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ADDING STRESS PLOT FUNCTION TO NASTRAN

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ABSTRACT

Stress plot function was developed and added to the NASTRAN level 15.5, the latest level available at IBM-Japan. Computed stress distribution can be displayed by this function, with vectors showing the principal stresses of the finite elements over the specified portions of the structure.

First, NASTRAN is reviewed in the aspect of plotting capabilities. Stress tensor field is examined in preparation of stress display. Then the stress plot function as added to the NASTRAN is described. A sample plotout by this function is shown.

PLOTTING CAPABILITIES OF NASTRAN

There is no question that plotouts are much more effective than printouts for the users to grasp global state of computed results. Plotted outputs are often included in analysis reports.

NASTRAN has extensive plotting capabilities. The level 15.5 can generate the following kinds of plot (ref. 1):

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 eigenvalue analysis by the same options stated in the above item.
4. Transient deformations of the structural model by displaying either vectors or the deformed shape for specified points of time.
5. X-Y graphs of transient response or frequency response.
6. Topological displays of matrices.

Structure plots (items 1-4) are available by either orthographic, perspective, or stereoscopic projections. Users can specify portions of structure to be plotted by SET definition cards. Various parameters can be specified or defaulted.

Examining the above list, we notice that, in spite of versatility of the NASTRAN plotting capabilities, we cannot get stress distribution display, which is often more necessary than deformation display and is desired by many NASTRAN users.

Contour plot function is reported to have been added to the current level NASTRAN, to which the author doesn't have access. It is useful for displaying a scalar field (a single-valued function over a field) such as temperature distribution, but seems to be insufficient for a vector or tensor field such as stress distribution. After some study, the author developed the stress plot function as will be introduced.

STRESS TENSOR FIELD

Stress distribution is a tensor field over a structure. And distribution of principal stress is a complete expression of the field. Numerically, a stress tensor at any point of a structure is described with a real symmetric matrix in reference to an orthogonal coordinate system. The eigenvalues and the unit eigenvectors of the matrix are the magnitudes and the unit direction vectors of the principal stresses at the point. Let the expression "principal stress vector" mean the unit eigenvector multiplied by the corresponding eigenvalue. Because the original matrix is completely represented by the eigenvalues and eigenvectors, the stress tensor is completely expressed by the principal stress vectors as defined above.

Therefore, stress distribution can be displayed with principal stress vectors at a number of points well scattered over the structure. Solution of a finite element structural program like NASTRAN gives us ready material for such display with the principal stresses at each structural element.

THE STRESS PLOT FUNCTION

Overview

In order to assist NASTRAN users in the interpretation of output, the stress plot function was developed and added locally to the NASTRAN level 15.5 at IBM-Japan. It was not designed as a postprocessor but was incorporated into the structure plotter of the NASTRAN in order to utilize the versatile capabilities of the existing structure plotting routines and to make the expanded usage simple and natural extension keeping uniformity. Any of the original capabilities were not deleted.

By this function, computed stress distribution is displayed with principal stress vectors of the specified finite elements. The portion of the structure is drawn underlying. Computed principal stress vectors are drawn on each structural element.

Stresses to be Displayed

For the one-dimensional elements ROD, CONROD, TUBE and BAR, the average axial stresses are displayed. For the two-dimensional elements TRMEM, TRPLT, TRIA1, TRIA2, QDMEM, QDMEM1, QDMEM2, QDPLT, QUAD1 and QUAD2, the principal fiber stresses are displayed. Z1 or Z2 can be specified to calculate the stress at the corresponding fiber distance from the mid plane for each two-dimensional element that has bending stiffness. It makes possible to take the stress due to the bending moment as well as the membrane stress into consideration.

It is difficult for viewers to grasp the directions of the three principal stress vectors of a three-dimensional stress tensor by means of the two-dimensional display. The condition that they are mutually perpendicular is a helpful but insufficient information to restore the three directions uniquely. For three-dimensional elements TETRA, WEDGE, HEXA1 and HEXA2, a convenient method is recommended instead. Users attach two-dimensional elements on appropriate sides of three-dimensional elements, and specify the two-dimensional elements rather than the three-dimensional elements for plotout of stresses. If the two-dimensional elements are thin enough, their stiffness is completely neglected in the computation of accumulated stiffness because of the finite precision of computer arithmetic. By this technique, stresses are obtained on sides rather than at the centroids of the three-dimensional elements.

Implementation

The functional module PLOT was modified: five existing subroutines DPLOT, PARAM, PLOT, HEAD and DRAW in the module were modified, and two GETSTR and DRWSTR were added. The number of input data blocks for the module was increased by one. The Module Property List (MPL) and the Rigid Formats were modified accordingly (ref. 2). The modification of Rigid Format 1 could have been expressed in the following form of ALTER packet in Executive Control Deck (ref. 1):

```
ALTER  15,15
PLOT   PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,,/
       PLOTX1/V,N,NSIL/V,N,LUSET/V,N,JUMPPLOT/V,N,PLTFLG/V,N,PFILE $
ALTER  123,123
PLOT   PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,PUGV1,,OES1/
       PLOTX2/V,N,NSIL/V,N,LUSET/V,N,JUMPPLOT/V,N,PLTFLG/V,N,PFILE $
ENDALTER
```

In the new tenth position of input data block section, substituted is the data block OES1, which corresponds to user's request for element stress output. This is the source which supply computed stresses to the functional module.

New Parameters

Several parameters were added for use in plot request packet. They are listed and explained subsequently, in the same way as the existing plot parameters are in reference 1.

```
MAXIMUM STRESS s

PLOT [{STATIC   }{DEFORMATION} i1,i2...] ... [MAXIMUM STRESS s] ... ,
     [{MODAL    }{STRESS     }         ]
     [{TRANSIENT}                      ]

     ... [PENS t,c] ... [Z1] ...
                        [Z2]
```

MAXIMUM STRESS card is interpreted by the modified PARAM subroutine. It must always be included if stress is to be plotted. The value of s represents the length to which the maximum absolute principal stress is scaled in each subcase. It must be specified in units of structure. This card for stress plot corresponds to the MAXIMUM DEFORMATION card for deformation plot.

New parameters in expanded PLOT logical card are interpreted by the modified PLOT subroutine.

Non-zero integers following the new keyword STRESS refer to subcases that are to be plotted. Zero to request underlying drawings is not used in stress plot request because stress plot always includes underlying drawings.

Real number following the keywords MAXIMUM STRESS is used as the maximum principal stress value in scaling the stress vectors for all subcases. Each subcase is separately scaled according its own maximum if this item is absent. This parameter in PLOT card for stress plot corresponds to the MAXIMUM DEFORMATION parameter in PLOT card for deformation plot.

Two integers following the keyword PENS identify pens to be used to draw tensile and compressive principal stress vectors respectively. Pen selection had been activated for our plotter routine before. Pen 1 is always used for underlying drawings.

Z1 and Z2 select fiber distances from the mid planes of two-dimensional elements that have bending stiffness, where stresses are to be calculated.

Headings

For a frame of stress plot, in the bottom line "STATIC STRESS ... " is written instead of "STATIC DEFOR. ... ". In the top line "MAX-STR." with the maximum absolute principal stress value is written instead of "MAX-DEF." with the maximum absolute component of deformation. These are done by the modified HEAD subroutine.

Underlying Drawings

Underlying drawings of structures for stress plots are written by the modified DRAW subroutine like those for deformation plots. Therefore, parameters applicable to underlying drawings are common.

Plot of Principal Stress Vectors

Computed principal stresses are fetched and plotted by the added subroutines GETSTR and DRWSTR under control of the modified PLOT subroutine. A principal stress vector is plotted in the shape of an arrow having heads at both ends. The arrow is located so that the middle point of the shaft expediently coincides with the gravity center of the vertices of the finite element. The direction of the arrow is that of the principal stress. The length of the shaft is proportionate to the magnitude of the principal stress. The size of the heads is also proportionate.

The heads are outward if the principal stress is tensile, and inward if compressive. Heads are drawn not as triangles but as trapezoids in order to avoid indistinctness of positions of the apexes of triangles when plotted. It is well known that a shaft looks to have different length if triangular heads are attached in two ways, outward and inward for comparison. To avoid this optical illusion, outward heads are drawn slender, and inward ones flat. When the absolute values of tension and compression are equal, the outward and the inward heads with equal areas have their centroids equally apart from the connecting points with the shafts.

Projection

Stress arrows are projected orthographically or perspectively along with underlying drawings.

Upon request, projected sizes of arrows can be retained to be proportionate to the magnitudes of principal stresses as before projection. Then users can compare magnitudes of principal stresses by measuring the projected sizes. For natural appearances viewing parameters should be so specified as the projection plane does not make large angles against significant principal stresses.

SAMPLE

Figure 1 was drawn by the stress plot function. Related part of the plot request packet was as follows:

```
OUTPUT(PLOT)
SET 1 ALL
...
PERSPECTIVE PROJECTION
MAXIMUM STRESS 10.0
VIEW 0.0 45.0 0.0
FIND SCALE SET 1 ORIG 1
PLOT STATIC STRESS 3 SET 1 Z1 ORIG 1 PENS 2,3
```

Pen 1 (black) was used for headings and underlying drawings, Pen 2 (blue) for tensile principal stresses, and Pen 3 (red) for compressive ones.

CONCLUDING REMARKS

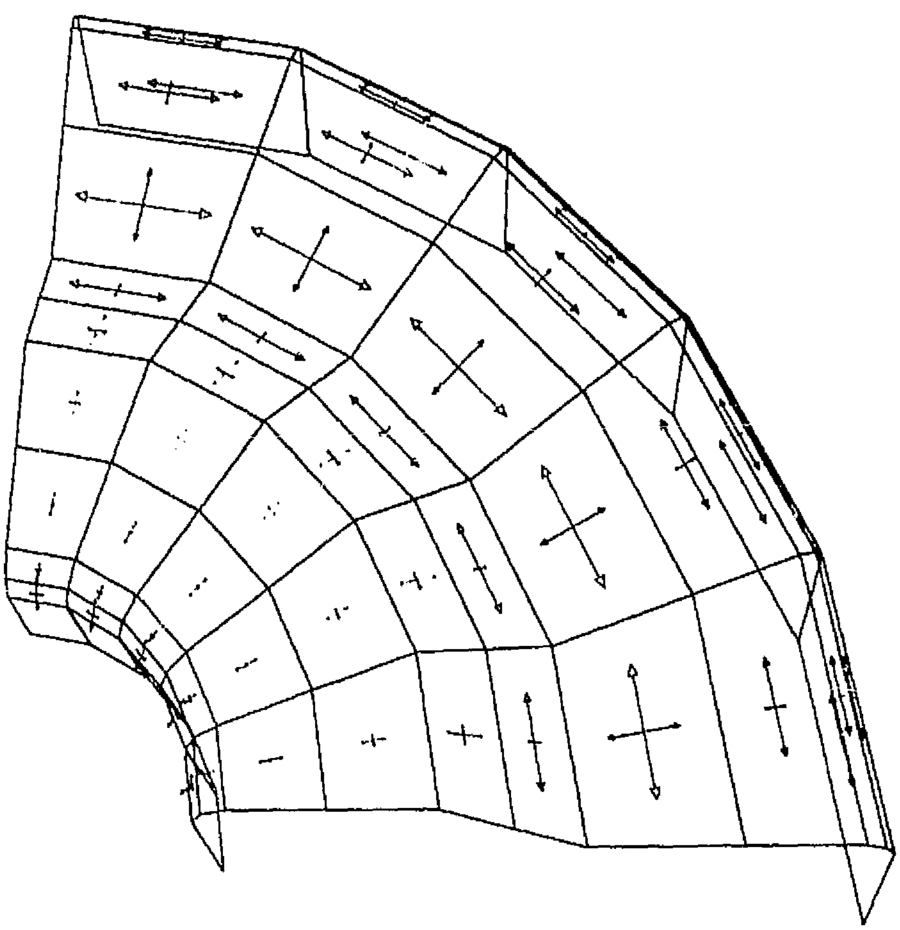
Utilizing existing capabilities of the NASTRAN structure plotter, stress plot function was developed and incorporated into the NASTRAN level 15.5 with relatively little effort. But it provides effective means for us to grasp global state of computed results.

REFERENCES

1. McCormick, C. W. (Ed.): The NASTRAN User's Manual, NASA SP-222(01), with Level 15.5 Supplement, May 1973.

2. The NASTRAN Programmer's Manual, NASA SP-223(01), with Level 15.5 Supplement, May 1973.

5/28/78   MAX-STR.   6.18534240



TEST
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STATIC STRESS SUBCASE 3   LOAD 300

Figure 1. SAMPLE PLOTOUT

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OF POOR QUALITY