Flexible Results Evaluation

by

Joseph L. Walsh
FEGS, INC.
Duluth, GA 30136

Martin Jones
FEGS Limited
Cambridge, UK

ABSTRACT

The evaluation of large amounts of MSC/NASTRAN results is becoming more and more common among MSC/NASTRAN users. The processing of this data can become a monumental task for the user without the proper tools. This paper discusses a flexible approach for results evaluation based on a hierarchical results database in which results are assigned as attributes to mesh entities (ie. nodes, elements, Elements at Nodes) and have assigned the results the attribute of their mathematical form (ie. scalar, vector, tensor). Since the mathematical form and relationship to mesh entities is stored in the hierarchical database any result entity may be converted to a different mathematical form and/or "averaged" to a different mesh entity. The results database stores all loadcases in one direct access file allowing for combination of load case values, and graphing of results across load cases or time steps. This paper outlines the hierarchical results data structure in FAM and the methoodology of accessing and manipulating this result data.

Introduction

The use of large MSC/NASTRAN models and/or complex analyses such as non-linear transient dynamics requires the evaluation of large amounts of results data. This evaluation of results data requires a postprocessing system that allows for flexible display and tabulation of results. FAM provides the user with a system for results evaluation based on a hierarchical database for results.

Hierarchical Results Database

FAM has implemented a hierarchical results database to handle MSC/NASTRAN results. The results from any MSC/NASTRAN analysis are collected into a single binary database containing all results from that particular analysis. The results database contains a copy of the model analyzed as well as the results of the analysis.

The actual results hierarchy created is a function of the MSC/NASTRAN analysis performed, elements used, and datablocks processed. "Subcase" will be included in the hierarchy for any solution sequence which uses subcases. "Mode" will be included in the hierarchy if eigenvectors are processed. "Surface" will be included in the hierarchy if averaged surface stresses are processed. "Volume" will be included in the hierarchy if averaged volume stresses are processed. "Fibre" will be included in the hierarchy if elements are processed which output Fibre results (ie. shell elements). Examples of results database hierarchy are illustrated in Figures 1 and 2 for Subcase results and Modal results respectively.

SUBCASE	FIBRE	DATASETS		
		NODE	N-SEQUENCE	ELEM
		E-SEQUENCE	SKEWSYS	CSYS
		N-CSYS	E-SKEW	E-PHYS
SC-1		DISPLACE-T	DISPLACE-R	REACTION-T
		REACTION-R		
SC-1	Z1	E-STRESS	E-STRAIN	
SC-1	Z2	E-STRESS	E-STRAIN	
SC-2		DISPLACE-T	DISPLACE-R	REACTION-T
		REACTION-R		
SC-2	Z1	E-STRESS	E-STRAIN	
SC-2	Z2	E-STRESS	E-STRAIN	

Figure 1: Example Results Hierarchy for Shell Elements with Two(2) Subcases

MODE	DATASETS		
	Node	N-Sequence	ELEM
	E-Sequence	SKEWSYS	CSYS
	N-CSYS	E-SKEW	E-PAYS
M-1	EIGEN-Value	EIGEN-VEC-T	EIGEN-VEC-R
M-2	EIGEN-Value	EIGEN-VEC-T	EIGEN-VEC-R
M-3	EIGEN-Value	EIGEN-VEC-T	EIGEN-VEC-R

Figure 2: Example Results Hierarchy for Modal Analysis

The information describing the model that was analyzed by MSC/NASTRAN is also stored as results in the hierarchical database and can be accessed and processed like any other result value. These results are stored in a group of datasets referred to as the model datasets and include the data oulined in Figure 3.

DATASETS	DESCRIPTION
NODE	Grid Coordinates
N-SEQUENCE	Grid Sequence
ELEM	Element Connectivity
E-SEQUENCE	Element Sequence
SKEWSYS	Element Transformations
CSYS	Coordinate Transformations
N-CSYS	Grid CD Direction
E-SKEW	Element Coordinate Systems
E-PHYS	Element Properity ID

Figure 3: Model Datasets

Since these datasets can be accessed as results the user may display these values graphically in any desired format. Some possible graphical displays are contours and/or graphs of node sequence to interrogate the effectiveness of the bandwidth optimization scheme employed. This provides the user with flexibilility to evaluate the model parameters used.

The results datasets in the FAM results model (.FRM) database are dependent on the element type used, analysis performed, and datablocks processed. Figure 4 illustrates the results datasets processed by FAM.

DATASET	DESCRIPTION
DISPLACE-T	Translational Displacement Components
DISPLACE-R	Relational Displacement Compenents
LOAD-T	Translational Grid Loading Components
LOAD-R	Relational Grid Loading Components
REACTION-T	Translational Reaction Force Components
REACTION-R	Rotational Reaction Force Components
BALANCE-T	Translational Grid Balance Force Components
BALANCE-R	Rotational Grid Balance Force Components
EIGEN-VEC-T	Translational Eigenvector Components
EIGEN-VEC-R	Rotational Eigenvector Components
EIGEN-VALUE	Eigenvalue
TEMPERATURE	Grid Temperature
SUR-STRESS	Grid Surface Stresses
VOL-STRESS	Grid Volume Stresses
E-STRESS	Element Stresses
SHEAR-STRESS	CShear Element Stresses
E-STRAIN	Element Strain
SHEAR-STAIN	CShear Element Strains
S-ENERGY	Element Strain Energy
BEAM-FORCES	Forces in CBAR,CROD, and CTUBE Elements
GAP-FORCES	Forces in CGAP Elements
TUBE-FORCES	Forces in CFTUBE Elements
SHELL-FORCES	Forces in Shell Elements
AXI-FORCES	Forces in Axisymmetric Elements
SHEAR-FORCES	Forces in Shear Elements

Figure 4: Results Datasets

Each dataset in the database consists of one or more components (ie. X, Y, Z for DISPLACE-T, or XX, XY, YY, XZ, YZ, ZZ for E-STRESS) Each component is stored as either a real or integer scalar value in accordance with the data type of the dataset.

A datatype is assigned to every dataset in the FAM result model (.FRM) database. The purpose of the datatype is to describe the type of data contained within that dataset and thereby define the operations that may be performed on that dataset. The different datatypes used for processing MSC/NASTRAN results are outlined in Figure 5:

DATATYPE	**DESCRIPTION**
REAL SCALAR	Real Scalar Values
REAL VECTOR	Vector Data Containing Three(3) Real Components
REAL SYMMETRIC TENSOR	3x3 Tensor Matrix Defined By 6 Components
INTEGER	Interger Scalar Values
COORD.SYS (Cart/Cyl/Sph)	4x4 Coordinate System Matrix Containing 16 Components
SKEW SYSTEM	3x3 Transformation Matrix Containing 9 Components

Figure 5: Datatypes for MSC/NASTRAN Results

Each dataset is also indexed by an appropriate meshpart as illustrated in Figure 6:

MESHPART	**DESCRIPTION**
DATA	Coordinate System Data
VOID	Not Related to Mesh Part
NODE	Values at Grid Points
ELEM	Values at Elements Centroid
ELNO	Values at Nodes of an Element

Figure 6: Meshpart Indexing

FAMfromNASTRAN

The hierarchical results database discussed here is created by the program FAMfromNASTRAN. FAMfromNASTRAN reads the MSC/NASTRAN binary Output2 file and converts the datablocks present in the Output2 file to the hierarchical data structure described earlier. It is necessary to include DMAP alters in the MSC/NASTRAN executive control and appropriate case control options to ensure that the appropriate datablocks are written to the Output2 file. Figure 7 below illustrates the programs and files used by MSC/NASTRAN and FAM for results processing.

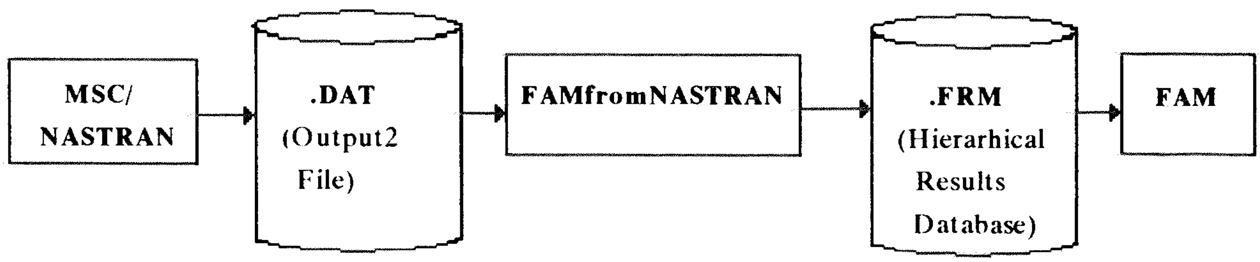

Figure 7: FAMfromNASTRAN

Accessing the Hierarchical Database

The hierarchical results database is accessed in FAM through the RDEF and RMOD commands which create and modify a result definition respectively. A result definition is an entity which defines a path through the results database hierarchy and any associated operations on the result data.

The following result definitions refer to the hierarchical results database as outlined in Figure 1 of this paper. The first result definition (RDEF) will store the path to the translational displacement vector for Subcase SC-1 in an entity called DISP. The second result definition (RDEF) will store the path to the X component of the translational displacements for Subcase SC-1 in an entry called DISX (Note the use of the COMP keyword to indicate selection of a component from the dataset). The result modification (RMOD) modifies the entity DISX to refer to Subcase SC-2 with all other items in the path through the hierarchy remaining unchanged.

```
RDEF DISP   SC-1   DISPLACE-T
RDEF DISX   SC-1   DISPLACE-T   COMP  X
RMOD DISX   SUBCASE  SC-2
```

Figure 8: Sample Result Definitions and Modification

Performing Calculations and Operations on Results

The result definition/modification may also specify calculations and/or operations to be performed on the result data. Since the datatype for each dataset is also stored as part of the results database it is possible to determine which calculations are applicable for the dataset under consideration. Several calculations are available for operating on real symmetric tensors as illustrated below in Figure 9.

PVAL	-	Principal Stress Values	(3 Scalars)
PVEC	-	Principal Stress Vectors	(3 Vectors)
PRES	-	Average of XX, YY, ZZ, Stresses	(1 Scalar)
OCTS	-	Octahedral Shear Stress	(1 Scalar)
VONM	-	Von Mises Stress	(1 Scalar)
PS3D	-	Principal Shear Stress	(3 Scalars)

Figure 9: Tensor Calulations

It is also possible to calculate the magnitude (MAG) of any vector resulting in a single real scalar value. Sample result definitions and modifications using calculations are shown below in Figure 10. The result definition DISM will calculate the magnitude of the displacement vector for subcase SC-1. While the result definition ESP1 will calculate the principal stress values based on element stresses and extract the first principal stress component. The result definition EVON will calculate element Von-Mises stressses based on element stress results.

```
RDEF  DISM  SC-1  DISPLACE-T  CALC  MAG
RDEF  ESP1  SC-1  Z1  E-STRESS  CALC  PVAL  COMP P1
RDEF  EVON  SC-1  Z1  E-STRESS  CALC  VONM
```

Figure 10: Sample Calculations

The results stored in the FAM result model (.FRM) database are stored as 3D vectors and 3D symmetric tensors as appropriate. Therefore, it is possible for the user to convert results to any coordinate system for display and tabulation simply by specifying which coordinate system is to be used in the CSYS option for result definitions/modifications.

FAM also provides the capability to average results to a particular meshpart that is different than the meshpart index stored for the dataset in the results database. Element, element nodal, and nodal results may be averaged to either of the two(2) remaining meshparts as desired by the user. The user may also specify whether averaging occurs on a global basis for the model or on a part (set) by part basis (ie. averaged within material boundaries but discontinuous at material boundaries).

Displaying Results

FAM offers a wide variety of options for displaying results as specified through result definitions/modifications. The display options available include Deformed Shape Plots, Contour Plots, Vector Plots, Graphs, and Tabulation of Results. Any of the available Plot options may also be superimposed on one another to build a desired picture.

Deformed Shape Plots are available with the deformation based on any vector result or on any scalar result with a specified direction vector for deformation. Tensor results my be converted to vector or scalar results through the use of calculations as described earlier. The standard result definition used for deformed shape plots is the translational displacement vector, however, it is possible to deform according to any desired result definition such as the Von Mises equivalent stresses for plasticity analysis.

Contour Plots are available as line contours, line contours on colored elements, line contours on light source illuminated elements, and color filled contours. Contouring is available for any scalar result value. Tensor and vector results may be converted to a scalar by means of the calculation options addressed earlier or by the specification of a particular component to be used (refer to DISM in Figure 10). Contour plots are available on deformed shape plots or undeformed plots.

Contouring of result values indexed by (or averaged to) nodes will result in smooth continuous contour lines. Contouring of result values indexed by element nodal (ELNO) will result in discontinuous contour lines which are discontinuous at each element edge. This contour plot may be useful in determining the validity of results based on the degree of discontinuity at element edges. Contouring of result values indexed by (or averaged to) element will result in each element being filled by a solid color based on the value at the element centroid.

Vector Plots are also available for any vector results or scalar results with a specified direction vector. Vector plots may be overlayed on contour and deformed shape plots.

Graphs

Graphing is available for any scalar results and results can be graphed versus a sequence of meshparts or versus a sequence of results (ie. Subcases) or versus another result. It is also possible to graph the results of a particular meshpart (ie. Grid 37) through multiple timesteps or subcases.

Combined Values

Result definitions (RDEF) can be combined at any level of the results hierarchy to evaluate combinations of results through the use of combined values (CVAL) as illustrated in Figure 11.

```
RDEF   LCS1   SC-1
RDEF   LCS2   SC-2
CVAL   AV12   LCS1   0.5   LCS2   0.5
RDEF   DISP   AV12   DISPLACE-T
```

Figure 11: Combined Values

This will produce a result definition DISP which will use the average for values of translational displacements for Subcases SC-1 and SC-2.

Conclusion

Processing results of large MSC/NASTRAN models and complex analyses requires a flexible post-processing system for the user to effectively evaluate the results.

FAM provides a flexible results evaluation system based on a hierarchical results database for MSC/NASTRAN results along with a wide breadth of operations on these results and a broad range of options for display. The hierarchical nature of the FAM result model (.FRM) database provides the user with the necessary flexibilty to manipulate and display his MSC/NASTRAN results.

References

"FAMfromNASTRAN Reference Manual, Version 2.0, Release 1.0 FEGS, Ltd., Cambridge UK, June 1989"

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