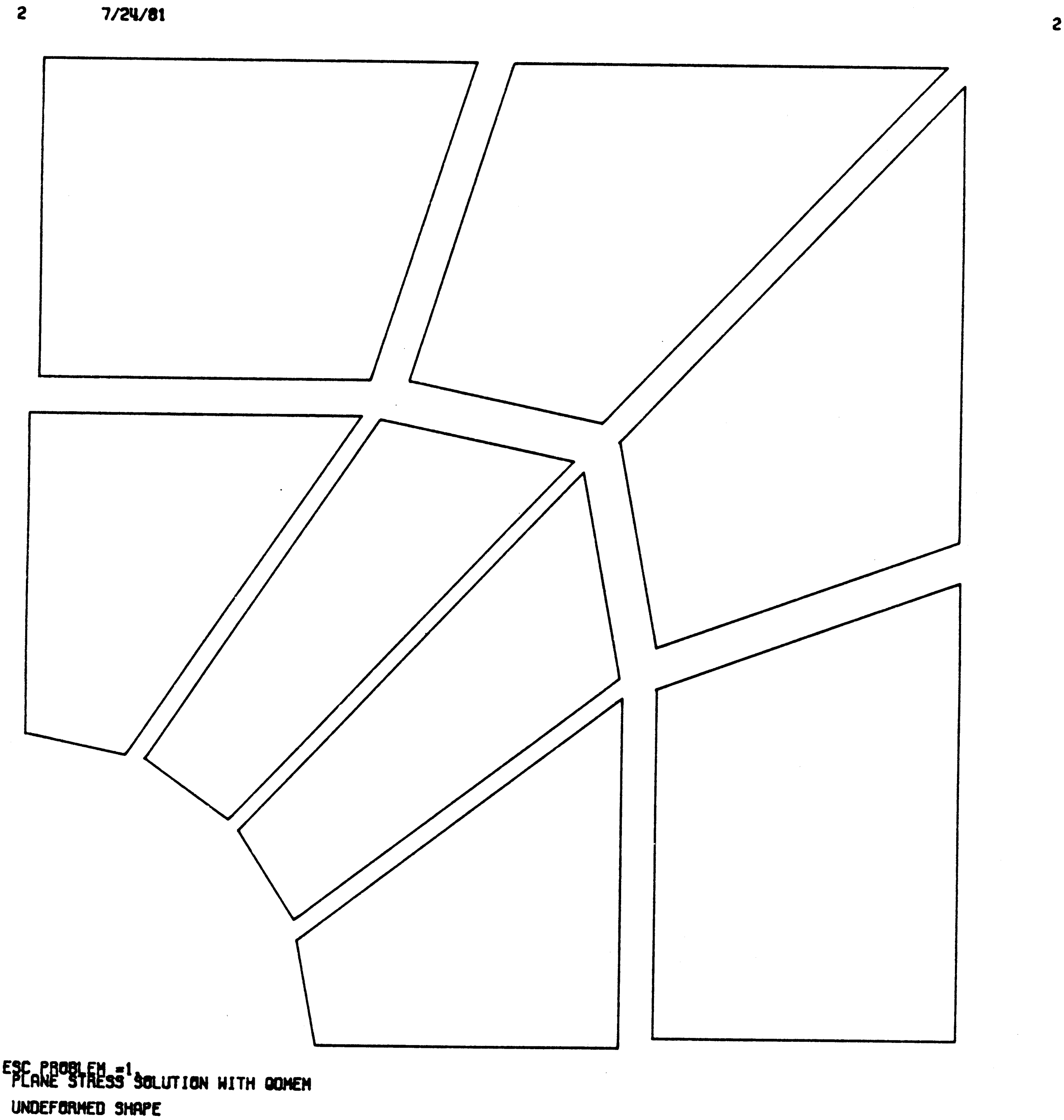
```
#LIST ESCDATA13
>     10      ID ANDERSON,AERO510   $ JULY 25, 1981.  DATA IN K4L7:ESCDATA13.
>     11      TIME 1
>     12      SOL 24
>     13      DIAG 14
>     14      CEND
>    100      TITLE=ESC PROBLEM #1.
>    101      SUBTITLE= PLANE STRESS SOLUTION WITH QDMEM.
>    102      ECHO=BOTH
>    104      DISPLACEMENT=ALL
>    105      STRESS=ALL
>    106      ELFORCE=ALL
>    107      SPCFORCES=ALL
>    111      SUBCASE 1
>    111.5    LOAD=1
>    140      OUTPUT(PLOT)
>    141      PLOTTER NASTRAN
>    142      SET 1 INCLUDE ALL
>    153      AXES Z,X,Y
>    154      VIEW 0.,0.,0.
>    155      FIND
>    156      PLOT LABEL BOTH
>    157      PLOT STATIC DEFORMATION 0 SET 1
>    158      PLOT SHRINK
>    159      CONTOUR MAJPRIN MAX
>    160      PLOT CONTOUR SET 1 OUTLINE
>    190      BEGIN BULK
>    191      PARAM   AUTOSPC   YES
>    192      GRDSET                                                      3456
>    201      GRID           1              0.0    150.000   0.0         13456
>    202      GRID           2              0.0    325.000   0.0         13456
>    203      GRID           3              0.0    500.000   0.0         13456
>    204      GRID           4           57.400   138.600   0.0
>    205      GRID           5          250.000   500.000   0.0
>    206      GRID           6          106.100   106.100   0.0
>    207      GRID           7          303.000   303.000   0.0
>    208      GRID           8          500.000   500.000   0.0
>    209      GRID           9          138.600    57.400   0.0
>    210      GRID          10          500.000   250.000   0.0
>    211      GRID          11          150.000     0.0     0.0         23456
>    212      GRID          12          325.000     0.0     0.0         23456
>    213      GRID          13          500.000     0.0     0.0         23456
>    214      GRID          14          191.200   325.000   0.0
>    215      GRID          15          325.000   191.200   0.0
>    301      CQDMEM         1      1       1        4       14       2
>    302      CQDMEM         2      1       2       14        5       3
>    303      CQDMEM         3      1       4        6        7      14
>    304      CQDMEM         4      1      14        7        8       5
>    305      CQDMEM         5      1       6        9       15       7
>    306      CQDMEM         6      1       7       15       10       8
>    307      CQDMEM         7      1       9       11       12      15
>    308      CQDMEM         8      1      15       12       13      10
>    401      PQDMEM         1      1 1.0
>    501      MAT1           16.90E+04       0.30
>    708.1    FORCE          1      8       0   1.0     12500.       0.       0.
>    710.1    FORCE          1     10       0   1.0     25000.       0.       0.
>    713.1    FORCE          1     13       0   1.0     12500.       0.       0.
>   1000      ENDDATA
#END OF FILE
```

```
#RUN AERO:NASTRAN SCARDS=ESCDATA13 SPRINT=ESCRES13
#EXECUTION BEGINS
 EXECUTION BEGINS
#$CONTROL -##N01 SIZE=1000P
#$CONTROL -##N02 SIZE=1000P
#$CONTROL -##N03 SIZE=1000P
#$CONTROL -##N04 SIZE=1000P
 EXECUTION BEGINS
 NASTRAN LOADED AT LOCATION  700000
       CPU      ELAP      I/O  EXCP COUNTS   TRACKS
       SEC       SEC      SEC NASTRAN   TOTAL   USED
     0.0         0.0      0.0       0       0      0     SEM1   BEGN
     0.212       8.0      0.5      11       0     16     XSOR
     0.452      12.0      1.0      21       0     32     IFP
     0.650      17.0      2.0      41       0     52     XGPI
     1.445      26.0      3.1      63       0     60     9      GP1     BEGN
     1.575      28.0      3.9      78       0     76     11     GP2     BEGN
     1.657      29.0      4.1      83       0     76     15     PLTHBDY BEGN
     1.703      32.0      4.3      85       0     76     17     PLTSET  BEGN
     1.813      35.0      4.9      98       0     92     19     PRTMSG  BEGN
     1.856      35.0      5.0     100       0     92     22     PLOT    BEGN
     3.346      43.0      5.7     114       0     92     23     PRTMSG  BEGN
     3.422      45.0      5.8     116       0     92     26     GP3     BEGN
     3.535      47.0      6.4     128       0     92     28     TA1     BEGN
     3.817      53.0      7.4     149       0     92     31     EMG     BEGN
     4.372      56.0      7.8     157       0     92     37     EMA     BEGN
     4.917      66.0      8.8     175       0     92     97     GP4     BEGN
     5.046      67.0      9.4     189       0     96     99     GPSP1   BEGN
     5.155      69.0      9.8     197       0     96     110    SCE1    BEGN
     5.333      72.0     10.4     209       0    108     140    RBMG2   BEGN
     5.506      75.0     10.8     215       0    108     145    SSG1    BEGN
     5.686      79.0     11.4     228       0    108     148    SSG2    BEGN
     5.867      82.0     12.1     243       0    120     155    SSG3    BEGN
     6.100      86.0     12.8     257       0    120     160    SDR1    BEGN
     6.477      92.0     14.3     286       0    128     176    SDR2    BEGN
     6.793      97.0     15.3     307       0    128     185    OFP     BEGN
     6.882      99.0     15.5     310       0    128     186    SDRX    BEGN
     6.960     100.0     15.8     316       0    128     188    OFP     BEGN
     7.117     104.0     16.0     320       0    128     189    GPFDR   BEGN
     7.253     106.0     16.2     324       0    128     190    OFP     BEGN
     7.296     107.0     16.3     325       0    128     193    OFP     BEGN
     7.465     111.0     16.5     330       0    128     205    PLTSET  BEGN
     7.581     113.0     17.1     343       0    128     206    PRTMSG  BEGN
     7.610     114.0     17.3     345       0    128     207    PLOT    BEGN
     9.683     125.0     18.8     377       0    128     208    PRTMSG  BEGN
     9.758     126.0     18.9     379       0    128     214    EXIT    BEGN
 IH0002I STOP      1
 VSSCMD238W NSTN04    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN03    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN02    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN01    - OPEN DSDEF BEING CLOSED


 PDS: PLOT DESCRIPTION GENERATION BEGINS.
#EXECUTION TERMINATED
```

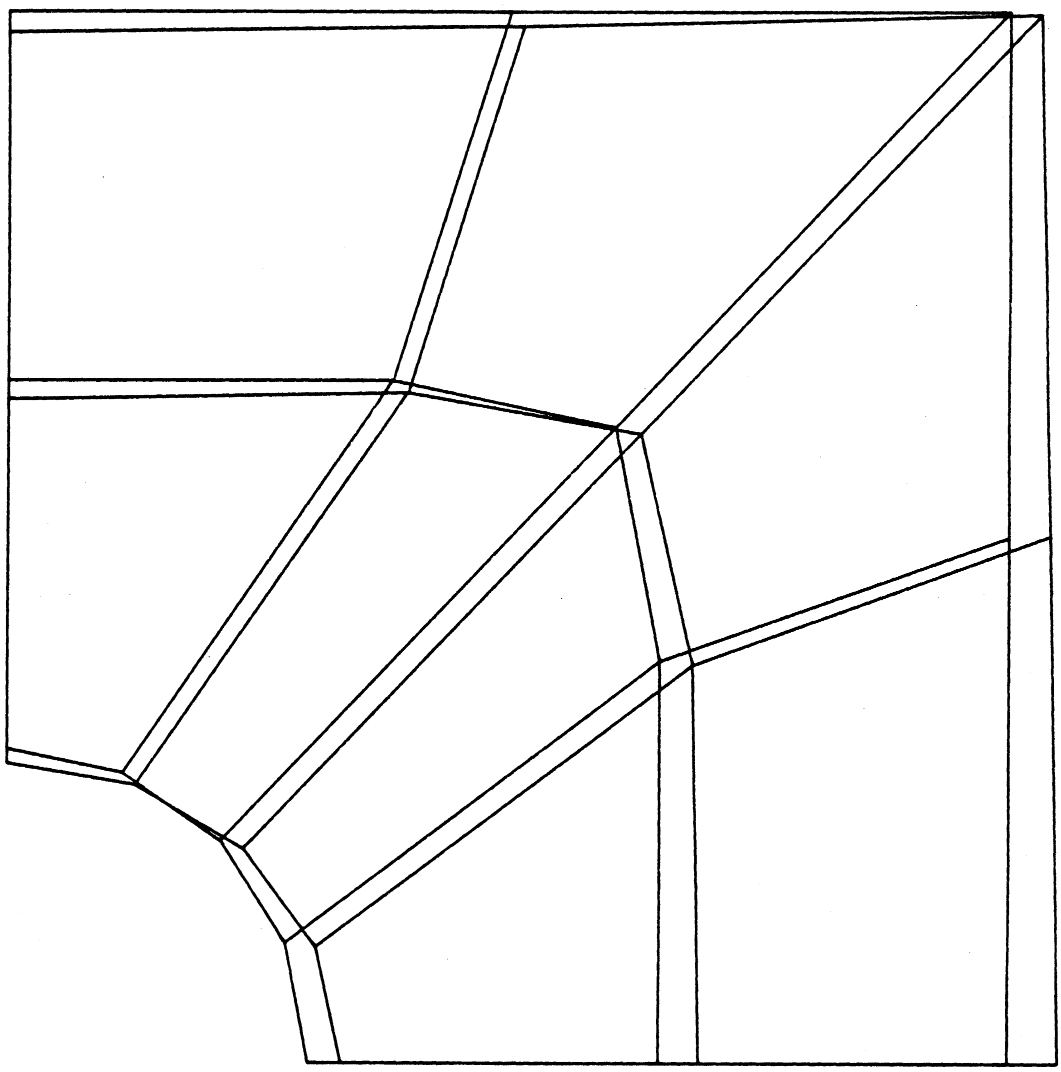
```
#L ESCDATA13 *PRINT*
>*PRINT* ASSIGNED RECEIPT NUMBER 603206
#*PRINT* 603206 RELEASED TO CNTR, 3 PAGES.
#C ESCRES13 *PRINT*
>*PRINT* ASSIGNED RECEIPT NUMBER 603207
#*PRINT* 603207 RELEASED TO CNTR, 19 PAGES.
#RENAME -PLOT ESCPLOT13
#DONE.
#RUN *CCQUEUE PAR=ESCPLOT13
#EXECUTION BEGINS
   4 PLOTS; PLOTTING REQUIRES    237 SEC. AND     47 IN.;      $.79
 PEN WAS UP  45% OF THE TIME.
 OK?
 OK
 "K4L7:ESCPLOT13    " HAS BEEN PERMITTED "R PKEY=*CCQUEUE".
 PLOT ASSIGNED RECEIPT # 724300.
#EXECUTION TERMINATED
```


7/24/81
ESC PROBLEM =1,
PLANE STRESS SOLUTION WITH QDMEM
UNDEFORMED SHAPE

Receipt 724300, Plot 039 K4L7 16:34:09 07-24-81



3 7/24/81 MAX-DEF. = 1.06167880 3

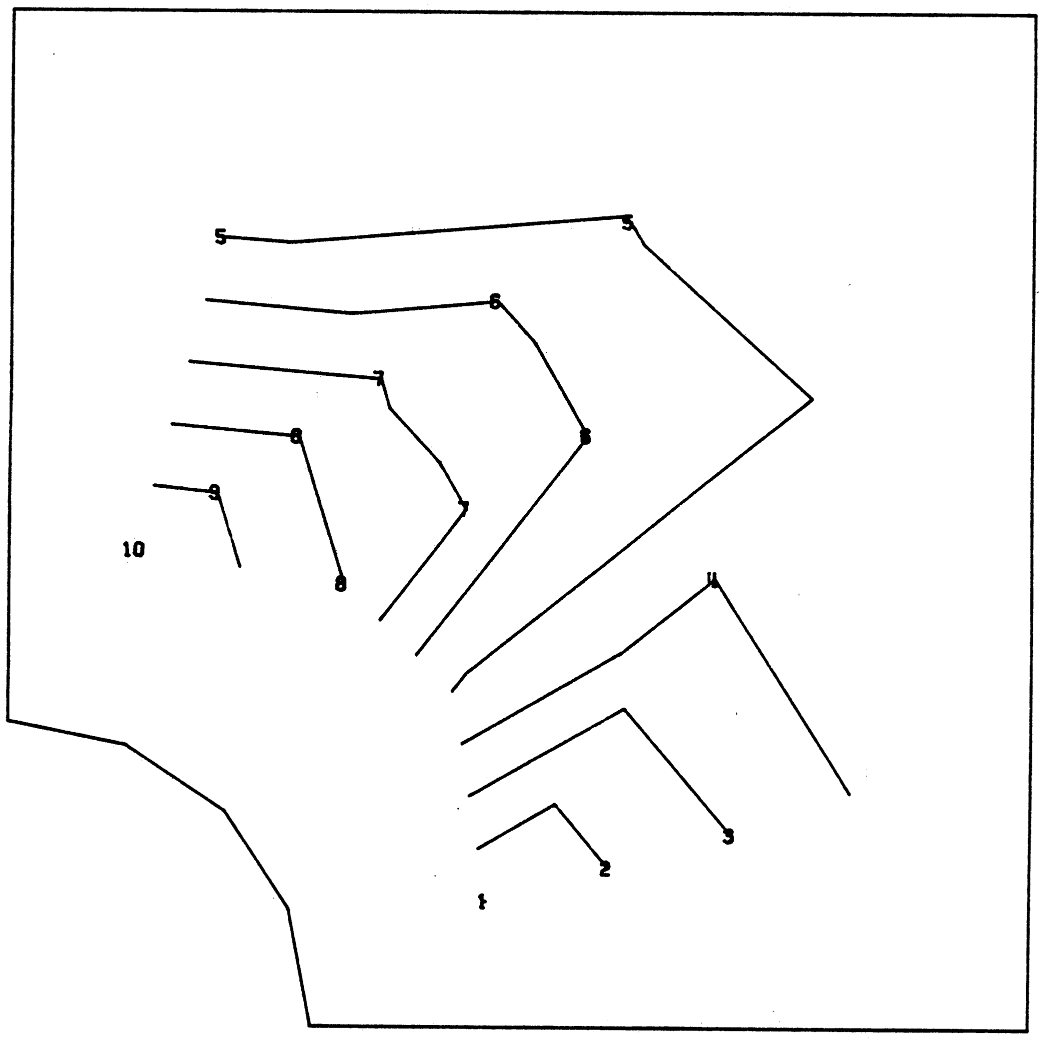


ESC PROBLEM =1,
PLANE STRESS SOLUTION WITH QDMEM
STATIC DEFOR. SUBCASE 1 LOAD 1

Receipt 7243300, Plot 040 K4L7 16:34:09 07-24-81

Receipt 724300, Plot 041 K4L7 16:34:09 07-24-81

4 7/24/81 4




ESC PROBLEM =1,
PLANE STRESS SOLUTION WITH QDMEM
STATIC STRESS SUBCASE 1 LOAD 1

# MSC/NASTRAN PROBLEM SET

## Sample Problem 2

## BAR SOLUTION

### I. Problem Statement

A slender, elastic, cantilever bar 3000 mm (118.11 in.) long is loaded as shown in Fig. 1. The beam is made of steel with properties:

$E = 206,840$ mPa $(30 \times 10^6$ psi)

$\nu = 0.3$

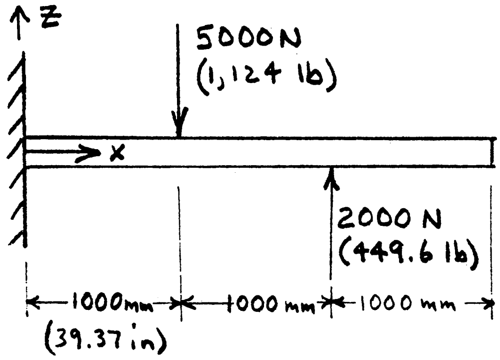



Fig. 1. Cantilever bar with concentrated vertical loads.

The beam has a solid rectangular cross section as shown in Fig. 2. The moments of inertia about the axes are:

$I_{yy} = 1.25 \times 10^7$ mm$^4$ (30.03 in$^4$)

$I_{zz} = 2.81 \times 10^7$ mm$^4$ (67.57 in$^4$)

It is desired to find deflections and stresses in the beam and to plot deflections.

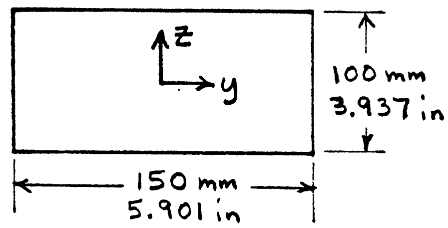



Fig. 2. Cross section of bar. Free-end view.

### II. Solution

The BAR element will be used. Three elements are the minimum permissible and will be used. In this case, with concentrated loads at the ends of each element, the solution should be exact. (The displacement field is modelled with a cubic shape function and this exactly represents a beam with concentrated loads at the ends.)

All finite element programs using beam-type elements have a problem in determining orientation of the principal axes in space. In general, the beam can be at some oblique angle to the coordinate system. In MSC/NASTRAN, this is solved by defining a "Plane 1" passing through a user-specified vector $\vec{V}$ and through the beam axis (Fig. 3.). The vector $\vec{v}$

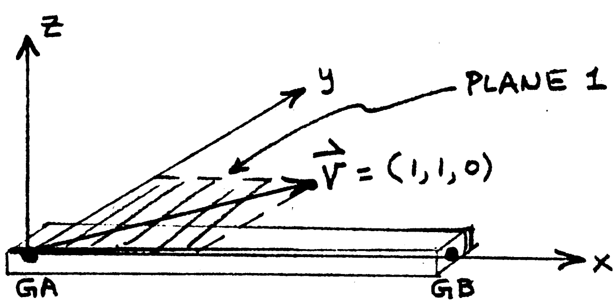



Fig. 3. Coordinate system.

is centered at the left end (the GA node) of the element in question. We will choose a vector $\vec{v}$ = (1., 1., 0.). For the left element, the global coordinate system coincides with the local system.

Bending in Plane 1 is controlled by the stiffness $I_{zz}$. NASTRAN designates, in this case,

$$I_1 \equiv I_{zz}$$

Plane 2 is defined as passing through the beam axis and perpendicular to Plane 1 (Fig. 4.) Bending in this plane is governed by $I_{yy}$ and

$$I_2 \equiv I_{yy}.$$

The most general case of beam orientation is shown on page 1.3-17 of the User's Manual.

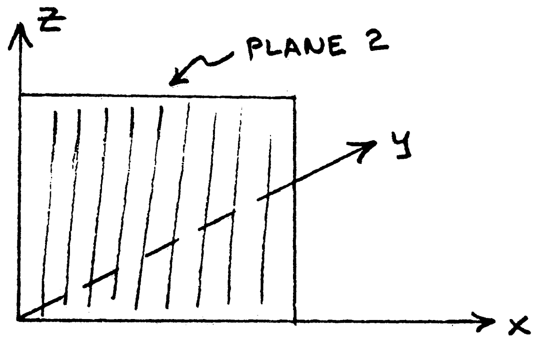



Fig. 4. Definition of Plane 2.

A proposed finite element model is shown in Fig. 5. The grid cards are:

GRID, 1, 0., 0., 0.
GRID, 2, 1000., 0., 0.
GRID, 3, 2000., 0., 0.
GRID, 4, 3000., 0., 0.

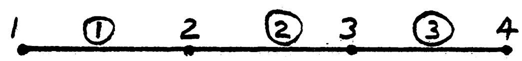



Fig. 5. F.E. model of beam.

The stresses can be read at four points. We will choose the four corners of the cross section as shown in Fig. 2. The property card will be:

PBAR, 1, 1, 1.50E+04, 2.81E+07, 1.25E+07, , , , +A1001
+A1001, 75., 50., -75., 50., -75., -50., 75., -50.

such that stresses will be printed for the four points on the cross section shown in Fig. 6.

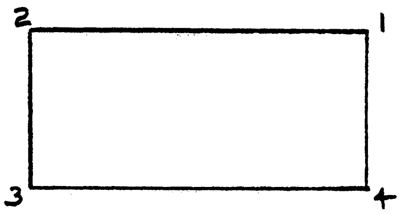



Fig. 6. Stresses given at four points on cross section.

```
L ESCDATA6
>    10      ID ANDERSON,AERO510   $ JULY 18, 1981.   DATA IN K4L7:ESCDATA6.
>    11      TIME 1
>    12      SOL 24
>    13      DIAG 14
>    14      CEND
>   100      TITLE=ESC PROBLEM #2.
>   101      SUBTITLE= CANTILEVER BEAM UNDER CONCENTRATED LOADS.
>   102      ECHO=BOTH
>   104      DISPLACEMENT=ALL
>   105      STRESS=ALL
>   106      ELFORCE=ALL
>   107      SPCFORCES=ALL
>   111      SUBCASE 1
>   111.5    LOAD=1
>   150      OUTPUT(PLOT)
>   151      PLOTTER NASTRAN
>   152      SET 1 INCLUDE ALL
>   153      AXES MY,X,Z
>   154      VIEW 0.,0.,0.
>   155      FIND
>   156      PLOT LABEL BOTH
>   157      PLOT STATIC DEFORMATION 0 SET 1
>   190      BEGIN BULK
>   191      PARAM   AUTOSPC   YES
>   192      GRDSET                                                          1246
>   201      GRID           1           0.0      0.0      0.0             123456
>   202      GRID           2      1000.000      0.0      0.0
>   203      GRID           3      2000.000      0.0      0.0
>   204      GRID           4      3000.000      0.0      0.0
>   301      CBAR           1       1       1       2   1.000   1.000   0.0
>   302      CBAR           2       1       2       3   1.000   1.000   0.0
>   303      CBAR           3       1       3       4   1.000   1.000   0.0
>   401      PBAR           1       11.50E+042.81E+071.25E+07                      +P1001
>   401.1    +P1001    75.000  50.000 -75.000  50.000 -75.000 -50.000  75.000 -50.000
>   501      MAT1           12.07E+05        0.30
>   702.1    FORCE          1       2       0   1.0       0.      0.  -5000.
>   703.1    FORCE          1       3       0   1.0       0.      0.   2000.
>  1000      ENDDATA
#END OF FILE
```

```
 RUN AERO:NASTRAN SCARDS=ESCDATA6 SPRINT=ESCRES6
#EXECUTION BEGINS
 EXECUTION BEGINS
#$CONTROL -##N01 SIZE=1000P
#$CONTROL -##N02 SIZE=1000P
#$CONTROL -##N03 SIZE=1000P
#$CONTROL -##N04 SIZE=1000P
 EXECUTION BEGINS
 NASTRAN LOADED AT LOCATION  700000
        CPU      ELAP      I/O  EXCP COUNTS  TRACKS
        SEC       SEC      SEC NASTRAN  TOTAL  USED
      0.0        0.0      0.0       0      0      0   SEM1   BEGN
      0.163      6.0      0.5      11      0     16   XSOR
      0.301      7.0      1.1      22      0     32   IFP
      0.477     10.0      2.1      42      0     52   XGPI
      1.248     17.0      3.2      64      0     60   9      GP1      BEGN
      1.366     19.0      3.9      79      0     76   11     GP2      BEGN
      1.442     20.0      4.2      84      0     76   15     PLTHBDY  BEGN
      1.485     22.0      4.3      86      0     76   17     PLTSET   BEGN
      1.585     26.0      4.9      99      0     92   19     PRTMSG   BEGN
      1.622     27.0      5.0     101      0     92   22     PLOT     BEGN
      2.373     31.0      5.6     112      0     92   23     PRTMSG   BEGN
      2.421     32.0      5.7     114      0     92   26     GP3      BEGN
      2.526     35.0      6.3     126      0     92   28     TA1      BEGN
      2.777     40.0      7.3     145      0     92   31     EMG      BEGN
      2.958     42.0      7.6     153      0     92   37     EMA      BEGN
      3.431     48.0      8.5     171      0     92   97     GP4      BEGN
      3.545     49.0      9.3     185      0     96   99     GPSP1    BEGN
      3.642     51.0      9.6     193      0     96   110    SCE1     BEGN
      3.802     54.0     10.3     205      0    108   140    RBMG2    BEGN
      3.956     57.0     10.5     211      0    108   145    SSG1     BEGN
      4.122     60.0     11.2     224      0    108   148    SSG2     BEGN
      4.290     62.0     11.9     239      0    120   155    SSG3     BEGN
      4.501     66.0     12.6     253      0    120   160    SDR1     BEGN
      4.840     70.0     14.1     282      0    128   176    SDR2     BEGN
      5.123     74.0     15.1     303      0    128   185    OFP      BEGN
      5.182     75.0     15.3     306      0    128   186    SDRX     BEGN
      5.252     77.0     15.6     312      0    128   188    OFP      BEGN
      5.396     80.0     15.8     316      0    128   189    GPFDR    BEGN
      5.526     83.0     16.0     320      0    128   190    OFP      BEGN
      5.566     84.0     16.0     321      0    128   193    OFP      BEGN
      5.723     88.0     16.3     326      0    128   205    PLTSET   BEGN
      5.831     90.0     16.9     339      0    128   206    PRTMSG   BEGN
      5.857     91.0     17.0     341      0    128   207    PLOT     BEGN
      6.765     97.0     17.7     354      0    128   208    PRTMSG   BEGN
      6.803     97.0     17.8     356      0    128   214    EXIT     BEGN
 IH0002I STOP      1
 VSSCMD238W NSTN04    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN03    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN02    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN01    - OPEN DSDEF BEING CLOSED


 PDS: PLOT DESCRIPTION GENERATION BEGINS.
#EXECUTION TERMINATED
#  $5.29,   $6.01T
```

```
#L ESCDATA6 *PRINT*
>*PRINT* ASSIGNED RECEIPT NUMBER 600048
#*PRINT* 600048 RELEASED TO CNTR, 3 PAGES.
#    $.15,    $6.15T
#C ESCRES6 *PRINT*
>*PRINT* ASSIGNED RECEIPT NUMBER 600051
#*PRINT* 600051 RELEASED TO CNTR, 17 PAGES.
#    $.27,    $6.42T
#RENAME -PLOT ESCPLOT6
#DONE.
#    $.01,    $6.44T
#RUN *CCQUEUE PAR=ESCPLOT6
#EXECUTION BEGINS
   2 PLOTS; PLOTTING REQUIRES     94 SEC. AND     24 IN.;      $.36
 PEN WAS UP  43% OF THE TIME.
 OK?
 OK
 "K4L7:ESCPLOT6     " HAS BEEN PERMITTED "R PKEY=*CCQUEUE".
 PLOT ASSIGNED RECEIPT # 718843.
#EXECUTION TERMINATED
#    $.45,    $6.88T
```

(END OF NORMAL PROCEDURE.)

7/18/81


ESC PROBLEM =2
CANTILEVER BEAM UNDER CONCENTRATED LOADS.
UNDEFORMED SHAPE

2 7/18/81 MAX-DEF. = 1.03059570 2

ESC PROBLEM =2
CANTILEVER BEAM UNDER CONCENTRATED LOADS.
STATIC DEFOR. SUBCASE 1 LOAD 1

MSC/NASTRAN PROBLEM SET

Sample Problem 3

PLATE UNDER CONCENTRATED LOADS

I. Modeling

Use six QUAD4 elements to model the plate. This is the simplest element for data input, yet allows contour plotting (not yet available on QUAD8 elements).

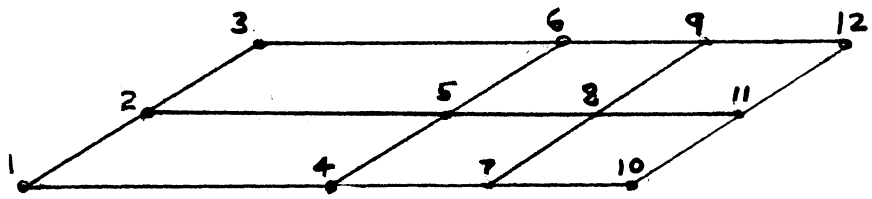



Fig. 1. F.E. mesh.

The plate element QUAD 4 (as well as QUAD8) does not contribute stiffness to nodal rotations about an axis normal to the plate (z direction). Hence the 6th degree of freedom at every node in this problem must be constrained.

The clamp at the wall constrains all degrees of freedom. The piano hinge constrains all degrees of freedom except rotation along its axis (5th d.o.f.).

To visualize deformations of a plate under lateral loads, it is best to take a 3/4 view, such as the default view angle in MSC/NASTRAN.

Your answer for deflections at the corners of the plate should be 10.76 mm (0.424 in).

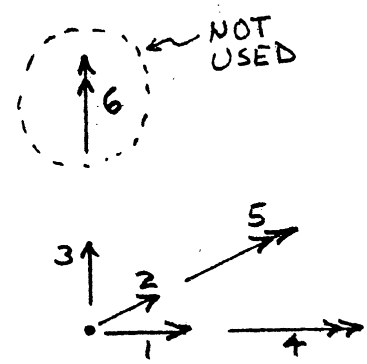



Fig. 2. Degrees of freedom.

```
#LIST ESCDATA12
>     10      ID ANDERSON,AERO510  $ JULY 22, 1981.  DATA IN K4L7:ESCDATA12.
>     11      TIME 1
>     12      SOL 24
>     13      DIAG 14
>     14      CEND
>    100      TITLE=ESC PROBLEM #3, FINER MESH (6 ELEMENTS).
>    101      SUBTITLE= PLATE UNDER CONCENTRATED LOADS.
>    102      ECHO=BOTH
>    104      DISPLACEMENT=ALL
>    105      STRESS=ALL
>    106      ELFORCE=ALL
>    107      SPCFORCES=ALL
>    111      SUBCASE 1
>    111.5    LOAD=1
>    140      OUTPUT(PLOT)
>    141      PLOTTER NASTRAN
>    142      SET 1 INCLUDE ALL
>    143      FIND SCALE ORIGIN 1
>    144      PLOT STATIC DEFORMATION 0 SET 1
>    153      AXES Z,X,Y
>    154      VIEW 0.,0.,0.
>    155      FIND SCALE ORIGIN 1
>    156      PLOT LABEL BOTH
>    158      PLOT SHRINK
>    159      CONTOUR ZDISP
>    160      PLOT CONTOUR SET 1 OUTLINE
>    190      BEGIN BULK
>    191      PARAM   AUTOSPC   YES
>    192      GRDSET                                                    6
>    201      GRID        1          0.0       0.0       0.0       123456
>    202      GRID        2          0.0     250.000     0.0       123456
>    203      GRID        3          0.0     500.000     0.0       123456
>    204      GRID        4        500.000     0.0       0.0        12346
>    205      GRID        5        500.000   250.000     0.0        12346
>    206      GRID        6        500.000   500.000     0.0        12346
>    207      GRID        7        750.000     0.0       0.0
>    208      GRID        8        750.000   250.000     0.0
>    209      GRID        9        750.000   500.000     0.0
>    210      GRID       10       1000.000     0.0       0.0
>    211      GRID       11       1000.000   250.000     0.0
>    212      GRID       12       1000.000   500.000     0.0
>    301      CQUAD4      1       1       1       4       5       2
>    302      CQUAD4      2       1       2       5       6       3
>    303      CQUAD4      3       1       4       7       8       5
>    304      CQUAD4      4       1       5       8       9       6
>    305      CQUAD4      5       1       7      10      11       8
>    306      CQUAD4      6       1       8      11      12       9
>    401      PSHELL -->  1       1 10.           1
>    501      MAT1        16.90E+04     0.30
>    710.1    FORCE       1      10       0    1.0      0.      0.   -1000.
>    712.1    FORCE       1      12       0    1.0      0.      0.    1000.
>   1000      ENDDATA
#END OF FILE
```

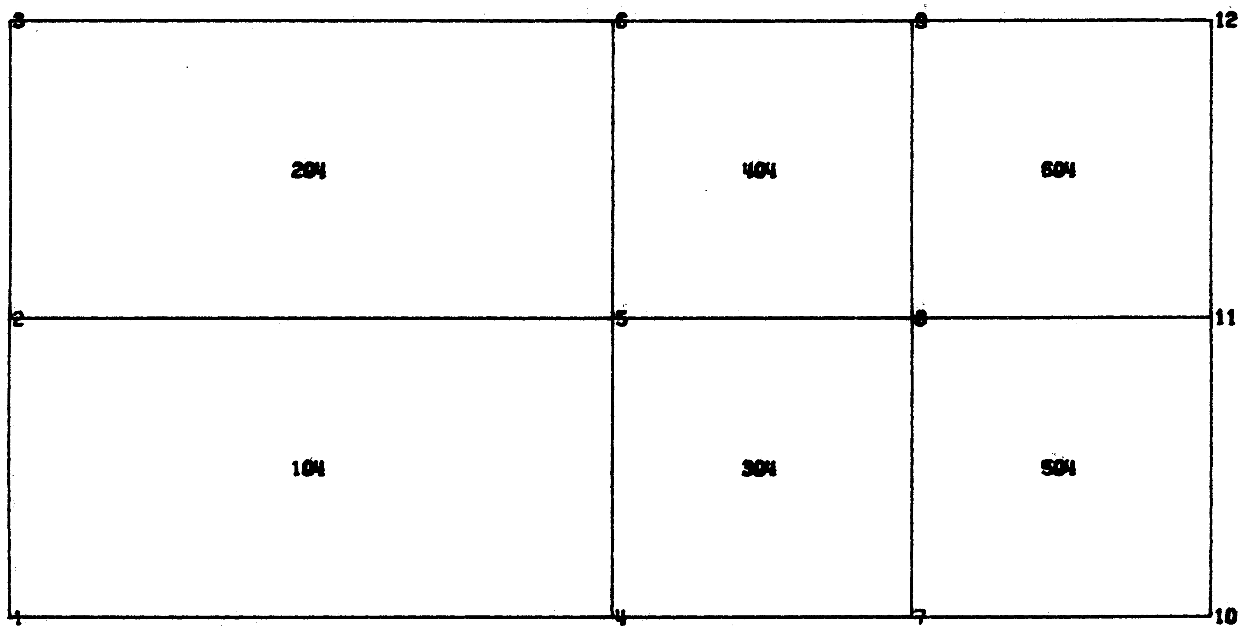
```
#RUN AERO:NASTRAN SCARDS=ESCDATA12 SPRINT=ESCRES12
#EXECUTION BEGINS
 EXECUTION BEGINS
#$CONTROL -##NO1 SIZE=1000P
#$CONTROL -##NO2 SIZE=1000P
#$CONTROL -##NO3 SIZE=1000P
#$CONTROL -##NO4 SIZE=1000P
 EXECUTION BEGINS
 NASTRAN LOADED AT LOCATION  700000
        CPU      ELAP       I/O  EXCP COUNTS   TRACKS
        SEC       SEC       SEC NASTRAN   TOTAL  USED
      0.0        0.0       0.0        0       0      0     SEM1   BEGN
      0.197      7.0       0.5       11       0     16     XSOR
      0.387     10.0       1.0       21       0     32     IFP
      0.550     12.0       2.0       41       0     52     XGPI
      1.285     17.0       3.1       63       0     60     9      GP1     BEGN
      1.390     19.0       3.9       78       0     76     11     GP2     BEGN
      1.457     20.0       4.1       83       0     76     15     PLTHBDY BEGN
      1.496     22.0       4.3       85       0     76     17     PLTSET  BEGN
      1.585     26.0       4.9       98       0     92     19     PRTMSG  BEGN
      1.620     27.0       5.0      100       0     92     22     PLOT    BEGN
      2.688     32.0       5.8      116       0     92     23     PRTMSG  BEGN
      2.763     33.0       5.9      118       0     92     26     GP3     BEGN
      2.853     35.0       6.5      130       0     92     28     TA1     BEGN
      3.092     40.0       7.5      151       0     92     31     EMG     BEGN
      3.277     42.0       8.0      160       0     92     37     EMA     BEGN
      3.760     47.0       9.0      180       0     92     97     GP4     BEGN
      3.863     49.0       9.7      194       0     96     99     GPSP1   BEGN
      3.956     51.0      10.1      203       0     96     110    SCE1    BEGN
      4.121     54.0      10.8      216       0    108     140    RBMG2   BEGN
      4.283     56.0      11.1      222       0    108     145    SSG1    BEGN
      4.432     60.0      11.8      235       0    108     148    SSG2    BEGN
      4.585     62.0      12.5      250       0    120     155    SSG3    BEGN
      4.780     65.0      13.2      264       0    120     160    SDR1    BEGN
      5.088     68.0      14.6      293       0    128     176    SDR2    BEGN
      5.370     72.0      15.8      316       0    128     185    OFP     BEGN
      5.453     74.0      15.9      319       0    128     186    SDRX    BEGN
      5.513     75.0      16.3      325       0    128     188    OFP     BEGN
      5.675     80.0      16.4      329       0    128     189    GPFDR   BEGN
      5.793     81.0      16.6      333       0    128     190    OFP     BEGN
      5.828     82.0      16.7      334       0    128     193    OFP     BEGN
      5.976     86.0      16.9      339       0    128     205    PLTSET  BEGN
      6.072     88.0      17.6      352       0    128     206    PRTMSG  BEGN
      6.096     89.0      17.7      354       0    128     207    PLOT    BEGN
      7.738     99.0      19.2      384       0    128     208    PRTMSG  BEGN
      7.812    100.0      19.3      386       0    128     214    EXIT    BEGN
 IH0002I STOP       1
 VSSCMD238W NSTN04    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN03    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN02    - OPEN DSDEF BEING CLOSED
 VSSCMD238W NSTN01    - OPEN DSDEF BEING CLOSED


 PDS: PLOT DESCRIPTION GENERATION BEGINS.
#EXECUTION TERMINATED
```

```
#CONTROL *PRINT* HOLD
#*PRINT* ASSIGNED RECEIPT NUMBER 601796
#L ESCDATA12 *PRINT*
#C ESCRES12 *PRINT*
#CONTROL *PRINT* RELEASE
#*PRINT* 601796 RELEASED TO CNTR, 22 PAGES.
#RENAME -PLOT ESCPLOT12
#DONE.
#RUN *CCQUEUE PAR=ESCPLOT12
#EXECUTION BEGINS
   4 PLOTS; PLOTTING REQUIRES   235 SEC. AND    47 IN.;      $.79
 PEN WAS UP  41% OF THE TIME.
 OK?
 OK
 "K4L7:ESCPLOT12    " HAS BEEN PERMITTED "R PKEY=*CCQUEUE".
 PLOT ASSIGNED RECEIPT # 723210.
#EXECUTION TERMINATED
```

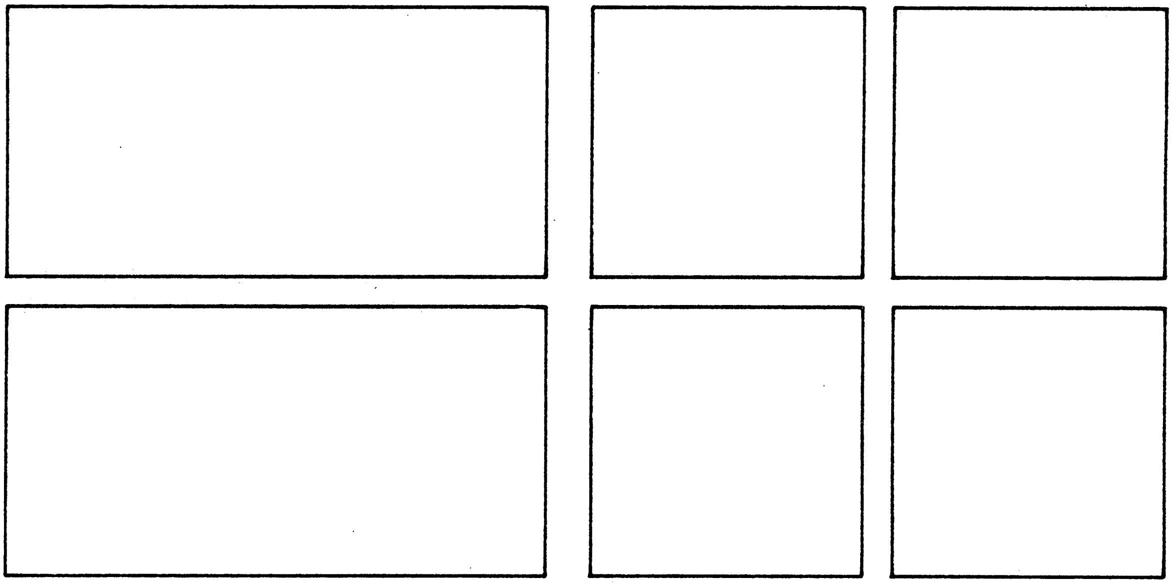
728914
728922
608163

1 7/23/81





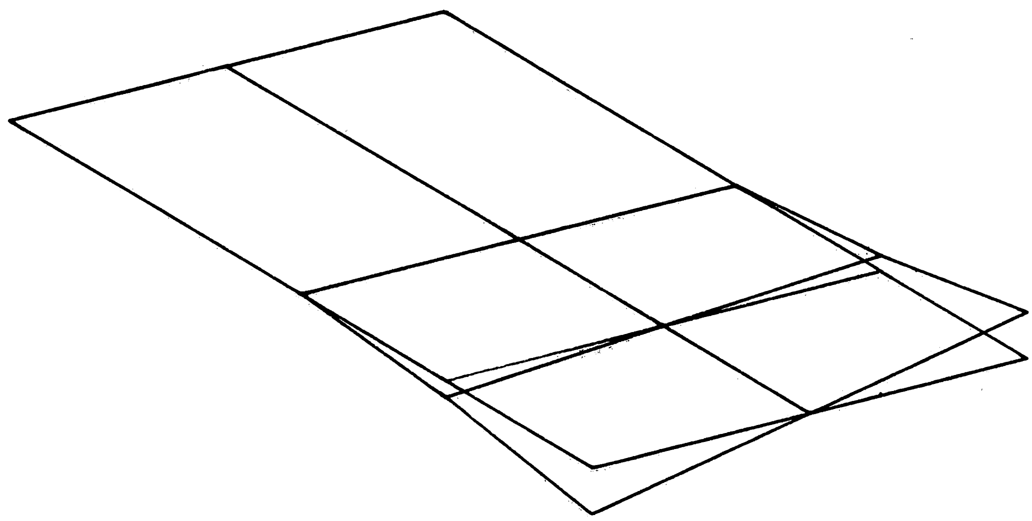

ESC PROBLEM -3. FINER MESH (6 ELEMENTS).
PLATE UNDER CONCENTRATED LOADS.
UNDEFORMED SHAPE



ESC PROBLEM -3, FINER MESH (6 ELEMENTS).
PLATE UNDER CONCENTRATED LOADS.

UNDEFORMED SHAPE

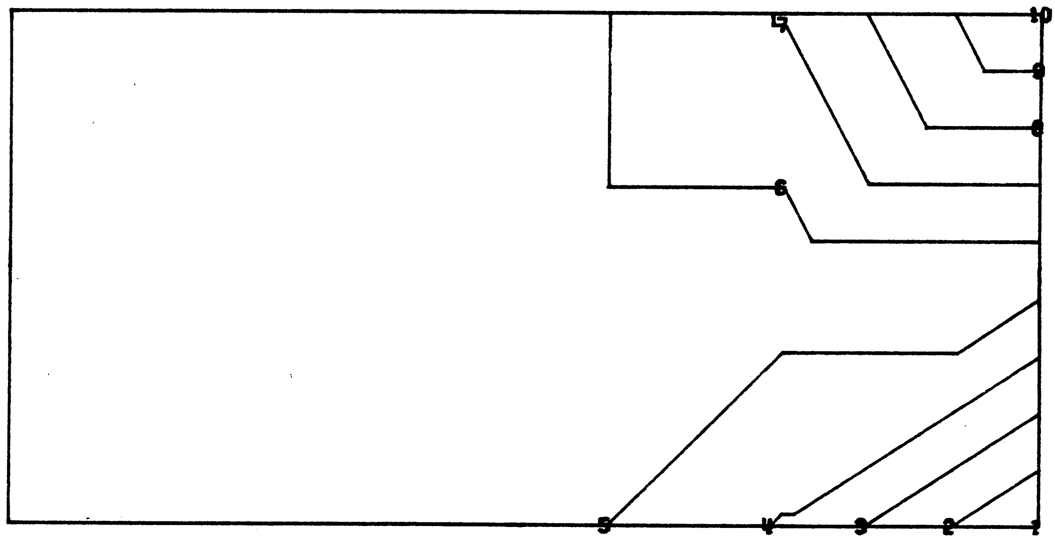
3 7/23/81 MAX-DEF. = 10.7619180 3



ESC PROBLEM -3. FINER MESH (8 ELEMENTS).
PLATE UNDER CONCENTRATED LOADS.
STATIC DEFOR. SUBCASE 1 LOAD 1

Receipt 723210, Plot 017 K4L7 22:06:37 07-23-81

4 7/23/81 MAX-DEF. = 10.7818180 4




ESC PROBLEM #3, FINER MESH (8 ELEMENTS).
PLATE UNDER CONCENTRATED LOADS.

STATIC DEFOR. SUBCASE 1 LOAD 1

# MSC/NASTRAN PROBLEM SET

## Sample Problem 4

## SPUR GEAR TOOTH

### I. Modeling

Use two HEXA solid elements with 20 nodes each as shown in Fig. 1. Align the element boundary at the pitch circle where the running load is applied. This means the equivalent nodal loads for case (A) will be applied to nodes 15, 16, 17 with values of 1000, 4000 and 1000N respectively. (These are the values consistent with a quadratic interpolating function. See Zienkiewicz, Ed. 3, pp. 222-235). For case B, the full 6000N (1, 349 lb.) acts on node 15. This will be our first example with multiple load cases.

The nodal coordinates, as determined from Fig. 2. of the problem statement, are:

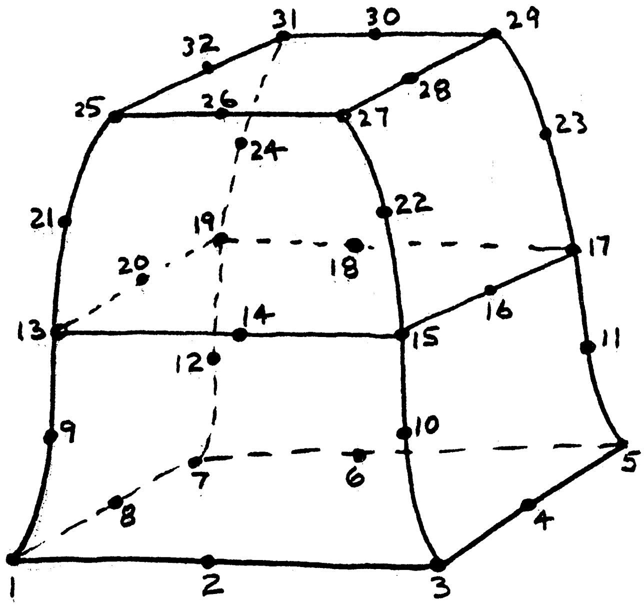



Fig. 1. Two-element model of spur gear tooth using HEXA elements.

| | | | |
|---|---|---|---|
| 1 | 86.500 | 12.700 | 5.000 |
| 2 | 86.500 | 0.0 | 5.000 |
| 3 | 86.500 | -12.700 | 5.000 |
| 4 | 86.500 | -12.700 | 0.0 |
| 5 | 86.500 | -12.700 | -5.000 |
| 6 | 86.500 | 0.0 | -5.000 |
| 7 | 86.500 | 12.700 | -5.000 |
| 8 | 86.500 | 12.700 | 0.0 |
| 9 | 93.000 | 8.700 | 5.000 |
| 10 | 93.000 | -8.700 | 5.000 |
| 11 | 93.000 | -8.700 | -5.000 |
| 12 | 93.000 | 8.700 | -5.000 |
| 13 | 99.600 | 7.800 | 5.000 |
| 14 | 100.000 | 0.0 | 5.000 |
| 15 | 99.600 | -7.800 | 5.000 |
| 16 | 99.600 | -7.800 | 0.0 |
| 17 | 99.600 | -7.800 | -5.000 |
| 18 | 100.000 | 0.0 | -5.000 |

| | | | |
|---|---|---|---|
| 19 | 99.600 | 7.800 | -5.000 |
| 20 | 99.600 | 7.800 | 0.0 |
| 21 | 105.000 | 5.700 | 5.000 |
| 22 | 105.000 | -5.700 | 5.000 |
| 23 | 105.000 | -5.700 | -5.000 |
| 24 | 105.000 | 5.700 | -5.000 |
| 25 | 110.000 | 3.500 | 5.000 |
| 26 | 110.000 | 0.0 | 5.000 |
| 27 | 110.000 | -3.500 | 5.000 |
| 28 | 110.000 | -3.500 | 0.0 |
| 29 | 110.000 | -3.500 | -5.000 |
| 30 | 110.000 | 0.0 | -5.000 |
| 31 | 110.000 | 3.500 | -5.000 |
| 32 | 110.000 | 3.500 | 0.0 |

The HEXA element connectivities, as seen from page 2.4-20? in the User's Manual, are

Element 1: 3, 5, 7, 1, (bottom, corners) 15, 17, 19, 13, (far side, corners) 4, 6, 8, 2, (bottom, midside) 10, 11, 12, 9, (middle, midside) 16, 18, 20, 14 (far side, midside)

Element 2: 15, 17, 19, 13, 27, 29. 31, 25, 16, 18, 20, 14, 22, 23, 24, 21, 28, 30, 32, 26

Plots of the gear tooth are best obtained by using:

AXES Z, X, Y
VIEW -20., -30., 80.

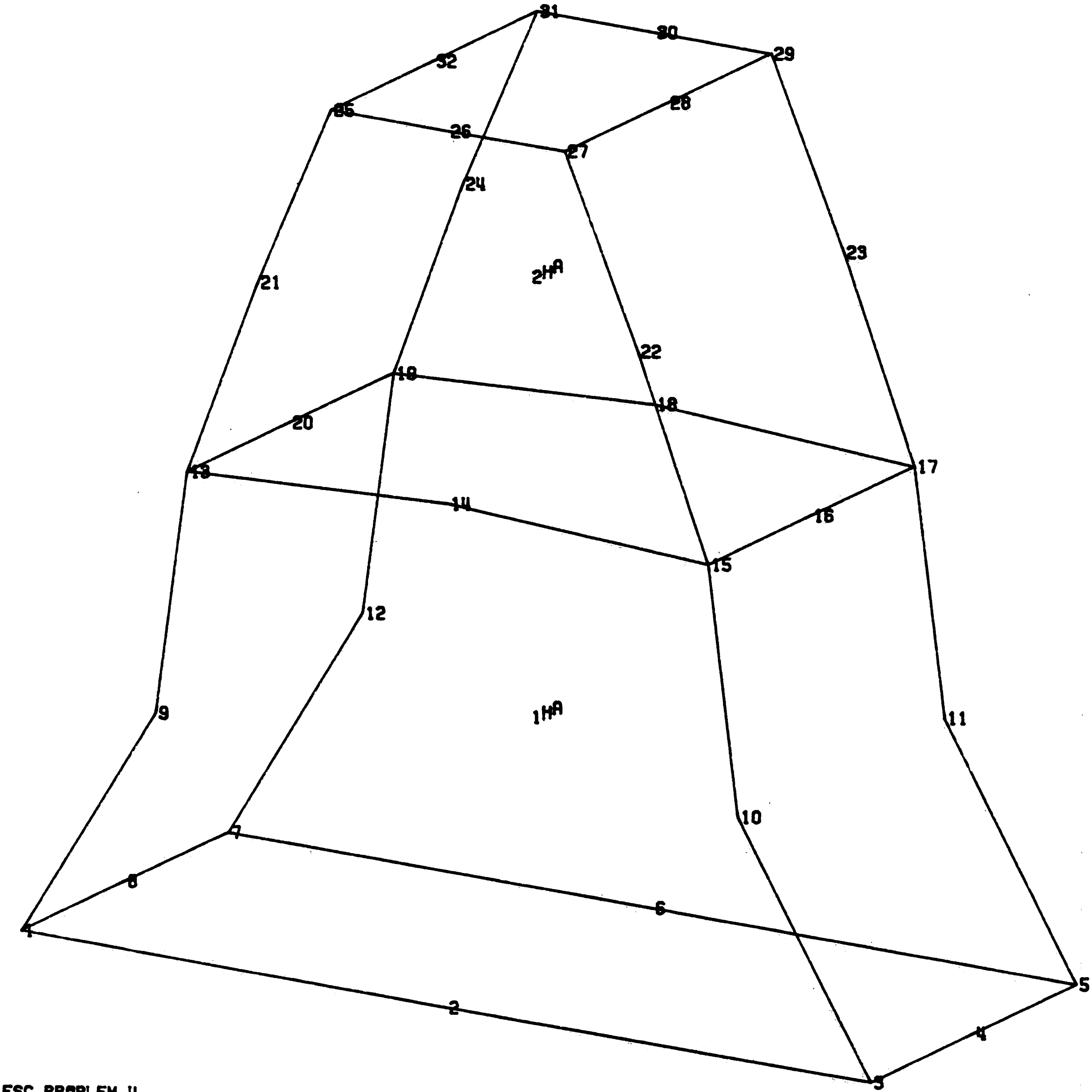
This shows the tooth in the upright configuration as in the problem statement.

```
#LIST ESCDATA10
>    10      ID ANDERSON,AERO510   $ JULY 19, 1981.   DATA IN K4L7:ESCDATA10.
>    11      TIME 1
>    12      SOL 24
>    13      DIAG 14
>    14      CEND
>   100      TITLE=ESC PROBLEM 4.
>   101      SUBTITLE= SOLID. GEAR TOOTH UNDER LINE AND CONCENTRATED LOADS.
>   102      ECHO=BOTH
>   104      DISPLACEMENT=ALL
>   105      STRESS=ALL
>   106      ELFORCE=ALL
>   107      SPCFORCES=ALL
>   111      SUBCASE 1
>   111.5    LOAD=1
>   112      SUBCASE 2
>   112.5    LOAD=2
>   150      OUTPUT(PLOT)
>   151      PLOTTER NASTRAN
>   152      SET 1 INCLUDE ALL
>   153      AXES Z,X,Y
>   154      VIEW -20.,-30.,80.
>   155      FIND
>   156      PLOT LABEL BOTH
>   157      PLOT STATIC DEFORMATION 0 SET 1
>   190      BEGIN BULK
>   191      PARAM   AUTOSPC   YES
>   192      GRDSET                                                    456
>   201      GRID          1          86.500  12.700   5.000         123456
>   202      GRID          2          86.500   0.0     5.000         123456
>   203      GRID          3          86.500 -12.700   5.000         123456
>   204      GRID          4          86.500 -12.700   0.0           123456
>   205      GRID          5          86.500 -12.700  -5.000         123456
>   206      GRID          6          86.500   0.0    -5.000         123456
>   207      GRID          7          86.500  12.700  -5.000         123456
>   208      GRID          8          86.500  12.700   0.0           123456
>   209      GRID          9          93.000   8.700   5.000
>   210      GRID         10          93.000  -8.700   5.000
>   211      GRID         11          93.000  -8.700  -5.000
>   212      GRID         12          93.000   8.700  -5.000
>   213      GRID         13          99.600   7.800   5.000
>   214      GRID         14         100.000   0.0     5.000
>   215      GRID         15          99.600  -7.800   5.000
```

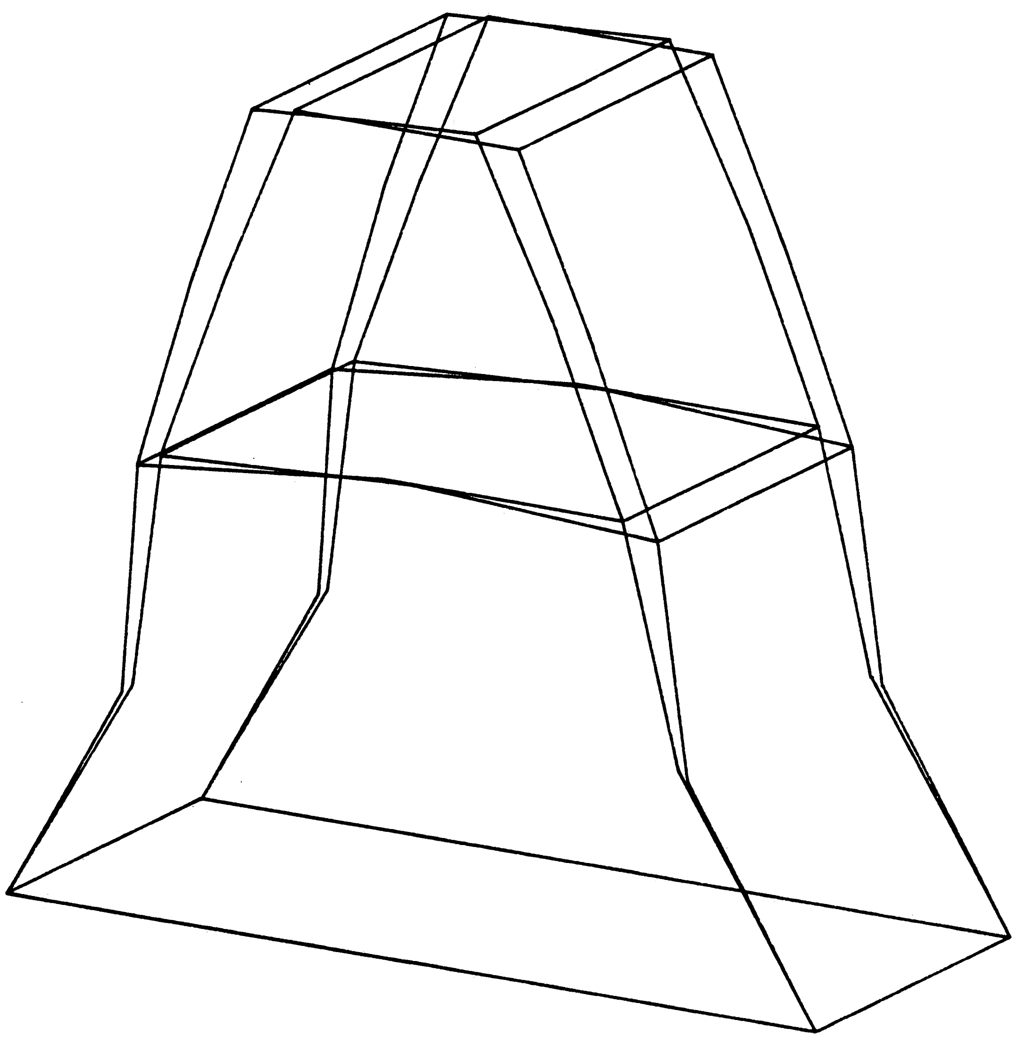
```
>    216     GRID         16              99.600  -7.800   0.0
>    217     GRID         17              99.600  -7.800  -5.000
>    218     GRID         18             100.000   0.0    -5.000
>    219     GRID         19              99.600   7.800  -5.000
>    220     GRID         20              99.600   7.800   0.0
>    221     GRID         21             105.000   5.700   5.000
>    222     GRID         22             105.000  -5.700   5.000
>    223     GRID         23             105.000  -5.700  -5.000
>    224     GRID         24             105.000   5.700  -5.000
>    225     GRID         25             110.000   3.500   5.000
>    226     GRID         26             110.000   0.0     5.000
>    227     GRID         27             110.000  -3.500   5.000
>    228     GRID         28             110.000  -3.500   0.0
>    229     GRID         29             110.000  -3.500  -5.000
>    230     GRID         30             110.000   0.0    -5.000
>    231     GRID         31             110.000   3.500  -5.000
>    232     GRID         32             110.000   3.500   0.0
>    301     CHEXA        ①       1       3       5       7       1       15      17+A1001
>    301.1   +A1001       19      13      4       6       8       2       10      11+B1001
>    301.2   +B1001       12      9       16      18      20      14
>    302     CHEXA        ②       1       15      17      19      13      27      29+A1002
>    302.1   +A1002       31      25      16      18      20      14      22      23+B1002
>    302.2   +B1002       24      21      28      30      32      26
>    401     PSOLID       1       1
>    501     MAT1          12.07E+05       0.30
>    715.1   FORCE        1       15      0    1.0        0.      1000.    0.
>    715.2   FORCE        2       15      0    1.0        0.      6000.    0.
>    716.1   FORCE        1       16      0    1.0        0.      4000.    0.
>    717.1   FORCE        1       17      0    1.0        0.      1000.    0.
>   1000     ENDDATA
#END OF FILE
```

```
#RUN AERO:NASTRAN SCARDS=ESCDATA10 SPRINT=ESCRES10
#EXECUTION BEGINS
 EXECUTION BEGINS
#$CONTROL -##NO1 SIZE=1000P
#$CONTROL -##NO2 SIZE=1000P
#$CONTROL -##NO3 SIZE=1000P
#$CONTROL -##NO4 SIZE=1000P
 EXECUTION BEGINS
 NASTRAN LOADED AT LOCATION  700000
       CPU     ELAP      I/O  EXCP COUNTS  TRACKS
       SEC      SEC      SEC NASTRAN  TOTAL  USED
     0.0       0.0      0.0       0      0      0   SEM1   BEGN
     0.180     7.0      0.5      11      0     16   XSOR
     0.436     9.0      1.1      23      0     32   IFP
     0.647    14.0      2.2      44      0     52   XGPI
     1.562    22.0      3.3      66      0     60   9      GP1     BEGN
     1.695    24.0      4.0      81      0     76   11     GP2     BEGN
     1.776    25.0      4.3      86      0     76   15     PLTHBDY BEGN
     1.822    27.0      4.4      88      0     76   17     PLTSET  BEGN
     1.931    31.0      5.0     101      0     92   19     PRTMSG  BEGN
     1.972    32.0      5.1     103      0     92   22     PLOT    BEGN
     2.867    37.0      5.7     114      0     92   23     PRTMSG  BEGN
     2.921    38.0      5.8     116      0     92   26     GP3     BEGN
     3.036    41.0      6.4     128      0     92   28     TA1     BEGN
     3.330    47.0      7.4     149      0     92   31     EMG     BEGN
     4.013    52.0      8.0     161      0     92   37     EMA     BEGN
     4.751    61.0      9.8     195      0     96   97     GP4     BEGN
     4.891    63.0     10.4     209      0    100   99     GPSP1   BEGN
     5.105    65.0     11.4     229      0    100   110    SCE1    BEGN
     5.505    70.0     13.0     260      0    112   140    RBMG2   BEGN
     5.861    75.0     14.0     280      0    112   145    SSG1    BEGN
     6.050    78.0     14.6     293      0    112   148    SSG2    BEGN
     6.243    82.0     15.4     308      0    124   155    SSG3    BEGN
     6.578    87.0     16.6     333      0    124   160    SDR1    BEGN
     6.990    93.0     18.1     363      0    132   176    SDR2    BEGN
     7.651   105.0     20.1     403      0    132   185    OFP     BEGN
     7.790   108.0     20.3     406      0    132   186    SDRX    BEGN
     7.871   109.0     20.6     412      0    132   188    OFP     BEGN
     8.125   115.0     20.8     416      0    132   189    GPFDR   BEGN
     8.265   117.0     21.0     420      0    132   190    OFP     BEGN
     8.310   118.0     21.0     421      0    132   193    OFP     BEGN
     8.485   123.0     21.3     426      0    132   205    PLTSET  BEGN
     8.610   124.0     21.9     439      0    132   206    PRTMSG  BEGN
```

```
   8.638    125.0    22.0     441      0   132    207   PLOT     BEGN
  10.760    137.0    23.0     460      0   132    208   PRTMSG   BEGN
  10.801    137.0    23.1     462      0   132    214   EXIT     BEGN
IH0002I STOP       1
VSSCMD238W NSTN04    - OPEN DSDEF BEING CLOSED
VSSCMD238W NSTN03    - OPEN DSDEF BEING CLOSED
VSSCMD238W NSTN02    - OPEN DSDEF BEING CLOSED
VSSCMD238W NSTN01    - OPEN DSDEF BEING CLOSED


PDS: PLOT DESCRIPTION GENERATION BEGINS.
#EXECUTION TERMINATED
#LIST ESCDATA10 *PRINT*
#COPY ESCRES10 *PRINT*
#RUN *CCQUEUE PAR=ESCPLOT10
#EXECUTION BEGINS
  3 PLOTS; PLOTTING REQUIRES   177 SEC. AND    36 IN.;     $.60
PEN WAS UP  40% OF THE TIME.
OK?
OK
"K4L7:ESCPLOT10   " HAS BEEN PERMITTED "R PKEY=*CCQUEUE".
PLOT ASSIGNED RECEIPT # 707479.
#EXECUTION TERMINATED
```



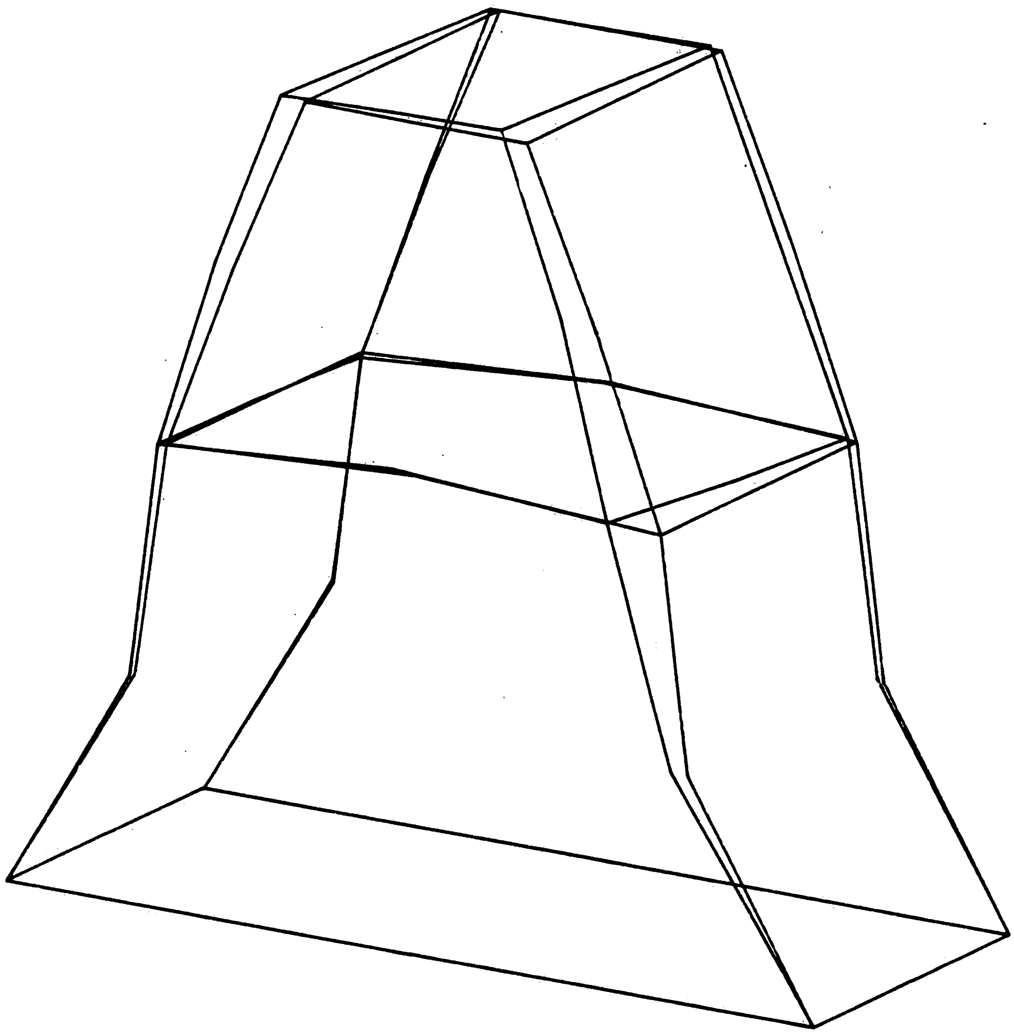

ESC PROBLEM 4.
SOLID. GEAR TOOTH UNDER LINE AND CONCENTRATED LOADS.
UNDEFORMED SHAPE



ESC PROBLEM 4.
SOLID. GEAR TOOTH UNDER LINE AND CONCENTRATED LOADS.
STATIC DEFOR. SUBCASE 1 LOAD 1

Receipt 707479, Plot 007 K4L7 11:11:51 07-23-81

3 7/23/81 MAX-DEF. = 0.02652046



ESC PROBLEM 4.

SOLID. GEAR TOOTH UNDER LINE AND CONCENTRATED LOADS.

STATIC DEFOR. SUBCASE 2 LOAD 2

Helen Buus
William J. Anderson
Edward Chmiel
February 22, 1982

# PRENASTRAN - A PREPROCESSOR FOR PREPARING MSC/NASTRAN DATA

## INTRODUCTION

The AERO:PRENASTRAN program allows the user to create a complete NASTRAN data file interactively which is suitable for input to AERO:NASTRAN or which can be punched on cards for execution on a system other than MTS. Such a data file can be generated for one of four types of problems:

1) Plane Stress (using CQDMEM or CQUAD8 elements)
2) Beam (using CBAR elements)
3) Plate (using CQUAD4 elements)
4) Solid (using CHEXA elements)

The program can be run three ways:

1) Create — to generate new NASTRAN file
2) Restart — in case of interruption during Create mode, this capability allows the user to continue generating the file at the point of interruption
3) Edit — to make minor modifications to an existing complete NASTRAN file.

While running the program, read all messages and prompts carefully before entering any information. The program accepts free format input of numerical data; simply separate items with commas or semicolons. Certain steps of file generation will continue until the user gives an "end-of-file" command. This can be done by "$ENDFILE."

The first time the program is run, a file named "DATA" will be created for the user and NASTRAN data will be put into it. If a new NASTRAN file is to be created later and this file still exists, the user can request to:

1) Enter a new file name to be created;
2) Empty the existing file and use it;
3) Use the Restart or Edit options on the existing file.

The program will prompt the user for information as required during file generation. There are eight steps in generating a file:

1) Executive Control Deck — problem identification
2) Case Control Deck — title, subtitle, and number of subcases
3) Grid Point Definitions — grid point id's and coordinates
4) Grid Point Constraints — grid point id's and constraint codes
5) Element Definitions — element id's, property id's and grid point connectivities
6) Property Definitions — material id's and thicknesses or section properties, if required
7) Material Definitions — Young's Modulus and Poisson's Ratio
8) Load Definitions — grid point id's and Cartesian components of forces.

This manual is divided into sections corresponding to each step of file generation. Each section describes what the program does and what information the user is expected to provide.

## EXECUTIVE CONTROL DECK

The user need only provide two 8-character names, typically last name and problem name, separated by a comma. Example:

```
Executive Control Deck
Enter Problem Identification (2.2-1):
ID? ANDERSON,STRESSES (carriage return)
```

Note the reference to the NASTRAN User's Manual, 2.2-1. This is the page number where information about the ID card can be found. The program provides this information throughout to direct the user to the appropriate page in the manual, should a question ever arise on a given type of NASTRAN card.

## CASE CONTROL DECK

Specify the problem type. Example:

```
Enter problem type (1=Plane Stress, 2=Beam, 3=Plate, 4=Solid):
? 1
```

For the plane stress cases only, the user must then choose between two elements, i.e., CQDMEM or CQUAD8. Example:

```
Choose element type for Plane Stress:
   1 - CQDMEM (for stress contour plots)
   2 - CQUAD8 (for better accuracy with fewer elements)
? 1
```

Once the problem type has been determined, the program sets up the appropriate output and plot requests automatically. The user must now provide a title and subtitle and specify how many different loading conditions are to be applied to the structure. Examole:

```
Case Control Deck
Enter Title (2.3-137):
TITLE=? PLATE ON PIANO HINGE SUPPORT
Enter Subtitle (2.3-117):
SUBTITLE=? FEB 4, 1982
From one to nine subcases may be requested to allow
application of different sets of loads to the model.
For each subcase, the user will be prompted for a
set of loads in Step 8 of file generation. Enter
desired number of subcases (2.3-55 and 2.3-111):
? 1
```

## GRID POINT DEFINITIONS

Grid points are used to define finite elements. Each grid point is identified by an integer number from 1 (one) to a user defined maximum which must be less than or equal to 99. No gaps in numbering are permitted, although grid points may be entered in any order. These points are defined by their X, Y and Z coordinates. If the problem type is plane stress, the user need only define X and Y coordinates. Example:

```
GRID Grid Point Definitions (2.4-205)
Define each grid point by entering its id number and
coordinates. Repeat process for each grid point. If
an error was made in defining a grid point, the same
id and correct coordinates may be re-entered, thereby
replacing the old information in the data file. When
all grid points have been defined, enter $ENDFILE or
CTRL-C to stop. The program will then check if all
grid points numbered from one to the user defined
maximum have been defined. Enter maximum grid id:
? 6
Maximum grid id = 6, please confirm (Y or N):
? Y
For each grid point, enter ID,X,Y,Z:
? 1,0,0,0
? 2,0,10,0
? 3,-8,0,0
? 4,-8,10,0
? 5,-16,0,0
? 6,-16,0,0
? $ENDFILE
```

## GRID POINT CONSTRAINTS

Grid point constraints are used to specify boundary conditions for a problem. They tell NASTRAN which degrees of freedom (d.o.f.) are to be constrained or fixed for each grid point. Any of the digits 1 through 6 may be specified corresponding to the degrees of freedom one wishes to constrain. The digits correspond to the degrees of freedom as follows:

1) Constrain translation in the X direction
2) Constrain translation in the Y direction
3) Constrain translation in the Z direction
4) Constrain rotation about the X axis
5) Constrain rotation about the Y axis
6) Constrain rotation about the Z axis.

Example:

```
Define the constraints for a grid point (GRID 2,3-205):
Enter grid number, constraints (any digits 1-6, no blanks).
Enter $ENDFILE or CRTL-C to stop.
? 3,12346
? 4,12346
? 5,123456
? 6,123456
? $ENDFILE
```

ELEMENT DEFINITIONS

Finite elements are defined by connecting them to previously defined grid points. Each element is identified by an integer number from 1 (one) to a user defined maximum ($\leq$ 99) as was the case with grid points. An element is defined by specifying the grid points to which it is connected in a well defined order, i.e. element connectivity. The user should read the appropriate page in the NASTRAN User's Manual for the element being used:

| | | |
|---|---|---|
| CQDMEM | - | 2.4-103 |
| CQUAD8 | - | 2.4-112c |
| CBAR | - | 2.4-39 |
| CQUAD4 | - | 2.4-112a |
| CHEXA | - | 2.4-69 |

The program expects the user to provide it with an element identification number or EID, for each element, followed by the grid point id's to which it is connected. If the user has specified problem type 4, he/she may choose to specify only the eight corner grid points of the solid CHEXA element or all twenty grid points for better accuracy. For all problem types, the user may choose to use the same property id (and orientation vector for CBAR elements) for all elements or he/she may choose to specify different property id's for each element. The property id's identified at this point in the program will be used later to define the appropriate property cards. Example:

```
CQUAD4  Element Definitions (2.4-112a)
Define each element by entering its id number and grid id's
specifying the element's connectivity. If an error was made
in defining an element, the same id and correct connectivity
may be re-entered, thereby replacing the old information in
the data file. When all elements have been defined, enter
$ENDFILE or CTRL-C to stop. The program will then check if
all elements numbered from one to the user defined maximum
have been defined. Enter maximum element id:
? 2
Maximum element id = 2, please confirm (Y or N):
? Y
For each element, enter EID,GID1,GID2,GID3,GID4 with grid
id's in counter-clockwise order:
NOTE — Following definition of the first element, there
       will be a prompt for property id number and an
       option will be given to either use the same prop-
       erty id for all elements or to enter a new id
       for each element
Enter element data:
? 1,1,3,4,2
Enter property id:
? 1
Is given property id to be used for all elements (Y or N)?
? Y
Enter element data:
? 2,3,4,6,4
? $ENDFILE
```

## PROPERTY DEFINITIONS

Property cards are used to define thicknesses of membrane and shell elements such as CQDMEM, CQUAD8 and CQUAD4 elements, or to define section properties of CBAR elements. All property cards require material id's for use on material cards defined later. The program keeps track of property id's specified while defining elements and prompts the user for the data required to prepare each property card. This data depend on the problem type:

```
1 — PQDMEM (2.4-307) or PSHELL (2.4-326a)
    Material id and thickness
2 — PBAR (2.4-273)
    Material id, cross section area, principle moments
    of inertia, I1 and I2, and dimensions of section
    (Dimensions are used to calculate stress points in
    the section.)
3 — PSHELL (2.4-326a)
    Material id and thickness
4 — PSOLID (2.4-326c)
    Material id.
```

All material id's must be in the range 1 to 99. An example for problem type 3 is given below:

```
PSHELL  Property Definitions (2.4-326a)
Enter material id and thickness for property id 1:
? 1,0.25
```

If the program is in Edit mode, the user will first be prompted for problem type. He/she may then enter the property id to be added or modified by the program. Property cards may be deleted by entering the negative of the unwanted property id. If a positive number is entered, the user will be prompted for the necessary property data described above.

## MATERIAL DEFINITIONS

Material cards are used to specify the Young's modulus and Poisson's ratio associated with the material in the finite element, e.g., steel, aluminum. The program keeps track of material id's specified during property definitions and prompts the user for Young's modulus and Poisson's ratio. Example:

```
MAT1 Material Definitions (2.4-215)
Enter Young's Modulus, Poisson's Ratio for material 1:
? 10.E6,0.3
```

In Edit mode, the user must first specify the material id to be added or modified. Or the nega-ive of an id may be entered to delete an unwanted card.

## FORCE DEFINITIONS

The last step in defining a NASTRAN data file is giving the forces on the structure. For each subcase requested in the Case Control Deck, the user must define a set of loads. Each load is defined by specifying the grid point to be loaded and the X,Y,Z components of the force to be applied at the point. Example:

```
FORCE Load Definitions (2.4-179)
   1 Load subcase(s) have been requested
Define loads for subcase 1
For each load, enter grid id defining point at which load
is to be applied, followed by X,Y,Z components of force,
i.e., GID,FX,FY,FZ.  To delete a load, enter -GID,0,0,0.
Enter $ENDFILE or CRTL-C to stop for given subcase:
? 1,0,0,100
? 2,0,0,100
? $ENDFILE
```

MSC / NASTRAN

USER'S MANUAL

FEB, 1981

VERSION 61

# PREFACE

MSC/NASTRAN is a large scale, general purpose digital computer program which solves a wide variety of engineering problems by the finite element method. MSC/NASTRAN, a version of the NASTRAN general purpose structural analysis program, has been developed and is maintained by The MacNeal-Schwendler Corporation (MSC). NASTRAN is a registered trademark of the National Aeronautics and Space Administration (NASA).

MSC/NASTRAN is marketed and serviced from MSC's offices in Los Angeles, Munich, and Tokyo, and is available at most major public data centers. The program is operational on most major computing systems, including IBM 360/370 series, IBM 3000 series, IBM 4300 series, Amdahl, Itel, Fujitsu M series, CDC 7600, CDC CYBER series, Univac 1100 series, Digital's VAX 11/780, and the CRAY.

The User's Manual is restricted to those items relating to the use of MSC/NASTRAN that are independent of the computing system being used. Computer-dependent matters such as operating system control cards are treated in Section 7 of the MSC/NASTRAN Application Manual. The Application Manual is updated monthly and also contains Newsletters, the Current Error List, Documentation for the rigid format alter library, and other current information which supplements the MSC/NASTRAN User's Manual.

In addition to the MSC/NASTRAN User's Manual, the following manuals are available for use with MSC/NASTRAN:

1. MSC/NASTRAN Primer: Static and Normal Modes Analysis
2. NASTRAN Theoretical Manual
3. MSC/NASTRAN Handbook for Linear Static Analysis
4. MSC/NASTRAN Application Manual
5. MSGMESH Analyst's Guide
6. MSC/NASTRAN Aeroelastic Supplement
7. MSC/NASTRAN Demonstration Problem Manual
8. MSC/NASTRAN Programmer's Manual

The MSC/NASTRAN Primer serves as a text on the basic concepts of finite element analysis and as an introduction to the use of MSC/NASTRAN for static analysis and real eigenvalue analysis. The Theoretical Manual not only presents the analytical and numerical procedures that underlie the program, but it also describes the structure and problem-solving capabilities of NASTRAN in a narrative style.

The NASTRAN Theoretical Manual presents the analytical and numerical procedures used in the program and also describes the structure of the problem solving capabilities of NASTRAN in a narrative style.

The MSC/NASTRAN Handbook for Linear Static Analysis is an introductory manual for beginning users of MSC/NASTRAN and is also a specialty manual for the most frequently used aspects of linear static analysis. Approximately two-thirds of the Handbook is devoted to detailed descriptions and classifications of input data cards with emphasis on ease of data retrieval. The remaining one-third of the Handbook is an original, easily read textual description of the capabilities of MSC/NASTRAN for linear static analysis and of the general procedures to be followed in preparing input data.

The MSC/NASTRAN Application Manual contains specific information relative to the following topics:

1. Estimation of resources required to execute a problem.
2. Procedures for problem execution on the analyst's computer.
3. Articles on special techniques and methods of analysis.
4. Articles on MSC/NASTRAN features. For example, there are several articles on the elements that are recommended for general use. These discussions, which include hints on modeling procedures and examples of specific applications, expand on the information available in the User's Manual.
5. The contents of the RFALTER library are described. This library, which is delivered with each new version of MSC/NASTRAN, contains DMAP Alters for the various solution sequences. These alters provide additional capability, improved efficiency and/or otherwise unavailable user convenience.
6. MSC/NASTRAN Application Notes and monthly Newsletters.

The MSC/NASTRAN Application Manual is updated monthly with Newsletters, Application Notes, articles, and additions to the other MSC/NASTRAN Manuals.

The MSGMESH Analyst's Guide describes the automatic data generation capabilities of MSC/NASTRAN. The MSC/NASTRAN Aeroelastic Supplement describes the theoretical aspects and the numerical techniques used to perform an aeroelastic analysis with MSC/NASTRAN. The MSC/NASTRAN Demonstration Problem Manual contains a group of small problems that illustrate the various analysis methods available in MSC/NASTRAN. The data decks for these demonstration problems are delivered as a separate file with each new release of the program. The MSC/NASTRAN Programmer's Manual contains a description of the program code, including the mathematical equations which are implemented in the functional modules.

The MSC/NASTRAN Aeroelastic Supplement describes the theoretical aspects and the numerical techniques used to perform an aeroelastic analysis with MSC/NASTRAN. The Supplement is not intended to be a self-contained text since it relies extensively upon information relative to the dynamic analysis of a finite element model that is provided in the MSC/NASTRAN User's Manual and the NASTRAN Theoretical Manual.

The MSC/NASTRAN Demonstration Problem Manual is a useful reference in the preparation of the NASTRAN Data Deck. This manual is a suite of relatively small problems that illustrate the various analysis methods available in MSC/NASTRAN. The data decks for these demonstration problems are delivered as a separate file with each new release of the program.

The MSC/NASTRAN Programmer's Manual contains a description of the program code including the mathematical equations that are implemented in the functional modules. It also contains information relative to the maintenance and modification of the program.

MSC/NASTRAN uses a finite element structural model, wherein the distributed physical properties of a structure are represented by a finite number of structure elements which are interconnected at a finite number of grid points to which loads are applied and for which displacements are calculated. Procedures for defining and loading a structural model are described in Section 1. The modeling procedures for heat transfer analysis, hydroelastic analysis, and acoustic cavity analysis are also described in Section 1.

The Data Deck, including the details for each of the data cards is described in Section 2. This section also discusses the control cards that are associated with the use of the program.

Section 3 contains a general description of solution procedures provided in the program, along with specific instructions for the use of each type of solution sequence. Each of the solution sequences is associated with the solution of problems for a particular type of static analysis, dynamic analysis, or heat transfer analysis.

The procedures for using the plotting capability are described in Section 4. Both deformed and undeformed plots in the structural model, as well as contour plots of output quantities, are available. Response curves are also available for transient response and frequency response analyses.

In addition to the solution sequences provided by the program, the user may choose to write his own direct matrix abstraction program (DMAP). This procedure permits the user to execute a series of matrix operations of his choice, along with any utility models or executive operations that he may need. The rules governing the creation of DMAP programs are described in Section 5.

The diagnostic messages are documented and explained in Section 6.

MSC/NASTRAN is intended for use by professional engineers to assist them in the solution of engineering problems. It is expected that MSC/NASTRAN will be used in combination with other analytical and experimental procedures in the practice of engineering analysis and design. A new edition of the MSC/NASTRAN User's Manual is printed for each new version of MSC/NASTRAN. New versions will include corrections to some of the errors on previous error lists. Others will be further noted on the Current Error List or moved to the General Limitations List, both of which are located in Section 6 of the MSC/NASTRAN Application Manual.

A great many people have been associated with the development of MSC/NASTRAN and all have had some influence on the preparation of the MSC/NASTRAN User's Manual. Much of the material for the original edition of this manual was taken from the NASTRAN User's Manual published by the National Aeronautics and Space Administration as NASA SP-222(01). Most of the members of both the programming staff and the engineering staff have made some direct contribution to the User's Manual. Particular recognition is due Mr. Steven E. Wall who rewrote Section 5 on Direct Matrix Abstraction Programs.

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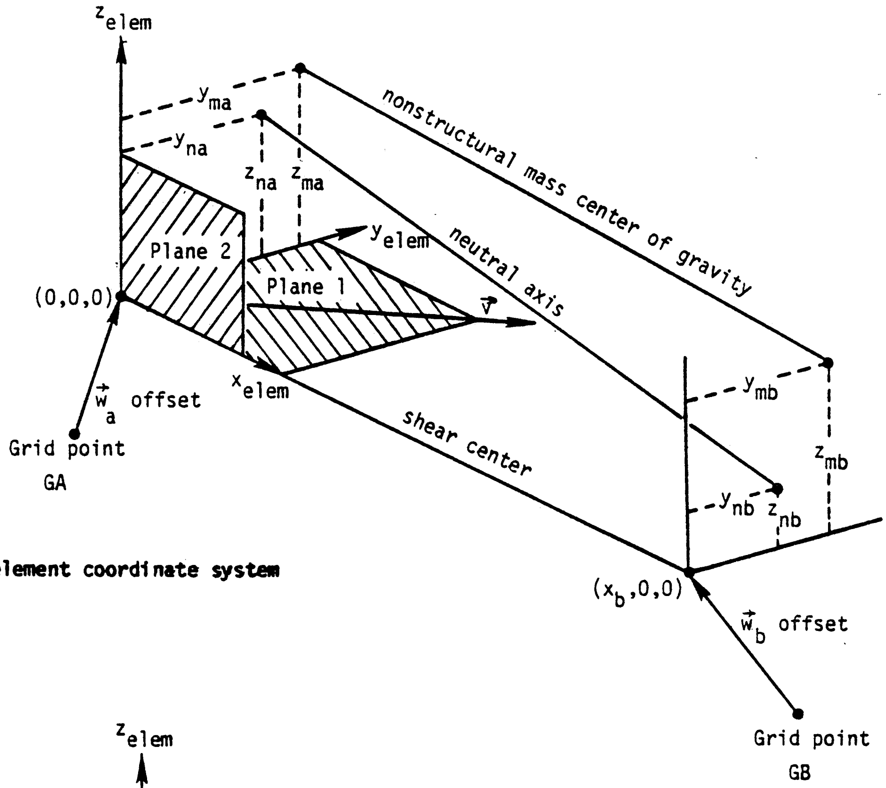
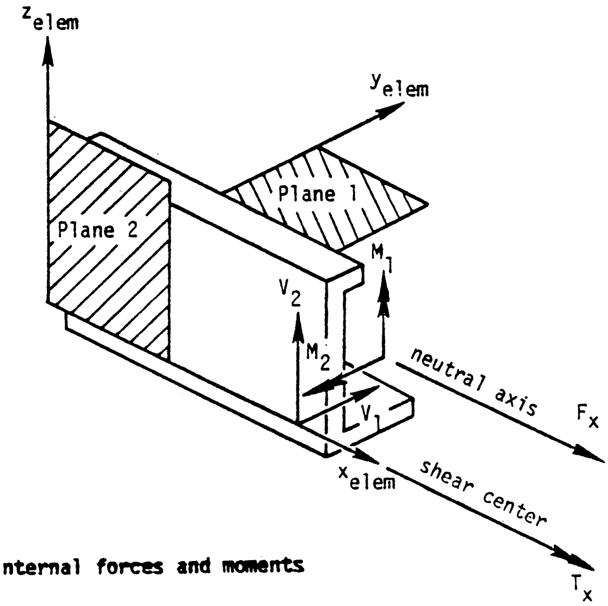


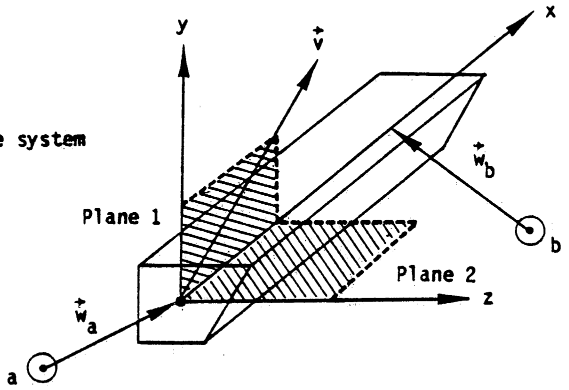

**(a) Beam element coordinate system**




**(b) Beam element internal forces and moments**

Figure 1. Beam, Bar and Bend Element Coordinate Systems and Element Forces.

(c) Bar element coordinate system




(d) Bar element forces

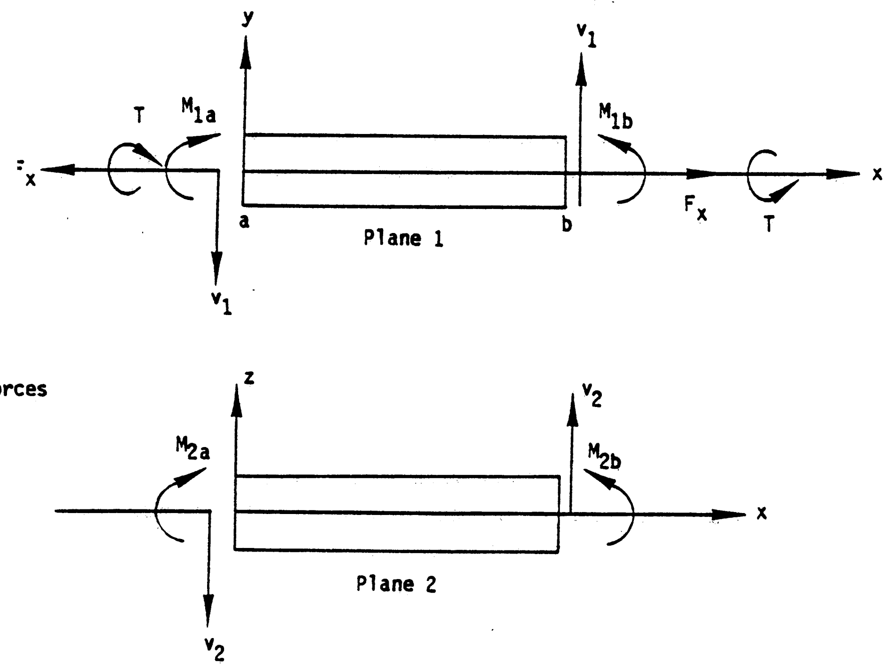
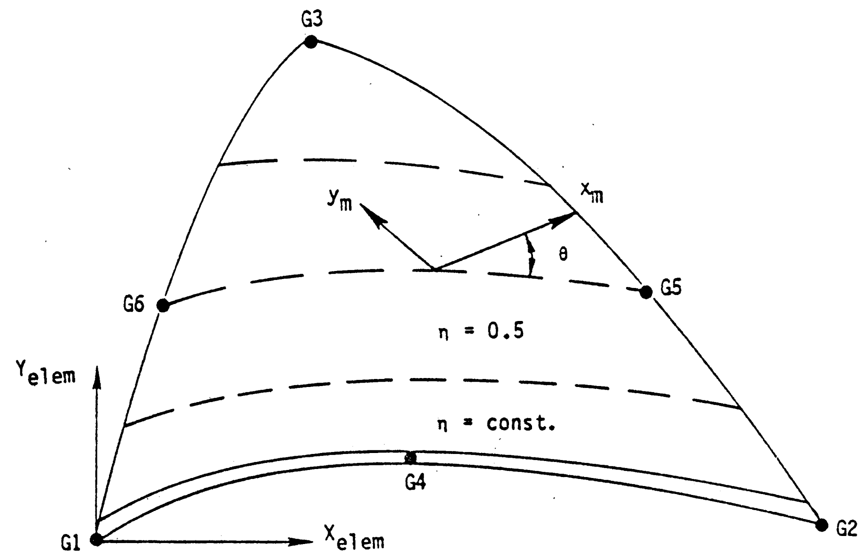
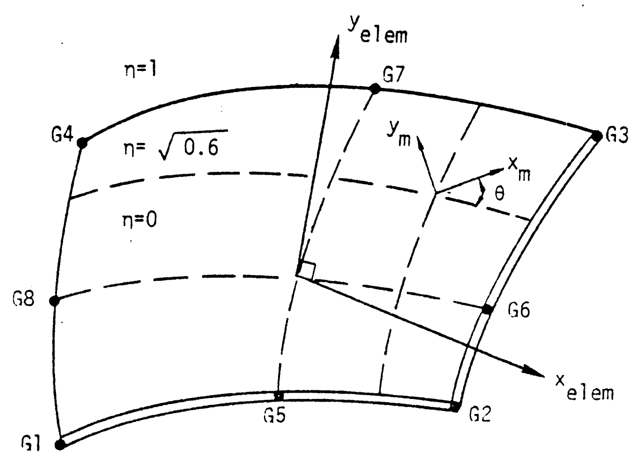



Figure 1. Beam, Bar and Bend Element Coordinate Systems and Element Forces. (Cont.)

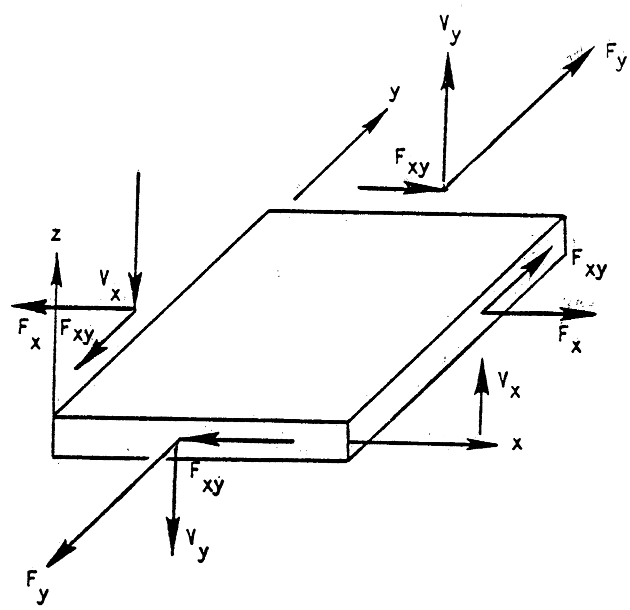



(c) TRIA6

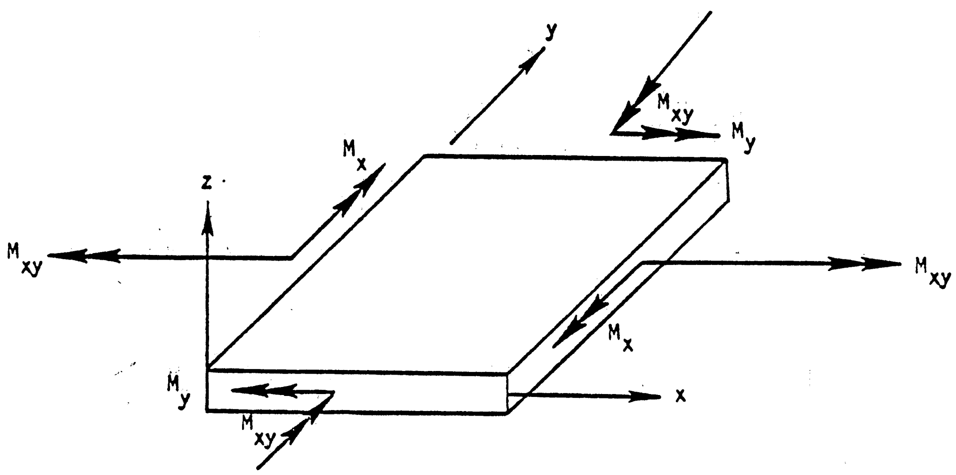



(d) QUAD8

Figure 4. Shell Element Coordinate Systems. (Cont.)

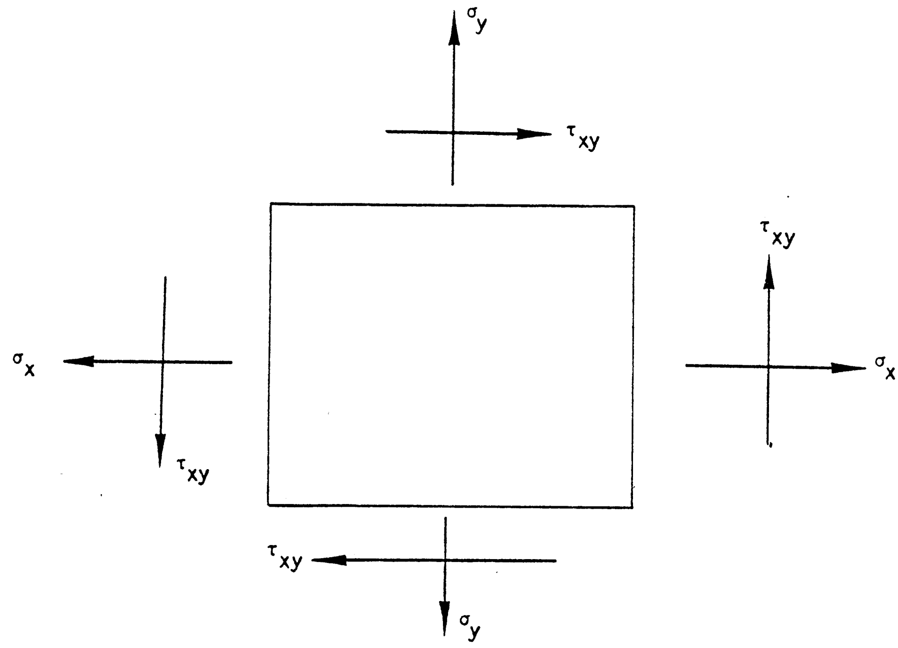



(a) Forces




(b) Moments

Figure 5. Forces, Moments, and Stresses in Plate Elements.




(c) Stresses

Figure 5. Forces, Moments, and Stresses in Plate Elements. (Cont.)

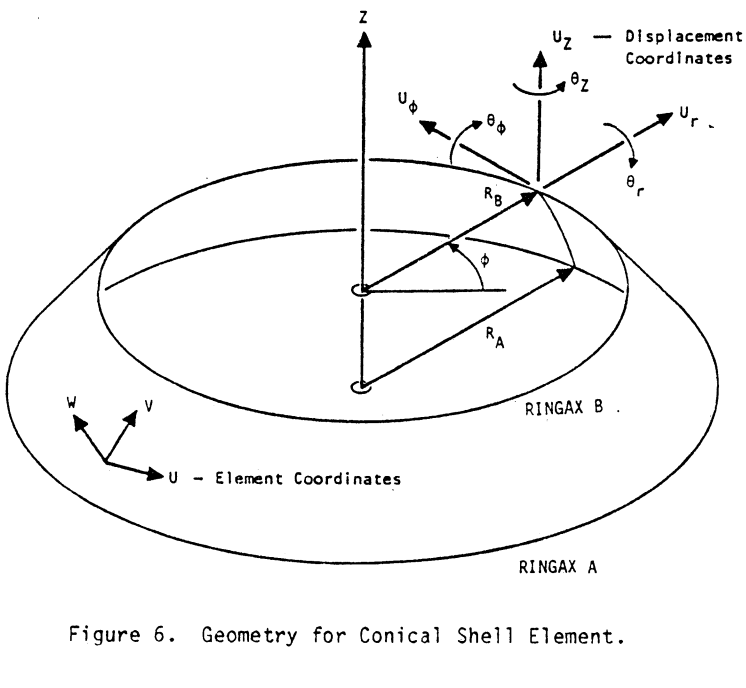



Figure 6. Geometry for Conical Shell Element.

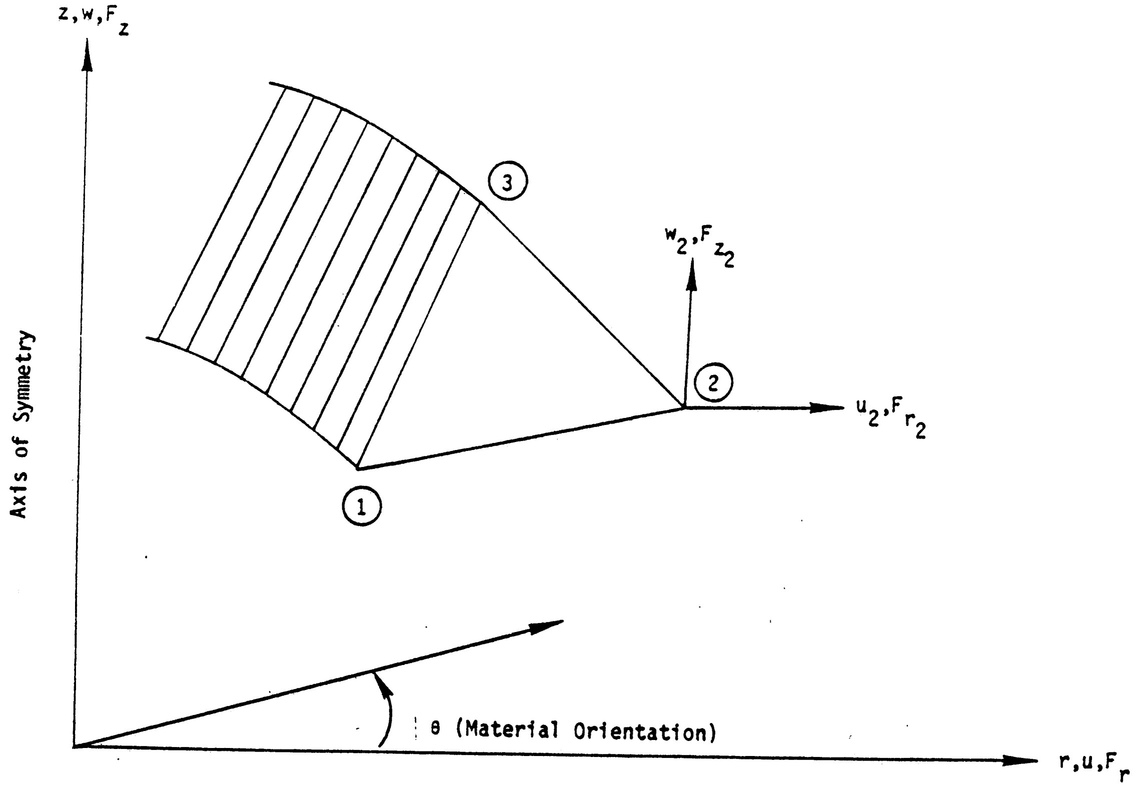



Figure 7. Triangular Ring Element Coordinate System.

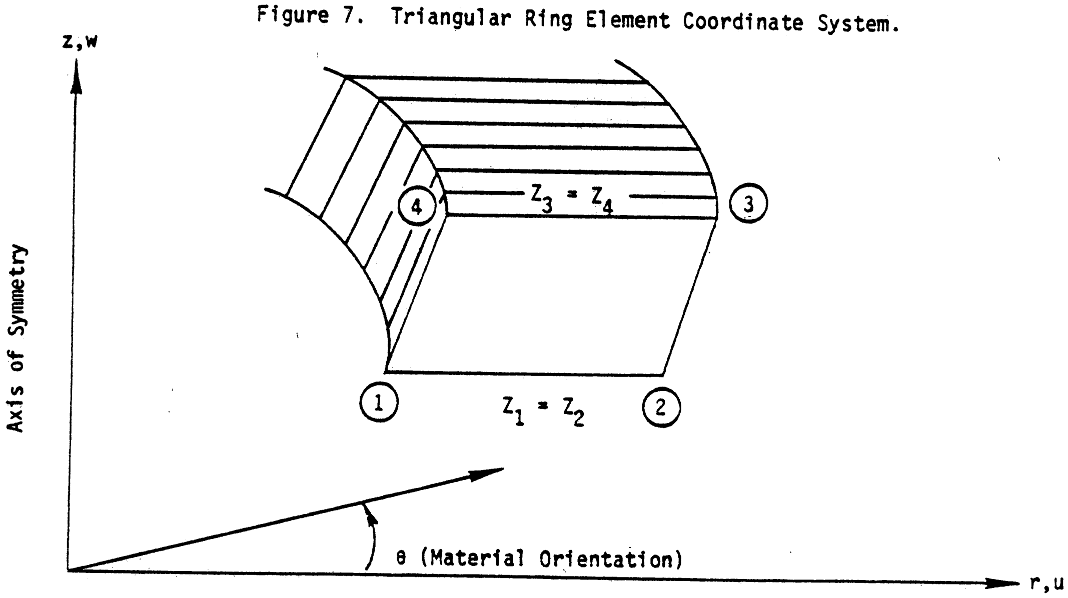



Figure 8. Trapezoidal Ring Element Coordinate System.

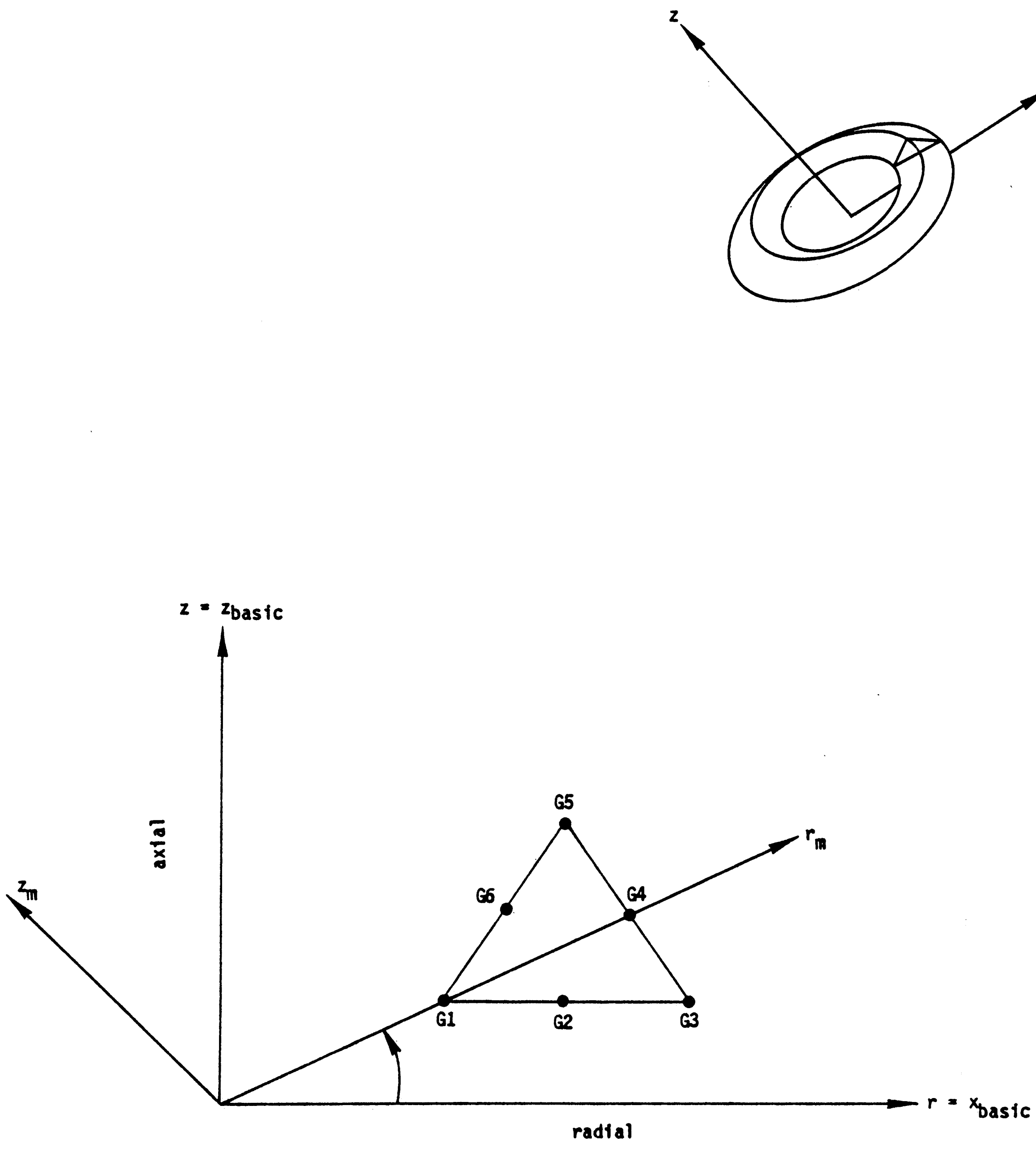



Figure 9. The TRIAX6 Solid of Revolution Element.

Table 1. Element Summary

| | STRUCTURAL MATRICES | | | | | | | MATERIALS | | | STATIC LOADS | | | | HEAT TRANSFER | | | DATA RECOVERY | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Element Type | Stiffness | Mass | Differential Stiffness | Geometric Nonlinear | Material Nonlinear | Viscous Damping | Axisymmetric | Isotropic | Anisotropic | Orthotropic | Thermal | Pressure | Gravity | Element Deformation | Heat Conduction | Heat Capacity | Thermal Load | Stress Real | Stress Complex | Force Real | Force Complex | Force Sum Global | Force Sum Element Edges | Structure Plot | Contour Plot | Grid Point Stresses | SØRT2 | MSGSTRESS | Heat Transfer | MSGMESH |
| AXIF1 | | | | | | | X | | | | | | | | | | | 12 | 23 | | | | | | | | X | | | |
| → BAR | X | LC | X | | | | | X | | | EB | X | X | X | X | X | X | 16 | 19 | 9 | 17 | X | X | X | | | X | | X | X |
| → BEAM | X | LC | X | X | X | | | X | | | EB | X | X | X | X | X | X | 89 | 111 | 89 | 177 | X | | X | | | X | | X | X |
| BEND | X | C | X | | | | | X | | | EB | X | X | | X | X | X | 23 | 23 | 17 | 31 | X | | X | | | X | X | X | X |
| CØNEAX | X | L | X | | | | X | X | X | X | E | X | X | | | | | 18 | | 7 | | | | X | | | | | | |
| CØNM1 | | LC | | | | | | | | | | | X | | | | | | | | | | | | | | | | | |
| CØNRØD | CS | LC | X | X | X | | | X | | | E | | X | X | X | X | X | 5 | 5 | 3 | 5 | X | X | X | | | X | | X | |
| DAMP1 | | | | | | X | | | | | | | | | | X | | | | | 3 | | | | | | | | | |
| → ELAS1 | X | | | | | | | X | | | | | | | X | | | 2 | 3 | 2 | 3 | X | | | | | X | | X | |
| FLUID1 | | | | | | | X | | | | | | | | | | | | | | | | | X | | | | | | |
| FTUBE | | | | | | | | | | | | | | | X | X | X | | | | | | | X | | | X | | X | X |
| GAP | X | | | | X | | | | | | | | | | | | | | | X | | X | | X | | | X | | | |
| HBDY | | | | | | | | | | | | | | | X | X | X | | | | | | | X | | | X | | X | X |
| → HEXA | I | C | X | X | | | | X | X | | E | X | X | | X | X | X | 193 | 121 | | | X | | X | | | X | X | X | X |
| HEX20 | I | C | X | | | | | X | | | E | X | X | | | | | 22 | 14 | | | X | | X | | | | X | | X |
| MASS1 | | L | | | | | | | | | | | X | | | | | | | | | | | | | | | | | |
| → PENTA | I | C | X | X | | | | X | X | | E | X | X | | X | X | X | 151 | 95 | | | X | | X | | | X | | X | |
| → QUAD4 | I | LC | X | X | X | | | X | X | | EB | X | X | | X | X | X | 17 | 15 | 9 | 17 | X | X | X | X | X | X | X | X | X |
| → QUAD8 | I | LC | X | | | | | X | X | | EB | X | X | | X | X | X | 87 | 77 | 47 | 87 | X | | X | | X | X | | X | X |
| RØD | CS | LC | X | X | X | | | X | | | E | | X | X | X | X | X | 5 | 5 | 3 | 5 | X | X | X | | | X | | X | X |

Table 1. Element Summary (Cont.)

| | STRUCTURAL MATRICES | | | | | | | MATERIALS | | | STATIC LOADS | | | | HEAT TRANSFER | | | DATA RECOVERY | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Element Type | Stiffness | Mass | Differential Stiffness | Geometric Nonlinear | Material Nonlinear | Viscous Damping | Axisymmetric | Isotropic | Anisotropic | Orthotropic | Thermal | Pressure | Gravity | Element Deformation | Heat Conduction | Heat Capacity | Thermal Load | Stress Real | Stress Complex | Force Real | Force Complex | Force Sum Global | Force Sum Element Edges | Structure Plot | Contour Plot | Grid Point Stresses | SØRT2 | MSGSTRESS | Heat Transfer | MSGMESH |
| SHEAR | CS | L | X | | | | | X | | | E | X | X | | | | | 8 | 5 | 17 | 33 | X | X | X | X | | X | | | X |
| SLØTi | | | | | | | X | | | | | | | | | | | 7 | 13 | | | | | X | | | X | | | |
| TETRA | CS | L | | | | | | X | | | E | | X | | X | X | X | 9 | 13 | | | X | | X | | | X | | X | |
| TRAPRG | CS | C | | | | | X | X | | X | E | | X | | X | X | X | 21 | | 13 | | X | | X | | | | | X | X |
| TRIA3 | I | LC | X | X | X | | | X | X | | EB | X | X | | X | X | X | 17 | 15 | 9 | 17 | X | X | X | X | X | X | X | X | X |
| → TRIA6 | I | LC | X | | | | | X | X | | EB | X | X | | X | X | X | 70 | 62 | 38 | 70 | X | | X | | X | X | | X | X |
| TRIARG | CS | C | | | | | X | X | | X | E | | X | | X | X | X | 5 | | 10 | | X | | X | | | | | X | X |
| → TRIAX6 | LS | LC | | | | | X | X | | X | E | X | X | | | | | 30 | | | | X | | X | X | | | X | | X |
| TUBE | CS | LC | X | X | X | | | X | | | E | | X | X | X | X | X | 5 | 5 | 3 | 5 | X | X | X | | | X | | X | X |
| VISC | | | | | | X | | | | | | | | | | | | | | | 5 | | | X | | | | | | |

<u>Stiffness Matrix</u>

CS - Constant strain element
LS - Linear strain element
I - Isoparametric element

<u>Data Recovery</u>

The integer indicates the number of output words.

<u>Mass Matrix</u>

L - Lumped mass only
C - Coupled mass only
LC - Lumped mass or coupled mass

<u>Static Thermal Load</u>

E - Extension load only
EB - Both extension and bending loads

NASTRAN
DATA
DECK

## 2.1 GENERAL DESCRIPTION OF DATA DECK

The input deck begins with the required resident operating system control cards. The type and number of these cards will vary with the installation. Instructions for the preparation of these control cards are given in Section 7.6 of the Application Manual.

The operating system control cards are followed by the MSC/NASTRAN Data Deck, which consists of the following three sections:

→ 1. Executive Control Deck

→ 2. Case Control Deck

→ 3. Bulk Data Deck

The Executive Control Deck and the Case Control Deck both have free-field formats. Only columns 1 thru 72 are used for data. Any information in columns 73 thru 80 will appear in the printed echo, but the data will not be used by the program. As explained in Section 2.4.1, limited use is made of the data in columns 73 thru 80 for the Bulk Data Deck.

The NASTRAN card is used to change the default values for certain operational parameters, such as buffer size or the number of data lines printed per page. The NASTRAN card is optional, but, if present, it must be the first card of the NASTRAN Data Deck. The NASTRAN card is a free-field card (similar to cards in the Executive Control Deck). Its format is as follows:

$$\text{NASTRAN keyword}_1 = \text{value, keyword}_2 = \text{value, ...}$$

These keywords set specific cells in the /SYSTEM/ common block. These same cells may be set dynamically (between DMAP statements) by the PARAM module (see Section 5). The number in parentheses after the keywords is the associated number of the system cell.

The most frequently used keywords are as follows:

1. BUFFSIZE(1) - Defines the number of words in a GINØ buffer. Usually this value is standardized at any particular installation. However, the desired value may be different from the default value. In any event, in a series of related runs, such as restarts, the same BUFFSIZE must be used for all of the runs.

2. NLINES(12) - Defines the number of data lines per page. This value is automatically set for a particular installation. However, when nonstandard paper is used, the use of this keyword will produce proper paging.

3. HICØRE(57) - Defines the maximum region request in words for UNIVAC and VAX.

4. DAYLIMIT(7) - Defines the number of entries allowed in dayfile (CDC).

5. PREFØPT(31) - Selects preprocessors for execution in the Preface. The following option is available:

| PREFØPT | Preprocessor |
|---|---|
| 2 | MSGMESH (limited release) |

6. FILES(45) - Used to declare permanent GINØ disk files on CDC machines.

7. MPYAD(66) - Deselects multiply/add methods as follows:

| MPYAD | Selection |
|---|---|
| 0 | Default value - all methods are available for program selection. |
| 1 | Deselect Method 1 Nontranspose |
| 2 | Deselect Method 1 Transpose |
| 4 | Deselect Method 2 Nontranspose |
| 8 | Deselect Method 2 Transpose |
| 16 | Deselect Method 3 Nontranspose |
| 32 | Deselect Method 3 Transpose |
| 64 | Deselect Method 4 Nontranspose |
| 128 | Deselect Method 4 Transpose |

Several methods can be deselected by using the sum of the values for deselecting the individual methods.

8. SDCØMP(69) - Controls options for the symmetric decomposition routine during the review of the matrix prior to beginning the actual decomposition operation as follows:

| SDCØMP | Action |
|---|---|
| 0 | Default - Print up to 50 messages for null columns and zero diagonals. Do not perform decomposition if there are any null columns or zero diagonal terms. |
| 1 | Terminate execution when first null column is encountered. |
| 2 | Suppress printing of message when a null column is encountered. |
| 4 | Terminate execution when first zero diagonal term is encountered. |

| SDCØMP | Action |
|---|---|
| 8 | Suppress printing of message when a zero diagonal term is encountered. |
| 16 | Place 1.0 in diagonal position for all null columns and proceed with the decomposition. |
| 32 | In case of zero diagonal terms, proceed with the decomposition unless the leading minor is zero. |
| 64 | Exit after execution of preface for symmetric decomposition. |

Combinations of program action are indicated by using the sum of the values for the individual actions.

If the ninth parameter of the DECØMP module is set to a non-default value, it overrides any value used with the SDCØMP keyword. This parameter is set to non-default values in some of the solution sequences. It can be changed by a DMAP alter. See the DECØMP module description in Section 5.4.

9. REAL(81) - Specifies directly the amount of ØPEN CØRE (single precision words) to be used. This information is used on virtual machines to prevent thrashing. The value for REAL should never be set to more than the amount of real address space available to the user. If REAL = 0, the ØPEN CØRE is calculated from the REGIØN request on the operating system JØB card. Default value for IBM machines is 100000. The default value on the VAX 11/780 depends on the working set (WSL). REAL = (WSL-200) 128.

10. HEAT(56) - the integer value of 1 specifies that the current problem is heat transfer analysis rather than structural analysis.

11. DBSET(None) - defines data base subsets as follows:

    DBSET $\ell$ = (DBij, DBij, ...), where $\ell$ is an integer from 1 thru 15 and DBij are data base file names. Default values are $\ell$ = 1 and ij = 01.

12. IØRATE(84) - I/Ø operations per second.

    MSC/NASTRAN will, by default, consider I/Ø time as well as CPU time in the internal decision logic used to select the most cost-effective method of matrix multiplication (MPYAD), forward-backward substitution (FBS), etc. The decision logic utilizes the following relation to estimate the number of equivalent CPU seconds required to perform the desired matrix operation by each of the available methods:

$$T = CPU + \frac{IØBLØCKS}{IØRATE}$$

where T = Equivalent CPU time

CPU = CPU time for matrix operation

IØBLØCKS = Number of transfers between memory and disk

IØRATE = 20 blocks/second (default)

The default value of 20 blocks/second for IØRATE is approximately the read/write rate for commonly used disk devices. Other values of IØRATE may be more effective in minimizing computer charges because of the characteristics of local charge algorithms. If IØRATE is explicitly set to zero on the NASTRAN card, method selection will be based solely on estimated CPU time.

13. UDCØMP(69) - Controls options for the unsymmetric decomposition routine during the review of the matrix prior to beginning the actual decomposition operation as follows:

| UDCØMP | Action |
|---|---|
| 0 | Default - Print up to 50 messages if both row and column are null. Do not perform decomposition if there are any null rows and columns. |
| 1 | Terminate execution if both row and column are null. |
| 2 | Suppress printing of message if both row and column are null. |
| 16 | Place 1.0 in diagonal position if both row and column are null and proceed with the decomposition. |
| 64 | Exit after execution of preface for unsymmetric decomposition. |

Combinations of program action are indicated by using the sum of the values for the individual actions.

14. FBSØPT(70) - Selects Forward/Backward Substitution methods as follows:

| FBSØPT | Selection |
|---|---|
| -1 | Select Method 1 FBS. |
| 0 | Program selects method based on minimum of I/Ø + CPU time. |
| +1 | Select Method 2 FBS. |

The effect of using keywords on the NASTRAN card is to place information in selected locations within a common block called SYSTEM. Information can also be placed in the SYSTEM common block by specifying the location directly. Section 2.4.1.8 of the MSC/NASTRAN Programmer's Manual gives a table correlating the keywords with their location number. For example, specifying SYSTEM (81) = 30000 is equivalent to REAL = 30000. The location number method can also be used to change information in the SYSTEM common block during the course of a run using DMAP statements. (See the PARAM module description in Section 5.4).

The checkpoint dictionary and other punched output are transmitted to the MSC/NASTRAN PUNCH file. The PUNCH file can be sent to an alternate FØRTRAN unit by use of SYSTEM(64)=(n), where (n) is the number of an alternate unit. See the ØUTPUT2 module description in Section 5.4 for a discussion of the machine-dependent FØRTRAN units. The checkpoint dictionary can be separated from the other punched output by sending it to the FØRTRAN unit defined by SYSTEM(83)=(m). The remainder of the punched output, such as MSGVIEW data, STRESS(PUNCH) files, etc., will go to the MSC/NASTRAN PUNCH file or the unit defined on SYSTEM(64).

## GENERAL DESCRIPTION OF DATA DECK

The Executive Control Deck begins with the ID card and ends with the CEND card, as indicated in Figure 1. It identifies the job and the type of solution to be performed. It also declares the general conditions under which the job is to be executed, such as maximum time allowed, type of system diagnostics desired, restart conditions, and whether or not the job is to be checkpointed. If the job is to be executed with a rigid format, the actual rigid format is declared along with any alterations to the rigid format that may be desired. If Direct Matrix Abstraction is used, the complete DMAP sequence must appear in the Executive Control Deck. The Executive Control Cards and examples of their use are described in Section 2.2.

The Case Control Deck begins with the first card following CEND and ends with the card, BEGIN BULK, as indicated in Figure 1. It defines the subcase structure for the problem, makes selections from the Bulk Data Deck, and makes output requests for printing, punching and plotting. A general discussion of the functions of the Case Control Deck and a detailed description of the cards used in this deck are given in Section 2.3. The special requirements of the Case Control Deck for each solution sequence are discussed in Section 3.

The Bulk Data Deck begins with the card following BEGIN BULK and ends with the card, ENDDATA, as indicated in Figure 1. It contains all of the details of the structural model and the conditions for the solution. The BEGIN BULK and ENDDATA cards must be present even though no new bulk data is being introduced into the problem or all of the bulk data is coming from an alternate source, such as user-generated input. The format of the BEGIN BULK card is free-field. The ENDDATA card must begin in column 1 or 2. Generally speaking, only one structural model can be defined in the Bulk Data Deck. However, some of the bulk data, such as cards assocated with loading conditions, constraints, direct input matrices, transfer functions and thermal fields may exist in multiple sets. Only sets selected in the Case Control Deck will be used in any particular solution. The bulk data cards are described in Section 2.4.

Comment cards may be inserted in any of the parts of the Data Deck. These cards are identified by a $ in column one. Columns 2-72 may contain any desired text.

All data cards must be punched using the character set shown in the table on the next page. The EBCDIC character set may also be used. Any EBCDIC characters are automatically translated into the character set shown in the table on the next page. The EBCDIC character card punch configurations are shown in parentheses for the five characters that differ from the standard character set.

| Character | Card Punch(es) | Character | Card Punch(es) | EBCDIC Punch(es) |
|---|---|---|---|---|
| blank | blank | N | 11-5 | |
| 0 | 0 | Ø | 11-6 | |
| 1 | 1 | P | 11-7 | |
| 2 | 2 | Q | 11-8 | |
| 3 | 3 | R | 11-9 | |
| 4 | 4 | S | 0-2 | |
| 5 | 5 | T | 0-3 | |
| 6 | 6 | U | 0-4 | |
| 7 | 7 | V | 0-5 | |
| 8 | 8 | W | 0-6 | |
| 9 | 9 | X | 0-7 | |
| A | 12-1 | Y | 0-8 | |
| B | 12-2 | Z | 0-9 | |
| C | 12-3 | $ | 11-3-8 | |
| D | 12-4 | / | 0-1 | |
| E | 12-5 | + | 12 | (12-6-8) |
| F | 12-6 | - | 11 | |
| G | 12-7 | ( | 0-4-8 | (12-5-8) |
| H | 12-8 | ) | 12-4-8 | (11-5-8) |
| I | 12-9 | (6-8) | 4-8 | (5-8) |
| J | 11-1 | = | 3-8 | (6-8) |
| K | 11-2 | , | 0-3-8 | |
| L | 11-3 | . | 12-3-8 | |
| M | 11-4 | * | 11-4-8 | |

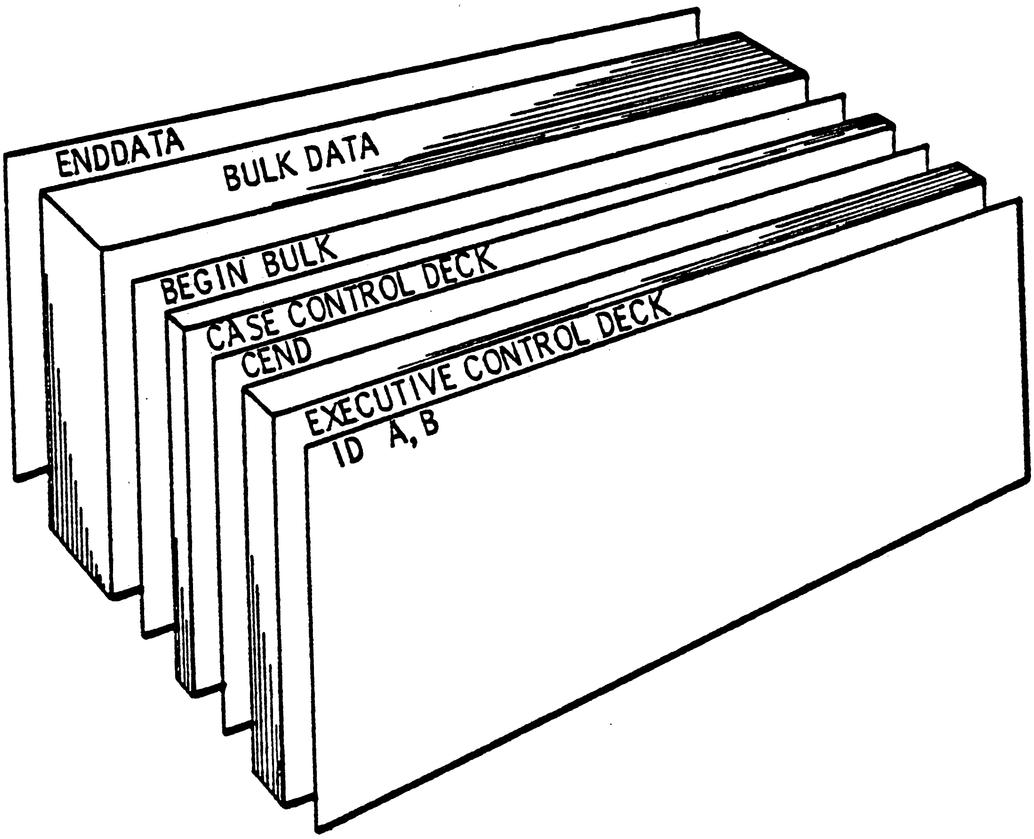



Figure 1. MSC/NASTRAN Data Deck.

EXECUTIVE
CONTROL
DECK

## 2.2 EXECUTIVE CONTROL DECK

The format of the Executive Control cards is free field. The name of the operation (e.g., CHKPNT) begins in column 1 and is separated from the operand by one or more blanks. The fields in the operand are separated by commas, and may be integers (Ki) or alphanumeric (Ai) as indicated in the following control card descriptions. The first character of an alphanumeric field must be alphabetic followed by up to 7 additional alphanumeric characters. Blank characters may be placed adjacent to separating commas if desired. The individual cards are described in Section 2.2.1 and examples follow in Section 2.2.2.

### 2.2.1 Executive Control Card Descriptions

→ ID A1, A2 Required.

A1, A2 -- Any legal alphanumeric fields chosen by the user for problem identification.

RESTART A1, A2, K1/K2/K3, K4, Required for Restart.

A1, A2 -- Fields taken from ID card of previously checkpointed problem.

K1/K2/K3, K4 -- Month/Day/Year, Time that Problem Tape was generated.

The complete restart dictionary consists of the RESTART card followed by one physical card for each file checkpointed and each reentry point. The restart dictionary is automatically punched when operating in the checkpoint mode. The complete restart dictionary is one logical card.

Each continuation card begins with a sequence number. Each type of continuation card will be documented separately.

1. Basic continuation card

   NO,DATABLØCK,FLAG=Y,REEL=Z,FILE=W

where: NO is the sequence number of the card. The entire dictionary must be in sequence by this number.

DATABLØCK is the name of the data block referenced by this card.

FLAG=Y defines the status of the data block where Y = 0 is the normal case and Y = 4 implies this data block is equivalenced to another data block. In this case (FLAG=4) the file number points to a previous data block which is the "actual" copy of the data.

REEL=Z specifies the reel number. Z=1 even if the Problem Tape is multi-reel.

FILE=W specifies the GINØ (internal) file number of the data block on the Problem Tape. A zero value indicates the data block is purged. For example:

1,GPL,FLAGS=0,REEL=1,FILE=7 says data block GPL occupies file 7 of reel 1.

2,KGG,FLAGS=4,REEL=1,FILE=20 says KGG is equivalenced to the data block which occupies file 20. (Note that FLAGS=4 cards usually occur in at least pairs at the equivalenced operation is at least binary.)

3,USETD,FLAGS=0,REEL=1,FILE=0 implies USETD is purged.

2. Reentry point card:

   NØ,REENTER AT DMAP SEQUENCE NUMBER N

   where NØ is the sequence number of the card. N is the sequence number associated with the DMAP instruction at which the problem will restart. This value may be changed by adding a final such card (i.e., only the last such card is operative). This may be necessary when restarting from a Rigid Format to a DMAP sequence (to print a matrix, for example). The REENTER card provides an easy way to accomplish this.

There are four types of restarts: Unmodified Restart; Modified Restart; Rigid Format Switch; and Pseudo Modified Restart. The function of the reentry point is different in each case. On an unmodified restart the program continues from the reentry point. On a modified restart, modules which must be run to process the modified data but which are ahead of the reentry point are executed first. The program then continues from the reentry point. On a Rigid Format Switch (going from a Rigid Format to another), the reentry point is meaningless in that it was determined for another DMAP sequence. In this case, the data blocks available are consulted to determine the proper sequence of modules to run. A Pseudo Modified Restart (defined by the existence of only changes to output producing data such as plotter requests) is treated like a modified restart. The type of restart is implied by the changes made in the NASTRAN Data Deck. No explicit request for a particular kind of restart is required. See Section 3.1 for additional information.

3. End of dictionary card:

   $ END ØF CHECKPØINT DICTIØNARY

This card is simply a comment card but is punched to signal the end of the dictionary for user convenience. The program does not need such a card. Terminations associated with non-NASTRAN failures (operator intervention, maximum time, etc.) will not have such a card punched.

REENTER K1 Optional.

This card directs the program to reenter at DMAP statement K1. This card is only effective on restart and overrides the directive given in the restart dictionary. Note that this card is ignored (as is any reentry point) on Rigid Format Switches.

TRUNCATE K1 Optional.

The restart dictionary will be truncated (ignored) after card number K1. The truncate card must precede the restart dictionary.

CHKPNT A1 or CHKPNT A1, A2 Optional.

A1-- YES if problem is to be checkpointed, NØ if problem is not to be checkpointed. Default=NØ.

A2-- DISK if checkpoint file is on direct access device. If the DISK option is used, the user must instruct the resident operating system to permanently catalog the checkpoint file.

APP A Optional.

A -- DISPLACEMENT indicates one of the Displacement solution sequences (default).

A -- HEAT indicates one of the Heat Transfer Approach solution sequences.

A -- DMAP indicates Direct Matrix Abstraction Approach (DMAP). Default if a DMAP sequence is submitted.

→ SØL K1 [,Ki] or SØL An [,Ki] Required when using a solution sequence.

K1-- Number of Solution Sequence (see table below).

Ki-- Subset numbers for solution K1, default = 0. Multiple subsets can be used by separating the subset numbers with commas. (See Section 3.1 for allowable subsets.)

An-- Name of Rigid Format (see table below)

Rigid Formats

| K1 | An | Parameter |
|---|---|---|
| 3 | NØRMAL MØDES | MØDES |
| 5 | BUCKLING | BUCKLING |
| → 24 | STATICS | STATICS |
| 25 | None - old Normal Modes | None |
| 26 | DIRECT FREQUENCY RESPØNSE | DFREQ |
| 27 | DIRECT TRANSIENT RESPØNSE | DTRAN |
| 28 | DIRECT CØMPLEX EIGENVALUES | DCEIG |
| 29 | MØDAL CØMPLEX EIGENVALUES | MCEIG |
| 30 | MØDAL FREQUENCY RESPØNSE | MFREQ |
| 31 | MØDAL TRANSIENT RESPØNSE | MTRAN |
| 45 | AERØDYNAMIC FLUTTER | FLUTTER |
| 46 | AERØDYNAMIC RESPØNSE | AERØ |
| 47 | CYCLIC STATICS | CYC STATICS |
| 48 | CYCLIC MØDES | CYC MØDES |

Solution Sequences

| K1 | An | Parameter |
|---|---|---|
| 60 | SUPERELEMENT MØDEL CHECKØUT | CHECKØUT |
| 61 | SUPERELEMENT STATICS | SE STATICS |
| 62 | ALTERNATE SUPERELEMENT STATICS | ALT SE STATICS |
| 63 | SUPERELEMENT NØRMAL MØDES | SE MØDES |
| 64 | GEØMETRIC NØNLINEAR | GNØLIN |
| 65 | SUPERELEMENT BUCKLING | SE BUCKLING |
| 66 | MATERIAL NØNLINEAR | MNØLIN |
| 67 | SUPERELEMENT DIRECT CØMPLEX EIGENVALUES | SE DCEIG |
| 68 | SUPERELEMENT DIRECT FREQUENCY RESPØNSE | SE DGREQ |
| 69 | SUPERELEMENT DIRECT TRANSIENT RESPØNSE | SE DTRAN |
| 70 | SUPERELEMENT MØDAL CØMPLEX EIGENVALUES | SE MCEIG |
| 71 | SUPERELEMENT MØDAL FREQUENCY RESPØNSE | SE MFREQ |
| 72 | SUPERELEMENT MØDAL TRANSIENT RESPØNSE | SE MTRAN |
| 74 | STEADY NØNLINEAR HEAT TRANSFER | None |
| 75 | SUPERELEMENT AERØDYNAMIC FLUTTER | SE FLUTTER |
| 76 | SUPERELEMENT AERØELASTIC RESPØNSE | SE AERØ |
| 77 | CYCLIC BUCKLING | CYC BUCKLING |
| 78 | CYCLIC FREQUENCY RESPØNSE | CYC FREQ |
| 81 | SUPERELEMENT CYCLIC STATICS | None |
| 83 | SUPERELEMENT CYCLIC MØDES | None |
| 88 | SUPERELEMENT CYCLIC FREQUENCY RESPØNSE | None |
| 89 | SUPERELEMENT TRANSIENT HEAT TRANSFER | None |

ALTER K1, K2 Optional.

K1,K2 -- First and last DMAP instructions of series to be deleted and replaced with any following DMAP instructions. Alter numbers do not need to be in sort; overlaps are resolved on a first come basis.

ALTER K Optional.

K -- Input any following DMAP instructions after statement K.

TIME K, M Required if K is greater than one minute.

K -- Maximum allowable execution time in minutes. K is a real or integer number; thus, 1.5 is equivalent to 90 seconds. The default for K is one minute.

M -- Reserved for an I/Ø limit.

ENDALTER Required when using ALTER unless the alter package ends with the CEND or RESTART card.

Indicates end of DMAP alters.

BEGIN Required when using DMAP approach.

Indicates beginning of DMAP sequence and terminates any DMAP alters.

END Required when using DMAP approach.

Indicates end of DMAP sequence. This card must begin in column 1 and contain a blank in column 4.

→ DIAG K  Optional request for diagnostic output.

| | |
|---|---|
| K = 1 | Dump memory when non-preface fatal message is generated. |
| K = 2 | Print File Allocation Table (FIAT) following each call to the File Allocator. |
| K = 3 | Print status of the Data Pool Dictionary (DPD) following each call to the Data Pool Housekeeper. |
| K = 4 | Print the DMAP cross reference. |
| K = 5 | Print BEGIN time on-line for each functional module on the operator's console. |
| K = 6 | Print END time on-line for each functional module on the operator's console. |
| K = 7 | Print eigenvalue extraction diagnostics for complex determinant method. |
| K = 8 | Print matrix trailers as the matrices are generated and data blocks used from ØPTP. |
| K = 9 | Echo checkpoint dictionary as cards are punched. |
| K = 10 | Use alternate nonlinear loading in TRD. Replace $N_{n+1}$ by $\frac{1}{3}(N_{n+1} + N_n + N_{n-1})$. |
| K = 11 | Not used. |
| K = 12 | Print eigenvalue extraction diagnostics for complex inverse power. |
| K = 13 | Print open core length. (REAL on the VAX). |
| → K = 14 | Print the DMAP Sequence (NASTRAN SØURCE PRØGRAM CØMPILATIØN). |
| K = 15 | Trace GINØ ØPEN/CLØSE operations. Print table trailers. |
| K = 16 | Trace real inverse power eigenvalue extraction operations. |
| K = 17 | Punch the DMAP sequence that is compiled. |
| K = 18 | Do not trace Heat Transfer iterations in module SSGHT. In Aeroelastic Analysis, print internal grid points picked by SET2 cards. |
| K = 19 | Print data for MPYAD and FBS method selection. |
| K = 20 | Print Data Base Manager fetch/store messages. |
| K = 21 | Not used. |
| K = 22 | Not used. |
| K = 23 | Compute strains rather than stresses for QUAD4, QUAD8, TRIA3, and TRIA6. Stresses will not be calculated for any elements. If ELFØRCE is used with DIAG 23 the calculated forces will be incorrect. |
| K = 24 | Print EXCP counts for files on IBM. Print secondary file allocation messages in run log for UNIVAC. |
| K = 25 | Øutput internal plot diagnostics. |
| K = 26 | Print material orientation angle θ for the QUAD4, QUAD8, TRIA3 or TRIA6 element corresponding to the user-supplied material orientation coordinate system ID. |
| K = 27 | Dump Input File Processor (IFP) tables. |

DIAG K (Cont.)

K = 28 Punch the link specification table (Deck XBSBD.)

K = 29 Process link specification table update deck. A module may be forced to run in a specified link by placing the following two cards after the ENDDATA card at the end of the data deck.

MØDNAME, EPNAME, I
ENDDATA

where MØDNAME is the name of the module, EPNAME is the entry point name and I is the link number.

K = 30 Punch the XSEMii decks (i.e., set ii via DIAG 1-15). (After Link 1, this turns on BUG output.)

K = 31 Print link specification table and module properties list data.

K = 32 Not used.

K = 33 Print Hencky-von Mises equivalent stresses instead of maximum shear stress.

K = 34 Turn off plot line optimization.

K = 35 Turn off automatic RFL on CDC 6000 and Univac computers. See Section 4.3.7 for effect on XYTRAN module.

K = 36 Turn off copying to FIAT on RESTARTs.

K = 37 Disable superelement congruence test option.

K = 38 Print material angles for QUAD4, QUAD8, TRIA3, and TRIA6 elements.

K = 39 Trace module FA1 operations.

K = 40 Show cards modified by 1VARY cards.

K = 41 Trace buffer manager on CDC 7600.

K = 42 Turn on page locking on the VAX.

K = 43 Not used.

K = 44 Print mini dump for fatal errors and suppress user message exit.

K = 45 Print FIAT before and after every module execution.

K = 46 Set by program if CHKPNT is YES.

K = 47 Generate automatic CHKPNT for all outputs if CHKPNT is YES. (Not needed for Solution Sequences.)

K = 48 Do not calculate stresses for elements using composite materials.

K = 49 Print stress output for composite materials from SDR2.

K = 50 Print nonlinear convergence values per iteration.

K = 51 Print nonlinear g-size displacement, unbalanced, and error vectors per iteration.

K = 52 thru K = 64 Not used.

Multiple options may be selected by using multiple integers separated by commas. Other options and other rules associated with the DIAG card which primarily concern the programmer can be found in Section 6.11.3 of the Programmer's Manual.

ECHØØFF Optional.
Suppresses echo of following cards such as a large ALTER package or a restart dictionary.

ECHØØN Optional.
Reactivates the echo after an ECHØØFF card.

CEND Required.
Indicates end of executive control cards.

The ID card must appear first and CEND must be the last card of the Executive Control Deck.

CØMPILER = A1, A2, A3, A4 Optional.

This card is an alternate for DIAGs 4, 14, and 17.

A1 -- LIST if the DMAP Library is to be printed. Default is NØLIST.

A2 -- DECK if a DMAP with any embedded ALTERs is to be punched. Default is NØDECK.

A3 -- REF if a cross reference table of the DMAP sequence is to be printed. Default is NØREF.

A4 -- NØGØ if the job is to be terminated after the preface even when no errors are detected. Default is GØ.

## 2.2.2 Executive Control Deck Examples

1. Cold start, no checkpoint, rigid format, diagnostic output.

```
ID    MYNAME, BRIDGE23
SØL     24
TIME    5
DIAG    8,13
CEND
```

2. Cold start, checkpoint, rigid format.

```
ID    PERSØNZZ, SPACECFT
CHKPNT  YES
SØL     24
TIME    15
CEND
```

3. Restart, no checkpoint, rigid format. The restart dictionary indicated by the brace is automatically punched on previous run in which the CHKPNT option was selected by the user.

```
ID    JØESCHMØE, PRØJECTX
SØL3
TIME10
RESTART PERSØNZZ, SPACECFT, 05/13/67, 15,
    1, XVPS, FLAGS=0, REEL=1, FILE=6
    2, REENTER AT DMAP SEQUENCE NUMBER 7
    3, GPL, FLAGS=0, REEL=1, FILE=7

$ END ØF CHECKPØINT DICTIØNARY
CEND
```

4. Cold start, no checkpoint, DMAP. User-written DMAP program is indicated by braces.

```
ID   IAM007, TRYIT
BEGIN $

{DMAP statements go here}

END $
TIME    8
CEND
```

5. Restart, checkpoint, altered rigid format, diagnostic output.

```
ID   GØØDGUY, NEATDEAL
CHKPNT  YES
CØMPILER LIST, REF
SØL     3
TIME    15
ALTER   56
MATPRN  KGGX// $
RESTART BADGUY, NØSHØW, 05/09/68, 25,
    1, XVPS, FLAGS=0, REEL=1, FILE=6
    2, REENTER AT DMAP SEQUENCE NUMBER 7
    3, GPL, FLAGS=0, REEL=1, FILE=7

$ END ØF CHECKPØINT DICTIØNARY
CEND
```

6. Superelement statics cold start or restart, diagnostic output.*

```
ID   SUPER,  CØLD $
DIAG    8
TIME    5
SØL     61
CEND
```

*The ØPTP-NPTP files may be used in the superelement rigid formats, but they are not required. If an ØPTP file is used, its checkpoint dictionary will consist of two cards, the first starting with the word "RESTART" and the second with "1,XVPS" etc. Only the first card should be used on restart. The second card causes the values of the parameters at the time of termination of the prior run to influence the present run, and may lead to restart errors.

CASE
CONTROL
DECK

## 2.3 CASE CONTROL DECK

The Case Control Deck defines the subcase structure for the problem, makes selections from the Bulk Data Deck, and makes output requests. A summary of all Case Control cards is given inSection 2.3.2. The individual cards are described in Section 2.3.3. Structure plotter output requests and curve plot requests are treated separately in Sections 4.2 and 4.3 respectively.

### 2.3.1 Subcase Definition

In general, a separate subcase is defined for each loading condition and/or each set of constraints. Subcases may also be used in connection with output requests, such as requesting different output for each mode in a real eigenvalue problem. Only one level of subcase definition is provided. All items placed above the subcase level (ahead of the first subcase) will be used for all following subcases unless overridden within the individual subcase.

In statics problems, provision has been made for the combination of the results of several subcases. This is convenient for studying various combinations of individual loading conditions and for the superposition of solutions for symmetrical and antisymmetrical boundaries.

The following examples of Case Control Decks indicate typical ways of defining subcases:

1. Static analysis with multiple loads.

```
    DISPLACEMENT = ALL
    MPC = 3
SUBCASE 1
    SPC = 2
    TEMPERATURE(LØAD) = 101
    LØAD = 11
SUBCASE 2
    SPC = 2
    DEFØRM = 52
    LØAD = 12
SUBCASE 3
    SPC = 4
    LØAD = 12
SUBCASE 4
    MPC = 4
    SPC = 4
```

Four subcases are defined in this example. The displacements at all grid points will be printed for all four subcases. MPC = 3 will be used for the first three subcases and will be overridden by MPC = 4 in the last subcase. Since the constraints are the same for subcases 1 and 2 and the subcases are contiguous, the static solutions will be performed simultaneously. In subcase 1, thermal load 101 and external load 11 are internally superimposed, as are the external and deformation loads in subcase 2. In subcase 4, the static loading will result entirely from enforced displacements of grid points.

2. Linear combination of subcases.

```
        SPC = 2
        SET 1 = 1 THRU 10,20,30
        DISPLACEMENT = ALL
        STRESS = 1
    SUBCASE 1
        LØAD = 101
        ØLØAD = ALL
    SUBCASE 2
        LØAD = 201
        ØLØAD = ALL
    SUBCØM 51
        SUBSEQ = 1.0,1.0
    SUBCØM 52
        SUBSEQ = 2.5,1.5
```

Two static loading conditions are defined in subcases 1 and 2. SUBCØM 51 defines the sum of subcases 1 and 2. SUBCØM 52 defines a linear combination consisting of 2.5 times subcase 1 plus 1.5 times subcase 2. The displacements at all grid points and the stresses for the element numbers in SET will be printed for all four subcases. In addition, the nonzero components of the static load vectors will be printed for subcases 1 and 2.

3. Statics problem with one plane of symmetry.

```
        SET 1 = 1,11,21,31,51
        SET 2 = 1 THRU 10, 101 THRU 110
        DISPLACEMENT = 1
        ELFØRCE = 2
    SYM 1
        SPC = 11
        LØAD = 21
        ØLØAD = ALL
    SYM 2
        SPC = 12
        LØAD = 22
    SYMCØM 3
    SYMCØM 4
        SYMSEQ 1.0,-1.0
```

Two SYM subcases are defined in subcases 1 and 2. SYMCØM 3 defines the sum and SYMCØM 4 the difference of the two SYM subcases. The nonzero components of the static load will be printed for subcase 1 and no output is requested for subcase 2. The displacements for the grid point numbers in set 1 and the forces for elements in set 2 will be printed for subcases 3 and 4.

4. Use of REPCASE in statics problems.

```
    SET 1 = 1 THRU 10, 101 THRU 110, 201 THRU 210
    SET 2 = 21 THRU 30, 121 THRU 130, 221 THRU 230
    SET 3 = 31 THRU 40, 131 THRU 140, 231 THRU 240
SUBCASE 1
    LØAD = 10
    SPC = 11
    DISP = ALL
    SPCFØRCE = 1
    ELFØRCE = 1
REPCASE 2
    ELFØRCE = 2
REPCASE 3
    ELFØRCE = 3
```

This example defines one subcase for solution and two subcases for output control. The displacements at all grid points and the nonzero components of the single-point forces of constraint along with forces for the elements in SET 1 will be printed for SUBCASE 1. The forces for elements in SET 2 will be printed for REPCASE 2 and the forces for elements in SET 3 will be printed for REPCASE 3.

5. Use of MØDES in eigenvalue problems.

```
    METHØD = 2
    SPC = 10
SUBCASE 1
    DISP = ALL
    STRESS = ALL
    MØDES = 2
SUBCASE 3
    DISP = ALL
```

In this example, the displacements at all grid points will be printed for all modes. The stresses in all elements will be printed for the first two.modes.

2.3.1.1 Superelement Subcase Structure

Subcases must be defined for each superelement to specify load, constraint, and output selection. The syntax rules described above also apply for superelements, i.e.,requests above the subcase level are over-ridden by requests inside the subcase level.

1. Static analysis with multiple loads, two superelements.

```
    DISP = ALL
    ESE = ALL
    SPC = 1000
SUBCASE 11
    SUPER = 10,1
    LØAD = 1000
SUBCASE 12
    SUPER = 10,2
    LØAD = 1002
SUBCASE 21
    SUPER = 20,1
    LØAD = 1000
```

Assume that the model generated in step 4 was used as a starting point. Superelement 100 is an alternate version of superelement 10. This run generates superelement 100, then reduces it and assembles and solves the residual structure. Superelement 10 is excluded (see SET 3), so that the alternate version of the structure is assembled, while maintaining the matrices for superelement 10 in the data base. If it is decided to return to the original structure on the next run, superelement 10 can be included and superelement 100 excluded by the sequence

```
SET 2 = 0
SET 3 = 100
SEMA  = 2
SELA  = 2
SEEX  = 3
```

## 2.3.2 Case Control Card Summary

This section contains a summary of all Case Control cards under the following headings:

2.3.2.1 Subcase Definition

1. Output Request Delimiters
2. Subcase Delimiters
3. Subcase Control

2.3.2.2 Data Selection

1. Static Load Selection
2. Dynamic Load Selection
3. Constraint Selection
4. Thermal Field Selection
5. Dynamic Solution Conditions
6. Direct Input Matrix Selection
7. Nonlinear Analysis

2.3.2.3 Output Selection

1. Output Control
2. Set Defintion
3. Physical Set Output Requests
4. Solution Set Output Requests

2.3.2.4 Superelement Control

### 2.3.2.1 Subcase Definition

1. Output Request Delimiters

| | |
|---|---|
| ØUTPUT | Beginning of printer output request (optional) |
| ØUTPUT(PLØT) | Beginning of structure plotter output request |
| ØUTPUT(PØST) | Beginning of grid point stress output requests |
| ØUTPUT(XYØUT) or ØUTPUT(XYPLØT) | Beginning of curve plotter output request |
| ØUTPUT(CARDS) | Suppresses processing of Bulk Data cards |
| ENDCARDS | Reactivates processing of Bulk Data cards |

2. Subcase Delimiters

| | |
|---|---|
| → SUBCASE | Defines beginning of subcase |
| SUBCØM | Defines beginning of subcase which is a linear combination of preceding subcases |
| SYM | Defines beginning of symmetry subcase |
| SYMCØM | Defines beginning of subcase for making symmetry combinations |
| REPCASE | Defines beginning of subcase for additional output requests |

3. Subcase Control

| | |
|---|---|
| SUBSEQ | Defines coefficients for linear combination in SUBCØM |
| SYMSEQ | Defines coefficients for symmetry combination in SYMCØM |
| MØDES | Specifies repetition of subcase for eigenvalue problems |
| MASTER | Defines a new MASTER subcase |

### 2.3.2.2 Data Selection

1. Static Load Selection

| | |
|---|---|
| → LØAD | Selects static loading condition |
| DEFØRM | Selects element deformation set |

2. Dynamic Load Selection

| | |
|---|---|
| DLØAD | Selects dynamic loading conditions |
| LØADSET | Selects static load sets for use in dynamic loading |
| NØNLINEAR | Selects nonlinear loading condition for transient response |

3. Constraint Selection

| | |
|---|---|
| → SPC | Selects set of single-point constraints |
| → MPC | Selects set of multipoint constraints |
| AXISYMMETRIC | Specifies boundary conditions for conical shell problems or hydroelastic problems |
| DYSM | Selects symmetry option in cyclic symmetry |

4. Thermal Field Selection

| | |
|---|---|
| TEMPERATURE(LØAD) | Selects temperature set for static thermal load |
| TEMPERATURE(MATERIAL) | Selects temperature set for temperature-dependent material properties |
| TEMPERATURE | Selects temperature set for both static load and material properties |
| TEMPERATURE(ESTIMATE) | Selects temperature for heat transfer problems |

5. Dynamic Solution Conditions

| | |
|---|---|
| DYNRED | Selects conditions for dynamic reduction |
| METHØD | Selects conditions for real eigenvalue analysis |
| CMETHØD | Selects conditions for complex eigenvalue analysis |
| SDAMPING | Selects table for determination of modal damping |
| FREQUENCY | Selects frequency set for frequency response analysis |
| RANDØM | Selects power spectral density functions for random analysis |
| IC | Selects initial conditions for direct transient response |
| TSTEP | Selects time steps to be used for integration in transient response |

6. Direct Input Matrix Selection

| | |
|---|---|
| B2GG | Selects damping matrices before constraints are applied |
| B2PP | Selects damping matrices |
| K2GG | Selects stiffness matrices before constraints are applied |
| K2PP | Selects stiffness matrices |
| M2GG | Selects mass matrices before constraints are applied |
| M2PP | Selects mass matrices |
| TFL | Selects transfer functions |
| P2G | Selects load matrices |
| MFLUID | Selects MFLUID Bulk Data cards |

7. Nonlinear Analysis

| | |
|---|---|
| NLPARM | Selects parameters for nonlinear analysis |

### 2.3.2.3 Output Selection

1. Output Control

| | |
|---|---|
| → TITLE | Specifies text for first line on each printed page |
| → SUBTITLE | Specifies text for second line on each printed page |
| → LABEL | Specifies text for third line on each printed page |
| LINE | Sets the number of data lines per printed page - default is installation dependent, usually 50 lines/page |
| MAXLINES | Sets maximum number of output lines - default is 100,000 |
| → ECHØ | Selects echo options for Bulk Data Deck - default is sorted echo |
| SKIPØN | Defines cards in the Case Control Deck that are not to be processed |
| SKIPØFF | Resumes processing of cards in the Case Control Deck |
| ECHØØFF | Suppresses echo of Case Control Deck |
| ECHØØN | Reactivates echo of Case Control Deck |
| PAGE | Causes a page eject in echo of Case Control Deck |
| PLØTID | Specifies BCD identification for first frame of plotter output |

2. Set Definition

| | |
|---|---|
| SET | Defines lists of point numbers, element numbers, frequencies, or time steps for use in output requests |
| ØFREQUENCY | Selects a set of frequencies for output requests in frequency response problems |
| TSTEP | Selects time steps for output requests in transient response problems |
| ØTIME | Selects a subset of time steps for output requests in transient response problems |
| PARTN | Specifies a list of grid points for partitioning operations |

3. Physical Set Output Requests

| | |
|---|---|
| → DISPLACEMENT or VECTØR | Requests displacements for a set of physical points |
| SVECTØR | Requests solution set modal eigenvector output |
| VELØCITY | Requests velocities for a set of physical points |
| ACCELERATIØN | Requests accelerations for a set of physical points |

| | |
|---|---|
| → ELFØRCE or FØRCE | Requests the forces for a set of structural elements |
| STRESS → or ELSTRESS | Requests the stresses for a set of structural elements |
| GPSTRESS | Requests the stresses at grid points |
| STRFIELD | Requests the stresses at grid points for postprocessing |
| GPFØRCE | Requests grid point force balance for a set of grid points |
| ESE | Requests strain energy for a set of elements |
| FLUX | Requests the flux and gradient for a set of heat transfer elements |
| → SPCFØRCES | Requests the single-point forces of constraint for a set of points |
| → ØLØAD | Selects a set of applied loads for output in static analysis |
| PRESSURE | Requests hydroelastic pressure output for a set of points |
| THERMAL | Requests temperatures for a set of points in heat transfer analysis |
| NØUTPUT | Requests physical output in cyclic symmetry problems |

4. <u>Solution Set Output Requests</u>

| | |
|---|---|
| HARMØNICS | Specifies harmonics for output requests for conical shell and hyrdroeleastic problems |
| HØUTPUT | Requests harmonic output in cyclic symmetry problems |
| SDISPLACEMENT or SVECTØR | Requests the displacements of the independent components for a set of points or modal coordinates |
| SVELØCITY | Requests the velocities of the independent components for a set of points or modal coordinates |
| SACCELERATIØN | Requests the accelerations of the independent components for a set of points or modal coordinates |
| NLLØAD | Selects a set of nonlinear loads for output in transient response |
| MPRES | Requests the pressure for selected surface elements |

2.3.2.4 Superelement Control

| | |
|---|---|
| SUPER | Specifies superelement identification number and the load sequence number |
| SEMGENERATE | Specifies the superelement identification numbers for which stiffness, mass, and damping matrices will be generated |
| SEMASSEMBLE | Specifies the superelement identification numbers for which stiffness matrices will be assembled and reduced |
| SELGENERATE | Specifies the superelement identification numbers for which load vectors will be generated |

| | |
|---|---|
| SELASSEMBLE | Specifies the superelement identification numbers for which the static load, mass or damping matrices will be assembled and reduced |
| SEALL | Combines the functions of SEMGENERATE, SEMASSEMBLE, SELGENERATE and SELASSEMBLE |
| SEKREDUCE | Specifies the superelement identification numbers for which stiffness matrices will be assembled and reduced |
| SEMREDUCE | Specifies the superelement identification numbers for which the mass and damping matrices will be assembled and reduced |
| SELREDUCE | Specifies the superelement identification numbers for which the static load matrices will be assembled and reduced |
| SEFINAL | Specifies the superelement identification number of the last superelement to be assembled |
| SEEXCLUDE | Specifies the superelements which are not to be assembled ("excluded") into their downstream superelement |
| SEDR | Specifies the superelement identification numbers for which data recovery will be performed |

## 2.3.3 Case Control Card Descriptions

The format of the Case Control cards is free-field. In presenting general formats for each card embodying all options, the following conventions are used:

1. Upper-case letters must be punched as shown.
2. Lower-case letters indicate that a substitution must be made.
3. Braces { } indicate that a choice of contents is mandatory.
4. Brackets [ ] contain an option that may be omitted or included by the user.
5. Underlined options or values are the default values.
6. Physical card consists of information punched in columns 1 through 72 of a card. Most Case Control cards are limited to a single physical card.
7. Logical card may have more than 72 columns with the use of continuation cards.

If the first four characters of a mnemonic are unique relative to all other Case Control cards, the characters following can be omitted.

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5. Underlined options or values are the default values.
6. Physical card consists of information punched in columns 1 thru 72 of a card. Most case control cards are limited to a single physical card.
7. Logical card may have more than 72 columns with the use of continuation cards.

If the first four characters of a mnemonic are unique relative to all other case control cards, the characters following can be omitted.

Case Control Data Card DISPLACEMENT - Displacement Output Request.

Description: Requests form and type of displacement vector output.

Format and Example(s):

$$\text{DISPLACEMENT}\quad \left[\left(\frac{\text{SØRT1}}{\text{SØRT2}},\ \frac{\text{PRINT}}{\text{PUNCH}},\ \frac{\text{REAL}}{\frac{\text{IMAG}}{\text{PHASE}}},\ \text{PLØT}\right)\right] = \begin{Bmatrix}\text{ALL}\\ n\\ \text{NØNE}\end{Bmatrix}$$

DISPLACEMENT = 5

DISPLACEMENT(REAL) = ALL

DISPLACEMENT(SØRT2, PUNCH, REAL) = ALL

| Option | Meaning |
|---|---|
| SØRT1 | Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available on Transient problems (where the default is SØRT2). |
| SØRT2 | Output will be presented as a tabular listing of frequency or time for each grid point. SØRT2 is available only in Transient and Frequency Response problems. |
| PRINT | The printer will be the output media. |
| PUNCH | The card punch will be the output media. |
| REAL or IMAG | Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems. |
| PHASE | Requests magnitude and phase ($0.0° \leq$ phase $< 360.0°$) on Complex Eigenvalue or Frequency Response problems. |
| PLØT | Generate, but do not print, displacement data. |
| ALL | Displacements for all points will be output. |
| NØNE | Displacement for no points will be output. |
| n | Set identification of previously appearing SET card. Only displacements of points whose identification numbers appear on this SET card will be output (Integer > 0). |

Remarks:

1. Both PRINT and PUNCH may be requested.
2. On a Frequency Response problem any request for Physical Set SØRT2 causes all Physical Set output to be SØRT2.
3. VECTØR and PRESSURE are alternate forms and are entirely equivalent to DISPLACEMENT.
4. DISPLACEMENT = NØNE allows overriding an overall output request.
5. The PLØT option is used when curve plots are desired in the magnitude/phase representation and no printer output request is present for magnitude/phase representation.

Case Control Data Card ECHØ Bulk Data Echo Request

Description: Requests echo of Bulk Data Deck.

Format and Example(s):

ECHØ = [SØRT,UNSØRT,BØTH,NØNE,PUNCH,NØSØRT,SØRT(cdn1,cdn2,...)]

ECHØ = NØSØRT,UNSØRT

ECHØ = BØTH

ECHØ = SØRT(MAT1,PARAM)

| Option | Meaning |
|---|---|
| SØRT | Sorted echo will be printed. |
| UNSØRT | Unsorted echo will be printed. |
| BØTH | Both sorted and unsorted echo will be printed. |
| NØNE | No echo will be printed. |
| PUNCH | The sorted Bulk Data Deck will be punched. |
| NØSØRT | Blocks the printing of the sorted echo. This allows the user to obtain a listing of changed cards with CHKPNT but not get a sorted echo. |
| SØRT(cdn1,cdn2) | This requests that card types cdn1 and cdn2 only be echoed (along with their line numbers). Up to 26 card types may be echoed. (Continuation cards are included.) |

Remarks:

1. If no ECHØ card appears, a sorted echo will be printed.
2. If CHKPNT YES, a sorted echo will be printed unless ECHØ = NØNE or ECHØ = NØSØRT.
3. Comment cards will be punched at the front of the sorted deck if ECHØ = PUNCH.
4. Portions of the unsorted deck can be selectively echoed by including the cards ECHØØN and ECHØØFF at various places within the Bulk Data Deck and requesting an unsorted echo. ECHØØFF stops the unsorted echo until an ECHØØN card is encountered. Many such pairs of cards may be used.
5. If the SØRT(cdn1,cdn2,...) option is used, and the card images are recovered from the ØPTP, the continuation cards will not be printed.
6. If the SØRT(cdn1,cdn2,...) option is used, it must be last in the list.

Case Control Data Card ELFØRCE - Element Force Output Request.

Description: Requests form and type of element force output.

Format and Example(s):

ELFØRCE $\left[\left(\frac{\text{SØRT1}}{\text{SØRT2}}, \frac{\text{PRINT}}{\text{PUNCH}}, \frac{\text{REAL}}{\frac{\text{IMAG}}{\text{PHASE}}}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{matrix}\right\}$

ELFØRCE = ALL

ELFØRCE(REAL, PUNCH, PRINT) = 17

ELFØRCE = 25

| Option | Meaning |
|---|---|
| SØRT1 | Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available on Transient problems (where the default is SØRT2). |
| SØRT2 | Output will be presented as a tabular listing of frequency or time for each element type. SØRT2 is available only in Transient and Frequency Response problems. |
| PRINT | The printer will be the output media. |
| PUNCH | The card punch will be the output media. |
| REAL or IMAG | Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems. |
| PHASE | Requests magnitude and phase (0.0° < phase < 360.0°) on Complex Eigenvalue or Frequency Response problems. |
| ALL | Forces for all elements will be output. |
| NØNE | Forces for no elements will be output. |
| n | Set identification of a previously appearing SET card. Only forces of elements whose identification numbers appear on this SET card will be output (Integer > 0). |

Remarks:

1. Both PRINT and PUNCH may be requested.
2. ALL should not be used in a Transient problem.
3. On a Frequency Response problem, any request for Physical Set SØRT2 output causes all Physical Set output to be SØRT2.
4. FØRCE is an alternate form and is entirely equivalent to ELFØRCE.
5. ELFØRCE = NØNE allows overriding an overall request.

Case Control Data Card <u>ELSTRESS</u> - Element Stress Output Request.

<u>Description</u>: Requests form and type of element stress output.

<u>Format and Example(s)</u>:

$$\text{ELSTRESS}\quad \left[\left(\begin{matrix}\text{SØRT1}\\ \text{SØRT2}\end{matrix},\ \begin{matrix}\text{PRINT}\\ \text{PUNCH}\end{matrix},\ \begin{matrix}\text{REAL}\\ \text{IMAG}\\ \text{PHASE}\end{matrix},\ \text{PLØT}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{matrix}\right\}$$

ELSTRESS = 5

ELSTRESS = ALL

ELSTRESS(SØRT1, PRINT, PUNCH, PHASE) = 15

ELSTRESS(PLØT) = ALL

| Option | Meaning |
|---|---|
| SØRT1 | Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available on Transient problems (where the default is SØRT2). |
| SØRT2 | Output will be presented as a tabular listing of frequency or time for each element type. SØRT2 is available only in Transient and Frequency Response problems. |
| PRINT | The printer will be the output media. |
| PUNCH | The card punch will be the output media. |
| REAL or IMAG | Requests real and imaginary printout on Complex Eigenvalue or Frequency Response problems. |
| PHASE | Requests magnitude and phase (0.0° < phase < 360.0°) on Complex Eigenvalue or Frequency Response problems. |
| PLØT | Generates stresses for requested set but no printer output. |
| ALL | Stresses for all elements will be output. |
| n | Set identification of a previously appearing SET card (Integer > 0). Only stresses for elements whose identification numbers appear on this SET card will be output. |
| NØNE | Stress for no elements will be output. |

<u>Remarks</u>:

1. Both PRINT and PUNCH may be requested.
2. ALL should not be used in a Transient problem.
3. On a Frequency Response problem, any request for Physical Set SØRT2 output causes all Physical Set output to be SØRT2.
4. STRESS is an alternate form and is entirely equivalent to ELSTRESS.
5. ELSTRESS = NØNE allows overriding an overall output request.
6. The PLØT option is used when contour plots of stresses are requested, but no printer output of stresses is desired.

Case Control Data Card LABEL - Output Label

Description: Defines a BCD label which will appear on the third heading line of each page of printer output.

Format and Example(s):

LABEL = {Any BCD data}

LABEL = DEMØNSTRATIØN PRØBLEM

Remarks:

1. LABEL appearing at the subcase level will label output for that subcase only.
2. LABEL appearing before all subcases will label any outputs which are not subcase dependent.
3. If no LABEL card is supplied, the label line will be blank.
4. LABEL information is also placed on plotter output as applicable.

Case Control Data Card LØAD - External Static Load Set Selection.

Description: Selects the external static load set to be applied to the structural model.

Format and Example(s):

LØAD = n

LØAD = 15

| Option | Meaning |
|---|---|
| n | Set identification of at least one external load card and hence must appear on at least one FØRCE, FØRCE1, FØRCE2, FØRCEAX, GRAV, MØMAX, MØMENT, MØMENT1, MØMENT2, LØAD, PLØAD, PLØAD1, PLØAD2, PLØAD3, PLØADX, QVØL, QVECT, QHBDY, QBDY1, QBDY2, PRESAX, RFØRCE, or SLØAD card (Integer > 0) |

Remarks:

1. The above static load cards will not be used by NASTRAN unless selected in Case Control.
2. A GRAV card cannot have the same set identification number as any of the other loading card types. If it is desired to apply a gravity load along with other static loads, a LØAD bulk data card must be used.
3. LØAD is only applicable in statics, inertia relief, differential stiffness, buckling, piecewise linear problems, linear and nonlinear heat transfer problems.
4. The total load applied will be the sum of external (LØAD), thermal (TEMP(LØAD)), element deformation (DEFØRM) and constrained displacement (SPC) loads.
5. Static, thermal and element deformation loads should have unique set identification numbers.

Case Control Data Card MPC - Multipoint Constraint Set Selection.

Description: Selects the multipoint constraint set to be applied to the structural model.

Format and Example(s):

MPC = n

MPC = 17

| Option | Meaning |
|---|---|
| n | "n" is the set identification of a Multipoint-Constraint Set and hence must appear on at least one MPC or MPCADD card. (Integer > 0). |

Remarks: MPC or MPCADD cards will not be used by NASTRAN unless selected in Case Control.

Case Control Data Card ØLØAD    Applied Load Output Request

Description: Requests form and type of applied load vector output.

Format and Example(s):

$$\text{ØLØAD}\left[\left(\begin{matrix}\text{SØRT1}\\\text{SØRT2}\end{matrix}\;,\;\begin{matrix}\text{PRINT}\\\text{PUNCH}\end{matrix}\;,\;\begin{matrix}\text{REAL}\\\text{IMAG}\\\text{PHASE}\end{matrix}\right)\right] = \left\{\begin{matrix}\text{ALL}\\ n\\ \text{NØNE}\end{matrix}\right\}$$

ØLØAD = ALL

ØLØAD(SØRT1,PHASE) = 5

| Option | Meaning |
|---|---|
| SØRT1 | Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available on transient problems (where the default is SØRT2). |
| SØRT2 | Output will be presented as a tabular listing of frequency or time for each grid point. SØRT2 is available only in transient and frequency response problems. |
| PRINT | The printer will be the output media. |
| PUNCH | The card punch will be the output media. |
| REAL or IMAG | Requests real and imaginary output on complex eigenvalue or frequency response problems. |
| PHASE | Requests magnitude and phase (0.0° < phase < 360.0°) on complex eigenvalue or frequency response problems. |
| ALL | Applied loads for all points will be output. (SØRT1 will only output nonzero values.) |
| NØNE | Applied load for no points will be output. |
| n | Set identification of previously appearing SET card. Only loads on points whose identification numbers appear on this SET card will be output (Integer > 0). |

Remarks:

1. Both PRINT and PUNCH may be requested.
2. On a frequency response problem any request for SØRT2 causes all output to be SØRT2.
3. In a statics problem a request for SØRT2 causes loads at all points (zero and non-zero) to be output.
4. ØLØAD = NØNE allows overriding an overall output request.
5. In the statics superelement rigid formats, only externally applied loads are printed, and not loads transmitted from upstream superelements. Transmitted loads can be obtained with GPFØRCE requests.

Case Control Data Card <u>ØUTPUT</u> - Output Request Delimiter

<u>Description:</u> Delimits the various output requests, structure plotter, curve plotter, and printer/punch

<u>Format and Example(s):</u>

```
          ⎡⎛PLØT  ⎞⎤
          ⎢⎜PØST  ⎟⎥
ØUTPUT    ⎢⎜XYØUT ⎟⎥
          ⎢⎜XYPLØT⎟⎥
          ⎣⎝CARDS ⎠⎦
```

ØUTPUT

ØUTPUT(PLØT)

ØUTPUT(XYØUT)

| Option | Meaning |
|---|---|
| No qualifier | Beginning of printer output request - this is not a required card. |
| PLØT | Beginning of structure plotter request. This card must precede all structure plotter control cards. |
| PØST | Beginning of grid point stress output request. This card must precede all postprocessor control cards. |
| XTØUT or XYPLØT | Beginning of curve plotter request. This card must precede all curve plotter control cards. XYPLØT and XYØUT are entirely equivalent. |
| CARDS | Beginning of the deck of cards which will be placed on Data Block FØRCE in 20A4 format. These cards have <u>no</u> format rules applied. This package <u>must</u> terminate with the card ENDCARDS (starting in column 1). |

<u>Remarks:</u>

1. The structure plotter request and the curve plotter request must be at the end of the Case Control Deck.
2. The delimiting of a printer request is completely optional.
3. The ØUTPUT(CARDS) packet is currently used by the MSGSTRES Module. See the MSGMESH Analyst's Guide for details.

Case Control Data Card SET - Set Definition Card

Description: 1. Lists identification numbers (point or element) for output requests.

2. Lists the frequencies for which output will be printed in Frequency Response Problems.

Format and Example(s):

1) SET n = $\{i_1[, i_2, i_3$ THRU $i_4$ EXCEPT $i_5, i_6, i_7, i_8$ THRU $i_9]\}$

SET 77 = 5

SET 88 = 5, 6, 7, 8, 9, 10 THRU 55 EXCEPT 15, 16, 77,
78, 79, 100 THRU 300

SET 99 = 1 THRU 100000

2) SET n = $\{r_1[, r_2, r_3, r_4]\}$

SET 101 = 1.0, 2.0, 3.0

SET 105 = 1.009, 10.2, 13.4,
14.0, 15.0

3) SET n = ALL

| Option | Meaning |
|---|---|
| n | Set identification (Integer > 0). Any set may be redefined by reassigning its identification number. Sets inside SUBCASE delimiters are local to the SUBCASE. |
| $i_1$, $i_2$, etc. | Element or point identification number at which output is requested. (Integer $\geq$ 0). If no such identification number exists, the request is ignored. |
| $i_3$ THRU $i_4$ | Output at set identification numbers $i_3$ thru $i_4$ ($i_4 > i_3$). |
| EXCEPT | Set identifiction numbers following EXCEPT will be deleted from output list as long as they are in the range of the set defined by the immediately preceding THRU. |
| $r_1$, $r_2$, etc. | Frequencies for output (Real > 0.0). The nearest solution frequency will be output. EXCEPT and THRU cannot be used. |
| ALL | All members of the set will be processed. |

Remarks: 1. A SET card may be more than one physical card. A comma (,) at the end of a physical card signifies a continuation card. Commas may not end a set.

2. Set identification numbers following EXCEPT within the range of the THRU must be in ascending order.

Case Control Data Card SPC - Single-Point Constraint Set Selection.

Description : Selects the single-point constraint set to be applied to the structural model.

Format and Example(s):

SPC = n

SPC = 10

| Option | Meaning |
|---|---|
| n | Set identification of a single-point constraint set and hence must appear on a SPC, SPC1 or SPCADD card (Integer > 0). |

Remarks: SPC, SPC1 or SPCADD cards will not be used by NASTRAN unless selected in Case Control.

Case Control Data Card <u>SPCFØRCES</u> - Single-Point Forces of Constraint Output Request.

<u>Description</u>: Requests form and type of Single-Point Force of constraint vector output.

<u>Format and Example(s)</u>:

```
SPCFØRCES   [( SØRT1   PRINT   REAL  )]     ( ALL  )
            [( -----,  -----,  ----  )]  =  (  n   )
            [( SØRT2   PUNCH   IMAG  )]     ( NØNE )
            [(                 PHASE )]
```

SPCFØRCES = 5

SPCFØRCES(SØRT2, PUNCH, PRINT, IMAG) = ALL

SPCFØRCES(PHASE) = NØNE

| Option | Meaning |
|---|---|
| SØRT1 | Output will be presented as a tabular listing of grid points for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available on Transient problems (where the default is SØRT2). |
| SØRT2 | Output will be presented as a tabular listing of frequency or time for each grid point. SØRT2 is available only in Transient and Frequency Response problems. |
| PRINT | The printer will be the output media. |
| PUNCH | The card punch will be the output media. |
| REAL or IMAG | Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems. |
| PHASE | Requests magnitude and phase (0.0° ≤ phase < 360.0°) on Complex Eigenvalue or Frequency Response problems. |
| ALL | Single-Point forces of constraint for all points will be output. (SØRT1 will only output nonzero values.) |
| NØNE | Single point forces of constraint for no points will be output. |
| n | Set identification of previously appearing SET card. Only single-point forces constraint for points whose identification numbers appear on this SET card will be output (Integer > 0). |

<u>Remarks</u>:

1. Both PRINT and PUNCH may be requested.
2. On a Frequency Response problem any request for solution set SØRT2 output causes all solution set output to be SØRT2.
3. In a Statics problem a request for SØRT2 causes loads at all points (zero and non-zero) to be output.
4. SPCFØRCES = NØNE allows overriding an overall output request.

Case Control Data Card <u>STRESS</u> - Element Stress Output Request.

<u>Description</u>: Requests form and type of element stress output.

<u>Format and Example(s)</u>:

$$\text{STRESS} \quad \left[\left(\frac{\text{SØRT1}}{\text{SØRT2}}, \frac{\text{PRINT}}{\text{PUNCH}}, \begin{matrix}\underline{\text{REAL}}\\ \text{IMAG}\\ \text{PHASE}\end{matrix}, \text{PLØT}\right)\right] = \begin{Bmatrix}\text{ALL}\\ \text{n}\\ \text{NØNE}\end{Bmatrix}$$

STRESS = 5

STRESS = ALL

STRESS(SØRT1, PRINT, PUNCH, PHASE) = 15

STRESS(PLØT) = ALL

| <u>Option</u> | <u>Meaning</u> |
| --- | --- |
| SØRT1 | Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available on Transient problems (where the default is SØRT2). |
| SØRT2 | Output will be presented as a tabular listing of frequency or time for each element type. SØRT2 is available only in Transient and Frequency Response problems. |
| PRINT | The printer will be the output media. |
| PUNCH | The card punch will be the output media. |
| REAL or IMAG | Requests real and imaginary printout on Complex Eigenvalue or Frequency Response problems. |
| PHASE | Requests magnitude and phase (0.0° < phase < 360.0°) on Complex Eigenvalue or Frequency Response problems. |
| PLØT | Generates stresses for requested set but no printer output. |
| ALL | Stresses for all elements will be output. |
| n | Set identification of a previously appearing SET card (Integer > 0). Only stresses for elements whose identification numbers appear on this SET card will be output. |
| NØNE | Stress for no elements will be output. |

<u>Remarks</u>:

1. Both PRINT and PUNCH may be requested.
2. ALL should not be used in a Transient problem.
3. On a Frequency Response problem, any request for solution set SØRT2 output causes all solution set output to be SØRT2.
4. ELSTRESS is an alternate form and is entirely equivalent to STRESS.
5. STRESS = NØNE allows overriding an overall output request.
6. The PLØT option is used when contour plots of stresses are requested, but no printer output of stresses is desired.

Case Control Data Card **STRFIELD** Grid Point Stress Output Request for Postprocessing

**Description:** Requests grid point stresses for postprocessing

**Format and Example(s):**

$$\text{STRFIELD} = \begin{Bmatrix} \text{ALL} \\ n \end{Bmatrix}$$

STRFIELD = ALL

STRFIELD = 21

| Option | Meaning |
|---|---|
| ALL | Grid point stress requests for all SURFACEs defined in the ØUTPUT(PØST) section will be saved for postprocessing. |
| n | Set identification number of previously appearing SET card. Only SURFACEs whose identification numbers appear on this SET card and in the ØUTPUT(PØST) section will be included in the grid point stress output request for postprocessing. |

Case Control Data Card SUBCASE - Subcase Delimiter.

Description: Delimits and identifies a subcase.

Format and Example(s):

SUBCASE n

SUBCASE 101

| Option | Meaning |
|---|---|
| n | Subcase identification number (Integer > 0). |

Remarks: 1. The subcase identification number, n, must be strictly increasing (i.e., greater than all previous subcase identification numbers).

2. Plot requests and RANDØM requests refer to n.

Case Control Data Card <u>SUBTITLE</u> - Output Subtitle

Description: Defines a BCD subtitle which will appear on the second heading line of each page of printer output.

Format and Example(s):

SUBTITLE = {Any BCD data}

SUBTITLE = PRØBLEM NØ. 5-1A

Remarks:
1. SUBTITLE appearing at the subcase level will title output for that subcase only.
2. SUBTITLE appearing before all subcases will title any outputs which are not subcase dependent.
3. If no SUBTITLE card is supplied, the subtitle line will be blank.
4. SUBTITLE information is also placed on plotter output as applicable.

Case Control Data Card TITLE - Output Title.

Description: Defines a BCD title which will appear on the first heading line of each page of NASTRAN printer output.

Format and Example(s):

TITLE = { Any BCD data }

TITLE = **$// ABCDEFGHI .... $

Remarks:

1. TITLE appearing at the subcase level will title output for that subcase only.
2. TITLE appearing before all subcases will title any outputs which are not subcase dependent.
3. If no TITLE card is supplied, the title line will contain data and page numbers only.
4. TITLE information is also placed on NASTRAN plotter output as applicable.

BULK DATA

DECK

## 2.4 BULK DATA DECK

The primary NASTRAN input medium is the Bulk Data card. These cards are used to define the structural model and various pools of data which may be selected by Case Control at execution time. For large problems the Bulk Data Deck may consist of several thousand cards. In order to minimize the handling of large numbers of cards, provision has been made in NASTRAN to store the Bulk Data on the Problem Tape, from which it may be modified on subsequent runs. See the MSGMESH Analyst's Guide for information on the use of the MSGMESH Program for the generation of Bulk Data cards.

For any cold start, the entire Bulk Data Deck must be submitted. Thereafter, if the original run was checkpointed, the Bulk Data Deck exists on the Problem Tape in sorted form where it may be modified and reused on restart. On restart the Bulk Data cards contained in the Bulk Data Deck are added to the Bulk Data contained on the Old Problem Tape. Cards are removed from the Old Problem Tape by the use of a delete card. Cards to be deleted are indicated by inserting a Bulk Data card with a slash (/) in column one and the sorted bulk data sequence numbers in fields two and three. All bulk data cards in the range of the sequence numbers in fields two and three will be deleted. In the case where only a single card is deleted, field three may be left blank.

The Bulk Data Deck may be submitted with the cards in any order as a sort is performed prior to the execution of the Input File Processor. It should be noted that the machine time to perform this is minimized for a deck that is already sorted. The sort time for a badly sorted deck will become significant for large decks. The user may obtain a printed copy of either the unsorted or sorted bulk data by selection in the Case Control Deck. A sorted echo is necessary in order to make modifications on a secondary execution using the Problem Tape. This echo is automatically provided unless specifically suppressed by the user.

### 2.4.1 Format of Bulk Data Cards

Bulk Data cards may be prepared either in the form of 8 or 16 column fields, or as free-field cards. The 8-column format is indicated in the following diagram.

Small Field Bulk Data Card

| 1a | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10a |
|---|---|---|---|---|---|---|---|---|---|
| ←8→ | ←8→ | ←8→ | ←8→ | ←8→ | ←8→ | ←8→ | ←8→ | ←8→ | ←8→ |

The mnemonic is punched in field 1 beginning in column 1. Fields 2-9 are for data items. The only limitations in data items are that they must lie completely within the designated field, have no inbedded blanks, and must be of the proper type, i.e., blank, integer, real, double precision, or BCD. All real numbers, including zero, must contain a decimal point. The SEQGP and SEQEP cards use the decimal point in a special way. A blank will be interpreted as a real zero or integer zero as required. Real numbers may be encoded in various ways. For example, the real number 7.0 may be encoded as 7.0, .7E1, 0.7+1, 70.-1, .70+1, 7+0, etc. A double precision number must contain both a decimal point and an exponent with the character D such as 7.0D0. Double precision data values are allowed only in a few situations, such as on the PARAM card. BCD data values consist of one to eight alphanumeric characters, the first of which must be alphabetic.

Normally, field 10 is reserved for optional user identification. However, in the case of continuation cards, field 10 (except column 73 which is not referenced) is used in conjunction with field 1 of the continuation card as an identifier and, hence, must contain a unique entry. The continuation card contains the symbol + in column 1 followed by the same seven characters that appeared in columns 74-80 of field 10 of the card that is being continued. This allows the data to be submitted as an unsorted deck. BCD values used as continuation mnemonics cannot contain the symbols *, =, or $. Continuation mnemonics may be generated automatically for continuation cards which are in sorted order. This option is triggered by placing a + in column 73 of the parent card and leaving field 1 of the continuation cards blank. The program will then generate the unique continuation mnemonics. This option may not be used for bulk data cards submitted on restart runs.

The small field data card should be adequate for most applications. Occasionally, however, the input is generated by another computer program or is available in a form where a wider field would be desirable. For this case, the larger field format with a 16-character data field is provided. Each logical card consists of <u>two</u> physical cards as indicated in the following diagram:

<u>Large Field Bulk Data Card</u>

| 1a | 2 | 3 | 4 | 5 | 10a |
|---|---|---|---|---|---|
| ←8→ | ←16→ | ←16→ | ←16→ | ←16→ | ←8→ |
| **1b** | **6** | **7** | **8** | **9** | **10b** |
| ←8→ | ←16→ | ←16→ | ←16→ | ←16→ | ←8→ |

The large field card is denoted by placing the symbol * after the mnemonic in field 1a and some unique character configuration in the last 7 columns of field 10a. The second physical card contains the symbol * in column 1 followed by the same seven characters that appeared after column 73 in field 10a of the first card. The second card may in turn be used to point to a large or small field continuation card, depending on whether the continuation card contains the symbol * or the symbol + in column 1. The use of multiple and large field cards are illustrated in the following examples:

<u>Small Field Card with Small Field Continuation Card</u>

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| TYPE | | | | | | | | | QED123 |
| +ED123 | | | | | | | | | |

<u>Large Field Card</u>

| | | | | | |
|---|---|---|---|---|---|
| TYPE* | | | | | QED124 |
| *ED124 | | | | | |

<u>Large Field Card with Large Field Continuation Card</u>

| | | | | | |
|---|---|---|---|---|---|
| TYPE* | | | | | QED301 |
| *ED301 | | | | | QED302 |
| *ED302 | | | | | QED305 |
| *ED305 | | | | | |

<u>Large Field Card Followed by a Small Field Continuation Card and a Large Field Continuation Card</u>

<table>
<tr><td>TYPE*</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>QED402</td></tr>
<tr><td>*ED402</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>QED421</td></tr>
<tr><td>+ED421</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>QED361</td></tr>
<tr><td>*ED361</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>QED291</td></tr>
<tr><td>*ED291</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
</table>

<u>Small Field Card with Large Field Continuation Card</u>

<table>
<tr><td>TYPE</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>QED632</td></tr>
<tr><td>*ED632</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td>QED204</td></tr>
<tr><td>*ED204</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
</table>

The free-field format also includes a limited data generation capability. The following rules apply to the use of the free-field format:

1. Only small-field cards can be created.
2. Continuation cards are not generated automatically.
3. Data items must be separated with a comma or one or more blanks. A comma or equal sign must appear in the first ten columns of the card.
4. Duplication of fields from the preceding card is accomplished by coding the symbol = .
5. Duplication of all trailing fields from the preceding card is accomplished by coding the symbol == .
6. Incrementing a value from the previous card is indicated by coding *(i), where i is the value of the increment.
7. Repeated replication is indicated by coding =(n), where n is the number of card images to be generated using the values of the increments on the preceding card.

The following is an example of the use of free-field cards:

```
GRID,101,17,1.0,10.5,,17,3456
=,*(1),=,*(0.2),== $
=(3)
```

The above free-field cards will generate the following bulk data cards in the 8-column format:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| GRID | 101 | 17 | 1.0 | 10.5 | | 17 | 3456 | | |
| GRID | 102 | 17 | 1.2 | 10.5 | | 17 | 3456 | | |
| GRID | 103 | 17 | 1.4 | 10.5 | | 17 | 3456 | | |
| GRID | 104 | 17 | 1.6 | 10.5 | | 17 | 3456 | | |
| GRID | 105 | 17 | 1.8 | 10.5 | | 17 | 3456 | | |

### 2.4.2 Bulk Data Card Summary

This section contains a summary of all Bulk Data cards under the following headings:

Section 2.4.2.1 Geometry

→ 1. Grid Points
→ 2. Coordinate Systems
3. Scalar Points
4. Fluid Points
5. Axisymmetry
6. Cyclic Symmetry
7. Superelement/Substructuring

# BULK DATA DECK

## Section 2.4.2.2 Elements

→ 1. Elastic Line Elements
→ 2. Elastic Surface Elements
→ 3. Elastic Solid Elements
→ 4. Elastic Scalar Elements
5. Axisymmetric Elements
6. Rigid Elements
7. Mass Elements
8. Damping Elements
9. Fluid Elements
10. Heat Transfer
11. Dummy Elements
12. Nonlinear Elements

## Section 2.4.2.3 Materials

→ 1. Isotropic
2. Anisotropic
3. Temperature Dependent
4. Stress Dependent
5. Fluid

## Section 2.4.2.4 Constraints

→ 1. Single-Point Constraints
→ 2. Multipoint Constraints
3. Partitioning
4. Free-Body Supports
5. Component Mode Boundary Conditions
6. User Sets

## Section 2.4.2.5 Loads

→ 1. Static Loads
2. Dynamic Loads
3. Heat Transfer

## Section 2.4.2.6 Problem Control

1. Buckling Analysis
2. Eigenvalue Analysis
3. Cyclic Symmetry
4. Dynamics
5. Frequency Response
6. Random Response
7. Transient Response
8. Nonlinear Analysis

## Section 2.4.2.7 Miscellaneous

→ 1. Comments
2. Delete
→ 3. Parameters
→ 4. Direct Matrix Input
5. Tabular Input
6. Output Control
7. Matrix Assembly

Section 2.4.2.8 Bulk Data Generator (MSGMESH)

1. Grid Point Generation
2. Element Generation
3. Temperature Definition
4. Load and Constraint Definition
5. MSGMESH Control

See the MSGMESH Analyst's Guide for information regarding the generation of Bulk Data cards.

Section 2.4.2.9 Variance Analysis

See Section 2.8 of the MSC/NASTRAN Application Manual for a discussion of variance analysis.

Section 2.4.2.10 Aeroelastic Analysis

1. Aerodynamic Elements
2. Aerodynamic Data
3. Aerodynamic-Structure Connection

Section 2.4.2.11 Deleted bulk data cards

This section contains a summary of all bulk data cards which have been deleted.

2.4.2.1 Geometry

1. Grid Points

| | | |
|---|---|---|
| → | GRID | Grid point location, coordinate system selection |
| | GRIDB | Grid point location on boundary of axisymmetric fluid problem |
| → | GRDSET | Default options for GRID cards |
| → | SEQGP | Grid and scalar point number resequencing |

2. Coordinate Systems

| | | |
|---|---|---|
| → | CØRDiC | Cylindrical coordinate system definition |
| | CØRDiR | Rectangular coordinate system definition |
| | CØRDiS | Spherical coordinate system definition |
| | BEAMØR | Orientation default for CBEAM |
| | BARØR | Orientation default for CBAR |

3. Scalar Points

| | |
|---|---|
| SPØINT | Scalar point definition |
| EPØINT | Extra point definition for dynamics |
| GRIDS | Scalar degree of freedom for acoustic cavity analysis |
| GRIDF | Scalar degree of freedom for acoustic cavity analysis |
| → SEQGP | Grid and scalar point number resequencing |
| SEQEP | Extra point number resequencing |

4. Fluid Points

| | |
|---|---|
| GRIDB | Grid point location on RINGFL |
| RINGFL | Circle (fluid point) definition |
| GRIDF | Scalar degree of freedom for acoustic cavity analysis |
| GRIDS | Scalar degree of freedom for acoustic cavity analysis |
| FREEPT | Surface point location for data recovery |
| PRESPT | Pressure point location for data recovery |
| FSLIST | List of fluid points (RINGFL) on free surface boundary |
| SLBDY | List of slot points on interface between fluid and radial slots |

5. Axisymmetry

| | |
|---|---|
| AXIC | Defines number of harmonics for conical shell problem |
| AXIF | Defines parameters for axisymmetric fluid analysis |
| FLSYM | Axisymmetric symmetry control |
| AXSLØT | Defines parameters for acoustic cavity analysis |
| RINGAX | Ring location for conical shell problem |
| SECTAX | Sector location on RINGAX |
| PØINTAX | Point location on RINGAX |

6. Cyclic Symmetry

| | |
|---|---|
| CYAX | Defines grid points on axis of symmetry |
| CYJØIN | Defines boundary points of a segment |

7. Superelement Analysis

| | |
|---|---|
| GRID | Defines interior points for a superelement |
| SESET | Defines interior points for a superelement |
| CSUPEXT | Defines exterior points for a superelement |

| | |
|---|---|
| CSUPER | Defines grid point connections for identical or mirror-image superelement or superelements from an external source |
| SEQSEP | Used with CSUPER card to define internal sequence of degrees of freedom for mirror-image or identical superelements |
| RELEASE | Defines released degrees of freedoms for superelement exterior grid points |
| SEELT | Changes superelement membership of elements |

### 2.4.2.2 Elements

1. <u>Elastic Line Elements</u>

| | |
|---|---|
| CBAR | Connection definition for prismatic beam |
| PBAR | Property definition for CBAR |
| BARØR | Default for orientation and property for CBAR |
| BEAMØR | Default for orientation and property for CBEAM |
| CBEAM | Connection definition for general beam element |
| PBEAM | Property definition for CBEAM |
| CBEND | Connection definition for curved beam |
| PBEND | Propery definition for CBEND |
| CØNRØD | Connection and property definition for rod with axial and torsional stiffness |
| CRØD | Connection definition for rod with axial and torsional stiffness |
| PRØD | Property definition for CRØD |
| CTUBE | Connection definition for tube with axial and torsional stiffness |
| PTUBE | Property definition for CTUBE |

2. <u>Elastic Surface Elements</u>

| | |
|---|---|
| CTRIA3 | Connection definition for an isoparametric triangle with bending and membrane stiffness |
| PSHELL | Property definition for CTRIA3, CTRIA6, CQUAD4, and CQUAD8 |
| CTRIA6 | Connection definition for curved triangular shell element with six grid points |
| CQUAD4 | Connection definition for an isoparametric quadrilateral with bending and membrane stiffness |
| CQUAD8 | Connection definition for curved quadrilateral shell element with eight grid points |
| CSHEAR | Connection definition for shear panel |

| | |
|---|---|
| PSHEAR | Property definition for CSHEAR |
| PCØMP | Property definition for composite material laminate |
| → CQDMEM | Connection definition for quadrilateral membrane composed of constant strain triangles |
| → PQDMEM | Property definition for CQDMEM |

3. Elastic Solid Elements

| | |
|---|---|
| CTETRA | Connection definition for constant strain tetrahedron |
| → CPENTA | Connection definition for five-sided solid element with from six to fifteen grid points |
| CHEXAi | Defines six-sided solid element composed of tetrahedra |
| → CHEXA | Connection definition for six-sided solid element with from eight to twenty grid points |
| CHEX20 | Connection definition for isoparametric hexahedron with a maximum of twenty nodes |
| PHEX | Property definition for CHEX20 |
| → PSØLID | Property definition for CHEXA and CPENTA |

4. Elastic Scalar Elements

| | |
|---|---|
| → CELASi | Connection definition for scalar spring, also property definition for i=2 or 4 |
| PELAS | Property definition for CELAS1 or CELAS3 |
| GENEL | Element definition in terms of stiffness coefficients or deflection influence coefficients |

5. Axisymmetric Elements

| | |
|---|---|
| CCØNEAX | Connection definition for conical shell |
| PCØNEAX | Property definition for CCØNEAX |
| CTRIARG | Connection and property definition for constant strain triangular ring |
| CTRAPRG | Connection and property definition for trapezoidal ring |
| → CTRIAX6 | Connection and property definition for linear strain triangular ring |

6. Rigid Elements

| | |
|---|---|
| → RBAR | Defines rigid bar with six degrees of freedom at each end |
| RBE1 | Defines rigid body connected to an arbitrary number of grid points |
| RBE2 | Defines rigid body with independent degrees of freedom at a single grid point |
| RBE3 | Defines the motion at a "reference" grid point as the weighted average of the motions at a set of other grid points |
| RRØD | Defines pin-ended rigid rod |

| | |
|---|---|
| RSPLINE | Defines multipoint constraints for interpolation of displacements at grid points |
| RTRPLT | Defines rigid triangular plate |

7. Mass Elements

| | |
|---|---|
| CMASSi | Connection definition for scalar mass, also property definition for i = 2 or 4 |
| PMASS | Property definition for CMASS1 or CMASS3 |
| CØNM1 | Defines 6x6 mass matrix at a grid point |
| CØNM2 | Defines concentrated mass at a grid point |

8. Damping Elements

| | |
|---|---|
| CDAMPi | Connection definition for a scalar damper, also property definition for i = 2 or 4 |
| PDAMP | Property definition for CDAMP1 or CDAMP3 |
| CVISC | Connection definition for viscous damper element |
| PVISC | Property definition for CVISC |

9. Fluid Elements

| | |
|---|---|
| CAXIFi | Defines axisymmetric fluid element for acoustic cavity analysis |
| CFLUIDi | Defines axisymmetric fluid element |
| CSLØTi | Defines slot element for acoustic cavity analysis |
| ELIST | Defines wetted side of structural elements |

10. Heat Transfer Elements

| | |
|---|---|
| CHBDY | Connection definition for boundary element |
| PHBDY | Property definition for CHBDY |
| CFTUBE | Connection definition for FTUBE element |
| PFTUBE | Property definition for FTUBE element |

The following elastic elements may also be used as heat conduction elements:

| | |
|---|---|
| Linear | BAR, RØD, CØNRØD, TUBE, BEAM, BEND |
| Membrane | TRIA3, TRIA6, QUAD4, QDMEM, QUAD8 |
| Axisymmetric | TRIARG, TRAPRG |
| Solid | TETRA, HEXA, PENTA, HEXA1, HEXA2 |

11. Dummy Elements

| | |
|---|---|
| ADUMi | Attributes for CDUMi element |
| CDUMi | Connection definitions for user-defined element |

| | |
|---|---|
| PDUMi | Property definition for CDUMi |
| PLØTEL | Defines plot element |

12. Nonlinear Elements

| | |
|---|---|
| CGAP | Defines gap or frictional element |
| PGAP | Property definition for CGAP |

2.4.2.3 Materials

1. Isotropic

| | |
|---|---|
| → MAT1 | Defines elastic material properties |
| MAT4 | Defines thermal material properties |

2. Anisotropic

| | |
|---|---|
| MAT2 | Defines anisotropic material properties for two-dimensional element |
| MAT3 | Defines orthotropic material properties for TRIARG, TRAPRG and TRIAX6 elements |
| MAT5 | Defines anisotropic thermal material properties |
| MAT8 | Defines orthotropic material properties |
| MAT9 | Defines anisotropic material properties for isoparametric solid elements |

3. Temperature Dependent

| | |
|---|---|
| MATT1-5 | Table references for temperature-dependent MAT1 - MAT5 materials |
| MATT9 | Table references for temperature-dependent MAT9 materials |
| TEMP | Defines temperature at grid points |
| TEMPD | Specifies default temperature at grid points |
| TEMPPi | Defines temperature field for surface elements |
| TEMPRB | Defines temperature field for line elements |
| TEMPAX | Defines temperature field for conical shell problem |
| TABLEMi | Tabular functions for generating temperature-dependent material properties |

4. Stress Dependent

| | |
|---|---|
| MATS1 | Table references for stress-dependent MAT1 materials |
| TABLES1 | Defines tabular stress-strain function |

5. Fluid

| | |
|---|---|
| AXIF | Includes default values for mass density and bulk modulus |
| AXSLØT | Includes default values for mass density and bulk modulus |
| BDYLIST | Includes mass density at boundary |
| CFLUIDi | Includes mass density and bulk modulus |
| CSLØTi | Includes mass density and bulk modulus |
| FSLIST | Includes mass density at free surface |
| SLBDY | Includes mass density at interface between fluid and radial slots |
| MFLUID | Defines properties for incompressible fluid |

2.4.2.4 Constraints and Partitioning

1. Single-Point Constraints

| | |
|---|---|
| → SPC | Defines single-point constraints and enforced displacements |
| → SPC1 | Defines single-point constraints |
| → SPCADD | Defines a union of single-point constraint sets on SPC of SPC1 cards |
| SPCAX | Defines single-point constraints for conical shell problems |
| → GRID | Includes single-point constraint definition |
| GRID8 | Includes single-point constraint definition |
| → GRDSET | Includes default for single-point constraints |
| FLSYM | Symmetry control for boundary in axisymmetric fluid problem |

2. Multipoint Constraints

| | |
|---|---|
| → MPC | Defines a linear relationship for two or more degrees of freedom |
| MPCADD | Defines a union of multipoint constraint sets on MPC cards |
| MPCAX | Defines multipoint constraints for conical shell problems |
| PØINTAX | Program generates MPC equations for point on conical shell |
| RBAR | Program generates MPC equations for rigid bar |
| RBE1-3 | Program generates MPC equations for RBE1, RBE2, RBE3 |
| RRØD | Program generates MPC equations for rigid rod |
| RSPLINE | Program generates MPC equations for spline element |
| RTRPLT | Program generates MPC equations for rigid triangular plate |

3. Partitioning

| | |
|---|---|
| ASET | Defines independent degrees of freedom in analysis set |
| ASET1 | Defines independent degrees of freedom in analysis set |
| ØMIT | Defines dependent degrees of freedom in omitted set |
| ØMIT1 | Defines dependent degrees of freedom in omitted set |
| ØMITAX | Defines omitted degrees of freedom for conical shell problems |
| GRID | Defines interior points for a superelement |
| SESET | Defines interior points for a superelement |
| CSUPEXT | Defines exterior points for a superelement |

4. Free Body Supports

| | |
|---|---|
| SUPØRT | Defines coordinates for determinate reactions |
| SUPAX | Defines determinate reactions for conical shell problems |
| CYSUP | Defines determinate reactions for cyclic symmetry problems |

5. Component Mode Boundary Conditions

| | |
|---|---|
| BSET | Defines fixed boundary points for residual structure |
| BSET1 | Defines fixed boundary points for residual structure |
| CSET | Defines free boundary points for residual structure |
| CSET1 | Defines free boundary points for residual structure |
| QSET | Defines generalized coordinates for residual structure |
| QSET1 | Defines generalized coordinates for residual structure |
| SEBSET | Defines fixed boundary points for superelement |
| SEBSET1 | Defines fixed boundary points for superelement |
| SECSET | Defines free boundary points for superelement |
| SECSET1 | Defines free boundary points for superelement |
| SEQSET | Defines generalized coordinates for superelement |
| SEQSET1 | Defines generalized coordinates for superelement |
| SESUP | Defines free boundary points used as references for rigid body modes for superelement |

6. User Sets

| | |
|---|---|
| DEFUSET | Defines names for user sets |
| SEUSET | Defines superelement user sets |

| | |
|---|---|
| SEUSET1 | Defines superelement user sets |
| USET | User set definition |
| USET1 | User set definition |

### 2.4.2.5 Loads

1. Static Loads

| | |
|---|---|
| DEFØRM | Enforced axial deformation for line elements |
| → FØRCE | Defines concentrated load at grid point |
| → FORCEi | Defines concentrated load at grid point |
| → GRAV | Defines gravity load vector |
| MØMENT | Defines moment at grid point |
| MØMENTi | Defines moment at grid point |
| PLØAD | Defines pressure load on an area |
| → PLØAD1 | Defines distributed and concentrated loads on BAR, BEAM, and BEND elements |
| → PLØAD2 | Defines pressure loads on surface elements |
| → PLØAD3 | Defines pressure loads on surfaces of HEX20 element |
| → PLØAD4 | Defines pressure loads on surfaces of HEXA, PENTA, TRIA3, QUAD4 and QUAD8 elements |
| → PLØADX | Defines pressure load on TRIAX6 |
| RFØRCE | Defines load due to centrifugal force field |
| SPCD | Defines value for enforced displacement |
| SLØAD | Defines load on scalar point |
| → LØAD | Linear combination of static load sets |
| TEMP | Defines temperature at grid points |
| TEMPD | Specifies default temperature at grid points |
| TEMPPi | Defines temperature field for surface elements |
| TEMPRB | Defines temperature field for line elements |
| FØRCEAX | Defines concentrated load for conical shell problem |
| MØMAX | Defines moment for conical shell problem |
| PRESAX | Defines pressure load for conical shell problem |

| | |
|---|---|
| TEMPAX | Defines temperature field for conical shell problem |
| LØADCYH | Defines harmonic coefficients of static load in cyclic symmetry analysis |
| LØADCYN | Defines physical load input in cyclic symmetry analysis |
| LØADCYT | Defines load input for AXI type cyclic symmetry problems |

2. Dynamic Loads

| | |
|---|---|
| DAREA | Dynamic load scale factor definition |
| DELAY | Dynamic load function time delay definition |
| DPHASE | Dynamic load function phase lead definition |
| RLØADi | Frequency dependent load definition |
| TLØADi | Time dependent load definition |
| NØLINi | Nonlinear transient load definition |
| TABLEDi | Tabular functions for generating dynamic loads |
| DLØAD | Linear combination of dynamic load sets |
| LØADCYH | Defines harmonic coefficients of dynamic load in cyclic symmetry analysis |
| LØADCYN | Defines physical load input in cyclic symmetry analysis |
| LSEQ | Defines static load sets for dynamic analysis |

3. Heat Transfer

| | |
|---|---|
| NFTUBE | Defines nonlinear transient load for heat convection |
| NØLINS | Defines nonlinear transient radiant heat transfer |
| QHBDY | Defines uniform heat flux into a set of grid points |
| QBDY1 | Defines uniform heat flux into HBDY element |
| QBDY2 | Defines grid point heat flux into HBDY element |
| QVECT | Defines thermal vector flux from distant source into HBDY element |
| QVØL | Defines internal heat generation |
| RADLST | Defines list of radiation areas |
| RADMTX | Defines matrix of radiation exchange coefficients |
| TEMP | Defines temperature at grid points |
| TEMPD | Specifies default temperature at grid points |
| VIEW | Defines shading and submesh sizes for radiation exchange calculations |

### 2.4.2.6 Problem Control

1. Buckling Analysis

   EIGB Defines eigenvalue extraction data

2. Eigenvalue Analysis

   EIGR Defines real eigenvalue extraction data

   EIGC Defines complex eigenvalue extraction data

   EIGP Defines poles for complex eigenvalue analysis

   TABDMP1 Defines structural damping as a tabular function of frequency

3. Cyclic Symmetry

   CYSYM Defines cyclic symmetry parameters

4. Dynamics

   DYNRED Defines data for dynamic reduction

5. Frequency Response

   FREQ List of frequencies for problem solution

   FREQi Defines a set of frequencies for problem solution

   TABDMP1 Defines structural damping as a tabular function of frequency

6. Random Response

   RANDPS Defines load set power spectral density factors

   RANDT1 Defines time lag constants for use in autocorrelation function computation

   TABRND1 Defines power spectral density as a tabular function of frequency

7. Transient Response

   TIC Specifies initial values for displacement and velocity

   TSTEP Specifies time step intervals for solution and output

8. Nonlinear Analysis

   NLPARM Defines parameters for nonlinear analysis

### 2.4.2.7 Miscellaneous

1. Comments

   → $ For inserting comment cards in unsorted echo of Bulk Data Deck

2. Delete

| | |
|---|---|
| / | For removing cards from the Bulk Data Deck on restart |

3. Parameters

| | |
|---|---|
| → PARAM | Specifies values for parameters used in DMAP sequences or rigid formats |

4. Direct Matrix Input

| | |
|---|---|
| CØNM1 | Define 6x6 mass matrix at a grid point |
| → DMI | User-defined direct matrix input |
| DMIG | Direct matrix input related to grid points |
| DMIAX | Direct matrix input for fluid analysis |
| TF | Defines dynamic transfer function |

5. Tabular Input

| | |
|---|---|
| DTI | User-defined direct table input |
| TABDMP1 | Defines structural damping as a tabular function of frequency |
| TABLEDi | Tabular functions for generating dynamic loads |
| TABLEMi | Tabular functions for generating temperature-dependent material properties |
| TABLES1 | Defines tabular stress-strain function |
| TABRND1 | Defines power spectral density as a tabular function of frequency |

6. Output Control

| | |
|---|---|
| CBARAØ | Defines auxiliary output points along axis of BAR element |
| FREEPT | Surface point location for data recovery in hydroelastic problems |
| PLØTEL | Defines dummy element for plotting |
| PØINTAX | Defines point on conical shell ring (RINGAX) for recovery of displacements |
| PRESPT | Pressure point location for data recovery in hydroelastic problems |
| SET1 | Defines a set of grid points |
| TSTEP | Specifies time step intervals for data recovery in transient response |

7. Matrix Assembly

| | |
|---|---|
| CNGRNT | Specifies congruent elements |

### 2.4.2.8 Bulk Data Generator (MSGMESH)

See the MSGMESH Analyst's Guide for the MSGMESH bulk data cards.

1. Grid Point Generation

| | |
|---|---|
| ACTIVE | Replaces (activates) a group of grid points in a grid point field by grid points in another grid point field |
| DELETE | Deletes a set of grid points within a grid field |
| DISTØRT | Modifies grid point location entries on generated GRID card |
| EGRID | Defines grid points for use by MSGMESH program |
| EQUIV | Equivalences (replaces) grid point identifications or activates automatic equivalence option |
| GRIDG | Defines a field of grid points and generates GRID cards |
| GRIDMØD | Modifies entries on generated GRID cards that do not affect grid point locations |
| GRIDU | Defines a user-defined grid point field |
| INSECT | Generates EGRID cards on the intersection of surfaces |
| LIST | Describes an unequal spacing of grid points in a GRIDG field |
| MAREA | Defines an active grid point area for automatic equivalencing |
| MLINE | Defines an active grid point line for automatic equivalencing |
| MPØINT | Defines a common grid point for automatic equivalencing |
| RENAME | Replaces (renumbers) a group of grid points in a grid point field by grid points in another or the same grid point field |

2. Element Generation

| | |
|---|---|
| CBARG | Generates CBAR cards |
| CGEN | Generates element connection cards |
| PGEN | Specifies property identificaiton numbers for generated connection cards |
| PLØTE | Generates PLØTEL cards which form the outlines of element sets |
| PLØTG | Generates PLØTEL cards which form the outlines of grid point fields |
| RSPLING | Generates a logical RSPLINE card that interconnects grid fields of different mesh sizes |
| TRICØN | Generates triangular elements that fill the space between two fields of different mesh sizes |

3. Temperature Definition

| | |
|---|---|
| ETEMP | Defines temperatures at the vertices of a grid point field |
| TEMPG | Generates TEMP cards for a grid point field |

4. Load and Constraint Definition

PLØADG Generates PLØAD or PLØAD3 cards for a grid point field

SPCG Generates SPC1 cards for a subset of grid points within a grid point field

5. MSGMESH Control

MESHØFF Suppresses the generation of bulk data cards

MESHØN Overrides a previous MESHØFF card

MESHØPT Controls MSGMESH output options and selects location numbers for HEX fields

PLØTØPT Selects MSGMESH plot options

2.4.2.9 Variance Analysis

VARIAN Deviation values for variance analysis

1PARM Parameter values for variance analysis

1VARY Functional relationships for variance analysis

2.4.2.10 Aeroelastic Analysis

See the Aeroelastic Supplement for the aeroelastic bulk data cards.

1. Aerodynamic Elements

AEFACT Specifies lists of real numbers

CAERØ1 Connection definition for aerodynamic panel

CAERØ2 Connection definition for aerodynamic body

CAERØ4 Connection definition for aerodynamic macro-strip

PAERØ1 Defines associated bodies for panels

PAERØ2 Property definition for aerodynamic bodies

PAERØ4 Property definition for strip elements

2. Aerodynamic Data

AERØ Specifies aerodynamic parameters

FLFACT Specifies aerodynamic data for flutter analysis

FLUTTER Specifies aerodynamic data for flutter analysis

Input Data Card $ Comment

Description: For user convenience in inserting commentary material into the unsorted echo of his input Bulk Data Deck. The $ card is otherwise ignored by the program. These cards will not appear in a sorted echo nor will they exist on the New Problem Tape.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| $ | followed | by any | legitimate | characters | in card | columns | 2-80 | | |
| $ | THIS IS | A REMARK | (*,'$$)-+/ | | | | | | |

Input Data Card CBAR Simple Beam Element Connection

Description: Defines a simple beam element (BAR) of the structural model.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CBAR | EID | PID | GA | GB | X1,GO | X2 | X3 | X | |
| CBAR | 2 | 39 | 7 | 3 | 13 | | | | 123 |
| | PA | PB | W1A | W2A | W3A | W1B | W2B | W3B | |
| +23 | | 513 | | | | | | | |

| Field | Contents |
|---|---|
| EID | Unique element identification number (Integer > 0). |
| PID | Identification number of a PBAR property card (Default is EID unless BARØR card has nonzero entry in field 3)(Integer > 0 or blank *). |
| GA,GB | Grid point identification numbers of connection points (Integer > 0; GA ≠ GB). |
| X1,X2,X3 | Components of vector v, at end A, (Figure 1(a) in Section 1.3) measured at end A, parallel to the components of the displacement coordinate system for GA, to determine (with the vector from end A to end B) the orientation of the element coordinate system for the BAR element (Real, 0 or blank*). |
| GO | Grid point identification number to optionally supply X1, X2, X3 (Integer > 0 or blank*). Direction of orientation vector is GA to GO. |
| PA,PB | Pin flags for bar ends A and B, respectively (up to 5 of the unique digits 1 - 6 anywhere in the field with no imbedded blanks; Integer > 0). Used to remove connections between the grid point and selected degrees of freedom of the bar. The degrees of freedom are defined in the element's coordinate system (see Figure 1(a), Section 1.3). The bar must have stiffness associated with the pin flag. For example, if PA=4 is specified, the PBAR card must have a value for J, the torsional stiffness. |
| W1A,W2A,W3A<br>W1B,W2B,W3B | Components of offset vectors wa and wb, respectively (see Figure 1(a), Section 1.3), in displacement coordinate systems at points GA and GB, respectively (Real or blank). |

*See the BARØR card for default options for fields 3 and 6 - 8.

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.

2. For an explanation of BAR element geometry, see Section 1.3.2.

3. If there are no pin flags or offsets, the continuation card may be omitted.

4. The old CBAR card used field 9 for a flag, F, which was used to specify the nature of fields 6 - 8 as follows:

| FIELD | 6 | 7 | 8 |
|---|---|---|---|
| F=1 | X1 | X2 | X3 |
| F=2 | GO | Blank or 0 | Blank or 0 |
| F=blank | Provided by BARØR card. | | |

This data item is no longer required but may continue to be used if desired (See Remark 5). If F=1 in field 9, a zero (0) in field 6, 7, or 8 will override entries on the BARØR card, but a blank will not.

5. For the case where field 9 is blank and not provided by the BARØR card, if X1,GO is integer, then GO is used; if X1,GO is blank or real, then X1, X2, X3 is used.

Input Data Card CBEAM Beam Element Connection

Description: Defines a beam element (BEAM) of the structural model.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CBEAM | EID | PID | GA | GB | X1,GO | X2 | X3 | | |
| CBEAM | 2 | 39 | 7 | 3 | 13 | | | | 123 |
| | PA | PB | W1A | W2A | W3A | W1B | W2B | W3B | |
| +23 | | 513 | | | 3.0 | | | | 234 |
| | SA | SB | | | | | | | |
| +34 | 8 | 5 | | | | | | | |

Field — Contents

EID — Unique element identification number (Integer > 0)

PID — Identification number of PBEAM property card (default is EID)(Integer > 0 or blank*)

GA.GB — Grid point identification numbers of connection points (Integer > 0; GA ≠ GB)

X1,X2,X3 — Components of vector v, at end A (shown in the following figure), measured at the offset point for end A, parallel to the components of the displacement coordinate system for GA, to determine (with the vector from offset end A to offset end B) the orientation of the element coordinate system for the beam element (Real or blank;* see Remark 3)

GO — Grid point identification number to optionally supply X1, X2, X3 (Integer > 0 or blank;* see Remark 3)

PA,PB — Pin flags for beam ends A and B respectively (Up to five of the unique digits 1 - 6 with no imbedded blanks; integer > 0). Used to move connections between the grid point and selected degrees of freedom of the beam. The degrees of freedom are defined in the element's coordinate system and the pin flags are applied at the offset ends of the beam (see the following figure). The beam must have stiffness associated with the pin flag. For example, if PA=4, the PBEAM card must have a nonzero value for J, the torsional stiffness.

W1A,W2A,W3A W1B,W2B,W3B — Components of offset vectors, measured in the displacement coordinate systems at grid points A and B, from the grid points to the end points of the axis of shear center (Real or blank)

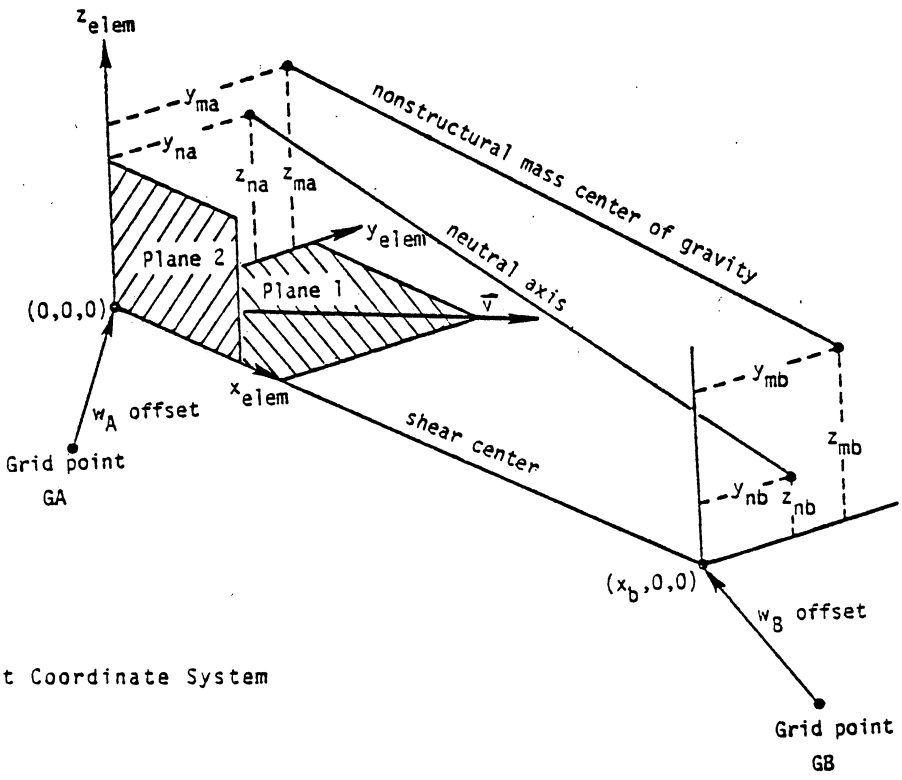
SA,SB — Scalar or grid point identification numbers for the ends A and B, respectively. The degrees of freedom at these points are the warping variables, dθ/dx (Integers > 0 or both blank).

*See the BEAMØR card for default options for fields 3 and 6 - 8.

(Continued)

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. For an explanation of beam element geometry, see Section 1.3.2.
3. If X1,G0 is integer, then G0 is used. If X1,G0 is blank or real, then X1,X2,X3 is used.
4. G0 ≠ GA or GB.
5. If there are no pin flags or offsets or warping variables, both continuation cards may be omitted.
6. The first continuation card must be included, even if all fields are blank, if the second continuation card is used.
7. If the second continuation card is omitted, torsional stiffness due to warping of the cross-section will not be considered.
8. If warping is allowed (SA and SB > 0), then SA and SB must be defined with SPØINT or GRID cards. If GRID cards are used, the warping degree of freedom is attached to the first (T1) component.




Element Coordinate System

Input Data Card CELAS2 Scalar Spring Property and Connection

Description: Defines a scalar spring element of the structural model without reference to a property card.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CELAS2 | EID | K | G1 | C1 | G2 | C2 | GE | S | |
| CELAS2 | 28 | 6.2+3 | 32 | | 19 | 4 | | | |

| Field | Contents |
|---|---|
| EID | Unique element identification number (Integer > 0) |
| K | The value of the scalar spring(Real) |
| G1, G2 | Geometric grid point identification number (Integer $\geq$ 0) |
| C1, C2 | Component number (6 $\geq$ Integer $\geq$ 0) |
| GE | Damping coefficient (Real) |
| S | Stress coefficient (Real) |

Remarks:

1. Scalar points may be used for G1 and/or G2 in which case the corresponding C1 and/or C2 must be zero or blank. Zero or blank may be used to indicate a grounded terminal G1 or G2 with a corresponding blank or zero C1 or C2. A grounded terminal is a point whose displacement is constrained to zero. If only scalar points and/or ground are involved, it is more efficient to use the CELAS4 card.

2. Element identification numbers must be unique with respect to all other element identification numbers.

3. This single card completely defines the element since no material or geometric properties are required.

4. The two connection points (G1, C1) and (G2, C2), must be distinct.

5. For a discussion of the scalar elements, see Section 5.6 of the Theoretical Manual.

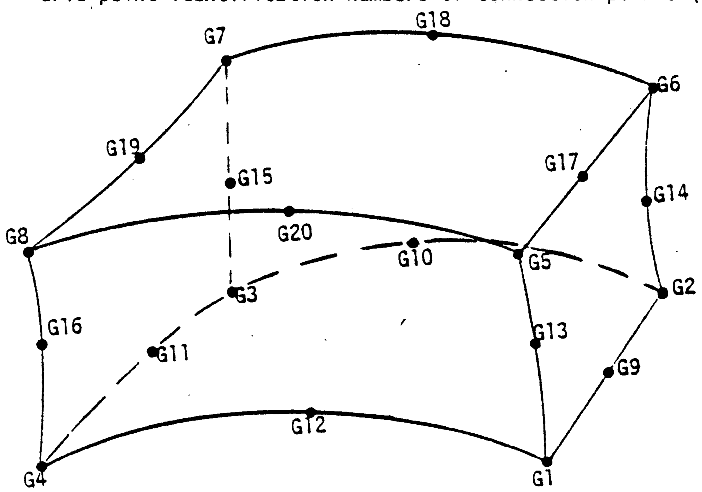
Input Data Card CHEXA Six-sided Solid Element with from Eight to Twenty Grid Points

Description: Defines the connections of the HEXA solid element.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CHEXA | EID | PID | G1 | G2 | G3 | G4 | G5 | G6 | |
| CHEXA | 71 | 4 | 3 | 4 | 5 | 6 | 7 | 8 | ABC |
| | G7 | G8 | G9 | G10 | G11 | G12 | G13 | G14 | |
| +BC | 9 | 10 | 0 | 0 | 30 | 31 | 53 | 54 | DEF |
| | G15 | G16 | G17 | G18 | G19 | G20 | | | |
| +EF | 55 | 56 | 57 | 58 | 59 | 60 | | | |

| Field | Contents |
|---|---|
| EID | Element identification number (Integer > 0) |
| PID | Identification number of a PSØLID property card (Integer > 0) |
| G1,...,G20 | Grid point identification numbers of connection points (Integer $\geq$ 0 or blank) |




Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.

2. Grid points G1, ..., G4 must be given in consecutive order about one quadrilateral face. G5, ..., G8 must be on the opposite face with G5 opposite G1, G6 opposite G2, etc.

3. The edge points, G9 to G20, are optional. Any or all of them may be deleted. If the ID of any edge connection point is left blank or set to zero (as for G9 and G10 in the example), the equations of the element are adjusted to give correct results for the reduced number of connections. Corner grid points can not be deleted. The element is an isoparametric element (with shear correction) in all cases.

4. Components of stress are output in the material coordinate system.

5. The second continuation card is not required.

(Continued)

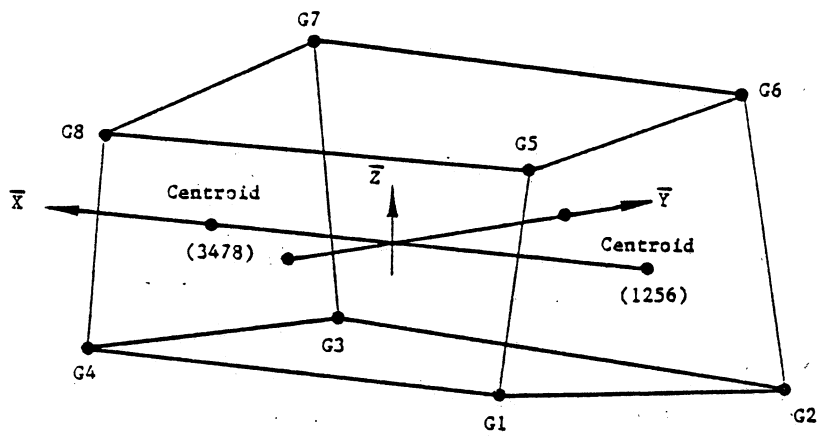
CHEXA (Cont.)

6. The element coordinate system for the HEXA element is defined in terms of the three face-to-face lines. The axes are chosen by the following rules:

   $\overline{X}$ axis: Longest line joining centroids of opposite faces.

   $\overline{XY}$ plane: Plane containing longest and next longest lines joining centroids of opposite faces.

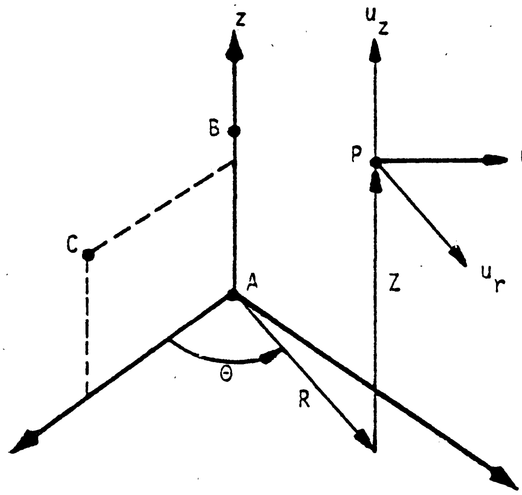
   XYZ axes: Permute $\overline{XYZ}$ axes to make X-axis approximately parallel to edge 1-2 and Y-axis approximately parallel to edge 1-4. In the example shown, $X = \overline{Y}$, $Y = \overline{X}$, $Z = \overline{Z}$.




7. It is recommended that the edge points be located within the middle third of the edge. If the edge point is located at the quarter point, the calculated stresses will be meaningless.

Input Data Card CØRD2C Cylindrical Coordinate System Definition, Form 2

Description: Defines a cylindrical coordinate system by reference to the coordinates of three points. The first point defines the origin. The second point defines the direction of the z-axis. The third lies in the plane of the azimuthal origin. The reference coordinate system must be independently defined.




Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CØRD2C | CID | RID | A1 | A2 | A3 | B1 | B2 | B3 | ABC |
| CØRD2C | 3 | 17 | -2.9 | 1.0 | 0.0 | 3.6 | 0.0 | 1.0 | 123 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| +BC | C1 | C2 | C3 | | | | | | |
| +23 | 5.2 | 1.0 | -2.9 | | | | | | |

| Field | Contents |
|---|---|
| CID | Coordinate system identification number (Integer > 0) |
| RID | Reference to a coordinate system which is defined independently of new coordinate system (Integer ≥ 0 or blank) |
| A1,A2,A3<br>B1,B2,B3<br>C1,C2,C3 | Coordinates of three points in coordinate system defined in field 3 (Real) |

(continued)

CØRD2C (cont.)

Remarks:

1. Continuation card must be present.
2. The three points (A1, A2, A3), (B1, B2, B3), (C1, C2, C3) must be unique and noncollinear. Noncollinearity is checked by the geometry processor.
3. Coordinate system identification numbers on all CØRD1R, CØRD1C, CØRD1S, CØRD2R, CØRD2C, and CØRD2S cards must all be unique.
4. An RID of zero references the basic coordinate system.
5. The location of a grid point (P in the sketch) in this coordinate system is given by (R, θ, Z) where θ is measured in degrees.
6. The displacement coordinate directions at P are dependent on the location of P as shown above by ($u_r$, $u_\theta$, $u_z$).
7. Points on the z-axis may not have their displacement direction defined in this coordinate system since an ambiguity results.

Input Data Card <u>CPENTA</u> Five-sided Solid Element with from 6 to 15 grid points

<u>Description</u>: Defines the connections of the CPENTA element.

<u>Format and Example</u>:

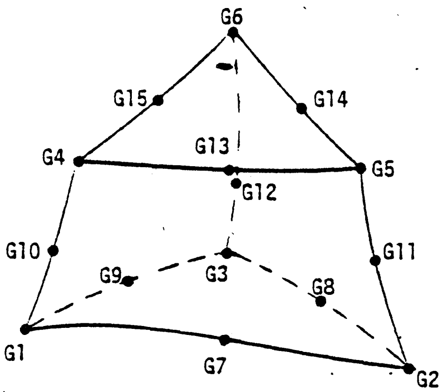
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CPENTA | EID | PID | G1 | G2 | G3 | G4 | G5 | G6 | |
| CPENTA | 112 | 2 | 3 | 15 | 14 | 4 | 103 | 115 | ABC |
| | G7 | G8 | G9 | G10 | G11 | G12 | G13 | G14 | |
| +BC | 5 | 16 | 8 | | | | 120 | 125 | BCD |
| | G15 | | | | | | | | |
| +CD | 130 | | | | | | | | |

<u>Field</u> <u>Contents</u>

EID Element identification number (Integer > 0)

PID Identification number of a PSØLID property card (Integer > 0).

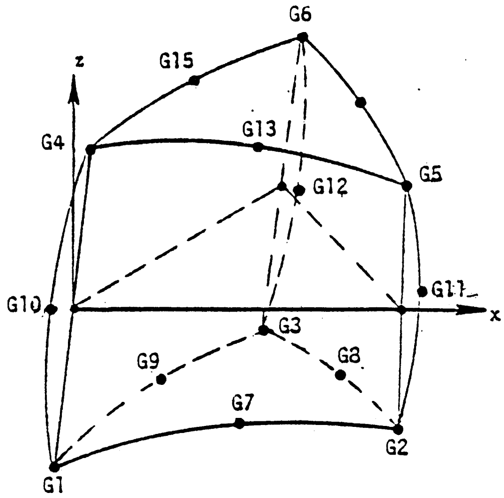
G1 - G15 Identification numbers of connected grid points (Integer $\geq$ 0 or blank)




<u>Remarks</u>:

1. Element ID numbers must be unique with respect to all other element ID numbers.
2. The topology of the diagram must be preserved, i.e., G1, G2, G3 define a triangular face, G1, G10 and G4 are on the same edge, etc.
3. The edge grid points, G7 to G15, are optional. Any or all of them may be deleted. In the example shown, G10, G11 and G12 have been deleted. The continuation cards are not required if all edge grid points are deleted.
4. Components of stress are output in the material coordinate system.
5. The element coordinate system is defined as follows:

(Continued)




where the x-axis joins the midpoints of straight lines joining points G1-G4 and G2-G5, and the z-axis is normal to a plane passing through the midpoints of straight lines joining G1-G4, G2-G5 and G3-G6.

6. It is recommended that the edge points be located within the middle third of the edge. If the edge point is located at the quarter point, the calculated stresses will be meaningless.

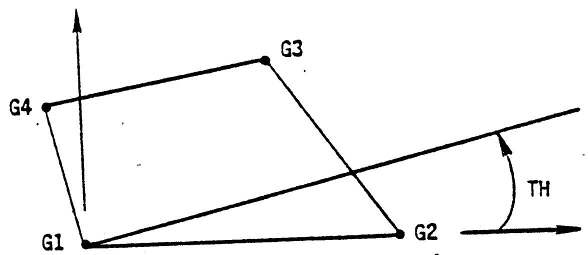
Input Data Card CQDMEM Quadilateral Element Connection

Description: Defines a quadrilateral membrane element (QDMEM) of the structural model consisting of four overlapping triangular membrane elements.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CQDMEM | EID | PID | G1 | G2 | G3 | G4 | TH | | |
| CQDMEM | 72 | 13 | 13 | 14 | 15 | 16 | 29.2 | | |

| Field | Contents |
|---|---|
| EID | Element identification number (Integer > 0) |
| PID | Identification number of a PQDMEM property card (Default is EID) (Integer > 0) |
| G1,G2,G3,G4 | Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2 ≠ G3 ≠ G4) |
| TH | Material property orientation angle in degrees (Real). The sketch below gives the sign convention for TH. |




Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. Grid points G1 thru G4 must be ordered consecutively around the perimter of the element.
3. All interior angles must be less than 180°.
4. This element is for heat transfer. The QUAD4 element should be used for structural problems.
5. This element may also be used for differential stiffness applications with membrane stiffness only.

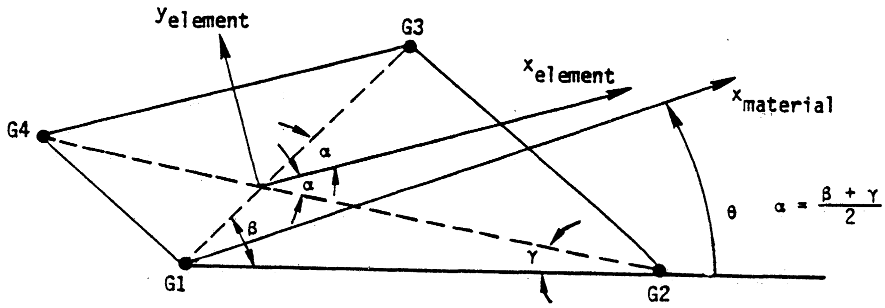
Input Data Card <u>CQUAD4</u> Quadrilateral Element Connection

<u>Description:</u> Defines a quadrilateral plate element (QUAD4) of the structural model. This is an isoparametric membrane-bending element.

<u>Format and Example:</u>

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CQUAD4 | EID | PID | G1 | G2 | G3 | G4 | θ | | |
| CQUAD4 | 111 | 203 | 31 | 74 | 75 | 32 | 2.6 | | ABC |
| | | | T1 | T2 | T3 | T4 | | | |
| +BC | | | 1.77 | 2.04 | 2.09 | 1.80 | | | |

| <u>Field</u> | <u>Contents</u> |
|---|---|
| EID | Element identification number (Unique integer > 0). |
| PID | Identification number of a PQUAD4 property card (Integer > 0 or blank, default is EID). |
| G1,G2,G3,G4 | Grid point identification numbers of connection points (Integers > 0, all unique). |
| θ | Material property orientation specification (Real or blank; or 0 ≤ Integer < 1,000,000). If Real or blank, specifies the material property orientation angle in degrees. If Integer, the orientation of the material x-axis is along the projection onto the plane of the element of the x-axis of the coordinate system specified by the integer value. The sketch below gives the sign convention for θ. |
| T1,T2,T3,T4 | Membrane thickness of element at grid points G1 through G4 (Real or blank, see PQUAD4 for default). |




<u>Remarks:</u> 1. Element identification numbers must be unique with respect to <u>all</u> other element identification numbers.

2. Grid points G1 through G4 must be ordered consecutively around the perimeter of the element.

3. All the interior angles must be less than 180°

(Continued)

4. The continuation card is optional. If it is not supplied, then T1 through T4 will be set equal to the value of T on the PSHELL data card.

5. Stresses are output in the element coordinate system.

6. The PQUAD4 card may be used in place of the PSHELL card. If a single PQUAD4 card is in the Bulk Data Deck, there must not be any references on CQUAD4 cards to PSHELL cards. The PSHELL card is recommended.

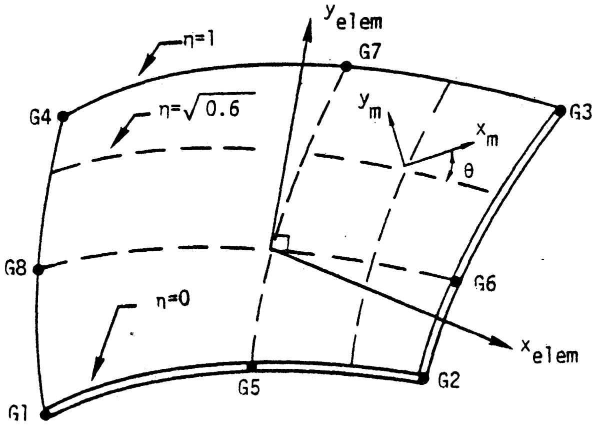
Input Data Card CQUAD8 Quadrilateral Element Connection

Description: Defines a curved quadrilateral shell element (QUAD8) with eight grid points.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CQUAD8 | EID | PID | G1 | G2 | G3 | G4 | G5 | G6 | |
| CQUAD8 | 207 | 3 | 31 | 33 | 73 | 71 | 32 | 51 | ABC |
| | G7 | G8 | T1 | T2 | T3 | T4 | θ | | |
| +BC | 53 | 72 | 0.125 | 0.025 | 0.030 | .025 | 30. | | |

| Field: | Contents |
|---|---|
| EID | Element identification number (Integer > 0) |
| PID | Identification number of a PSHELL property card (Integer > 0) |
| G1,G2,G3,G4 | Identification numbers of connected corner grid points (Unique integers > 0). Required data for all four grid points. |
| G5,G6,G7,G8 | Identification numbers of connected edge grid points (Integer ≥ 0 or blank). Optional data for any or all four grid points. |
| TI,T2,T3,T4 | Membrane thickness of element at corner grid points. See Remark 4 for default. |
| θ | Material property orientation specification (Real or blank; or 0 ≤ Integer < 1,000,000). If Real or blank, specifies the material property orientation angle in degrees. If Integer, the orientation of the material x-axis is along the projection on to the plane of the element of the x-axis of the coordinate system specified by the integer value. The sketch below gives the sign convention for θ. |




(Continued)

Remarks:
1. Element identification numbers must be unique with respect to all other element ID's of any kind.
2. Grid points G1 to G8 must be numbered as shown.
3. The material property orientation angle, $\theta$, is defined locally at each interior integration point as the angle made by x-axis of the material coordinate system with a line, $\eta$=const. If the shape of the element is a parallelogram and if edge points are located at midpoints of the sides, the lines $\eta$=const. are parallel to side 1-2.
4. T1, T2, T3 and T4 are optional. If not supplied they will be set equal to the value of T on the PSHELL card.
5. It is recommended that the edge points be located within the middle third of the edge. If the edge point is located at the quarter point, the program may fail with a divide by zero or the calculated stresses will be meaningless.

Input Data Card CRØD Rod Element Connection

Description: Defines a tension-compression-torsion element (RØD) of the structural model.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CRØD | EID | PID | G1 | G2 | | | | | |
| CRØD | 12 | 13 | 21 | 23 | | | | | |

| Field | Contents |
|---|---|
| EID | Element identification number (Integer > 0) |
| PID | Identification number of a PRØD property card (Default is EID) (Integer > 0) |
| G1, G2 | Grid point identification numbers of connection points (Integer > 0; G1 ≠ G2) |

Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. See CØNRØD for alternative method of rod definition.
3. Only one RØD element may be defined on a single card.

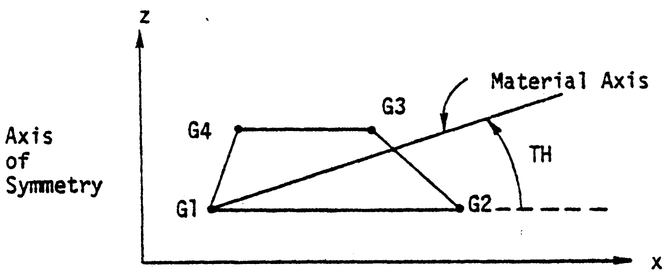
Input Data Card CTRAPRG Trapezoidal Ring Element Connection

Description: Defines an axisymmetric trapezoidal cross-section ring element (TRAPRG) of the structural model without reference to a property card.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CTRAPRG | EID | G1 | G2 | G3 | G4 | TH | MID | | |
| CTRAPRG | 72 | 13 | 14 | 15 | 16 | 29.2 | 13 | | |

| Field | Contents |
|---|---|
| EID | Element identification number (Integer > 0). |
| G1,G2,G3,G4 | Grid point identification number of connection points (Integers > 0; G1 ≠ G2 ≠ G3 ≠ G4). |
| TH | Material property orientation angle in degrees (Real) - The sketch below gives the sign convention for TH. |
| MID | Material property identification number (Integer > 0). |




Remarks:
1. Element identification numbers must be unique with respect to all other element identification numbers.
2. The four grid points must lie in the x-z plane of the basic coordinate system and to the right of the axis of symmetry (the z-axis). Either (X1 thru X4 > 0.) or (X1 = X4 = 0 with X2, X3 > 0.).
3. Grid points G1, G2, G3 and G4 must be ordered counterclockwise around the perimeter of the element as in the above sketch.
4. The line connecting grid points G1 and G2 and the line connecting grid points G3 and G4 must both be parallel to the x-axis.
5. All interior angles must be less than 180°.
6. For structural problems, the material property identification number must reference only a MAT1 or MAT3 card.
7. For heat transfer problems, the material property identification number must reference only a MAT4 or MAT5 card.
8. See Section 5.11 of the Theoretical Manual for mathematical details.
9. For a core element, X1 = X4 = 0, the x-component should be constrained at G1 and G4 to avoid matrix singularity.

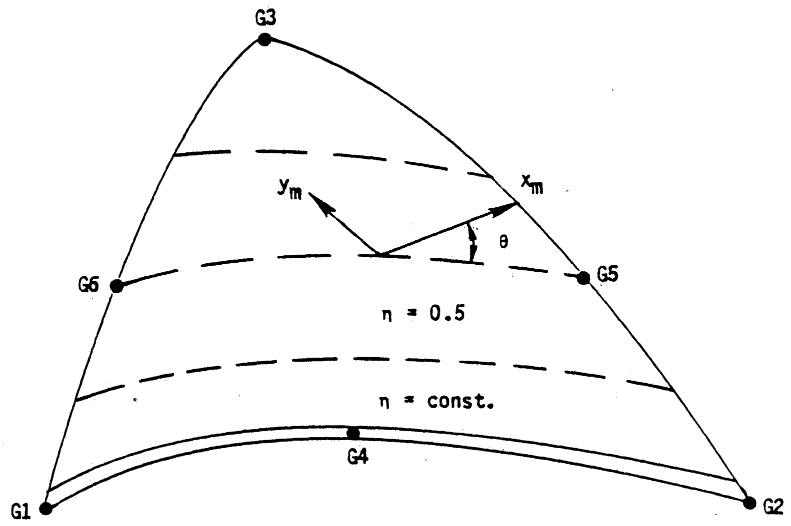
Input Data Card CTRIA6 Triangular Element Connection

Description: Defines a curved triangular shell element (TRIA6) with six grid points.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CTRIA6 | EID | PID | G1 | G2 | G3 | G4 | G5 | G6 | |
| CTRIA6 | 302 | 3 | 31 | 33 | 71 | 32 | 51 | 52 | ABC |
| | θ | | T1 | T2 | T3 | | | | |
| +BC | 45. | | .020 | .025 | .025 | | | | |

| Field | Contents |
|---|---|
| EID | Element Identification number (Integer > 0). |
| PID | Identification number of PSHELL property card (Integer > 0). |
| G1 to G3 | Identification numbers of connected corner grid points (Unique integers > 0). |
| G4 to G6 | Identification number of connected edge grid points (Integer ≥ 0 or blank). Optional data for any or all three points. |
| θ | Material property orientation specification (Real or blank; or 0 ≤ Integer < 1,000,000). If Real or blank, specifies the material property orientation angle in degrees. If Integer, the orientation of the material x-axis is along the projection on to the plane of the element of the x-axis of the coordinate system specified by the integer value. The sketch below gives the sign convention for θ. |
| T1,T1,T3 | Membrane thickness of element at corner grid points. See Remark 4 for default. |



Remarks:

1. Element identification numbers must be unique with respect to all other element ID's of any kind.

2. Grid points G1 to G6 must be numbered as shown.

3. The material property orientation angle, $\theta$, is defined locally at each interior integration point as the angle made by x-axis of the material coordinate system with a line, $\eta$ =const. If the sides are straight and if edge grid points are located at the midpoints of the sides, the lines $\eta$=const. are parallel to side 1-2.

4. T1, T2 and T3 are optional. If not supplied they will be set equal to the value of T on the PSHELL card.

5. It is recommended that the edge points be located within the middle third of the edge. If the edge point is located at the quarter point, the program may fail with a divide by zero and the calculated stresses will be meaningless.

Input Data Card <u>CTRIAX6</u> Connections for TRIAX6 Element

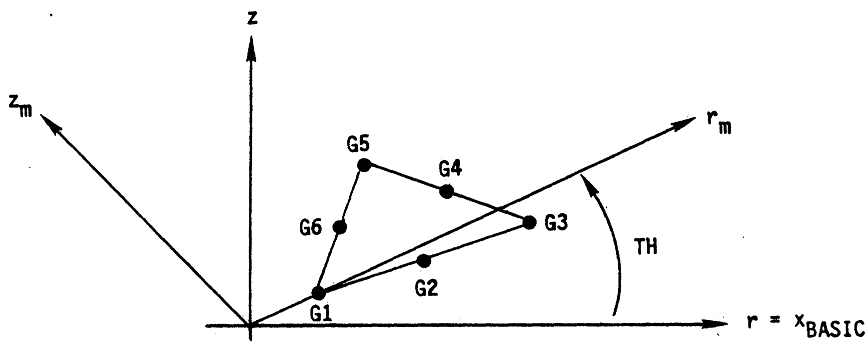
<u>Description</u>: Defines a linear strain axisymmetric triangular cross section ring element (TRIAX6) with midside grid points.

<u>Format and Example</u>:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| CTRIAX6 | EID | MID | G1 | G2 | G3 | G4 | G5 | G6 | |
| CTRIAX6 | 22 | 999 | 10 | 11 | 12 | 21 | 22 | 32 | +C22 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | TH | X | X | X | X | X | X | X | |
| +C22 | 9.0 | | | | | | | | |

| <u>Field</u> | <u>Contents</u> |
|---|---|
| EID | Element identification number (Integer > 0) |
| MID | Material identification number (Integer > 0) |
| G1 thru G6 | Grid point identification numbers of connected points (unique Integers > 0) |
| TH | Material orientation angle (Real, in degrees) |




<u>Remarks</u>:

1. The grid points must lie in the x-z plane of the basic coordinate system, with $x = r \geq 0$. The grid points must be listed consecutively beginning at a vertex and proceeding around the perimeter in either direction.

2. For structural problems, the material may be MAT1 or MAT3.

3. The continuation card is not required.

4. Material properties (if MAT3) and stresses are given in the $(r_m, z_m)$ coordinate system shown in the sketch.

5. Concentrated loads on grid circles for this element must be computed for 360°, i.e., multiply load per unit length by $2\pi r$.

6. G2, G4, and G6 are assumed to lie at the midpoints of the sides. The locations of these grid points (on GRID bulk data cards) are used only for global coordinate system definition, GPWG (weight generator module), centrifugal forces, and deformed structure plotting.

Input Data Card DMI Direct Matrix Input

Description: Used to define matrix data blocks directly. Generates a matrix of the form

$$[A] = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \vdots & \vdots & & \vdots \\ A_{m1} & \cdots & \cdots & A_{mn} \end{bmatrix}$$

where the elements $A_{ij}$ may be real or complex numbers.

Formats and Example: (The first logical card is a header card.)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| DMI | NAME | "0" | FØRM | TIN | TØUT | X | M | N | |
| DMI | QQQ | 0 | 2 | 3 | 3 | | 4 | 2 | |
| DMI | NAME | J | I1 | A(I1,J) | A(I1+1,J) | | etc. | I2 | |
| DMI | QQQ | 1 | 1 | 1.0 | 2.0 | 3.0 | 4.0 | 3 | +1 |
| | A(I2,J) | | -etc.- | | | | | | |
| +1 | 5.0 | 6.0 | | | | | | | |
| | | | | | | | | | |
| DMI | QQQ | 2 | 2 | 6.0 | 7.0 | 4 | 8.0 | 9.0 | |

(etc. for each non-null column)

| Field | Contents |
|---|---|
| NAME | Any NASTRAN BCD value (1-8 alphanumeric characters, the first of which must be alphabetic) which will be used in the DMAP sequence to reference the data block. |
| FØRM | 1 Square matrix (not symmetric)<br>2 General rectangular matrix<br>3 Diagonal matrix (M = number of rows, N = 1)<br>4 Lower triangular factor<br>5 Upper triangular factor<br>6 Symmetric matrix<br>7 Row matrix (M = number of columns, N = 1)<br>8 Identity matrix (M = number of rows, N = M) |
| TIN | Type of matrix being input, as follows:<br>1 Real, S.P. (one field used/element) 3 Complex, S.P. (two fields used/element)<br>2 Real, D.P. (one field used/element) 4 Complex, D.P. (two fields used/element) |

(Continued)

TØUT Type of matrix being output, as follows:
0 Set by precision cell
1 Real, single-precision
2 Real, double-precision
3 Complex, single-precision
4 Complex, double-precision

M Number of rows in A (Integer > 0). Except for a row matrix, FØRM 7.

N Number of columns in A (Integer > 0). Except for FØRMS 3, 7, AND 8.

J Column number of A (Integer > 0).

I1, I2, etc. Row number of A (Integer > 0).

A(Ix,J) Values of element of A (see TIN) (Real)

Remarks:

1. The user must write a DMAP (or make alterations to a solution sequence) in order to use the DMI feature since he is defining a data block. All of the rules governing the use of data blocks in DMAP sequences apply. In the example shown above, the data block QQQ is defined to be the complex, single-precision rectangular 4 x 2 matrix

$$[QQQ] = \begin{bmatrix} (1.0,\ 2.0) & (0.0,\ 0.0) \\ (3.0,\ 4.0) & (6.0,\ 7.0) \\ (5.0,\ 6.0) & (0.0,\ 0.0) \\ (0.0,\ 0.0) & (8.0,\ 9.0) \end{bmatrix}$$

2. A limit to the number of DMI's which may be defined is set by the size of the Data Pool Dictionary. The total number of DMIs and DTIs may not exceed 79.

3. There are a number of reserved words which may not be used for DMI names. These are PØØL, NPTP, ØPTP, DBØJ, INPT, PLT2, GEØM1, GEØM2, GEØM3, GEØM4, GEØM5, EDT, MPT, EPT, DIT, DYNAMICS, IFPFILE, AXIC, FØRCE, MATPØØL, PCDB, XYCDB, CASECC, any DTI names, and SCRATCH1 thru SCRATCH9.

4. Field 3 of the header card must contain an integer of zero (0).

5. For symmetric matrices, the entire matrix must be input.

6. Only nonzero terms need be entered.

7. A blank field on this card is not equivalent to a zero. If zero input is desired, the appropriate type zero must be entered (i.e., 0.0 or 0.0D0).

8. Complex input must have both the real and imaginary parts entered if either part is nonzero.

9. If A(Ix,J) is followed by "THRU" in the next field and an integer row number "IX" after the THRU, then A(Ix,J) will be repeated in each row thru IX. The "THRU" must follow an element value. For example, the entries for a real matrix RRR would appear as follows:

(Continued)

DMI (Cont.)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| DMI | NAME | J | I1 | A(I1,J) | | | I2 | A(I2,J) | |
| DMI | RRR | I | 2 | 1.0 | THRU | 10 | 12 | 2.0 | +1 |

These entries will cause the first column of the matrix RRR to have a zero in row 1, the values 1.0 in rows 2 through 10, a zero in row 11, and 2.0 in row 12.

10. Each column must be a single logical card. The terms in each column must be specified in increasing row number order.

11. The "FØRM" options 3, 4, 5, 7, and 8 are nonstandard forms and may be used only in conjunction with the modules indicated in the following table.

| | | Modules | | | |
|---|---|---|---|---|---|
| FØRM | Matrix Description | ADD | FBS | MATPRN | MPYAD |
| 3 | Diagonal | X | | X | X |
| 4 | Lower Triangular Factor | | X | X | |
| 5 | Upper Triangular Factor | | X | X | |
| 7 | Row | X | | X | |
| 8 | Identity | X | X | X | X |

12. The maximum number of DMI and DTI data blocks is 79.

Input Data Card FØRCE Static Load

Description: Defines a static load at a grid point by specifying a vector.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| FØRCE | SID | G | CID | F | N1 | N2 | N3 | | |
| FØRCE | 2 | 5 | 6 | 2.9 | 0.0 | 1.0 | 0.0 | | |

| Field | Contents |
|---|---|
| SID | Load set identification number (Integer > 0) |
| G | Grid point identification number (Integer > 0) |
| CID | Coordinate system identification number (Integer $\geq$ 0, or blank) (Default = 0) |
| F | Scale factor (Real) |
| N1,N2,N3 | Components of Vector measured in coordinate system defined by CID (Real; must have at least one nonzero component) |

Remarks:

1. The static load applied to grid point G is given by

$$\vec{f} = F\,\vec{N}$$

where $\vec{N}$ is the vector defined in fields 6, 7 and 8.

2. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by MSC/NASTRAN.

3. A CID of zero references the basic coordinate system.

Input Data Card FØRCE1 Static Load, Alternate Form 1

Description: Used to define a static load by specification of a value and two grid points which determine the direction.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| FØRCE1 | SID | G | F | G1 | G2 | | | | |
| FØRCE1 | 6 | 13 | -2.93 | 16 | 13 | | | | |

| Field | Contents |
|---|---|
| SID | Load set identification number (Integer > 0) |
| G | Grid point identification number (Integer > 0) |
| F | Value of load (Real) |
| G1, G2 | Grid point identification numbers (Integer > 0; G1 ≠ G2) |

Remarks:

1. The direction of the force is determined by the vector from G1 to G2.
2. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by NASTRAN.

Input Data Card GRAV Gravity Vector

Description: Used to define gravity vectors for use in determining gravity loading for the structural model.

Format and Example :

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| GRAV | SID | CID | G | N1 | N2 | N3 | | | |
| GRAV | 1 | 3 | 32.2 | 0.0 | 0.0 | -1.0 | | | |

| Field | Contents |
|---|---|
| SID | Set identification number (Integer > 0) |
| CID | Coordinate system identification number (Integer $\geq$ 0) |
| G | Gravity vector scale factor (Real) |
| N1, N2, N3 | Gravity vector components (Real; at least one nonzero component) |

Remarks:

1. The gravity vector is defined by $\vec{g}$ = G(N1, N2, N3). The direction of $\vec{g}$ is the direction of free fall.
2. A CID of zero references the basic coordinate system.
3. Gravity loads may be combined with "simple loads" (e.g., FØRCE, MØMENT) only by specification on a LØAD card. That is, the SID on a GRAV card may not be the same as that on a simple load card.
4. Load sets must be selected in the Case Control Deck (LØAD=SID) to be used by MSC/NASTRAN.
5. At most nine GRAV cards can be selected in a given run either by Case Control or the LØAD Bulk Data card. Multiples or reflections of a given gravity load can be economically accomplished by use of the LØAD Bulk Data card.
6. In Type II solution sequence cyclic symmetry analyses, the T3 axis of the coordinate system referenced in field 3 must be parallel to the axis of symmetry. In the DIH type of cyclic symmetry the T1 axis must, in addition, be parallel to Side 1 of segment 1R of the model.

Input Data Card GRDSET Grid Point Default

Description: Defines default options for fields 3, 7 and 8 of all GRID cards.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| GRDSET | X | CP | X | X | X | CD | PS | X | |
| GRDSET | | 16 | | | | 32 | 3456 | | |

| Field | Contents |
|---|---|
| CP | Identification number of coordinate system in which the location of the grid point is defined (Integer ≥ 0) |
| CD | Identification number of coordinate system in which displacements are measured at grid point (Integer ≥ 0) |
| PS | Permanent single-point constraints associated with grid point (any of the digits 1-6 with no imbedded blanks) (Integer ≥ 0). |

Remarks:

1. The contents of fields 3, 7 or 8 of this card are assumed for the corresponding fields of any GRID card whose field 3, 7 and 8 are blank. If any of these fields on the GRID card are blank, the default option defined by this card occurs for that field. If no permanent single-point constraints are desired or one of the coordinate systems is basic, the default may be overridden on the GRID card by making one of fields 3, 7 or 8 zero (rather than blank). Only one GRDSET card may appear in the user's Bulk Data Deck.
2. The primary purpose of this card is to minimize the burden of preparing data for problems with a large amount of repetition (e.g., two-dimensional pinned-joint problems).
3. At least one of the entries CP, CD, or PS must be nonzero.

Input Data Card GRID Grid Point

Description: Defines the location of a geometric grid point of the structural model, the directions of its displacement, and its permanent single-point constraints.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| GRID | ID | CP | X1 | X2 | X3 | CD | PS | SEID | |
| GRID | 2 | 3 | 1.0 | -2.0 | 3.0 | | 316 | | |

| Field | Contents |
|---|---|
| ID | Grid point identification number (1,000,000 > Integer > 0) |
| CP | Identification number of coordinate system in which the location of the grid point is defined (Integer ≥ 0 or blank*) |
| X1,X2,X3 | Location of the grid point in coordinate system CP (Real) |
| CD | Identification number of coordinate system in which displacements, degrees of freedom, constraints, and solution vectors are defined at the grid point (Integer ≥ 0 or blank*) |
| PS | Permanent single-point constraints associated with grid point (any of the digits 1-6 with no imbedded blanks) (Integer ≥ 0 or blank*) |
| SEID | Superelement identification number (Integer ≥ 0 or blank) |

Remarks:

1. All grid point identification numbers must be unique with respect to all other structural, scalar and fluid points.

2. The meaning of X1, X2 and X3 depend on the type of coordinate system, CP, as follows: (see CØRDi card descriptions)

| Type | X1 | X2 | X3 |
|---|---|---|---|
| Rectangular | X | Y | Z |
| Cylindrical | R | $\theta$(degrees) | Z |
| Spherical | R | $\theta$(degrees) | $\phi$(degrees) |

3. The collection of all CD coordinate systems defined on all GRID cards is called the Global Coordinate System. All degrees-of-freedom, constraints, and solution vectors are expressed in the Global Coordinate System.

4. The SEID entry can be overridden by use of the SESET Bulk Data card.

*See the GRDSET card for default options for fields 3, 7 and 8.

Input Data Card <u>LØAD</u> Static Load Combination (Superposition)

<u>Description:</u> Defines a static load as a linear combination of load sets defined via FØRCE, MØMENT, FØRCE1, MØMENT1, FØRCE2, MØMENT2, PLØAD, PLØAD1, PLØAD2, PLØAD3, PLØAD4, PLØADX, SLØAD, RFØRCE, and GRAV cards.

<u>Format and Example:</u>

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| LØAD | SID | S | S1 | L1 | S2 | L2 | S3 | L3 | |
| LØAD | 101 | -0.5 | 1.0 | 3 | 6.2 | 4 | | | ABC |
| | S4 | L4 | | -etc.- | | | | | |
| +BC | | | | | | | | | |

(etc.)

| <u>Field</u> | <u>Contents</u> |
|---|---|
| SID | Load set identification number (Integer > 0) |
| S | Scale factor (Real) |
| Si | Scale factors (Real) |
| Li | Load set identification numbers defined via card types enumerated above (Integer > 0) |

<u>Remarks:</u> 1. The load vector defined is given by

$$\{P\} = S \sum_i S_i \{P_{Li}\}$$

2. The Li must be unique. The remainder of the physical card containing the last entry must be blank.

3. This card must be used if gravity loads (GRAV) are to be used with any of the other types.

4. Load sets must be selected in the Case Control Deck (LØAD=SID) if they are to be applied to the structural model.

5. A LØAD card may not reference a set identification number defined by another LØAD card.

6. There may be at most 300 ($S_i$, $L_i$) pairs.

Input Data Card MAT1 Material Property Definition, Form 1

Description: Defines the material properties for linear, temperature-independent, isotropic materials.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| MAT1 | MID | E | G | NU | RHØ | A | TREF | GE | |
| MAT1 | 17 | 3.+7 | | 0.33 | 4.28 | 6.5-6 | 5.37+2 | 0.23 | ABC |
| | ST | SC | SS | MCSID | | | | | |
| +BC | 20.+4 | 15.+4 | 12.+4 | 1003 | | | | | |

| Field | Contents |
|---|---|
| MID | Material identification number (Integer > 0) |
| E | Young's modulus (Real or blank) |
| G | Shear modulus (Real or blank) |
| NU | Poisson's ratio ($-1.0 < \text{Real} \leq 0.5$ or blank) |
| RHØ | Mass density (Real) |
| A | Thermal expansion coefficient (Real) |
| TREF | Thermal expansion reference temperature (Real) |
| GE | Structural element damping coefficient (Real) |
| ST,SC,SS | Stress limits for tension, compression, and shear (Real). (Used only to compute margins of safety in certain elements; they have no effect on the computational procedures.) |
| MCSID | Material Coordinate System identification number (Integer $\geq$ 0 or blank) |

Remarks:

1. The material identification number must be unique for all MAT1, MAT2, MAT3 and MAT9 cards.
2. MAT1 materials may be made temperature dependent by use of the MATT1 card.
3. The mass density, RHØ, will be used to automatically compute mass for all structural elements.
4. Weight density may be used in field 6 if the value 1/g is entered on the PARAM card WTMASS, where g is the acceleration of gravity (see Section 3.1.5).
5. MCSID must be nonzero if the CURV module is used to calculate stresses or strains at grid points.
6. To obtain the damping coefficient, GE, multiply the critical damping ratio $C/C_0$, by 2.0.

(Continued)

Input Data Card MPC Multipoint Constraint

Description: Defines a multipoint constraint equation of the form

$$\Sigma_j A_j u_j = 0$$

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| MPC | SID | G | C | A | G | C | A | | abc |
| MPC | 3 | 28 | 3 | 6.2 | 2 | | 4.29 | | +B |
| +bc | | G | C | A | -etc.- | | | | |
| +B | | 1 | 4 | -2.91 | | | | | |

| Field | Contents |
|---|---|
| SID | Set identification number (Integer > 0). |
| G | Identification number of grid or scalar point (Integer > 0). |
| C | Component number - any one of the digits 1-6 in the case of geometric grid points; blank or zero in the case of scalar points (Integer). |
| A | Coefficient (Real; the first A must be nonzero). |

Remarks:

1. The first coordinate in the sequence is assumed to be the dependent coordinate. A dependent degree of freedom assigned by one MPC card cannot be assigned dependent by another MPC card or by a rigid element.
2. Forces of multipoint constraint are not recovered.
3. Multipoint constraint sets must be selected in the Case Control Deck (MPC=SID) to be used by NASTRAN.
4. The m-set coordinates specified on this card may not be specified on other cards that define mutually exclusive sets. See Section 1.4.1 for a list of these cards.

Input Data Card PARAM Parameter

Description: Specifies values for parameters used in solution sequence.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| PARAM | N | V1 | V2 | | | | | | |
| PARAM | IRES | 1 | | | | | | | |

Field | Contents

N — Parameter name (one to eight alphanumeric characters, the first of which is alphabetic).

V1,V2 — Parameter value based on parameter type as follows:

| Type | V1 | V2 |
|---|---|---|
| Integer | Integer | Blank |
| Real, single-precision | Real | Blank |
| BCD | BCD | Blank |
| Real, double-precision | Double-precision | Blank |
| Complex, single-precision | Real | Real |
| Complex, double-precision | Double-precision | Double-precision |

Remarks:

1. Only parameters for which assigned values are allowed may be given values via the PARAM card. Section 5 describes parameters as used in DMAP.
2. See Section 3.1.3 for a list of parameters used in solution sequences which may be set by the user on PARAM cards.

Input Data Card PBAR Simple Beam Property

Description: Defines the properties of a simple beam (bar) which is used to create bar elements via the CBAR card.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| PBAR | PID | MID | A | I1 | I2 | J | NSM | X | |
| PBAR | 39 | 6 | 2.9 | | 5.97 | | | | 123 |
| | C1 | C2 | D1 | D2 | E1 | E2 | F1 | F2 | |
| +23 | | | 2.0 | 4.0 | | | | | |
| | K1 | K2 | I12 | | | | | | |
| | | | | | | | | | |

| Field | Contents |
|---|---|
| PID | Property identification number (Integer > 0) |
| MID | Material identification number (Integer > 0) |
| A | Area of bar cross-section (Real) |
| I1, I2, I12 | Area moments of inertia (Real) $(I_1 \geq 0., I_2 \geq 0., I_1 I_2 > I_{12}^2)$ |
| J | Torsional constant (Real) |
| NSM | Nonstructural mass per unit length (Real) |
| K1, K2 | Area factor for shear (Real) |
| Ci,Di,Ei,Fi | Stress recovery coefficients (Real) |

Remarks:

1. For structural problems, PBAR cards may only reference MAT1 material cards.
2. See Section 1.3.2 for a discussion of bar element geometry.
3. For heat transfer problems, PBAR cards may only reference MAT4 or MAT5 material cards.
4. The transverse shear stiffnesses in planes 1 and 2 are (K1)AG and (K2)AG, respectively. The default values for K1 and K2 are infinite; in other words, the transverse shear flexibilities are set equal to zero. K1 and K2 are ignored if I12 ≠ 0.
5. The stress recovery coefficients C1 and C2, etc., are the y and z coordinates in the BAR element coordinate system of a point at which stresses are computed. Stresses are computed at both ends of the BAR.

Input Data Card PBEAM Beam Property

Description: Defines the properties of a beam which is used to create beam elements via the CBEAM card.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| PBEAM | PID | MID | A(A) | I1(A) | I2(A) | I12(A) | J(A) | NSM(A) | |
| PBEAM | 39 | 6 | 2.9 | 3.5 | 5.97 | | | | 123 |
| | C1(A) | C2(A) | D1(A) | D2(A) | E1(A) | E2(A) | F1(A) | F2(A) | |
| +23 | | | 2.0 | -4.0 | | | | | 234 |
| | SØ | X/XB | A | I1 | I2 | I12 | J | NSM | |
| +34 | YES | 1.0 | 5.3 | 56.2 | 78.6 | | | | 345 |
| | C1 | C2 | D1 | D2 | E1 | E2 | F1 | F2 | |
| +45 | | | 2.5 | -5.0 | | | | | 456 |
| | K1 | K2 | S1 | S2 | NSI(A) | NSI(B) | CW(A) | CW(B) | |
| +56 | | | 1.1 | | 2.1 | | 0.21 | | 567 |
| | M1(A) | M2(A) | M1(B) | M2(B) | N1(A) | N2(A) | N1(B) | N2(B) | |
| +67 | | | | | 0.5 | | 0.0 | | |

| Field | Contents | Default Values |
|---|---|---|
| PID | Property identification number (Integer > 0) | Required |
| MID | Material identification number (Integer > 0) | Required |
| A(A) | Area of beam cross section at end A (Real > 0.0) | Required |
| I1(A) | Area moment of inertia at end A in plane 1 about the neutral axis (Real > 0.0) | Required |
| I2(A) | Area moment of inertia at end A in plane 2 about the neutral axis (Real > 0.0) | Required |
| I12(A) | Area product of inertia at end A (Real $(I_1 I_2 - I_{12}^2 > 0)$ | 0.0 |
| J(A) | Torsional stiffness parameter at end A (Real) J > 0.0 if warping is present) | 0.0 |
| NSM(A) | Nonstructural mass per unit length at end A (Real) | 0.0 |
| Ci(A),Di(A) Ei(A),Fi(A) | The y,z locations in element coordinates (see diagram following Remarks) at end A for stress data recovery (Real) | $y_i = z_i = 0.0$ |

(Continued)

PBEAM (Cont.)

| Field | Contents | Default Values |
|---|---|---|
| SØ | Stress output request option (BCD)<br>YES: Stresses recovered at points C,D,E,F on next continuation card<br>YESA: Stresses recovered at points with the same y,z location as end A.<br>NØ: No stresses or forces are recovered (see Remark 9). | Required* |
| X/XB | Distance from end A in the element coordinate system divided by the length of the element (Real > 0.0). See following figure. | Required*<br>See Remark 5 |
| A,I1,I2,I12,<br>J,NSM | Area, moments of inertia, torsional stiffness parameter and nonstructural mass for the cross-section located at x (Real) (J > 0.0 if warping is present.) | See Remark 6 |
| Ci,Di,Ei,Fi | The y,z locations in element coordinates (see diagram following Remarks) for the cross-section located at $x/x_b$. The values are fiber locations for stress data recovery (Real) | |
| K1,K2 | Shear stiffness factor K in KAG for plane 1 and plane 2 (Real) | 1.0,1.0 |
| S1,S2 | Shear relief coefficient due to taper for plane 1 and plane 2 (Real) | 0.0,0.0 |
| NSI(A),NSI(B) | Nonstructural mass moment of inertia per unit length about nonstructural mass center of gravity at end A and end B (Real) (see following figure). | 0.0, same as end A |
| CW(A),CW(B) | Warping coefficient for end A and end B (Real) | 0.0, same as end A |
| M1(A),M2(1),<br>M1(B),M2(B) | (y,z) coordinates of center of gravity of nonstructural mass for end A and end B (see following figure) | 0.0 (no offset from shear center), same values as end A |
| N1(A),N2(A) | (y,z) coordinates of neutral axis for end A and end B (see following figure) | 0.0 (no offset from shear center) same values as end A |

Remarks:

1. For structural problems, PBEAM cards may reference only MAT1 material cards.
2. For heat transfer problems, PBEAM cards may reference only MAT4 and MAT5 material cards.
3. If no stress data at end A is to be recovered, and a continuation card with the BCD stress option is present, the continuation card +23 which contains the C,D,E and F (y,z) coordinates may be omitted.

---

*Required only if card is present.

(Continued)

4. If SØ is YESA or NØ, the following continuation card for the C,D,E and F locations must be omitted. If SØ is YES, the continuation card for C,D,E and F must be the next card.

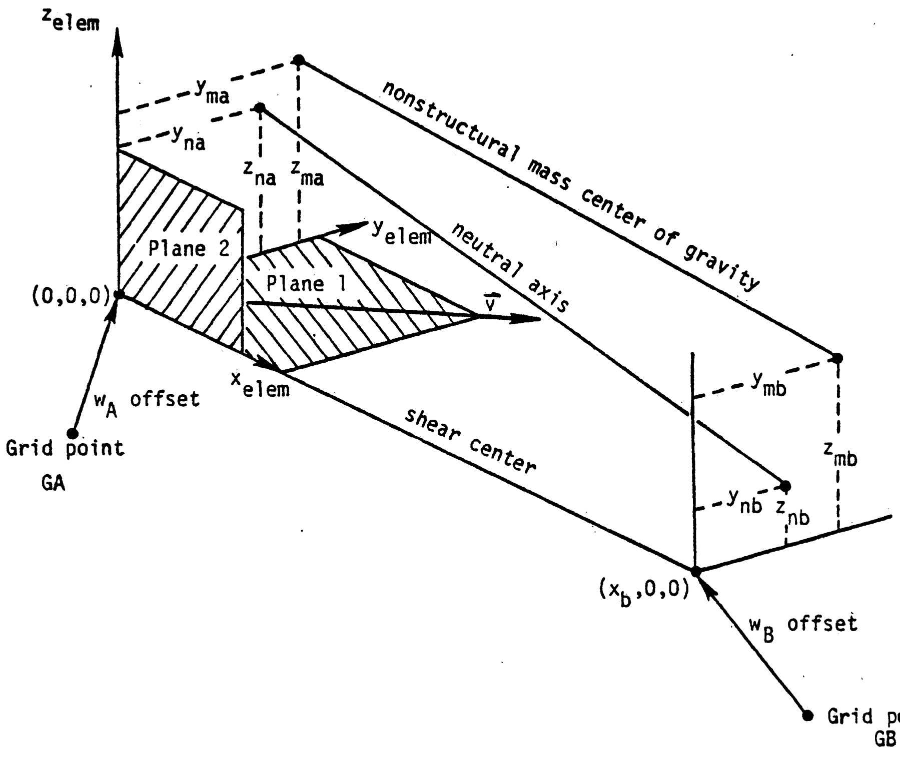
5. Continuation cards +34 and +45 shown above may be repeated nine (9) more times for intermediate $x/s_b$ values. The order of the +34, +45 pairs is independent of the $x/x_b$ value; however, one value of $x/x_b$ must be 1.0, corresponding to end B.

6. If any fields 4 through 9 are blank on the continuation card with the value of $x/x_b$ = 1.0, then the values for A, I1, I2, I12, J and NSM are set to the values given for end A. For the continuation cards which have intermediate values of $x/x_b$ between 0.0 and 1.0, and which use the default option (any of the fields 4 through 9 are blank), a linear interpolation between the values at ends A and B is performed to obtain the missing section properties.

7. If SØ is YES, blank fields are defaulted to 0.0.

8. Blank fields for K1, K2 are defaulted to 1.0. If a value of 0.0 is used for K1 and K2, the transverse shear flexibilities are set to infinity.

9. If end B forces are desired, put YESA in the BCD field even when no end A stress points are input.



Input Data Card PLØADX     Pressure Load on TRIAX6 Element

Description: Defines a pressure load to be used with the TRIAX6 axisymmetric element.

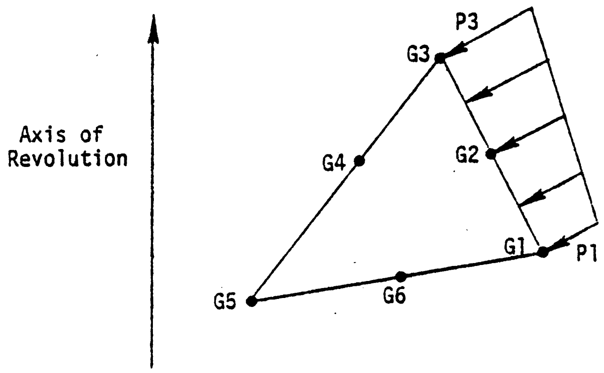
Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| PLØADX | SID | P1 | P3 | G1 | G2 | G3 | | | |
| PLØADX | 200 | 3.5 | 10.5 | 10 | 20 | 30 | | | |

| Field | Contents |
|---|---|
| SID | Load set identification number (integer > 0). |
| P1, P3 | Pressure at first and third listed points (real). |
| G1, G2, G3 | Grid point identification numbers (integers > 0). |

Remarks: 1. This load card is designed for use with the TRIAX6 element. G1 and G3 should be vertices of a TRIAX6 element, and G2 the corresponding midside grid point.

2. The pressure is assumed to vary linearly between grid points 1 and 3. If G1, G2, G3 appear in the order determined by going around an element in counterclockwise direction, a positive pressure will produce a force directed toward the element interior.




3. The pressure is input as force per unit area.

Input Data Card PQDMEM Quadrilateral Membrane Property

Description: Used to define the properties of a quadrilateral membrane. Referenced by the CQDMEM card. No bending properties are included.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| PQDMEM | PID | MID | T | NSM | | | | | |
| PQDMEM | 235 | 2 | 0.5 | 0.0 | | | | | |

| Field | Contents |
|---|---|
| PID | Property identification number (Integer > 0) |
| MID | Material identification number (Integer > 0) |
| T | Thickness of membrane (Real > 0.0) |
| NSM | Nonstructural mass per unit area (Real) |

Remarks: 1. All PQDMEM cards must have unique property identification numbers.

Input Data Card PRØD Rod Property

Description: Defines the properties of a rod which is referenced by the CRØD card.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| PRØD | PID | MID | A | J | C | NSM | | | |
| PRØD | 17 | 23 | 42.6 | 17.92 | 4.236 | 0.5 | | | |

| Field | Contents |
|---|---|
| PID | Property identification number (Integer > 0) |
| MID | Material identification number (Integer > 0) |
| A | Area of rod (Real) |
| J | Torsional constant (Real) |
| C | Coefficient to determine torsional stress (Real) |
| NSM | Nonstructual mass per unit length (Real) |

Remarks:
1. PRØD cards must all have unique property identification numbers.
2. For structural problems, PRØD cards may only reference MAT1 material cards.
3. For heat transfer problems, PRØD cards may only reference MAT4 or MAT5 cards.
4. The formula used to compute torsional stress is

$$\tau = \frac{CM_\theta}{J}$$

where $M_\theta$ is the torsional moment.

Input Data Card PSHELL Shell Element Property

Description: Defines the membrane, bending, transverse shear, and coupling properties of thin shell elements.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| PSHELL | PID | MID1 | T | MID2 | $12I/T^3$ | MID3 | TS/T | NSM | |
| PSHELL | 203 | 204 | 1.90 | 205 | 1.2 | 206 | 0.8 | 6.32 | BCD |
| | Z1 | Z2 | MID4 | | | | | | |
| +CD | +.95 | -.95 | | | | | | | |

| Field | Contents |
|---|---|
| PID | Property identification number (Integer > 0) |
| MID1 | Material identification number for membrane (Integer > 0 or blank) |
| T | Default value for membrane thickness (Real) |
| MID2 | Material identification number for bending (Integer > 0 or blank) |
| $12I/T^3$ | Bending stiffness parameter (Real or blank, default = 1.0) |
| MID3 | Material identification number for transverse shear (Integer > 0 or blank), must be blank unless MID2 > 0) |
| TS/T | Transverse shear thickness divided by membrane thickness (Real or blank, default = .833333) |
| NSM | Nonstructural mass per unit area (Real) |
| Z1,Z2 | Fiber distances for stress computation. The positive direction is determined by the righthand rule and the order in which the grid points are listed on the connection card. (Real or blank, defaults are -1/2 T for Z1 and 1/2 T for Z2.) |
| MID4 | Material identification number for membrane-bending coupling (Integer > 0 or blank, must be blank unless MID1 > 0 and MID2 > 0, may not equal MID1 or MID2) |

Remarks:

1. All PSHELL property cards must have unique identification numbers.
2. The structural mass is computed from the density using the membrane thickness and membrane material properties.
3. The results of leaving an MID field blank are:

   MID1 No membrane or coupling stiffness.
   MID2 No bending, coupling, or transverse shear stiffness.
   MID3 No transverse shear flexibility.
   MID4 No bending-membrane coupling.

(Continued)

PSHELL (Cont.)

4. The continuation card is not required.

5. The structural damping (for dynamics rigid formats) uses the values defined for the MID1 material.

6. The MID4 field should be left blank if the material properties are symmetric with respect to the middle surface of the shell.

7. This card is used in connection with the CTRIA3, CTRIA6, CQUAD4 and CQUAD8 cards.

8. For structural problems, PSHELL cards may reference MAT1 or MAT2 material property cards.

9. For heat transfer problems, PSHELL cards may reference MAT4 or MAT5 material property cards.

Input Data Card PSØLID Properties of HEXA and PENTA Solid Elements

Description: Defines the properties of solid elements. Referenced by CHEXA and CPENTA cards.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| PSØLID | PID | MID | CØRDM | IN | | | | | |
| PSØLID | 2 | 100 | 6 | | | | | | |

| Field | Contents |
|---|---|
| PID | Property identification number (Integer > 0) |
| MID | Identification number of a MAT1, MAT4, MAT5, or MAT9 card (Integer > 0) |
| CØRDM | Identification number of material coordinate system (Integer, Default = -1) |
| IN | Integration network (Integer, 0, 2, 3, or blank) |

Remarks:

1. PSØLID cards must have unique ID numbers.
2. Either isotropic (MAT1, OR MAT4) or anisotropic (MAT5 or MAT9) materials may be referenced.
3. See the CHEXA or CPENTA card for the definition of the element coordinate system. The material coordinate system may be the basic system (0), any defined system (Integer > 0) or the element coordinate system (-1 or blank).
4. Stress components are output in the material coordinate system for the corner points and the midpoint of the element.
5. There is a choice of two integration networks for each element.

| | HEXA | PENTA |
|---|---|---|
| IN=2 | 8 point | 6 point |
| IN=3 | 27 point | 9 point |

The recommendation is to use the default (zero or blank) which selects IN=2 if all edge points are deleted and IN=3 if any edge points are present.

Input Data Card RBAR    Rigid Bar

Description: Defines a rigid bar with six degrees of freedom at each end.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| RBAR | EID | GA | GB | CNA | CNB | CMA | CMB | | |
| RBAR | 5 | 1 | 2 | 234 | 123 | | | | |

| Field | Contents |
|---|---|
| EID | Identification number of rigid element. |
| GA, GB | Grid point identification number of connection points (integer > 0). |
| CNA, CNB | Independent degrees of freedom in the global coordinate system for the element at grid points GA and GB, indicated by any of the digits 1 - 6 with no imbedded blanks (integer $\geq$ 0 or blank). See Remark 1. |
| CMA, CMB | Component numbers of dependent degrees of freedom in the global coordinate system assigned by the element at grid points GA and GB, indicated by any of the digits 1 - 6 with no imbedded blanks (integer $\geq$ 0 or blank). See Remarks 2 and 3. |

Remarks:

1. The total number of components in CNA and CNB must equal six; for example, CNA = 1236, CNB = 34. Furthermore, they must jointly be capable of representing any general rigid body motion of the element.
2. If both CMA and CMB are zero or blank, all of the degrees of freedom not in CNA and CNB will be made dependent; i.e., they will be made members of the $\{u_m\}$ set.
3. The m-set coordinates specified on this card may not be specified on other cards that define mutually exclusive sets. See Section 1.4.1 for a list of these cards.
4. Element identification numbers must be unique.
5. Rigid elements, unlike MPC's, are not selected through the Case Control Deck.
6. Forces of constraint are not recovered.
7. Rigid elements are ignored in heat transfer problems.
8. See Section 2.10 of the Application Manual for a discussion of rigid elements.

Input Data Card SEQGP Grid and Scalar Point Resequencing

Description: Used to order the grid points and user-supplied scalar points of the problem. The purpose of this card is to allow the user to reidentify the formation sequence of the grid and scalar points of his structural model in such a way as to optimize bandwidth which is essential for efficient solutions by the displacement method.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| SEQGP | ID | SEQID | ID | SEQID | ID | SEQID | ID | SEQID | |
| SEQGP | 5392 | 15.6 | 596 | 0.2 | 2 | 1.9.2.6 | 3 | 2 | |

Field / Contents

ID Grid or scalar point identification number (Integer > 0).

SEQID Sequenced identification number (a special number described below).

Remarks:

1. ID is any grid or scalar point identification number which is to be reidentified for sequencing purposes. The grid point sequence number (SEQID) is a special number which may have any of the following forms where X is a decimal integer digit - XXXX.X.X.X, XXXX.X.X, XXXX.X or XXXX where any of the leading X's may be omitted. This number must contain no imbedded blanks. The leading character must not be a decimal point.

2. If the user wishes to insert a grid point between two already existing grid points, such as 15 and 16, for example, he would define it as, say 5392, and then use this card to insert grid point number 5392 between them by equivalencing it to, say 15.6. All output referencing this point will refer to 5392.

3. The SEQID numbers must be unique and may not be the same as a point ID which is not being changed. No grid point ID may be referenced more than once.

4. No continuation cards (small field or large field) are allowed with either the SEQGP or SEQEP card.

5. From one to four grid or scalar points may be resequenced on a single card.

6. If a grid point ID is referenced more than once, the last reference will determine its sequence.

Input Data Card <u>SPC</u> Single-Point Constraint

<u>Description</u>: Defines sets of single-point constraints and enforced displacements.

<u>Format and Example</u>:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| SPC | SID | G | C | D | G | C | D | | |
| SPC | 2 | 32 | 436 | -2.6 | 5 | | +2.9 | | |

| Field | Contents |
|---|---|
| SID | Identification number of single-point constraint set (Integer > 0). |
| G | Grid or scalar point identification number (Integer > 0). |
| C | Component number (6 ≥ Integer ≥ 0; up to six unique digits may be placed in the field with no imbedded blanks). |
| D | Value of enforced displacement for all coordinates designated by G and C (Real). |

<u>Remarks</u>:

1. Coordinates specified on this card form members of a mutually exclusive set. They may not be specified on other cards that define mutually exclusive sets. See Section 1.4.1 for a list of these cards.
2. Single-point forces of constraint <u>are</u> recovered during stress data recovery.
3. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.
4. From one to twelve single-point constraints may be defined on a single card.
5. SPC degrees of freedom may be redundantly specified as permanent constraints on the GRID card.
6. Continuation cards are not allowed.

Input Data Card SPC1 Single-Point Constraint, Alternate Form

Description: Defines sets of single-point constraints.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| SPC1 | SID | C | G1 | G2 | G3 | G4 | G5 | G6 | abc |
| SPC1 | 3 | 2 | 1 | 3 | 10 | 9 | 6 | 5 | ABC |
| +bc | G7 | G8 | G9 | -etc- | | | | | |
| +BC | 2 | 8 | | | | | | | |

Alternate Form

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SPC1 | SID | C | GID1 | "THRU" | GID2 | | | | |
| SPC1 | 313 | 12456 | 6 | THRU | 32 | | | | |

| Field | Contents |
|---|---|
| SID | Identification number of single-point constraint set (Integer > 0). |
| C | Component number (any unique combination of the digits 1-6 (with no imbedded blanks) when point identification numbers are grid points; must be null if point identification numbers are scalar points). |
| Gi,GIDi | Grid or scalar point identification numbers (Integer > 0). |

Remarks:

1. Note that enforced displacements are not available via this card. As many continuation cards as desired may appear when "THRU" is not used.

2. Coordinates specified on this card form members of a mutually exclusive set. They may not be specified on other cards that define mutually exclusive sets. See Section 1.4.1 for a list of these cards.

3. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.

4. SPC degrees of freedom may be redundantly specified as permanent constraints on the GRID card.

5. If the alternate form is used, points in the sequence GID1 thru GID2 are not required to exist. Points which do not exist will collectively produce a warning message but will otherwise be ignored.

Input Data Card SPCADD Single-Point Constraint Set Combination

Description: Defines a single-point constraint set as a union of single-point constraint sets defined via SPC or SPC1 cards.

Format and Example:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| SPCADD | SID | S1 | S2 | S3 | S4 | S5 | S6 | S7 | abc |
| SPCADD | 101 | 3 | 2 | 9 | 1 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| +bc | S8 | S9 | -etc. | | | | | | |
| | | | | | | | | | |

-etc.-

| Field | Contents |
|---|---|
| SID | Identification number for new single-point constraint set (Integer > 0). |
| Si | Identification numbers of single-point constraint sets defined via SPC or SPC1 cards (Integer > 0; SID ≠ Si). |

Remarks:

1. Single-point constraint sets must be selected in the Case Control Deck (SPC=SID) to be used by NASTRAN.
2. No Si may be the identification number of a single-point constraint set defined by another SPCADD card.
3. The Si values must be unique.
4. SPCADD cards take precedence over SPC or SPC1 cards. If both have the same set ID, only the SPCADD card will be used.

# PLOTTING

# 4.1 PLOTTING

## 4.1.1 General Capability

MSC/NASTRAN provides the capability for generating the following kinds of plots:

→ 1. Undeformed geometric projections of the structural model.

→ 2. Static deformations of the structural model by either displaying the deformed shape (alone or superimposed on the undeformed shape), or displaying the displacement vectors at the grid points (superimposed on either the deformed or undeformed shape).

3. Modal deformations resulting from real or complex eigenvalue analysis by the same options stated in 2 above. Complex modes for flutter analysis may be plotted for any user-chosen phase lag.

4. Deformations of the structural model for transient response or frequency response by displaying either vectors or the deformed shape for specified times or frequencies.

5. X-Y graphs of transient response or frequency response.

6. V-F and V-G graphs for flutter analysis.

→ 7. Contour plots of displacements, temperature and stress on the structure.

Structural plots (items 1-4) are discussed in Section 4.2, while X-Y plots (item 5) are discussed in Section 4.3. Requests for structure plots or X-Y plots are accomplished in the Case Control Deck by submitting a structure plot request or an X-Y output request. The optional PLØTID card is considered to be part of the plot request (although it must precede any ØUTPUT(PLØT), ØUTPUT(XYØUT) or ØUTPUT(XYPLØT) cards. See Section 2.3 for a description of the PLØTID card.

Plot requests are separated from case control by the ØUTPUT(PLØT), ØUTPUT(XYPLØT) or ØUTPUT(XYØUT) cards. Data above this card (except PLØTID) will not be recognized by the plotter, even though it may have the same name (for example, the SET card).

## 4.1.2 Superelement Plotting

Plotting may take place at four different places in the superelement solution sequences. There are two plot commands, SEPLØT and SEUPPLØT, used with other case control and PARAM cards to control the type of plot to be prepared. A flow chart of the solution process is given in Figure 1.

Undeformed structure plots are made early during the SEMG process. They can be made for either one superelement only, or for a superelement and all of its upstream members, as controlled by PARAM, PLØTSUP (see Figure 1, block 1). Plots are made for superelements selected for the SEMG process, and listed in a plot request headed by SEPLØT SEID, where SEID is the superelement identification number (see Section 4.3.8 for an example of a complete superelement plot packet). Undeformed plots can be used to check geometry and connectivity, and do not require the presence of property or material cards. A branch to the end of the loop immediately after the plot module can be made by use of the PARAM,PLØT,-1 card.

In dynamic analysis, solution set XY-plots are requested by use of SEPLØT 0 (see Figure 1, block 2). In the data recovery phase, XY-plots and deformed structure plots for elements in one superelement only are requested by the SEPLØT command (see Figure 1, block 3). Deformed structure plots for a superelement and all its upstream plots are requested with the SEUPPLØT command (see Figure 1, block 4).

Undeformed plots require the presence of the SEMG case control card for all superelements listed on SEPLØT requests. XY-plots and deformed structure plots are regarded as output requests, and will result in automatic execution of the data recovery loop as is required to produce the plots requested. For example, the command SEUPPLØT 0 will result in data recovery being performed on the entire model, even in the absence of any other output requests. For SEUPPLØT requests, if SUBCØM or SYMCØM subcases are used, each superelement must have identical SUBCØM and SYMCØM structure.

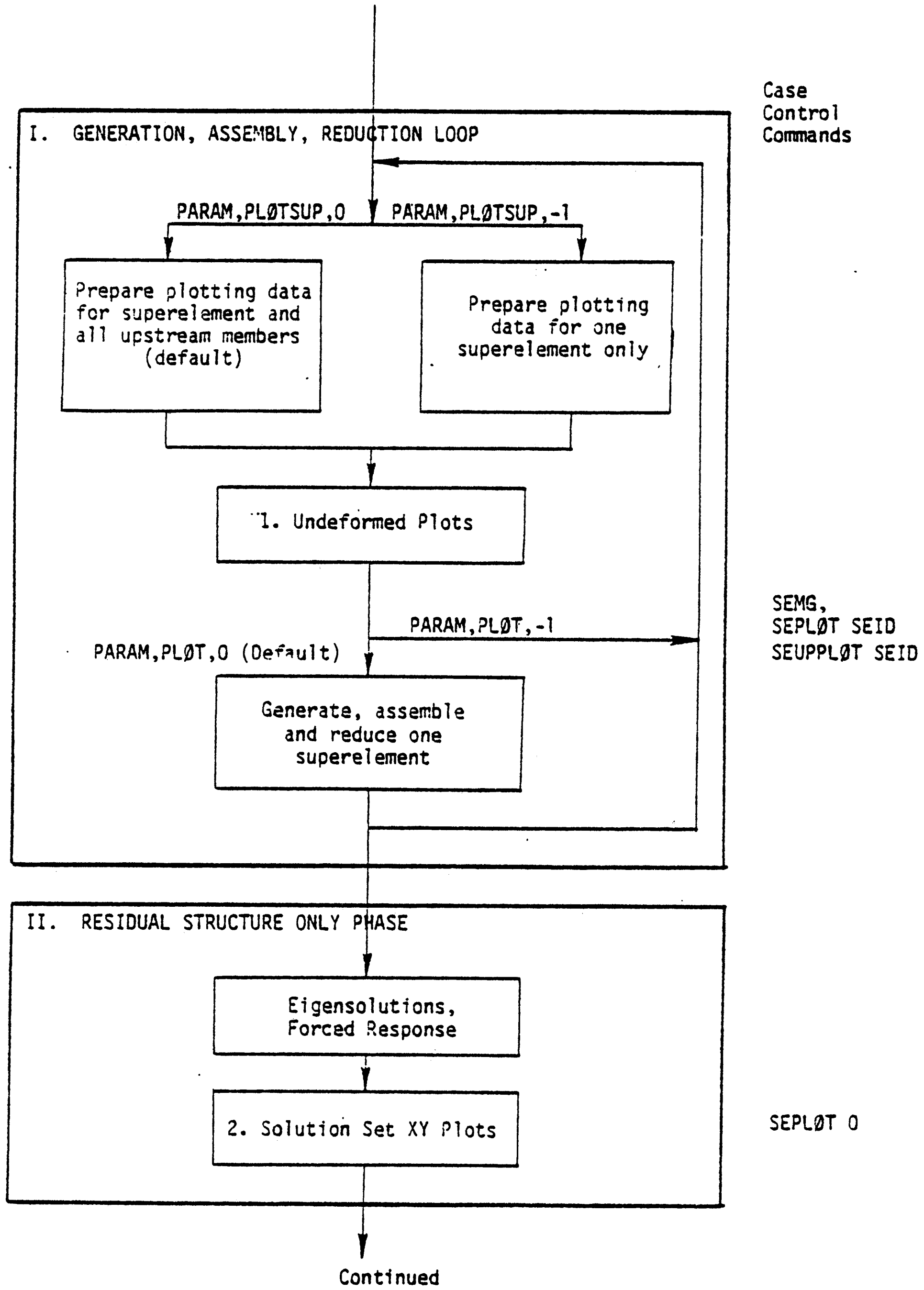



Figure 1. Superelement Plot Control

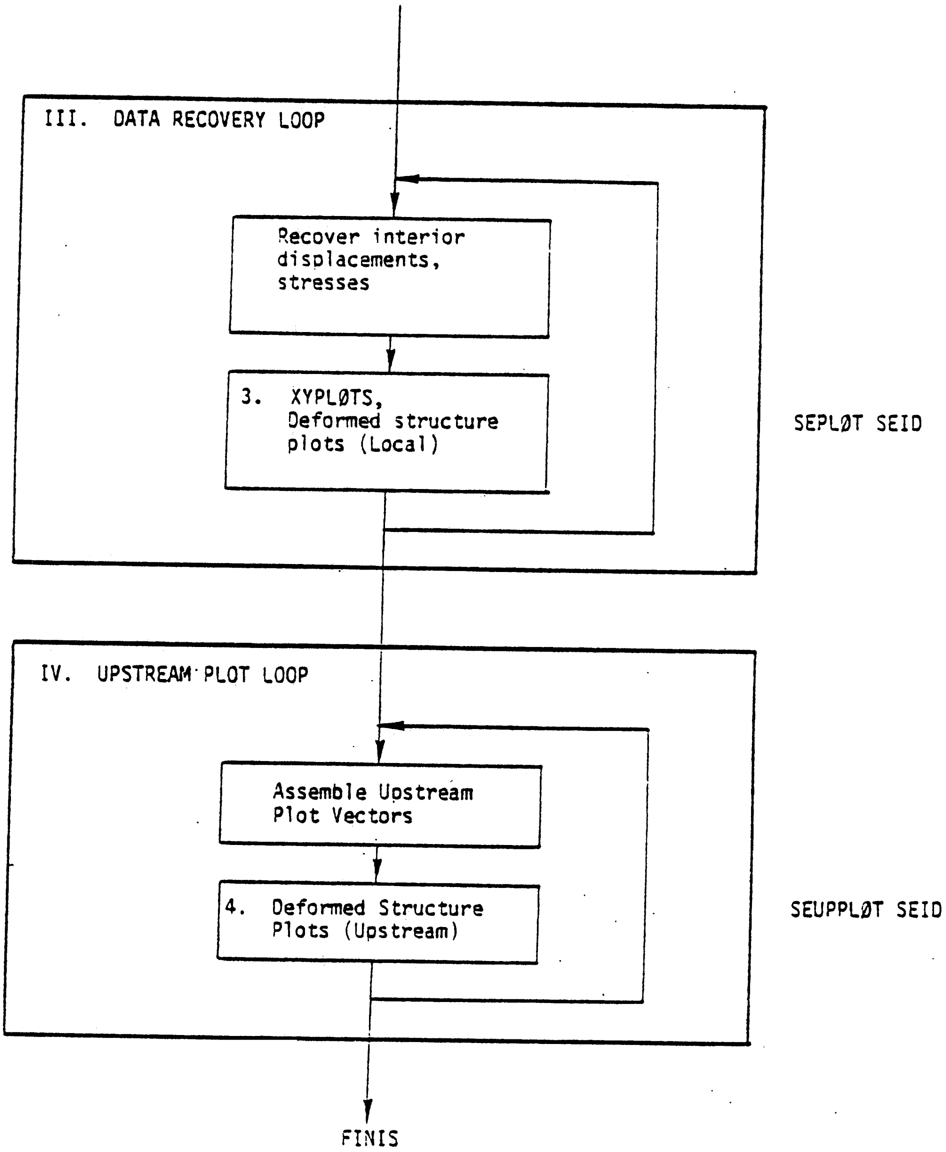



Figure 1. Superelement Plot Control (Cont.).

## 4.2 STRUCTURE PLOTTING

In order to assist users both in the preparation of the analytical model and in the interpretation of output, the structure plotter provides the following capabilities for undeformed structures:

1. Connect the grid points in a predetermined manner using the structural elements or PLØTEL elements.
2. Place a symbol at connected grid point locations. (optional)
3. Identify connected grid points by placing the grid point identification number to the right of the grid point locations. (optional)
4. Identify elements by placing the element identification number and element symbol at the center of each element. (optional)
5. Identify connected grid points that are constrained to zero with single point constraints by placing the grid point number and integers defining the constrained degrees of freedom to the right of the grid point locations.
6. Identify elements by placing the element identification number, the element symbol, and the property identification number at the center of each element.
7. Draw an outline of the structure. (optional)
8. Shrink one- and two-dimensional elements by a fraction. (optional)

The following capabilities are provided for deformed structures:

1. Connect the deflected grid points in a predetermined manner using the structural elements or PLØTEL elements.
2. Place a symbol at the deflected grid point location. (optional)
3. Identify the deflected grid points by placing the grid point identification number to the right of the deflected grid point location. (optional)
4. Draw lines originating at the undeflected or deflected grid point location, drawn to user-specified scale, representing the X, Y, Z components or resultant summations of the grid point deflections.
5. Draw an outline of the structure. (optional)
6. Shrink one- and two-dimensional elements by a fraction. (optional)
7. Contours of element stresses.
8. Contours of displacements or temperatures.

The above plots are available in either orthographic, perspective, or stereoscopic projections. Stereoscopic plots are normally made only on microfilm plotters since a stereoscopic viewer or projector must be used to obtain the stereoscopic effect. A request for structure plotting is made in the Case Control Deck by means of a plot request which includes all cards from an ØUTPUT(PLØT) card to either a BEGIN BULK or ØUTPUT(XYØUT) [or ØUTPUT(XYPLØT)] card. It should be noted that only elements can be plotted. Grid points that are not associated with elements cannot be plotted. Grid points may be connected with PLØTEL elements for plotting purposes.

The data card format is free-field, subject to rules in paragraphs below. The cards are basically sequence-dependent even though some interchanging in sequence of defining parameters is permissible. The elements and grid points to be plotted may be defined anywhere in the plot package, but the parameters describing the characteristics of the plot are evaluated on the current basis every time a PLØT or FIND card (see Section 4.2.2.2) is encountered. In order to minimize mistakes, it is suggested that a strict sequence dependency be assumed.

## 4.2.1 General Rules

### 4.2.1.1 Rules for Free-Field Card Specification

1. Only columns 1 thru 72 are available. Any information specified in columns 73 thru 80 will be ignored.
2. If the last character on a card is a comma (not necessarily in column 72), the next card is a continuation of this physical card. Any number of continuation cards may be specified, and together they form a logical card.
3. The mnemonics or values can be placed anywhere on the card, but must be separated by delimiters.
4. The following delimiters are used:
   a. blank
   b. comma (,)
   c. left parenthesis [(]
   d. right parenthesis [)]
   e. equal sign (=)

   All of these delimiters can be used as needed to aid the legibility of the data.

### 4.2.1.2 Plot Request Packet Card Format

In the plot request packet card descriptions presented in Section 4.2.2, the following notation will be used to describe the card format:

1. Upper case letters must be punched exactly as shown.
2. Lower-case letters indicate that a substitution must be made.
3. Braces { } indicate that a choice of the contents is mandatory.
4. Brackets [ ] contain an option that may be omitted or included by the user.
5. Underlined options or values are those for which a default option or an initialized (or computed) value was programmed.
6. A physical card consists of information punched in columns 1 thru 72 of a card.
7. A logical card may consist of more than one physical card through the use of continuation cards.
8. Numerical values may usually be either integer or real numbers, even though a specific type is at times suggested in order to conform to the input in other sections of the program.

If the first four characters of a mnemonic are unique relative to all other case control cards, the characters following can be omitted.

### 4.2.1.3 Plot Titles

Up to four lines of title information will be printed in the lower left-hand corner of each plot. The text for the top three lines is taken from the TITLE, SUBTITLE, and LABEL cards in the Case Control Deck. (See Section 2.3 for a description of the TITLE, SUBTITLE, and LABEL cards.) The text for the bottom line may be of two forms depending on the type plot requested. One form contains the word UNDEFØRMED SHAPE. The other form contains the type of plot (statics, modal, etc.), subcase number, load set or mode number, frequency or eigenvalue or time, and (for complex quantities) the phase lag or magnitude.

The sequence number for each plot is printed in the upper corners of each frame. The sequence number is determined by the relative position of each PLØT execution card in the plot package. The information on the PTITLE card will be printed on the line below the sequence number. The date and (for deformed plots) the maximum deformation are also printed at the top of each frame.

### 4.2.2 Plot Request Card Descriptions

The general form for each card of the plot request is shown enclosed in a box. Description of the card contents then follows for each card.

#### 4.2.2.1 SET Definition Cards

These cards specify sets of elements, corresponding to portions of the structure, which may be referenced by PLØT and FIND cards. The SET card is required.

Each set of elements defines by implication a set of grid points connected by those elements. The set may be modified by deleting some of its grid points. The elements are used for creating the plot itself and element labeling while the grid points are used for labeling, symbol printing, and drawing deformation vectors.

```
SET i [INCLUDE][ELEMENTS] j1, j2, j3 THRU j4, j5, etc.

      INCLUDE
      EXCLUDE   ELEMENTS     k1, k2, k3 THRU k4, k5, etc.
      EXCEPT    GRID PØINTS
```

i = set identification number (positive integer, unique for each set)

j = element identification numbers or element types

k = element identification numbers or grid point identification numbers or element types

Permissible element types and plotting labels are:

| Element Type | Plot Label | Element Type | Plot Label |
|---|---|---|---|
| AERØ1 | AE | PENTA | PA |
| AXIF2 | A2 | PLØTEL | PL |
| AXIF3 | A3 | QUAD4 | Q4 |
| AXIF4 | A4 | QUAD8 | Q8 |
| BAR | BR | RØD | RD |
| BEAM | BM | SHEAR | SH |
| BEND | BD | SLØT3 | S3 |
| CØNE | CN | SLØT4 | S4 |
| CØNRØD | CR | TETRA | TE |
| DUMi | Di | TRAPRG | TA |
| FLMASS | FM | TRIAX6 | D1 |
| FLUID2 | F2 | TRIA3 | T3 |
| FLUID3 | F3 | TRIA6 | T6 |
| FLUID4 | F4 | TRIM6 | D2 |
| HBDY* | HB | TRIARG | T1 |
| HEXA | HA | TUBE | TU |
| HEX20 | XQ | VISC | VS |

*The boundary condition elements for the MSC/NASTRAN heat conduction analyzer can be plotted for undeformed structure plots. There are several types of HBDY elements, as follows:

| Type | PØINT | LINE | AREA3 | AREA4 | REV | ELCYL | FTUBE |
|---|---|---|---|---|---|---|---|
| No. of Primary Grid Pts. | 1 | 2 | 3 | 4 | 2 | 2 | 2 |
| Normals Available | yes | yes | yes | yes | no | no | yes |

The secondary grid points are used for "ambient" conditions and are ignored by the plotter. Type PØINT must have a nonzero associated area (see AF on the associated PHBDY data card) and a defined normal direction (see V1, V2, V3 on the CHBDY data card) to be plotted. It is plotted as a hexagon with approximately the correct area. Type LINE must have a nonzero width (see AF on the associated PHBDY data card) and a normal defined in order to plot.

ALL may be used to select all permissible element types.

INCLUDE may be used at any time for element information.

EXCLUDE can be used to delete elements or element types. All grid points that are associated with deleted elements are also deleted.

INCLUDE or EXCLUDE, when used for grid points, will have the first reference to a grid point used.

EXCEPT is a modifier to an INCLUDE or an EXCLUDE statement for elements.

THRU is used to indicate all of the integers in a sequence of identification numbers, starting with the integer preceding THRU and ending with the integer following THRU. The integers in the range of the THRU statement need not be consecutive, e.g., the sequence 2, 4, 7, 9 may be specified as 2 THRU 9. THRU is not applicable if element types are specified. THRU should not be used for large open sets because of high computation cost.

Each SET must be a logical card. Redefinition of sets previously defined is not permitted; however, there is no restriction on the number of sets. The sets of identification numbers can be assembled by use of the word ALL, or by individually listing the integers in any order such as 1065, 32, 46, 47, 7020, or by listing sequences using THRU, EXCLUDE, and EXCEPT such as 100 THRU 1000 EXCEPT 182 EXCLUDE 877 THRU 911. Examples of SET cards:

1. SET 1 INCLUDE 1, 5, 10 THRU 15 EXCEPT 12
   (Set will consist of elements 1, 5, 10, 11, 13, 14 and 15)
2. SET 2 = RØD, CØNRØD, EXCEPT 21
   (Set will consist of all RØD and CØNRØD elements except element 21)
3. SET 10 SHEAR INCLUDE GRID PØINTS 35, 36 EXCLUDE GRID PØINTS 20, 30 THRU 60, INCLUDE ELEMENTS 70 THRU 80.
   (This set will include all shear elements plus elements 70 thru 80, and the associated grid point set will contain all grid points connected by these elements. Grid points 20, 30 thru 34 and 37 thru 60 will not appear on the plots with their symbols, labels, or vectors.
4. SET(15) = (15 THRU 100) EXCEPT (21 THRU 25)
   (This set will include all elements from 15 to 20 and from 26 to 100)
5. SET 2 = ALL EXCEPT BAR
   (This set will include all elements except bars)

Notes: The equal signs, commas, and parentheses above are delimiters and are not required, because blanks also serve as delimiters. Plotter sets must be specified after the ØUTPUT(PLØT) card. Case Control sets are ignored.

#### 4.2.2.2 Cards Defining Parameters

These cards specify how the structure will be plotted, i.e., type of projection, view angles, scales, etc. All the multiple choice parameters are defaulted to a preselected choice if not specified. Each parameter requiring a numerical value that is not specified by the user can either be established internally in the program by means of the FIND card or can assume default values. The FIND card is used to request that the program select a SCALE, ØRIGIN, and/or VANTAGE PØINT to allow the construction of a plot in a user-specified region of the paper or film. The FIND card is described at the end of this section, following the discussion of the associated parameters.

The parameter cards are listed here in a logical sequence; however, they need not be so specified. Any order may be used, but if a parameter is specified more than once, the value or choice stated last will be used. Each parameter may be either an individual card, or any number of them may be combined on one logical card.

All the parameters used in the generation of the various plots will be printed out as part of the output, whether they are directly specified, defaulted or established using the FIND card.

Initialization of parameters to default values occurs only once. Subsequently, these values remain until altered by a direct input. The only exceptions are the view angles, scale factors, vantage point parameters, and the origins. Whenever the plotter or the method of projection is changed, the view angles are reset to the default values, unless they are respecified by the user. In addition, the scale factors, vantage point parameters, and the origin must be redefined by the user.

| |
|---|
| PLØTTER { SC / <u>NAST</u> } |

The default option (NAST) is the NASTRAN general purpose plotter. The NASTRAN plotter option prepares a general purpose plot file which must be interpreted by a postprocessing program. The format of the NASTRAN general purpose plot file is described in Section 6 of the Programmer's Manual. See Section 2.3 of the Application Manual for a description of NASPLØT, a utility routine for interpreting the NASTRAN plot file. SC selects the Stromberg Carlson 4020 microfilm plotter.

| |
|---|
| <u>ØRTHØGRAPHIC</u><br>PERSPECTIVE<br>STEREØSCØPIC |

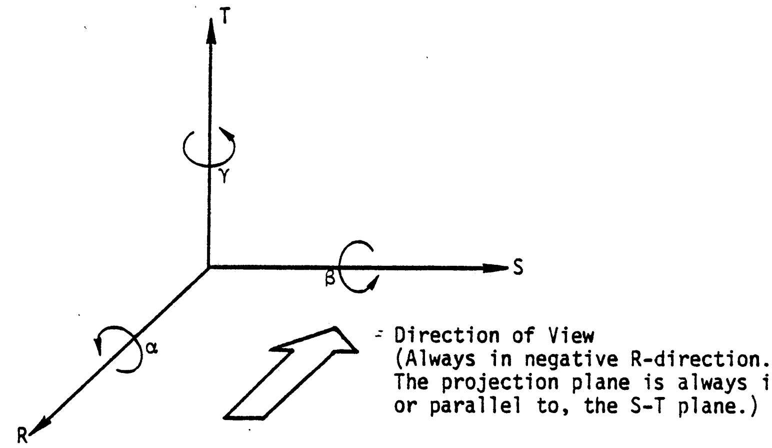
The default option is orthographic projection. See Section 13 of the Theoretical Manual for a discussion of the various projections. This card is optional.

| | |
|---|---|
| AXES r,s,t | { <u>SYMMETRIC</u> / ANTISYMMETRIC } |
| VIEW $\gamma,\beta,\alpha$ | |

r, s, t = X or MX, Y or MY, Z or MZ (where "M" implies the negative axis)

$\gamma$, $\beta$, $\alpha$ = three angles of rotation in degrees (real numbers)

These two parameter cards define the orientation of the object in relation to the observer, that is the angles of view. Both of these cards are optional. Defining the observer's coordinate system as R, S, T and the basic coordinate system of the object as X, Y, Z, the angular relationship between the two systems is defined by the three angles $\gamma$, $\beta$ and $\alpha$ as follows:




Using the above convention, $\gamma$ and $\beta$ represent the angles of turn and tilt. The default values are:

$\gamma = 34.27°$

$\beta = 23.17°$ for orthographic and stereoscopic projections, 0.0° for perspective projection

$\alpha = 0.0°$

The order in which $\gamma$, $\beta$, and $\alpha$ are specified is critically important as illustrated in Figure 1, at the end of this section. Also, see Section 13.1.1 of the Theoretical Manual.

The AXES card can be used to preposition the object in 90° increments in such a manner that only rotations less than 90° are required by the VIEW card to obtain the desired orientation. This is accomplished by entering X, Y, Z, MX, MY or MZ in the fields corresponding to R, S, T axes, where MX, MY and MZ represent the negative, X, Y and Z axis directions respectively. The default values are X, Y, Z. The M values can also be used to define left-handed coordinate systems. (Note that the default system is right-handed.)

An undeformed or deformed plot of the symmetric portion of an object can be obtained by reversing the sign of the axis that is normal to the plane of symmetry. In the case of multiple planes of symmetry, the signs of all associated planes should be reversed. The ANTISYMMETRIC option should be specified when a symmetric structure is loaded in an unsymmetric manner. This will cause the deformations to be plotted antisymmetrically with respect to the specified plane or planes. Since the AXES card applies to all parts (SETS) of a single frame, symmetric and anti-symmetric combinations cannot be made with this card (see the symmetry option on the the PLØT execution card in Section 4.2.2.3).

| MAXIMUM DEFØRMATIØN $\left\{\frac{\text{5\% structure dimension}}{\text{d}}\right\}$ |
|---|

The value of d represents the length to which the maximum displacement component is scaled in each subcase. The maximum deformation must be specified in units of the structure (not inches of paper).

$$\left(\frac{\text{actual displacement}}{\text{actual maximum displacement}}\right) \text{ d}$$

The default value for d is 5% of the maximum dimension of the structure. This data is necessary since the actual deformations are usually too small to be distinguishable from the undeformed structure if they were plotted to true scale. If FIND card parameters are to be based on the deformed structure, the FIND card must be preceded by the MAXIMUM DEFØRMATIØN card.

| SCALE a[ , b] |
|---|

a = real number representing scale to which the model is drawn

b = ratio of model size/real object size (stereoscopic projection only)

For orthographic or perspective projections, the scale "a" is the ratio of the plotted object in inches to the real object in the units of the structural model, i.e., one inch of paper equals one unit of structure. For stereoscopic projection, the stereoscopic effect is enhanced by first reducing the real object to a smaller model (scale "b"), and then applying scale "a." The ratio of plotted/real object is then the product a x b. A scale must be defined in order to make a plot. However, the SCALE card is not recommended for general use. See the FIND card described at the end of this section in order to have the scale determined automatically.

If the NASTRAN general purpose plotter is used in combination with the MSC/NASPLØT post-processing routine, the user may determine a scale as follows:

$$a = p \times \frac{20}{7} \times \frac{1}{SF(NASPLØT)}$$

where p = ratio of object size to plot size

$\frac{20}{7}$ = ratio of default PAPER SIZE to default NASPLØT frame size

SF(NASPLØT) = scale factor on NASPLØT data card (default = 1.0)

| DISTØRTIØN $\left\{ \frac{1.0,\ 1.0,\ 1.0}{x,y,z} \right\}$ |
|---|

This card specifies the distortion factor in the X, Y and Z directions. The X, Y and Z coordinates are multiplied by the distortion factors prior to any other scaling operations. The default values are all 1.0. If this card is used, all three values must be specified even though one or two of the values are the default.

| CSCALE $\left[ \frac{0.5}{cs} \right]$ |
|---|

This card is used to control the spacing of characters when plots are made with the NASTRAN plotter and they are postprocessed with the MSC/NASPLØT routine. For example, if the SCALE FACTØR on the NASPLØT data card is 2.0, a value for cs of 0.5 will result in characters of default size (.07 inches) at the regular spacing. On the other hand, if the user wishes to double the size of both the plot and the characters, the SCALE FACTØR and the CSCALE FACTØR on the NASPLØT data card should both be set equal to 2.0. The CSCALE card must immediately precede the PLØTTER selection card. If a second CSCALE card is used, a second PLØTTER selection crd must also be used.

| ØRIGIN i, u, v |
|---|

i = origin identification number (any positive integer)

u = horizontal displacement of paper origin from RST origin

v = vertical displacement of paper origin from RST origin

In the transformation performed for any of the three projections, the origins of both the object (XYZ system) and of the observer (RST system) are assumed to be coincident.

This card refers to the paper origin. It represents the displacement of the paper origin (lower left hand corner) from the RST origin. The units are inches and are not subject to the scaling of the plotted object. The ØRIGIN card is not recommended for general use. See the FIND card described at the end of this section in order to have the origin located so as to place the plotted object in the center of the image area.

Ten (10) origins are permitted to be active at one time. However, any one can be redefined at any time. An eleventh origin is also provided if more than ten origins are erroneously defined (i.e., only the last of these surplus origins will be retained). CAUTION: When a new projection or plotter is called for, all previously-defined origins are deleted.

| VANTAGE PØINT $r_0$, $s_0$, $t_0$, $d_0$ [, $s_{or}$] |
|---|

(perspective and stereoscopic projections only)

$r_0$ = R-coordinate of the observer

$s_0$ = S-coordinate of the observer in perspective projection or
S-coordinate of the left eye of the observer in the stereoscopic projection

$t_0$ = T-coordinate of the observer

$d_0$ = R-direction separation of the observer and the projection plane

$s_{or}$ = S-coordinate of the right eye of the observer in the stereoscopic projection (required in stereoscopic projection)

This card defines the location of the observer with respect to the structural model. A vantage point is required for either perspective or stereoscopic projections. The VANTAGE PØINT card is not recommended for general use. See the FIND card described at the end of this section. A theoretical description of the vantage point is contained in Section 13 of the Theoretical Manual.

| |
|---|
| PRØJECTIØN PLANE SEPARATIØN $\left\{\frac{2.0}{d_o}\right\}$ |

(stereoscopic projections only)

This card specifies the R-direction of the observer and the projection plane when a VANTAGE PØINT card is not used. The default value is 2.0. The PRØJECTIØN PLANE SEPARATIØN card is not recommended for general use. See the FIND card described at the end of this section. A theoretical description of projection plane separation is contained in Section 13 of the Theoretical Manual.

| |
|---|
| ØCULAR SEPARATIØN $\left\{\frac{2.756 \text{ in}}{os}\right\}$ |

(stereoscopic projection only)

Ocular separation - S-coordinate separation of the two vantage points in the stereoscopic projection is defaulted to 2.756 inches, which is the separation used in the standard stereoscopic cameras and viewers (70mm). It is recommended that the default value be used.

| |
|---|
| CAMERA $\left\{\begin{array}{l}\text{FILM}\\ \underline{\text{PAPER}}\\ \text{BØTH}\end{array}\right\}$ [, BLANK FRAMES $\left\{\frac{0}{n}\right\}$ ] |

(microfilm plotters only)

This card offers three options of different cameras or combinations:

FILM - 35mm or 16mm film (positive or negative images)

PAPER - positive prints

BØTH - positive prints and 35mm or 16mm film

The request for a 35mm or 16mm camera and positive or negative images must be communicated to the plotter operator through normal means of communications at the installation. Insertion of blank frames between plots is optional and is applicable only to plots generated on film. The type option must be FILM or BØTH if blank frames are desired. The plotter must be operated in the manual mode in order to have blank frames inserted between positive prints. If blank frames are desired only on film, and not on paper, the plotter must be operated in the automatic mode. The default values are PAPER and n = 0. This card is completely optional.

$$\text{PAPER SIZE} \begin{Bmatrix} \underline{7.5} \\ a \end{Bmatrix} \begin{Bmatrix} \underline{X} \\ BY \end{Bmatrix} \begin{Bmatrix} \underline{7.5} \\ b \end{Bmatrix} \text{ [, TYPE } \begin{Bmatrix} \underline{\text{VELLUM}} \\ \text{name} \end{Bmatrix} \text{ ]}$$

(SC plotters)

$$\text{PAPER SIZE} \begin{Bmatrix} \underline{20.0} \\ a \end{Bmatrix} \begin{Bmatrix} \underline{X} \\ BY \end{Bmatrix} \begin{Bmatrix} \underline{20.0} \\ b \end{Bmatrix} \text{ [, TYPE } \begin{Bmatrix} \underline{\text{VELLUM}} \\ \text{name} \end{Bmatrix}$$

(NASTRAN plotters)

a = horizontal size of paper in inches

b = vertical size of paper in inches

name = any BCD value desired by user for identification purposes.

The default parameter for SC plotters is 7.5 x 7.5, type VELLUM.

The default paper size for the NASTRAN plotter is 20 x 20 inches and this is converted to a 7 x 7 inch plot frame by the NASPLØT postprocessor. The PAPER SIZE parameter can be used along with the NASPLØT postprocessor to create rectangular plots. For example, the card will result in a 14 x 7 inch plot frame if the default value of 1.0 is used for the SCALE FACTØR on the NASPLØT data card. The SCALE FACTØR on the NASPLØT data card can be used to make larger plots having the shape defined with PAPER SIZE.

The PAPER SIZE parameter is also used to control the raster count for the NASTRAN plotter. The default raster count is 1000 for a paper size of 20 x 20. Doubling the paper size to 40 x 40 will double the raster count to 2000.

| PEN i [CØLØR name] |
|---|

i = pen designation number (1 to 4)

name = color desired

This card generates a message on the printed output which may be used to inform the plotter operator as to what size and which color pen point to mount in various pen holders. The actual number of pens available will depend on the plotter hardware configuration at each installation. This card does not control the pen used in generating the plot (see the PEN option on the PLØT execution card in Section 4.2.2.3). The PEN card is optional, and is not appropriate for microfilm plotters.

| PTITLE = { <u>blanks</u> / plot title text } |
|---|

The plot title text on this card is printed at the top of the plot on the line below the sequence number. The complete text must be on a single physical card. The default value for the text is all blanks.

| FIND [SCALE], [ØRIGIN i],[VANTAGE PØINT],[SET j], REGIØN { <u>0.0</u>,<u>0.0</u>,<u>1.0</u>,<u>1.0</u> / le, be, re, te } |
|---|

i = origin identification number (any positive integer)

j = set identification number (any positive integer)

le = fractional distance of <u>left</u> edge of plot region from the lower left corner of the image area (default = 0.0)

be = fractional distance of <u>bottom</u> edge of plot region from the lower left corner of the image area (default = 0.0)

re = fractional distance of <u>right</u> edge of plot region from the lower left corner of the image area (default = 1.0)

te = fractional distance of <u>top</u> edge of plot region from the lower left corner of the image area (default = 1.0)

The FIND card requests the structure plotter to compute any of the parameters SCALE, ØRIGINi, and/or VANTAGE PØINT indicated by the user based on 1) the plotter requested on the PLØTTER card, 2) the projection requested on the PRØJECTIØN card, 3) SETj and REGIØN le, be, re, te requested on the FIND card, 4) the orientation requested on the VIEW and/or AXES card(s), 5) the deformation scaling requested on the MAXIMUM DEFØRMATIØN card, and 6) the paper size as requested on the PAPER SIZE card. All dependencies on which a FIND card is based must precede the FIND card. It is recommended that the FIND card be placed just before the PLØT card or the CØNTØUR card, if present.

Any one, two or all three parameters may be computed by the program by using this card, provided that the parameters not requested have already been defined. If no set is specified on this card, the first set defined is used by default. If no options are specified on the FIND card, a SCALE and VANTAGE PØINT are selected and ØRIGIN 1 is located, using the first defined SET, so that the plotter object is located within the image area. The plot region is defined as some fraction of the image area (image area = 0., 0., 1., 1. and first quadrant = .5, .5, 1., 1.). The image area is located inside the margins on the paper. Each FIND card must be <u>one</u> (1) logical card. The FIND card is recommended for general use.

```
          ( MAJPRIN   )
          ( MINPRIN   )
          ( MAXSHEAR  )
          ( XNØRMAL   )  ( EVEN 10      )  ( Z1  )
CØNTØUR   < YNØRMAL   >  < EVEN n       >  < Z2  >  ( CØMMØN )
          ( ZNØRMAL   )  ( LIST a,b,... )  < MAX >  ( LØCAL  )
          ( XYSHEAR   )                    ( MID )
          ( XZSHEAR   )
          ( YZSHEAR   )
```

(stress contour plots only)

1. <u>Type of Stress</u>

   MAJPRIN - Major principal stress (default)

   MINPRIN - Minor principal stress

   MAXSHEAR - Maximum shear stress

   XNØRMAL
   YNØRMAL } - X, Y, Z components of normal stress
   ZNØRMAL

   XYSHEAR
   XZSHEAR } - Components of shear stress
   YZSHEAR

2. <u>Number of Stress Contours</u>

   EVEN - Integer following is number of stress contours (default is 10, maximum is 50).

   LIST - Real numbers following are values of stress contours.

3. <u>Location of Stress</u> (Z1 and Z2 specified on property card)

   Z1 - Distance Z1 from neutral plane

   Z2 - Distance Z2 from neutral plane

   MAX - Maximum of stress at Z1 and Z2

   MID - Average of stress (membrane stress) at Z1 and Z2

4. <u>Coordinate System</u>

   CØMMØN - Plot stress contours in basic coordinate system (default)

   LØCAL - Plot stress contours in element coordinate system

Stress contour plots are available for the following elements: TRIA3, QUAD4, SHEAR, and TRIAX6. The connection cards for all elements must list the grid points in either clockwise or counterclockwise order. Some in each order will result in meaningless plots.

When selecting contour options, note:

1. MAJPRIN, MINPRIN, MAXSHEAR are the same in CØMMØN and LØCAL.
2. ZNØRMAL, XZSHEAR, YZSHEAR, if selected in LØCAL, will be changed to CØMMØN.
3. SHEAR elements only have the MAXSHEAR value.

The TRIAX6 stress contour plots are different in that they must be selected as CØMMØN, then the following equivalence table applies:

XNØRMAL = RADIAL
YNØRMAL = AZIMUTH
ZNØRMAL = AXIAL
XYSHEAR = SHEAR
XZSHEAR = MAX PRINCIPAL
YZSHEAR = MAX SHEAR
MAXSHEAR = ØCTAHEDRAL

The CØNTØUR card should be placed immediately before the associated PLØT execution card in order to be certain that all applicable parameters have been previously defined. A STRESS request must appear in the Case Control Deck for all elements included in a CØNTØUR request. If printed output is not desired, the request can be of the form STRESS(PLØT) = $\left\{\frac{\text{ALL}}{\text{n}}\right\}$.

| | | |
|---|---|---|
| CØNTØUR | XDISP<br>YDISP<br>ZDISP<br>MAGNIT | <u>EVEN10</u><br>EVENn<br>LIST a,b,... |

(displacement or temperature contour plots only)

1. <u>Type of Displacement</u>

   XDISP, YDISP, ZDISP — X,Y,Z components of displacement in global coordinate system

   MAGNIT — Magnitude of deformation, also used for contours of temperatures

2. <u>Number of Displacement Contours</u>

   EVEN - Integer following is number of displacement contours (default is 10, maximum is 50).

   LIST - Real numbers following are values of displacement contours.

### 4.2.2.3 PLØT Execution Card

```
      ┌ ⎧STATIC    ⎫ ┐   ┌ ⎧DEFØRMATIØN ⎫ ┐                                          ┌ ⎧RANGE f1, f2⎫ ┐
      │ ⎪MØDAL     ⎪ │   │ ⎨VELØCITY    ⎬ │   {CØNTØUR}   [i1, i2 THRU i3, i4, etc.]   │ ⎨RANGE λ1, λ2⎬ │ ,
PLØT  │ ⎨CMØDAL    ⎬ │   └ ⎩ACCELERATIØN⎭ ┘                                          └ ⎩TIME  t1, t2⎭ ┘
      │ ⎪TRANSIENT ⎪ │
      │ ⎪FREQUENCY ⎪ │
      └ ⎩blank     ⎭ ┘

      [⎧PHASE LAG φ⎫]   [MAXIMUM DEFØRMATIØN d]   ,
      [⎩MAGNITUDE  ⎭]

[SET j1]   [ØRIGIN k1]   [⎧SYMMETRY    ⎫] w   [⎧PEN    ⎫] p     [SYMBØLS m [,n]]   ,
                         [⎩ANTISYMMETRY⎭]     [⎩DENSITY⎭]

            ┌ ⎧GRID PØINTS⎫ ┐
            │ ⎪ELEMENTS   ⎪ │
      LABEL │ ⎨BØTH       ⎬ │   [⎧SHAPE  ⎫]   [VECTØR v]   ,   [PRINT]   ,
            │ ⎪EPID       ⎪ │   [⎩ØUTLINE⎭]
            └ ⎩GSPC       ⎭ ┘

[SHRINK t,o]  [NØRMALS]   ,

[ SET j2]  [ØRIGIN k2] ..., etc.
```

This logical card will cause one picture to be generated for each subcase, mode or time step requested using the current parameter values. If only the word PLØT appears on the card, a picture of the undeformed structure will be prepared using the first defined set and the first defined origin. Options 1 thru 6, if used, must be in the order shown. The available plot options and their meanings are:

1. STATIC - Plot static deformations

   MØDAL - Plot mode shapes

   CMØDAL - Plot complex mode shapes

   TRANSIENT - Plot transient solutions

   FREQUENCY - Plot frequency solutions

   blank - No entry is a request for either undeformed plots or undeformed underlay for contour plots

2. DEFØRMATIØN - Plot displacements or temperatures (in the Z direction) (default value)

VELØCITY - Plot velocities

ACCELERATIØN - Plot accelerations

3. CØNTØUR - Request for contour plots

4. i1, i2, ... - Nonzero integers following refer to subcase numbers that are to be plotted. Default is all subcases. See SHAPE and VECTØR for use of "0" (underlay) command.

In eigenvalue problems, the list of subcases must refer to subcase IDs whenever the number of modes recovered is equal to or less than the number of subcases defined. If the number of modes recovered is more than the subcases defined, the plot request for those modes associated with the subcases must refer to subcase IDs. After the mode associated with the last defined subcase, higher modes will be identified by incrementing the last defined subcase ID by one for each such higher mode.

In eigenvalue problems using Type II cyclic symmetry solution sequences (Rigid Format 48 and buckling analysis solution sequence DMAP5CY) the plot requests for segments of the model must refer to the coded subcase IDs (see Section 1.11 for definition of coded subcase IDs). All eigenvectors recovered for the segment will be plotted. The RANGE option can be used to select a subset of all eigenvectors for plotting.

5. RANGE - Refers to range of eigenvalues (buckling) or frequencies using requested subcases, for which plots will be prepared.

TIME - Refers to time interval, using requested subcases and output time steps, for which plots will be prepared.

6. PHASE LAG - Real number, $\phi$, in degrees (default is 0.0). The plotted value is $u_R \cos + u_I \sin \phi$, where $u_R$ and $u_I$ are the real and imaginary parts of the response quantity.

MAGNITUDE - plotted value is $\sqrt{u_R^2 + U_I^2}$ .

7. MAXIMUM DEFØRMATIØN - Real number following is used instead of the actual maximum displacement component in scaling the displacements for all subcases. This option is not recommended for general use. Each subcase is separately scaled according to its own maximum if this item is absent. If d is omitted, the set will be scaled to the maximum within the set being plotted.

8. SET - Integer following identifies a set which defines the portion of the structure to be plotted. Default is first set defined.

9. ØRIGIN - Integer following identifies the origin to be used for the plot. Default is first origin defined.

10. SYMMETRY w - Prepare an undeformed or deformed plot of the symmetric portion of the object which is defined by SET j. This symmetric portion will be located in the space adjacent to the region originally defined by ØRIGIN k, and will appear as a reflection of the antisymmetrically deformed structure about the plane whose normal is oriented parallel to the coordinate direction w.

ANTISYMMETRY w - Prepare a deformed plot of the symmetric portion of the anti-symmetrically loaded object which is defined by SET j. This symmetric portion will be located in the space adjacent to the region originally defined by ØRIGIN k, and will appear as a reflection of the antisymmetrically deformed structure about the plane whose normal is oriented parallel to the coordinated direction w.

The symbol w may specify the basic coordinates X, Y or Z or any combination thereof. This option allows the plotting of symmetric and/or antisymmetric combinations, provided that an origin is selected for the portion of the structure defined by the bulk data that allows sufficient room for the complete plot. This does not permit the combination of symmetric and antisymmetric subcases, as each plot must represent a single subcase. In the case of a double reflection, the figure will appear as one reflected about the plane whose normal is parallel to the first of the coordinates w, followed by a reflection about the plane whose normal is oriented parallel to the second of the coordinates w. This capability is primarily used in the plotting of structures that are loaded in a symmetric or an antisymmetric manner. The plane of symmetry must be one of the basic coordinate planes.

11. PEN - Integer following controls the internal NASTRAN pen number that is used to generate the plot.

DENSITY - Integer following specifies line density for film plotters. A line density of d is d times heavier than a line density of 1.

12. SYMBØLS m[,n] - All the grid points associated with the specified set will have symbol m overprinted with symbol n printed at its location. If n is not specified, only symbol m will be printed. Grid points excluded from the set will not have a symbol. Grid points in an undeformed underlay will be identified with symbol 2.

Following is a table of symbols available on each plotter. Symbols that are not available on a given plotter are defaulted to a similar symbol indicated in parentheses.

| SYMBOL NØ. m or n | SYMBOL | AVAILABILITY SC4020 | AVAILABILITY NAST |
|---|---|---|---|
| 0 | no symbol | X | X |
| 1 | X | X | X |
| 2 | * | X | X |
| 3 | + | X | X |
| 4 | - | X | X |
| 5 | . | X | X |
| 6 | ○ | X | X |
| 7 | □ | X | X |
| 8 | ◇ | (7) | X |
| 9 | △ | (7) | X |

13. LABEL GRID - All the grid points included in the specified set have their identification number printed to the right of the undeflected or deflected location (undeflected location in the case of superimposed plots).

LABEL ELEMENTS - All the elements included in the specified set are identified by the element identification number and type at the center of each element (undeflected location in the case of superimposed plots).

LABEL BØTH - Label both the grid points and elements.

LABEL GSPC - Label those degrees of freedom that are constrained to zero through permanent single point constraints on GRID and GRDSET bulk data cards or are constrained through SPC and SPC1 bulk data cards. The label consists of the grid point ID number and the constrained degrees of freedom. For superelements, this type of plot is available only after restarting from a run which completes the SEMG operation. For non-superelements, RFxxD20 is required.

LABEL EPID - Label elements with their respective property card identification (PID) numbers. The label consists of the standard element labels and element PID. For non-superelements, RFxxD20 is required.

14. SHAPE - All the elements included in the specified set are shown by connecting the associated grid points in a predetermined manner.

ØUTLINE - Only the outline of all the elements in the specified set are shown. Elements not supported by contour plots are ignored. Outlines are always drawn with PEN 1.

Both deformed and undeformed shapes or outlines may be specified. All the deformed shapes relating to the subcases listed may be underlaid on each of their plots by including "0" with the subcase string on the PLØT card. The undeformed plot will be drawn using PEN 1 or DENSITY 1 and symbol 2 (if SYMBØLS is specified). Omitting both on contour requests gives undeformed shape.

15. VECTØR v - A line will be plotted at the grid points of the set, representing in length and direction the deformation of the point.

Vectors representing the total deformation or its principal components may be plotted by insertion of the proper letter(s) for variable v. Possible vector combinations are:

X or Y or Z - requesting individual components

XY or XZ or YZ - requesting two specified components

XYZ - requesting all three components

RXY or RXZ or RYZ - requesting vector sum of two components

R - requesting total vector deformation

N - used with any of the above combinations to request no underlay shape be drawn

All plots requesting the VECTØR option will have an underlay generated of the undeformed shape using the same sets, PEN 1 or DENSITY 1, and symbol 2 (if SYMBØLS is specified). If "SHAPE" and "VECTØR" are specified, the underlay will depend on whether "0" is used with DEFØRMATIØN. It will be the deformed shape when not used and will be both deformed and undeformed shapes when it is used. The part of the vector at the grid point will be the tail when the underlay is undeformed and the head when it is deformed. If the "N" parameter is used, no shape will be drawn but other options such as SYMBØLS will still be valid.

16. PRINT - A list of the average stresses at the interior grid points in the set will be printed for contour stress plots

17. SHRINK - The real number (t) following is used to shrink two-dimensional elements with three or four grid points (0 < t < 1.0). If t is omitted, the default value is 0.1 which results in a 10% reduction. The second real number (o) is used to shrink one-dimensional elements. If o is omitted, the one-dimensional elements are not reduced. Both t and o must be nonzero in order to shrink one-dimensional elements. QUAD8 and TRIA6 do not shrink, regardless of number of deleted midside nodes.

18. NØRMALS - Plot vector normal to HBDY elements

Examples of PLØT Cards

1. PLØT

   Undeformed SHAPE using first defined SET, first defined ØRIGIN and PEN 1 (or DENSITY 1).

2. PLØT SET 3 ØRIGIN 4 PEN 2 SHAPE SYMBØLS 3 LABEL

   Undeformed SHAPE using SET 3, ØRIGIN 4, PEN 2 (or DENSITY 2) with each grid point of the set having a + placed at its location, and its identification number printed adjacent to it.

3. PLØT MØDAL DEFØRMATIØN 5 SHAPE

   Modal deformations as defined in subcase 5 using first defined SET, first defined ØRIGIN, and PEN 1 (or DENSITY 1).

4. PLØT STATIC DEFØRMATIØN 0, 3 THRU 5, 8 PEN 4, SHAPE

   STATIC deformations as defined in subcases 3, 4, 5 and 8, deformed SHAPE; drawn with PEN 4, using first defined SET and ØRIGIN, underlayed with undeformed SHAPE drawn with PEN 1. This command will cause for plots to be generated.

5. PLØT STATIC DEFØRMATIØN 0 THRU 5,
   SET 2 ØRIGIN 3 PEN 3 SHAPE,
   SET 2 ØRIGIN 4 PEN 4 VECTØRS XYZ SYMBØLS 0,
   SET 35 SHAPE

   Deformations as defined in subcases 1, 2, 3, 4, and 5, undeformed underlay with PEN 1, consisting of SET 2 at ØRIGIN 3, SET 2 at ØRIGIN 4 (with an * placed at each grid point location), and SET 35 at ØRIGIN 4. Deflected data as follows: SHAPE using SET 2 at ØRIGIN 3 (PEN 3) and SET 35 at ØRIGIN 4 (PEN 4); 3 VECTØRS (X, Y and Z) drawn at each grid point of SET 2 at ØRIGIN 4 (PEN 4) (less any excluded grid points), with o placed at the end of each vector.

6. PLØT STATIC DEFØRMATIØNS 0, 3, 4,
   SET 1 ØRIGIN 2 DENSITY 3 SHAPE,
   SET 1 SYMMETRY Z SHAPE,
   SET 2 ØRIGIN 3 SHAPE,
   SET 2 SYMMETRY Z SHAPE

Static deformations as defined in subcases 3 and 4, both halves of a problem solved by symmetry using the X-Y principal plane as the plane of symmetry. SET 1 at ØRIGIN 2 and SET 2 at ØRIGIN 3, with the deformed shape plotted using DENSITY 3 and the undeformed structure plotted using DENSITY 1. The deformations of the "opposite" half will be plotted to correspond to symmetric loading. This command will cause two plots to be generated.

7. PLØT TRANSIENT DEFØRMATIØN 1, TIME 0.1, 0.2, MAXIMUM DEFØRMATIØN 2.0, SET 1, ØRIGIN 1, PEN 2, SYMBØLS 2, VECTØR R

   Transient deformations as defined in subcase 1 for time = 0.1 to time = 0.2, using SET 1 at ØRIGIN 1. The undeformed SHAPE using PEN or DENSITY 1 with an * at each grid point location will be drawn as an underlay for the resultant deformation vectors using PEN or DENSITY 2 with an * typed at the end of each vector drawn. In addition, a plotted value of 2.0 will be used for the single maximum deformation occurring on any of the plots produced. All other deformations on all other plots will be scaled relative to this single maximum deformation. This command will cause a plot to be generated for each output time step which lies between 0.1 and 0.2.

8. CØNTØUR XNØRMAL
   PLØT CØNTØUR, SET 2, ØRIGIN 4, ØUTLINE

   Contour plot of x-component of normal stress for elements in SET 2 in basic coordinate system at a distance Z1 from neutral plane with 10 contour lines, an outline of elements in SET 2, and using ØRIGIN 4.

9. CØNTØUR MAGNIT, LIST 2., 4., 6., 8., 10
   PLØT CØNTØUR, SET 5, ØUTLINE

   Contour plot of magnitude of displacements at grid points associated with elements in SET 5 with 5 contours having values of 2., 4., 6., 8., 10., and an outline of the elements in SET 5 using ØRIGIN 4.

10. PLØT CMØDAL DEFØRMATIØN PHASE LAG 90. SET 1 VECTØR R

    The imaginary part of the complex mode shape will be plotted for SET 1.

### 4.2.3 Examples of Structure Plot Requests

The BEGIN BULK card is shown in each of the examples to remind the user to place the structure plot request at the end of the Case Control Deck.

Example 1

```
ØUTPUT(PLØT)
PLØTTER NAST
SET 2 = ALL
FIND SCALE, ØRIGIN 5, SET 2
PLØT SET 2, ØRIGIN 5
BEGIN BULK
```

A single undeformed plot using all elements will be produced for the NASTRAN general purpose plotter.

Example 2

```
ØUTPUT(PLØT)
PLØTTER NAST
CSCALE = 1.8
SET 10 = RØD
AXES Z,X,Y
VIEW 0.0, 0.0, 0.0
FIND SCALE, ØRIGIN 5, SET 10
PLØT SET 10, ØRIGIN 5, LABEL
BEGIN BULK
```

A single undeformed plot using all RØD elements will be produced for the NASTRAN general purpose plotter. The grid points will be labeled with the grid point identification numbers. The view will be along the z-axis, or normal to the X-Y plane.

Example 3

```
     ØUTPUT(PLØT)
     PLØTTER NAST
     CSCALE = 1.8
     SET 2 = 1 THRU 50
     SET 3 = 101 THRU 199
     FIND SCALE, ØRIGIN 20, SET 2
PLØT STATIC DEFØRMATIØN SET 2, ØRIGIN 20
     FIND SCALE, ØRIGIN 25, SET 3
PLØT STATIC DEFØRMATIØN 0, 2, SET 3, ØRIGIN 25
     PTITLE = THERMAL LØAD
PLØT STATIC DEFØRMATIØN 3 THRU 10, SET 3, ØRIGIN 25, LABEL
BEGIN BULK
```

Several deformed plots will be produced for the NASTRAN plotter. The maximum deformation will be scaled to the default value of 5% of the maximum dimension of the model.

The first PLØT command card will produce one deformed plot for each subcase in the Case Control Deck. All elements having identification numbers in the range of 1 through 50 will be included on the plot. All plots will be located at ØRIGIN 20, as determined by the first FIND card.

The second PLØT command card will produce one deformed plot for subcase 2 with an underlay of the undeformed structure. All elements having identification numbers in the range of 101 through 199 will be included on the plot. The plot will be located at ØRIGIN 25, as determined by the second FIND card.

The third PLØT command card will produce one deformed plot for each subcase having an identification number in the range 3 through 10. All elements having identification numbers in the range of 101 through 199 will be included on the plot. The grid points will be labeled with the grid point identification numbers. The plot will be located at ØRIGIN 25, as determined by the second FIND card.

## 4.2.4 Summary of Structure Plot Request Packet Cards

SET Definition - Required

```
SET i [INCLUDE][ELEMENTS] j1, j2, j3 THRU j4, j5, etc.
[INCLUDE]  [ELEMENTS   ]
[EXCLUDE]  [GRID PØINTS]  k1, k2, k3 THRU k4, k5, etc.
[EXCEPT ]
```

Parameter Definition - Optional, except as noted

```
PLØTTER { SC / NAST }          (required if not NAST)

{ ØRTHØGRAPHIC / PERSPECTIVE / STEREØSCØPIC }

AXES R, S, T [{ SYMMETRIC / ANTISYMMETRIC }]

VIEW γ, β, α

SCALE a[, b]                   (Required if not on FIND card)

ØRIGIN i, u, v                 (Required if not on FIND card)

VANTAGE PØINT r0,s0,t0,d0[,s0r]   (Required for perspective and stereoscopic
                                    projections if not on FIND card)

PRØJECTIØN PLANE SEPARATIØN { 2.0 / d0 }

ØCULAR SEPARATIØN { 2.756 in / os }

MAXIMUM DEFØRMATIØN d

PEN i [CØLØR name]
```

```
CAMERA { FILM  }  [,BLANK FRAMES { 0 }]
       { PAPER }                 { n }
       { BØTH  }
```

```
PAPER SIZE { 7.5 } { X  } { 7.5 }  [ , TYPE { VELLUM } ]      (SC plotters)
           {  a  } { BY } {  b  }           {  name  }
```

```
PAPER SIZE { 20.0 } { X  } { 20.0 }  [ , TYPE { VELLUM } ]      (NASTRAN plotters)
           {  a   } { BY } {  b   }           {  name  }
```

```
PTITLE = {      blanks     }
         { plot title text }
```

```
DISTØRTIØN x,y,z
```

```
FIND [SCALE],[ØRIGIN i],[VANTAGE PØINT],[SET j],[REGIØN le, be, re, te]
```

```
CØNTØUR { MAJPRIN   }  { EVEN  10       }  { Z1  }  { CØMMØN }
        { MINPRIN   }  { EVEN  n        }  { Z2  }  { LØCAL  }
        { MAXSHEAR  }  { LIST a,b,...   }  { MAX }
        { XNØRMAL   }                      { MID }
        { YNØRMAL   }
        { ZNØRMAL   }
        { XYSHEAR   }
        { XZSHEAR   }
        { YZSHEAR   }
```

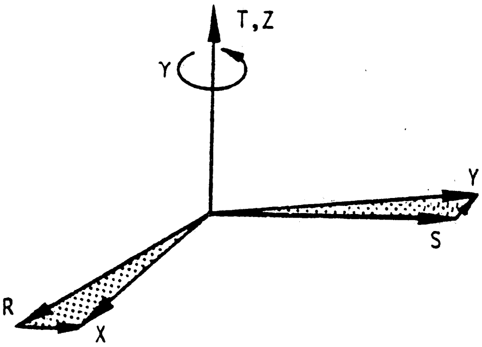
(stress contour plots only)

```
CØNTØUR { XDISP  }  { EVEN  10      }
        { XDISP  }  { EVEN  n       }
        { ZDISP  }  { LIST a,b,...  }
        { MAGNIT }
```

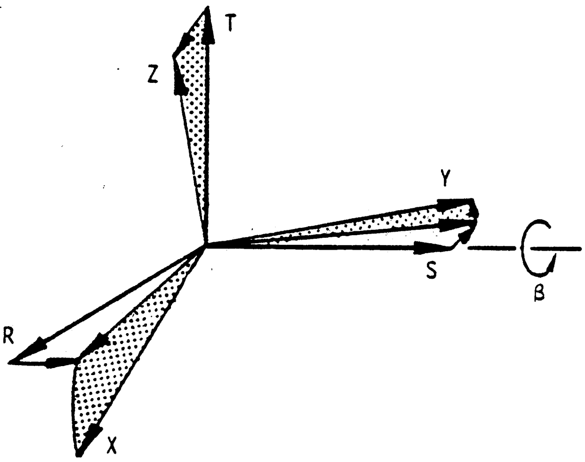
(displacement contour plots only)

PLØT Execution Card - Required

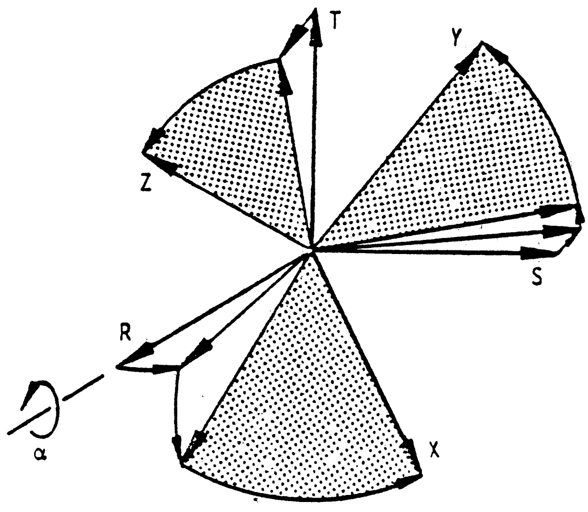
```
     ┌ STATIC     ┐   ┌ DEFØRMATIØN  ┐                                                    ┌ RANGE f1, f2 ┐
     │ MØDAL      │   │ VELØCITY     │  {CØNTØUR}   [i1, i2 THRU i3, i4, etc.]             │ RANGE λ1, λ2 │ ,
PLØT │ CMØDAL     │   └ ACCELERATIØN ┘                                                    └ TIME  t1, t2 ┘
     │ TRANSIENT  │
     │ FREQUENCY  │
     └ blank      ┘

     ┌ PHASE LAG φ ┐   [MAXIMUM DEFØRMATIØN d]   ,
     └ MAGNITUDE   ┘

[SET j1] [ØRIGIN k1]   ┌ SYMMETRY     ┐ w   ┌ PEN     ┐ p     [SYMBØLS m[,n]]   ,
                       └ ANTISYMMETRY ┘     └ DENSITY ┘

     ┌       ┌ GRID PØINTS ┐ ┐
     │       │ ELEMENTS    │ │   ┌ SHAPE   ┐
     │ LABEL │ BØTH        │ │   └ ØUTLINE ┘    [VECTØR v]   ,      [PRINT]   ,
     │       │ EPID        │ │
     └       └ GSPC        ┘ ┘

[SHRINK t,o], [NØRMALS]   ,

[SET j2] [ØRIGIN k2]..., etc.
```




(a) γ - rotation about T-axis.




(b) β — rotation about S-axis




(c) α - rotation about R-axis

Figure 1. Plotter Coordinate System-model Orientation.

DIRECT MATRIX ABSTRACTION

## 5.1 GENERAL

In addition to using the solution sequences provided by MSC/NASTRAN, the user may wish to execute a series of modules in a different manner than provided by a Solution Sequence. Or, he may wish to perform a series of matrix operations which are not contained in any existing Solution Sequence. If the modifications to an existing solution sequence are minor, the ALTER feature described in Sections 2 and 5.2.4 may be employed. Otherwise, a user-written Direct Matrix Abstraction Program (DMAP) should be used.

DMAP is the Data Block-oriented language used by MSC/NASTRAN to solve problems. A solution sequence is basically a collection of statements in this language. DMAP, like English or FØRTRAN, has many grammatical rules which must be followed to be interpretable by the MSC/NASTRAN DMAP compiler. Section 5.2 provides the user with the rules of DMAP which will allow him to understand the solution sequence DMAP sequences, write ALTER packages, and construct his own DMAP sequences using the many modules contained in the DMAP repertoire.

Section 5.3 provides general examples of DMAP usage. Section 5.4 describes individually the many DMAP programmer-oriented modules contained in the DMAP library.

Before proceeding with the specific rules of DMAP program creation, a few general comments on the nature of the language and its relation to the MSC/NASTRAN program are in order.

DMAP began as a spur capability of a structurally-oriented computer program. Its purpose was to allow the user of MSC/NASTRAN access to the matrix routines which would support the structural solution. However, DMAP grew as a language until today it dominates MSC/NASTRAN. In fact, all operations undertaken by MSC/NASTRAN are specified via DMAP. A DMAP programmer has access to all parts of the program.

The MSC/NASTRAN program is separated into functional blocks called <u>modules</u> each of which has a name (module name) and a specific function to perform (purpose). Modules are not order-constrained in that the DMAP programmer can schedule any module order that is meaningful to him. Modules are constrained in their methods of communication with subsequent modules. In fact, one module can communicate with another module only through the MSC/NASTRAN Executive System (NES). In particular, modules must write their answers on disk space provided by the NES. These logical collections of data are given names and called <u>data blocks</u>. A good example of a data block is a matrix. The DMAP language then expresses a logical relation between data blocks as operated on by modules. Data block names are arbitrary; the content of the data block is important, not its name. A typical DMAP program might appear as follows:

```
BEGIN     $
ADD       A,B/C $
MATPRN    C//$
END       $
```

This program adds the two matrices (data blocks) A and B together forming C, which is then printed. Four modules are invoked, BEGIN, ADD, MATPRN and END. If C were changed to ANSWER in both its occurrences, the DMAP program would be unchanged.

In any language another class of objects is needed. These control the flow and communicate options to operations taking place. In MSC/NASTRAN these scalar values are called parameters. Most modules provide for one or more parameters to express options. Thus, the add matrix routine allows a scalar multiplier for each matrix. Parameters, however, may have default values, and the example program used them. If the DMAP programmer wanted to multiply [A] by 5.0, he could code

```
ADD       A,B/C/(5.0,0.0) $
```

A DMAP module then reads its input data blocks (A,B), operates as specified by its parameters ((5.0,0.0)), and writes its outputs (C). Meanwhile, the NES is establishing and controlling the sequence of module executions (according to the DMAP program), establishing, protecting and communicating values of parameters, allocating disk space (files) to data blocks, and potentially providing a restart capability.

To learn to write a DMAP program, the user must accomplish a number of steps. He must learn the basic syntax rules of the DMAP compiler and how to correctly specify the inputs and outputs to a module (Section 5.2.1). He must then learn to write sequences of modules which properly link together (Section 5.2.2). As his sequences become more complex, he will want to invoke special functions of the NES (Section 5.2.3). Examples of DMAP programs are provided in Section 5.3 as well as by the solution sequences (which can be printed by including DIAG 14 in the Executive Control Deck).

The DMAP programmer must also expand his DMAP vocabulary. Section 5.4 provides a list of commonly used modules which may serve as a beginning. Of course, all modules may be used in a DMAP program. A list of all modules can be printed out by DIAG 31. Descriptions of all modules are found in the MSC/NASTRAN Programmer's Manual, Section 4.

A particularly valuable use of DMAP is to modify one of the existing DMAP programs (Solution Sequences) via the ALTER package to provide for a specialized application. New capability, if expressed through new modules, is only available through the use of DMAP ALTERs. Many prewritten ALTERs are available through the MSC/NASTRAN RFALTER Library. Section 5.2.4 will discuss the ALTER process in some detail.

I. NAME: MATPRN (General Matrix Printer)

II. PURPOSE: To print general matrix data block.

III. DMAP CALLING SEQUENCE:

MATPRN M1,M2,M3,M4,M5// S

IV. INPUT DATA BLOCKS:

Mi - Matrix data blocks, any of which may be purged. (See Remark 2).

V. OUTPUT DATA BLOCKS: None

VI. PARAMETERS: None

VII. OUTPUT:

The nonzero band of each column of each input matrix data block is printed (see Remark 4).

VIII. REMARKS:

1. Any or all input data blocks may be purged.
2. If any data block is not a matrix, it will be printed as if it were a table.
3. MATPRN prints the row index for the term which begins each line of printout.
4. MATPRN will not printout two or more consecutive lines of zeroes, but instead will issue a message of the form:

   RØW PØSITIØNS xxxx THRU yyyy NØT PRINTED - ALL = 0.0.

5. If DIAG 30 is set by the PARAM module before MATPRN (see Example 3), and turned off after MATPRN, most of the digits of the internal representation will be printed. Normally, the output is truncated to five or six digits.
6. For large, sparse matrices with scattered terms, the user is advised to use either the MATPRT or MATGPR modules.

IX. EXAMPLES:

1. MATPRN KGG// S
2. MATPRN KGG,PL,PG,BGG,UPV// S
3. PARAM //DIAGØN // 30 S PRINT EXTENDED PRECISIØN

   MATPRN KGG// S

   PARAM // DIAGØFF // 30 S

I. NAME: SØLVE (Linear System Solver)

II. PURPOSE: To solve the matrix equation [A][X] = ±[B]

III. DMAP CALLING SEQUENCE:

```
SØLVE    A,B/X/V,Y,SYM/V,Y,SIGN $
```

IV. INPUT DATA BLOCKS:

A - square real or complex matrix

B - rectangular real or complex matrix (if purged, the identity matrix is assumed)

V. OUTPUT DATA BLOCKS:

X - a rectangular matrix

Note: A standard matrix trailer will be written, identifying [X] as a rectangular matrix with the same dimensions as [B] and the type specified.

VI. PARAMETERS:

| | | |
|---|---|---|
| SYM | - Input-integer-default = 0 | 0 - use decomposition consistent with form of [A]<br>1 - use symmetric decomposition<br>-1 - use unsymmetric decomposition |
| SIGN | - Input-integer-default = 1 | 1 - solve [A][X] = [B]<br>-1 - solve [A][X] = -[B] |

VII. METHOD: Depending on the SYM flag and the type of [A], one of subroutines SDCØMP or UDCØMP is called to form [A] = [L][U]. One of FBS or UFBS is then called to solve [L][Y] = ± [B] and [L][X] = [Y], as appropriate.

VIII. EXAMPLES:

1. Solve a system of equations [A][U] = [P]

```
SØLVE A,P/U/ $
```

2. Invert [A]

```
SØLVE A,/AINV/ $
```