

UNDERSTANDING THE NASTRAN STRUCTURAL PLOTTER

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SUMMARY

Functions of the plotting hardware and the operations performed by the NASTRAN structural plotter are summarized to provide the user an insight into how the program works. The processing performed in response to each plot command is described and the interrelationships of the various parameters are explained. To assist in the effective and efficient utilization of the system, examples are provided which also illustrate several not yet documented capabilities of the Level 16 structural plotter.

INTRODUCTION

The NASTRAN structural plotting capability is used extensively for checking the structural geometry, plotting the deformations and preparing figures for reports. This paper is written, therefore, to provide some insight into the plotting procedures used by the upcoming NASTRAN Level 16. With this insight, the user can more confidently prepare his input to efficiently and effectively exploit this plotting capability.

The interface between NASTRAN and the basic plotting hardware is described. The key words input by the user to drive the NASTRAN plotter are explained in terms of the tasks performed according to each command. The algorithms which translate the structural data into plotting hardware commands are described in order to show how simple changes in the user's input can have significant effects on efficiency. Many illustrative examples are used. However, for brevity, the reader is assumed to have some familiarity with the basic input and access to the NASTRAN User's Manual (ref. 1).

In order to establish a common background of plotting terminology, the typical plotter hardware is described first, and the principles of computer graphics for structural plotting are summarized. Then, the NASTRAN plot files are identified, the algorithms are presented, and finally, examples of efficient input sequences are explained.

PLOTTING HARDWARE

All the plotting hardware supported by NASTRAN (see Table 1) requires the same basic output from NASTRAN. Therefore, rather than describing each plotter in

detail, only the fundamental characteristics are presented. The basic commands used by all plotters provide for the following:

1. Moving to a position
2. Drawing a line segment
3. "Typing" or drawing an alphanumeric or special character

The execution of these commands will differ, of course, depending on the type of plotter. If the plotter is a cathode ray tube type (CRT), these commands are translated into the movement of an electron beam across a luminescent screen (much like a television screen) from which a photograph is taken. That film can then be viewed through an enlarger or it can be printed on paper. In any case, the viewing area, or frame, is limited in size to the area provided by the CRT.

The other plotters use a pen and draw directly on paper or other media. These may be table plotters which are limited to an area the size of the table. Drum plotters, which use rolls of paper, are limited only to the width of the roll. Some maximum frame dimensions are always required to establish the working area. In place of pens, some plotters may use heat sensitive tips and special paper. In any case, the principles are the same.

To execute the plot commands, each plotter requires a method of positioning the pen or the electron beam. To accomplish this, each plotter works in an internal system of units usually called "rasters". This orthogonal, two-dimensional X and Y reference system has maximum raster values in the X and Y directions, limited mainly by the paper or film size. The number of rasters per inch is a constant value for the plotter selected.

Care must be taken in defining the sequence of positioning commands. For the CRT, this is not a great problem in that the electron beam can be moved virtually instantaneously. However, for pen plotters, the movement of the pen from one location to another requires considerable time with the pen either up or down. This is true even if the plotter provides a "zip" mode. An efficient sequence will also utilize a shorter magnetic tape, the normal output media for the plot commands.

The procedures for converting each of these commands for the plotter selected are supplied by functional utilities in NASTRAN. These routines convert the structural data into line segments and issue the commands to draw the lines desired, to "type" or draw the characters required for titles and other identifiers, and to start and stop the plotter.

BASIC FUNCTIONS

The tasks performed by the NASTRAN structural plot module are relatively simple. The plot routines must make two-dimensional drawings, provide labeling information and control the plotting sequence. The key words given here in

otation marks are used and will be illustrated later as key words of the NASTRAN plot control language.

To create the two-dimensional image of a structural model, the program assumes a "plotting surface" exists in between the object to be plotted and the viewer. For orthographic plots, the viewing point is assumed to be an infinite distance from the plotting surface so as to prevent perspective line distortions. For perspective plots, a finite distance is used and line distortions are computed. For stereographic plots, two perspective plots are created from two different locations of the viewing point. The mathematical transformations used are presented in the Theoretical Manual (ref. 2) under Computer Graphics.

Once the plotter is selected and the frame size is established, a plotting "region" is established. This region, which allows for margins on each edge of the plot frame, will be varied to accommodate titling information, frame identification, and user-specified plot region sizes. Thus, the size may expand or contract at different phases of the plotting computations, but it never goes beyond the specified plotter's frame limits. All lines and characters must appear within the outer margins of the plot frame, otherwise they will be "clipped".

The picture on the plotting surface must not only be contained in the plotting region; it should be centered. To appropriately place the picture in the plotting region, a "scale" and "origin" approach is used. Note that for orthographic plots, moving the plotting surface towards or away from the object will not change the image size as it will for perspective plots. The program will select, or the user must specify, the scale and origin to be used. This scale is used as a conversion factor for transforming the model's projected structural coordinates into the two-dimensional raster coordinates within the frame's limits for the plotter. These raster coordinates are then shifted relative to the origin calculated for centering the final picture.

The viewable output is obtained by drawing lines to represent the element connectivities in either the model's deformed or undeformed "shape". Due to the difficulties encountered in viewing a complex three-dimensional deformed shape on paper, a line or "vector" can be requested to show only the components of deformation. These vectors are lines which may be attached to either the deformed or the undeformed shape of the model.

Since the relative dimensions of the grid point deformations are small compared with the structural coordinates of the model, NASTRAN exaggerates the magnitude of the deformations. This magnification factor must be specified by the user. He must give the length (in the structure's and not the plotter's raster coordinates) to which the maximum component of displacement is to be scaled.

To further assist the user in the task of checking out his NASTRAN input and/or output, the object to be plotted may be rotated for viewing from any angle. The picture to be plotted will show the view facing the plotting surface. This rotation is performed by specifying either "view" angles and/or "axes" to be interchanged. Symmetric plots may be requested. They necessitate

the interchange of axes to get a "left hand" coordinate system. Specifying view angles alone will not suffice.

Finally, a complex structure requires labels and special symbols to help identify the structural components for both the deformed and undeformed plots. Selected "symbols" may be used or identification numbers may be requested for grid points. For elements, "labels" can be requested to provide both the identification numbers and the element type information. Special care is taken in NASTRAN to position these labels to avoid misinterpretation and to enhance their legibility.

The processing to translate the structural data into two-dimensional plots using line segments, symbols and characters can be expensive. The resulting data files, described next, can be sizeable. To help avoid inefficient use of the basic functions, the subsequent chapters explain how the structural plotter commands are processed by the NASTRAN plot modules.

PLOTTING DATA FILES

The data files to be processed by the NASTRAN structural plot modules consist of control information and model data. The functions of the various input files will be shown. The names of the files, however, may differ depending on the rigid format.

The user defines his desired plot output via a separate section of the Case Control Deck. These physical cards are read and interpreted by a special preface routine. Unlike the other usual case control cards, the plot control commands are simply interpreted as BCD, real or integer data and stored in one file (PCDB) for future processing by the plot modules. All cards between the OUTPUT(PLOT) and the BEGIN BULK or the OUTPUT(XYPLOT) cards are assumed to be structural plot control cards.

The first phase of data analysis is performed by the PLTSET module which is executed only once in each run. Its function is to analyze the SET cards, output the GPSETS and ELSETS data files, issue error messages pertinent to the SET data on the PLTSETX file and rewrite the PCDB control data to the PLTPAR file with all SET definitions removed.

The two files GPSETS and ELSETS contain all the data required to specify the objects to be plotted. For every set of elements defined, one record of data is placed on each file whether it will later be used for plotting or not. Once these files have been established in the PLTSET module, no modification of these data is ever attempted.

For each set of elements, the ELSETS file lists the element type, its identification number and its connection points, which are entered as pointers into the GPSETS file. The corresponding GPSETS file contains the flags specifying all the grid points needed to draw those elements. It also specifies which points are to be identified by symbols or labels.

The actual plot tape is written by the PLOT module. The PLOT module analyzes the remaining plotter commands by sequentially interpreting the PLTPAR file. The processing of the data stored in each record of the ELSETS and GPSETS files is supported by the following standard input files as required:

- CASECC - provides plot headings
- BGPDT - provides undeformed grid coordinates
- EQEXIN - provides grid identification numbers
- SIL - controls use of PLTDSP1 and PLTDSP2 files
- PLTDSP1 - provides deformations for requests using STATIC
- PLTDSP2 - provides deformations for all other requests

The PLOT module is executed twice in most runs, first for undeformed and then for deformed plots depending on the value of a DMAP parameter. Input data on the PLTPAR file is interpreted sequentially. Plot requests applicable to the second pass are skipped on the first pass. Error messages and plot identification messages also occur in sequential order. Error messages pertinent to either the undeformed or deformed plots appear during the undeformed analysis. Messages pertinent to the deformed plots appear only on the second pass. All messages are output on the PLOTX file.

The deformation files, PLTDSP1 and PLTDSP2, are created for use by the PLOT module by the normal output processing modules of NASTRAN (e.g.,SDR1). These data files contain only the three translational components in the basic coordinate system. Each set of data is identified as to type, subcase, and the appropriate frequency, eigenvalue or time.

The actual sequence of operations on these files is described next.

PROCESSING SEQUENCE

Lengthy calculations may be required of the plot modules, which suggests that care be given in the usage of certain input commands. These are described below to give the user insight into how the plotter will interpret each command. Since each card is acted upon in sequence, the usual structural plotter commands are presented below in the sequence that they should be input to the program. More detailed definitions for each key word can be obtained from reference 1. Table 2 illustrates the interaction of the plotting parameters for the discussion below. The next chapter presents many examples along with some interesting undocumented options.

The OUTPUT(PLOT) Card

This card indicates that the Case Control cards to follow are plot commands. All such cards up to an OUTPUT(XYPLLOT) or a BEGIN BULK are assumed to be structural plot commands.

The SET Card

This card initiates the creation of a scratch file containing all the plottable elements. These elements are those with geometric coordinates and at least two grid points. Only data on connections, element type and element number are on this file. This list is then scanned for each SET the user defines. Each SET card is then interpreted. Each element in the scratch file is scanned, and if its type and/or number is INCLUDED and not later EXCLUDED*, that element is accepted.

The SET card may also be used to restrict the output of grid point related labels, symbols and deformation vectors. The basic grid point data is obtained from the element set connectivities and therefore can not be expanded. Thus, INCLUDE GRID has no meaning unless it follows EXCLUDE GRID. Note here, that the key word GRID must always follow the INCLUDE, EXCLUDE or EXCEPT commands. In Level 16, some elements (e.g., AERØ) automatically use EXCLUDE GRID.

The CSCALE Card

If used, this card must appear before each PLOTTER request to set the scaling parameter which allows the user to change the raster dimensions of the characters to be used in all subsequent operations. This scaling is useful if the plot output is to be post processed to enlarge a frame without also enlarging the characters or destroying their spacing. Thus, this parameter is input as the inverse of the factor the post processor will use to magnify the frame. Table 1 shows the character size for each plotter supported by NASTRAN.

The PLOTTER Card

To define the desired plotting hardware, the PLOTTER, PAPER SIZE and CAMERA or PEN parameters are specified. The first two set the parameters shown in Table 1 and initialize the plotter. PAPER SIZE controls the maximum plotting area for table or drum plotters. If a size larger than the maximum fixed dimension for that plotter is specified, the default is used. If the PLOTTER command is encountered later in the input stream, either by error or by design to change plotters, only those parameters following that card can be relied upon for use in subsequent computations. Therefore, all but the CSCALE parameter should be respecified.

The AXES, VIEW and MAXIMUM DEFORMATION Parameter

These three cards are used to orient and define the size of the object to be plotted. These parameters must be set before the FIND card is input. Once set,

* This feature now works in Level 16.

they are changed only by another AXES, VIEW, or MAXIMUM DEFØRMATION card. However, if any one of these cards occur between a FIND and a PLOT card, the results may not be properly scaled and centered.

The MAXIMUM DEFØRMATION parameter is used to scale up the deformations which are usually very small compared to the overall dimensions of the structural model. If the user does not specify a value, the program assumes a default of 5% of the maximum X or Y range in the structural coordinates of the current view. This is usually adequate. However, small deformations may not show up. Large deformations may cause undesirable distortions if this parameter is too large.

The SCALE and ØRIGIN Card

Once the overall size of the object to be plotted is determined using the above parameters, it must be scaled and an origin selected to fit the picture in the frame. With these cards, the user can set the parameters himself, but the calculation process is error prone and the FIND option is recommended.

The FIND Card

This card is optional but it is recommended to let the program compute the SCALE, ØRIGIN, and VANTAGE PØINT parameters. The latter is only calculated if PERSPECTIVE or STEREO plots have been requested. If any word appears following the FIND, no defaults are used. Instead, it is assumed the unspecified parameters already have been set. Only the specified parameters will be calculated.

The data operations caused by the FIND card are extensive. After interpreting the input, the GPSETS record for the SET specified on the FIND card, or the first well-defined set in the plot input is read into core. The three geometric coordinates for the grid points in that set are read from the BGPDT file. These coordinates are transformed to correspond to the VIEW and AXES specified. From this transformed data, the minimum and maximum X and Y locations are obtained and added to the previously defined MAXIMUM DEFØRMATION to determine the SCALE and ØRIGIN required to place the object within the frame.

Another parameter, REGION, is a convenience parameter used to set up an origin and scale such that only part of the frame is available for plotting a given SET. Thus, more than one SET could be plotted on the same frame, but in different locations and with different options. Because only one SCALE exists, the sets to be plotted should be of similar dimensions. Different sets may be used but each will be plotted using the SCALE from the last FIND card processed before the PLOT command. Note, however, plotting may occur outside of this region since REGION is only a convenience parameter used by the FIND card. Its designed use is to facilitate the SYMMETRY option on the PLOT card. For user convenience when defining the REGION, the frame dimensions are scaled from 0.0 on the lower left to 1.0 on the upper right.

The PLOT Card

After the FIND card is processed, the program is ready to process the PLOT card. Following the word PLOT, additional identifying data are expected only if the request is to be for deformed plots. Otherwise, it defaults to undeformed plots. If a scale or an origin had not been set up, a default value is obtained and the first well-defined set is utilized. The words STATIC, MODAL, CMODAL, TRANSIENT or FREQUENCY may be used followed by DEFORMATION, VELOCITY or ACCELERATION. Note that the latter two are only valid for FREQUENCY or TRANSIENT requests. For deformed plots additional control parameters can be input. These parameters include RANGE or TIME and PHASE LAG or MAGNITUDE. RANGE or TIME (which are interchangeable key words) restrict the cases to be plotted. Units of frequency are used for RANGE when MODAL, CMODAL or FREQUENCY follow the word PLOT. For buckling analyses, the eigenvalue itself is used. For TRANSIENT, units of time are used. For STATICS, only the subcase number can be used to select the displacement set to be plotted. For CMODAL and FREQUENCY where complex variable deformations U are to be plotted, the user has a choice of PHASE LAG θ ($U = U_R \cos \theta + U_I \sin \theta$ with θ in degrees with a default of 0.0) or MAGNITUDE ($U = \sqrt{U_R^2 + U_I^2}$).

NASTRAN first processes all requests for undeformed plots. Then, once the desired solution is obtained, the plot requests are again scanned. On this pass, the undeformed plot requests are skipped and only the deformed plot requests are honored. On this second pass, each case on the appropriate deformation input file is checked against the subcase and range parameters specified. If not requested, that case is skipped until either one is found or no more cases exist.

Once a valid PLOT request is identified, the remaining parameters on the card are read. These parameters include SET, ORIGIN, SHAPE, SYMBOL, LABEL, VECTOR, DENSITY, PEN, SYMMETRY, ANTISYMMETRY, and MAXIMUM DEFORMATION. The first occurrence of SET is stored. Thereafter either an end-of-logical card or another SET request causes the stored parameters to be plotted. Before reading parameters for the next SET to be plotted, some parameters are reinitialized. These are LABEL, SHAPE, SYMBOL, SYMMETRY or ANTISYMMETRY, and VECTOR. These parameters must be respecified if they are to be used for plotting the next SET. SHAPE is used as a default.

For stereo plots, the control parameters are kept in core and the data files are reprocessed.

Plotting the SET

So far, the call to plot a set of elements has been described only in sketchy terms. This call needs to be explained in more detail. First, the remaining words of open core must exceed

NGP + 3 * NGPSET + N (undeformed plots)
NGP + 8 * NGPSET + M (deformed plots)

where NGP is the number of grid and scalar points in the model, NGPSET is the number of grids in the set being plotted, and where N is the number of words in NASTRAN buffers plus the plotter buffer. To find the size of the plotter buffer, take the record size from Table 1 and divide by the number of characters per word for the machine being used. M is one NASTRAN buffer-size larger than N. What remains of open core is used, unless VECTOR NR is requested, to create a pen optimization sequence. This adds to the space required by at least NGPSET plus two times the number of edges on the elements in the set.

For the element set to be plotted, the displacements, velocities or accelerations for points in the set are read into core from the appropriate file and, if necessary, are converted from complex to real numbers as described above. At this time the maximum component is also found and stored. This is the maximum for all grid points, not just for those in the set.

For deformed plots, the deformations are processed according to the symmetry options and the values are rotated and scaled to the user requests. The scaling function is

$$u \left(\frac{M_c}{M_p} \right)$$

where M_c is from the MAXIMUM DEFORMATION card, M_p is the maximum specified on the PLOT card or alternatively the actual maximum component value, and u is each input component of the displacement, velocity or acceleration vector.

If the SHAPE (outline of each element) is to be drawn, phase one of the pen optimization is performed. The output is a list of pointers to a second array that lists all connections to the grid associated with the pointer. This process involves two sorts on the lines in the set. The core used for this operation may be monitored by turning on DIAG 25 in the Executive Control Deck. These sorts involve extensive calculations proportional to the square of the number of lines in the set.

These arrays are used for drawing the lines in both the undeformed and deformed SHAPE plots (phase 2). If the arrays could not be created in phase 1 due to core restrictions, optimization is not performed and all edges are drawn for each element directly from the ELSETS file.

The resultant plot for Demonstration Problem 1-2-1 shown in Figure 1 provides the following statistics for using the SHAPE option:

Number of rasters movement for	With Array	Without Array	Percentage increase
drawing lines.....	8,127	14,314	76%
repositioning pen.....	0	6,343	-
	8,127	20,657	154%

This data was calculated from a DIAG 30 dump using an SC 4020 plotter. Note DIAG 30 is special purpose and must not be set in the Executive Control Deck.

Drawing the VECTOR requests causes additional computation. Depending on the requests, as many as three lines may have to be calculated for plotting at each grid point, one for each component of deformation. These calculations, whether for components or the vector resultant, must include the appropriate axes transformation, rotation and projection onto the plotting surface.

Grid identification includes SYMBOLS and LABELS. The SYMBOLS are simply drawn (or typed) from standard tables available. The grid identification LABELS are obtained by searching the EQEXIN file to obtain the external grid point ID. Element identification numbers and element type identification LABELS are found by rereading the ELSETS file. These LABELS are centered and aligned relative to one of the element's edges. Such effort in locating and orienting each of these labels and symbols adds considerably to the computation time required for the PLOT module.

EXAMPLES AND ALTERNATIVES

Various input techniques are illustrated. Ways are shown for improving efficiency, simplifying the input, and exploiting the capabilities of the NASTRAN structural plotter.

Input Syntax

The formatting rules for the NASTRAN Case Control deck apply also to the plot command segment of that deck. Delimiters (e.g., "/", "=", "(", ")", and ",") may be used freely since they are ignored, that is, except for the comma if it is the last character on the card. Only the first four characters of the key word suffice unless the word would not be unique (e.g., PLOTTER and PLOT). Element names (QUAD1 and QUAD2, etc.) must be completely specified. Unlike normal Case Control, real numbers may be input as integers on the plot control card.

The four key commands (SET, PLOTTER, FIND and PLOT) must be the first word on the card. All the other key words may share the same card since they identify parameters which are stored. For example:

```
$ FIRST VIEW
VIEW = 10.0, 20.5, 0.0
AXES = Z, X, Y
```

could be specified as

```
VIEW 10, 20.5, AXES Z, X, Y $ FIRST VIEW.
```

This card also illustrates the use of "\$" for comments on a command card, and the acceptance of default values for the third VIEW angle. That default is 0.0 in this case because it is the "FIRST VIEW". Otherwise, the default would be the previously set value. If two angles had not been specified, the program would use the defaults for the second and third angle. Incidentally, using this combin

feature will not only reduce the size of the data files but will help preserve the sequence of the input deck if it is dropped.

Using the FIND Card

The FIND card is optional but recommended. The parameters SCALE and ØRIGIN could be calculated manually and input directly. An undocumented feature, used to manipulate the SCALE factor for special effects, illustrated by

```
FIND SCALE 0.9, ØRIGIN 100, SET 20
```

would reduce the calculated scaling factor to 90%. Note that SET 20 need not contain all the elements to be pictured later with the PLOT command. This set can be uniquely defined to establish a special scale factor and origin so that a limited area of a model may be selectively plotted. This concept depends on the fact that lines will be "clipped" if they fall outside the range of the plotter frame area. Hence, any elements outside the bounds of the SET used to define SCALE and ØRIGIN will be eliminated automatically.

The element SET created especially for use by the FIND card should be small. Recall that the coordinates for all grid points defined by a SET are read into open core. A 3 x 3 matrix transformation is performed to rotate them to the current view. Then, only the maximum and minimum values on the plotting surface are used to calculate SCALE and ØRIGIN. Also, the elements of the SET must be carefully selected to include the extremities of the object as it will appear when projected onto the plotting surface. For perspective projections, all three dimensions of the object must be considered.

For the plate model shown in Figure 2, the following commands could be used assuming the model includes only the first quadrant of the plate:

```
ØUTPUT(PLOT)
SET 2 = 1, 5, 31, 36
SET 1 = ALL
VIEW ...
AXES ...
FIND
PLOT SET 1
```

Note that the FIND card without any other key parameter will request all the defaults to be taken. SET 2 will be used since it is the first well-defined set. Had SET 1 been used, 36/16 more work would have been performed to find SCALE and ØRIGIN. On larger models, these savings would be substantial.

The REGION parameter on the FIND card can be used for plotting symmetric segments of the model illustrated in Figure 2. Assuming only the first quadrant of the square plate is specified in the model, all four quadrants could be plotted on the same frame with:

```

SET 1 = 1, 5, 31, 36
SET 2 = ALL
VIEW 60, 20, 0
FIND SCALE ØRIGIN 10 SET 1 REGION .43, .26, 1, 1
PLOT SET 1, SET 1, SYMMETRY X,
SET 1, SYMM Y, SET 1, SYMMETRY XY

```

Assuming the entire plate is to be centered in the plotting frame, the parameters were selected so that the first quadrant would be centered in the REGION specified. It should also be noted that the symmetry axes specified on the PLOT card are always assumed to refer to the basic coordinate system, not the axes of the plot frame. The SYMM plotter option can only work correctly if the plane(s) of structural symmetry align with the basic coordinate system axes.

An alternate method is available for plotting the entire plate shown in Figure 2 using the AXES card as follows:

```

ØUTPUT(PLOT)
SET 1 = 1, 5, 31, 36
SET 2 = ALL
VIEW 60, 20 $(QUAD 1 - AXES Z, X, Y)
PLOT SET 2
AXES Z, MX, Y
FIND $(QUAD 2)
PLOT SET 2
AXES Z, MX, MY
FIND $(QUAD 3)
PLOT SET 2
AXES Z, X, MY
FIND $(QUAD 4)
PLOT SET 2

```

This approach is more expensive due to the number of FIND requests. Also, not one, but four plots are required. If care is taken in defining the SET used to define SCALE, all the plots will be to the same scale and can later be integrated into one large figure. A more subtle method of forcing the same scale would be to add "ØRIGIN 1, SET 1" to all but the first FIND card. The first FIND would compute the scale factor. Because "SCALE" is not input on the subsequent FIND cards, that factor is used as the default.

PLOT Card - Deformation Selection

Eigenvalue analysis results usually include eigenvectors that need not be plotted. These may be the rigid body modes or, on restart, they might be the first 10 modes which were plotted previously. For these cases, since the frequency (or eigenvalue) already is known, the RANGE parameter on the PLOT card can be used. However, when the frequency is not known beforehand, a different approach must be used. Here is where the MODES Case Control card can be used to advantage. An example for plotting modes 5, 6, and 7 follows:

```

:
METHOD = 100 $ FIRST THRU FOURTH SUBCASE - MODES 1 THROUGH 4
SUBCASE 11
MODES = 4 $ FIFTH THRU SEVENTH SUBCASE - MODES 5 THROUGH 7
SUBCASE 15
MODES = 3
SUBCASE 18 $ REMAINING SUBCASE - ALL OTHER MODES
OUTPUT(PL0T)
SET 1 = PL0TEL $ USED ONLY FOR * FIND * CARD
SET 3 = ALL EXCLUDE PL0TEL
MAXI DEF0 6, AXES Y, Z, X, VIEW 30, 45
FIND SCALE 1.1, ORIGIN 1, SET 1, REGION 0.4, 0, 1, 1
PL0T MODAL DEF0 15 to 17, SET 1, SET 1 SYMMETRY X

```

These plots are controlled by the subcase numbers (e.g., 15 & 17) and not the mode number or RANGE of frequency. Note that Subcase 18 in Case Control had to be specified since MODES must not be used in the last subcase. The PL0TEL elements are introduced to define the model extremities for use by the FIND card. Notice that using the SYMMETRY option, mirror images are plotted for both the deformation and the model on the left and right sides of the plot frame. If instead, the ANTISYMMETRIC option were used, the direction of the deformation would be reversed for the mirror image only.

PL0T Card - Restricted Labeling

Being able to plot multiple sets per frame can be useful in providing different plot options for each SET. For example:

```

SET 4 = PL0TEL $ FOR USE BY * FIND * CARD
SET 3 = SHEAR, EXCLUDE GRIDS 100 THRU 276,
      EXCEPT GRID POINTS 123, 192
SET 5 = BAR
      FIND SCALE, ORIGIN 5, SET 4
PL0T FREQ VELOCITY 0, SET 3, SHAPE, LABEL (BOTH)
      SET 5, VECTOR NR, SYMBOL 7

```

illustrates a method for selectively labeling elements and grid points. Notice that all SHEAR elements, and not the BAR elements will be drawn and labeled. The BAR element set is used only to define the grid points to be associated with the VECTOR option. Only a portion of the grid points in SET 3 will be identified by number. Those in SET 5 will be identified by a symbol. Hence, some grids may be given both a symbol and a label.

The VECTOR NR option applies only to grid points in SET 5 preventing the plot of any underlay for these elements. However, the SHAPE of SET 3 will be drawn. Had grids been excluded from SET 5, both the vector and the symbol for those grids would not be plotted.

PLØT Card - MAXIMUM DEFØRMATION Parameter

With CRT film plots, a movie can be made from a transient solution. This requires the user to select a value for the maximum displacement applicable to all time steps. This value is specified with the MAXI DEFØ parameter on the PLØT card. If not used, the PLØT module would scale each time step vector differently, based on the maximum component for that one vector only. With the MAXI DEFØ parameter on the PLØT card, all time steps will be plotted to the same scale in order to preserve the relative difference from frame to frame.

The MAXI DEFØ parameter can also be used to modify the scale used in plotting the deformations of a subset of elements. This becomes important when a SET is located in the model where displacements are small relative to the overall maximum. Otherwise, the plotted deformations will be scaled to the maximum over all grid points in the model and not the maximum deformation of the grids contained in the SET.

PLØT Card - Element SET Selection

The issue here is efficiency. By choosing element SETs carefully, significant gains can be realized.

The SHAPE option on the PLØT card initiates two expensive sort operations which are always executed, unless open core is too limited. This sorting eliminates redundant lines encountered when more than one element connects the same pair of grid points. Once the unique lines have been identified, an optimum sequence for plotting these lines is established as described earlier and illustrated in Figure 1. However, if VECTØR NR is specified, any SHAPE or underlay requests and the associated line processing is bypassed.

Complicated models often include elements that add no unique lines. For instance, shear panels are frequently used with rod elements on all four edges. The most efficient choice would be to EXCLUDE the shear panel elements by its type or by the individual element number:

SET 5 = ALL EXCLUDE SHEAR 526, 15, 1025

Of course, for checking out a model, all elements should be plotted to verify overall consistency of the input. The alternative here is to divide the elements into subsets and request several SETs to be plotted on the same or on separate PLØT commands. Thus, the open core required to store data for any one set is reduced. Because the sorting time is proportional to the square of the number of lines in a SET, the CPU time also will be reduced.

CONCLUDING REMARKS

The examples throughout the paper have been designed to illustrate the flexibility and utility of the NASTRAN structural plotter. Each set of input commands as presented as a functional entity. The purpose was not to describe it in detail. The purpose was to inspire the reader to experiment.

REFERENCES

- McCormick, C. W., Editor: The NASTRAN User's Manual. NASA SP-222, 1973.
- MacNeal, Richard H., Editor: The NASTRAN Theoretical Manual. NASA SP-221, 1972.

TABLE 1. NASTRAN PLOTTER DATA

[1 inch = 0.0254 m]

Plotter Identification Data		Line Size (Inch)	Rasters Per Inch	Character Rasters X by Y	Max. Line Length (Rasters)	Record Size (Characters)
Model	Type					
EAI 3500	TABLE	30x30	666.7	66.7x133.3	83.33	2400
EAI 3500	TABLE	45x45	444.4	44.4x88.8	55.56	2400
BENSON LEHNER	TABLE	30x30	200.0	20x40	12	2400
CALCOMP 565, 765	DRUM	12	200.0	16x32	2	2400
CALCOMP 565, 765	DRUM	12	400.0	32x64	2	2400
CALCOMP 563, 763	DRUM	30	200.0	16x32	2	2400
CALCOMP 563, 763	DRUM	30	400.0	32x64	2	2400
DATA DISPLAY 80	CRT		146.1	8x16	1023	1020
STROMBERG CARLSON	CRT		136.4	8x16	63	720
NASPLOT	CRT		146.1	8x16	1023	3000
NASPLOT	TABLE/ DRUM		48.0	16x16	1000	3000

TABLE 2. INTERACTION OF PLOTTING PARAMETERS

Other Parameters Affected	Default Options	Parameter Specified by User											
		ØRTHØGRAPHIC	PERSPECTIVE	STEREØ	PLØTTER	PAPER SIZE	ØRIGIN	SCALE	CSCALE	PRØJ PLANE	VANT PØINT	FIND	PLØT
ØRTHØGRAPHIC	YES	S						U				U	U
PERSPECTIVE	NO		S					U	U	U	U	U	U
STEREØ	NO			S				U	U	U	U	U	U
PLØTTER	SC, 4020				A	U	U	U	U			U	U
PAPER SIZE	8-1/2 x 11				U	A						U	U
ØRIGIN	*	D	D	D	D		S					U	U
SCALE	*	D	D	D	D			S				U	U
CSCALE	1.0				U			U	S			U	U
PRØJ PLANE	1.0									S		U	U
VANT PØINT	*		D	D	D						S	R	U
FIND	*											A	
PLØT	REQUIRED												A
VIEW [†]	*	D	D	D								U	U
AXES [†]	X,Y,Z											U	U
MAXI DEFØ [†]	0.0											U	U
CAMERA [†]	PAPER				D								U
PEN [†]	1												U
BLANK FRAME [†]	1												U
ØCULAR SEPA [†]	2.756											U	U
SET	REQUIRED											U	U

Code

- * - Program generates all values required if not set by user.
- A - Action parameter. Activates computation when encountered.
- D - Default values restored. User must respecify if alternate values desired.
- R - Recalculated if requested.
- S - Stored for later use. Minor calculations may be initiated.
- U - Existing values utilized if required for projection, plotter.
- † - Stored for later use, does not cause change in other parameters.

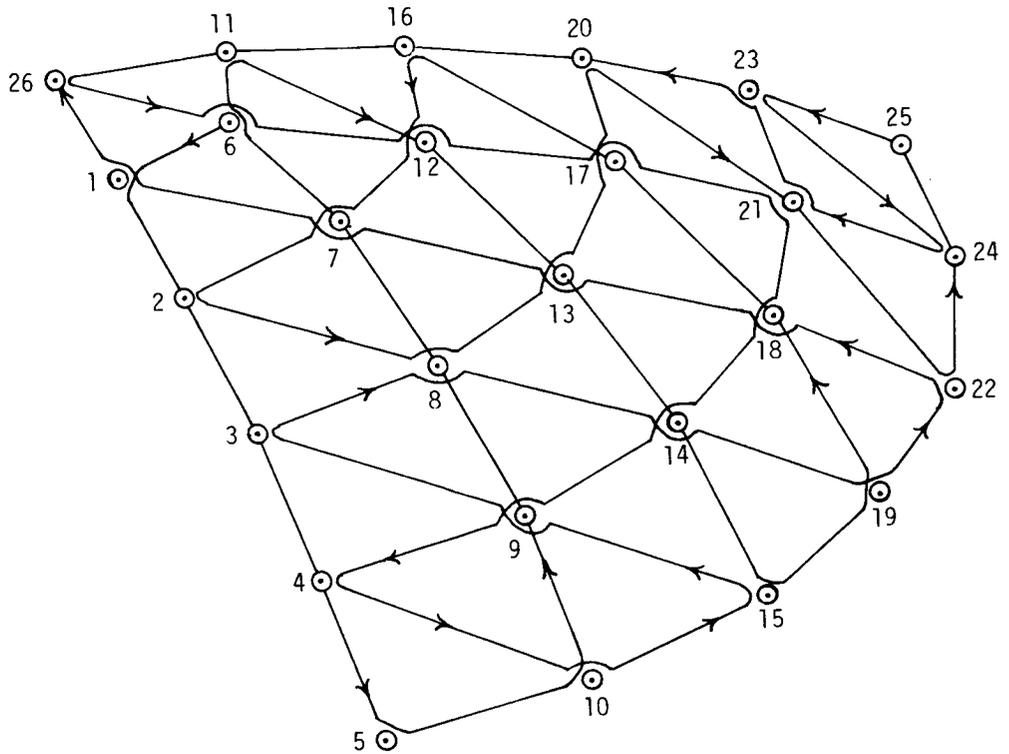


Figure 1.- Path of plotting pen for Demonstration Problem 1-2-1.

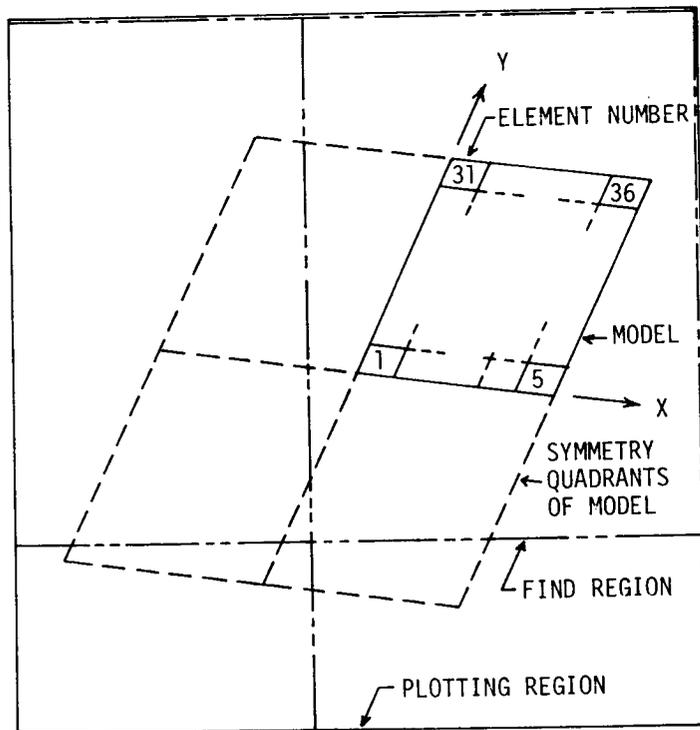


Figure 2.- Example illustrating SYMMETRY, REGION and SET, as used with the FIND and PLOT commands.