

N84 15593 ^{D3}

USING PAFEC AS A PREPROCESSOR FOR COSMIC/NASTRAN*

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SUMMARY

Programs for Automatic Finite Element Calculations (PAFEC) is a general purpose, three-dimensional linear and nonlinear finite element program (ref. 1). PAFEC's features include free-format input utilizing engineering keywords, powerful mesh generating facilities, sophisticated database management procedures, and extensive data validation checks. Presented here is a description of a software interface that permits PAFEC to be used as a preprocessor for COSMIC/NASTRAN. This user-friendly software, called PAFCOS, frees the stress analyst from the laborious and error prone procedure of creating and debugging a rigid-format COSMIC/NASTRAN bulk data deck. By interactively creating and debugging a finite element model with PAFEC, thus taking full advantage of the free-format engineering-keyword-oriented data structure of PAFEC, the amount of time spent during model generation can be drastically reduced. The PAFCOS software will automatically convert a PAFEC data structure into a COSMIC/NASTRAN bulk data deck. The capabilities and limitations of the PAFCOS software are fully discussed in the following report.

INTRODUCTION

Numerous general purpose programs are currently available to assist engineers during the data preparation phase of a NASTRAN finite element method problem. The goal of these preprocessors is to accept a minimum amount of user data and create the rigid-format input data structure required by the COSMIC/NASTRAN Bulk Data (NBD), since the NBD is devoid of any sophisticated automatic data generation schemes. Two such sets of software (ref. 2 and 3) based upon other programs were presented at last year's COSMIC/NASTRAN conference. Many others have been presented in previous years. Properly designed preprocessing aids, like these, can greatly reduce the time spent by an engineer in creating the rigid-format required by the NBD. If these aids are interactively executed, much correcting and debugging of a finite element model can be accomplished prior to submission of even the first COSMIC/NASTRAN execution for a new problem. Although most of the available preprocessing aids for COSMIC/NASTRAN meet their design goals, the authors of this paper prefer to use the free-format data preparation and automatic mesh generation capabilities of the PAFEC suite of finite

*Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under contract W-7405-eng-26 with the Union Carbide Corporation.

element computer programs. This paper describes software developed for utilizing PAFEC as a preprocessor for COSMIC/NASTRAN.

At the Oak Ridge National Laboratory (ORNL) COSMIC/NASTRAN is leased upon IBM computer equipment. It is generally executed in a batch processing mode. Serving as an interactive front-end to the IBM machines are several DECsystem-10 computers. Within ORNL's computer environment, users generally prefer to interactively create data and IBM Job Control Language (JCL) on the user-friendly DECsystem-10s and then to route these jobs to the IBM mainframe batch queues for number crunching. Because PAFEC can best be utilized in an interactive environment, the DECsystem-10s were chosen as the computers upon which to execute PAFEC.

The PAFEC suite of program modules is executed as a collection of ten separate phases that create and operate upon a database called the Backing Store (BS) file. Among other capabilities, PAFEC has extensive mesh generation facilities; a free-format, engineering-keyword-oriented, modular data preparation scheme; extremely simple methods to represent repetitive data values; automatic load generation facilities; and a complete graphics software package to display the created finite element data. An optionally available interactive program, the PAFEC Interactive Graphics Suite (PIGS), can be obtained to enhance all the above mentioned capabilities. PAFEC is not simply a preprocessor. Solution sequences exist for linear static and dynamic structural mechanics problems as well as for treating certain classes of nonlinear structural mechanics and heat transfer problems.

On the ORNL DECsystem-10s an additional facility has been implemented in the PAFEC control scheme that will automatically invoke the PAFEC to COSMIC/NASTRAN preprocessor for a stress analyst. Mnemonically designated PAFCOS (ref. 4), this software contains several subroutines. The main subroutine, called PAFNBD, serves as a controller for the other subroutines. The other subroutines convert the PAFEC BS internal format for the axis systems, nodal points, material properties, element topologies, element properties, and single- or multipoint constraints into the rigid-format of the COSMIC/NASTRAN NBD. Unique rigid-format continuation card mnemonics are generated as necessary. Upon successful completion of PAFEC PHASE 4, the user's job will have created a disk file, <name>04.NBD, that contains the COSMIC/NASTRAN NBD (<name> symbolically represents the user's PAFEC finite element model job name and 04 is appended to the job name to indicate the file was created in PHASE 4). Thus, the stress analyst can interactively generate, debug, and display a finite element model with PAFEC; convert a model to COSMIC/NASTRAN rigid-format bulk data using user-friendly software; and then solve the model using COSMIC/NASTRAN upon one of the larger mainframe computers at ORNL.

ORGANIZATION

First, a discussion of the most salient features of the model generating capabilities of PAFEC is presented. (Although PAFEC has complete solution capability, it will not be discussed here as it is not germane to the subject of this report.) Secondly, in the remainder of this report, we describe the details of subprogram PAFCOS, its supporting software, and the modifications to the PAFEC executive control. Finally, an example using this software is presented.

MODEL GENERATION WITH PAFEC

The PAFEC modular data system has many advantages. From the user's standpoint, the finite element data are very easy to input and are intelligible without additional documentation. Additionally, data prepared for other finite element programs can be used as input data by PAFEC with less text-editing manipulation. From the system's standpoint, the data modules are easily scanned to determine the solution sequence and the software required to perform the user's specific finite element task (ref. 5).

A PAFEC data module consists of three parts: (1) the module header card, (2) the module contents card, and (3) the free-format numerical data. The module header card and the numerical data are required for every module that the user inputs for a particular finite element problem. (Only those data modules that are needed are entered as data.) The contents card is optional and is used to alter the default definition of certain parts of the data or to change the order of the numerical data located in the third part of the data module. An example of the NODES data module, a fundamental data module, is presented to demonstrate the three parts of the PAFEC modular data:

```
NODES
Z=0.0
NODE      X      Y
  1      0.0    0.0
  2      0.0    1.0
  3      1.0    1.0
  4      1.0    0.0
```

The first card represents the module header card, the second card is a constant contents data card, the third card is a contents data card, and the last four cards present the free-format nodal numerical data.

Other data modules can be used to define nodal coordinates; among these are:

NODES	The NODES module can be used to define nodal coordinates in any axis set.
AXES	The AXES module can be used to define different axis sets.
SIMILAR.NODES	Once any number of nodes have been defined, the SIMILAR.NODES module can be used to define other nodes that are similar but perhaps more conveniently located in another axis system.
LINE.NODES	The LINE.NODES module can be used to define any number of nodes to lie upon the same straight line.
ARC.NODES	Similar to the LINE.NODES module, the ARC.NODES module can be used to define any number of nodes to lie upon the same circular arc.

PAFBLOCKS

When used in conjunction with the MESH module, the PAFBLOCKS module will cause two- and three-dimensional blocks of nodes and elements to be generated.

Several data modules are used in the description of finite element topology, types, material properties, and thicknesses. These modules include:

ELEMENTS

The ELEMENTS module describes the element type, properties, group number, and topology for individual elements.

PAFBLOCKS

When used in conjunction with the MESH module, the PAFBLOCKS module will cause two- and three-dimensional blocks of nodes and elements to be generated.

REFERENCE.IN.PAFBLOCKS

The REFERENCE.IN.PAFBLOCKS module permits modification of generated elements within a PAFBLOCK.

PLATES.AND.SHELLS

The PLATES.AND.SHELLS module describes element thicknesses, material number, and other information for membrane, bending, and axisymmetric finite element analysis.

BEAMS

The BEAMS module describes pertinent information for beam elements.

MASSES

The MASSES module is used in dynamic finite element analyses to add mass at nodes.

SPRINGS

The SPRINGS module is used to input simple axial and torsional springs into a finite element analysis.

GROUP.OF.SIMILAR.ELEMENTS

The GROUP.OF.SIMILAR.ELEMENTS module copies selected elements into new elements by simply incrementing element topology. This facility can be used to conveniently describe finite element geometries that contain repetitious sections.

PAFEC examines the data modules describing a structure and the user's control module to determine how many degrees of freedom to permit at each nodal coordinate. To apply constraints at individual or groups of nodes, the following data modules can be used:

RESTRAINTS

The RESTRAINTS module is the most generally used module for describing the degrees of freedom to be constrained. Each row in the data module can be used to describe the constraints at one node, or, by using the PLANE and possibly AXIS entry, all the nodes that lie on a line or on a plane can be constrained at once.

ENCASTRE

The ENCASTRE module can be used to constrain all the degrees of freedom for a set of nodes.

SIMPLE.SUPPORTS

The **SIMPLE.SUPPORTS** module can be used to constrain all the translational degrees of freedom for a set of nodes while leaving the rotational degrees of freedom unchanged.

DISPLACEMENTS.PRESCRIBED

The **DISPLACEMENTS.PRESCRIBED** module can be used to apply nonzero displacements at certain nodes.

REPEATED.FREEDOMS

The **REPEATED.FREEDOMS** module is used to constrain two or more nodes to move by an identical amount in a particular direction. This module is useful when there is slippage possible at some joint in a structure. By arranging two nodes to be coincident and therefore to have separate and unrelated degrees of freedom, the **REPEATED.FREEDOMS** module can be used to define those degrees of freedom that are to be continuous across the joint.

HINGES.AND.SLIDES

The **HINGES.AND.SLIDES** module is the complement of the **REPEATED.FREEDOMS** module. Instead of specifying constrained degrees of freedom, this module is used to specify unconstrained degrees of freedom.

LOCAL.DIRECTIONS

The **LOCAL.DIRECTIONS** module does not describe constraints directly. However, this module can be used to force PAFEC to resolve degrees of freedom in different directions other than the global coordinate axes directions.

GENERALIZED.CONSTRAINTS

The **GENERALIZED.CONSTRAINTS** module permits writing arbitrary linear functions relating displacements among any number of nodes. Rigid links may be specified with this module.

THE PAFCOS SOFTWARE INTERFACE

The PAFCOS software developed at ORNL permits the user to define a finite element model, using the previously discussed modular data dictionary, and then to automatically create a rigid-format, COSMIC/NASTRAN bulk data deck. Subroutine PAFNBD serves as a controller for several other subroutines, individually discussed below, that are collectively located in the PAFCOS subroutine library. When the user includes the COSMIC/NASTRAN control directive in a PAFEC control module, then a call to subroutine PAFNBD will be inserted in the PHASE 4 FORTRAN generated for the job. Execution of the PAFNBD subroutine will cause the axis systems, nodal coordinates, material properties, element topologies, element properties, and constrained degrees of freedom to be successively converted from internal PAFEC BS format to COSMIC/NASTRAN bulk data rigid format. Upon successful completion of the constraint conversion, subroutine PAFNBD returns to the PHASE 4 FORTRAN and normal PAFEC execution.

The PAFCOS software is written in FORTRAN-66 and uses the PAFEC series R09800 subroutines exclusively for accessing the data nodules contained in the user's BS file. Therefore, this software is easily implemented in any system where PAFEC has been installed. (A FORTRAN-77 version of the software is being created.) The next several sections discuss the functions of the individual subprograms contained within the PAFCOS software library.

Subroutine PNCOR

Subroutine PNCOR performs the processing of axis definitions from PAFEC BS to COSMIC/NASTRAN format. This subprogram processes each entry of BS module 68 (the internal storage number given to PAFEC axis sets) and writes the appropriate COSMIC/NASTRAN CORD2R, CORD2C, or CORD2S data cards, depending upon whether the PAFEC coordinate system is rectangular, cylindrical, or spherical, respectively. Unique continuation card mnemonics are generated as necessary.

Subroutine PNNOD

Subroutine PNNOD generates COSMIC/NASTRAN GRID cards from the PAFEC BS module 1 (the internal storage number given to PAFEC global, cartesian nodal coordinates). All GRID cards are specified in global coordinates. If PAFEC BS module 4 is not empty, then the GRID card will also contain the appropriate output coordinate system designation. Otherwise, the output coordinate system will be the global rectangular coordinate system.

Subroutine PNMAT

Subroutine PNMAT creates COSMIC/NASTRAN MAT1 data cards from the PAFEC BS module 31 (the internal storage number given to the PAFEC materials data). Only isotropic elastic materials are converted, a subprogram PNMAT limitation. Each material in the data module is reformatted and written onto the output file with unique continuation card mnemonics.

Subroutine PNETOP

Subroutine PNETOP processes the element data stored in PAFEC BS modules 17 and 18. Each element definition is processed individually with mappings from PAFEC element types and topologies to COSMIC/NASTRAN element types and their corresponding topologies. The following element mappings are currently supported.

PAFEC element mnemonic	COSMIC/NASTRAN element card	Element type
30100	CELAS2	Spring element
30200	CMASS2	Mass element
34000	CBAR	Simple beam element
34200	CBAR	Offset beam element
34400	CROD	Simple rod element
36100	CTRMEM	Triangular membrane element
36200	CQDMEM1	Quadrilateral membrane element
37100	CIHEX1	8-node brick element

37120	CIHEX2	20-node brick element
37130	CIHEX3	32-node brick element
37200	CWEDGE	6-node wedge element
41320	CTRIA2	Triangular plate element
43110	CTRSHL	6-node triangular plate element
44100	CTRIA2	Triangular plate element
44200	CQUAD2	4-node quadrilateral plate element

Unique continuation card mnemonics are generated for each element type requiring a multiscard element topology. Also, special processing is required for each PAFEC spring element (number 30100) and mass element (number 30200) since each of these elements may yield as many as six COSMIC/NASTRAN CELAS2 or CMASS2 element data cards. (Unique element numbers are generated for any newly created elements.)

Subroutine PNPROP

Subroutine PNPROP performs generation of COSMIC/NASTRAN element property cards. Several PAFEC BS modules are examined and the following mapping is used to create the appropriate COSMIC/NASTRAN property cards.

PAFEC element mnemonic	COSMIC/NASTRAN property card
30100	PELAS
34000	PBAR
34200	PBAR
34400	PROD
36100	PTRMEM
36200	PQMEM
37100	PIHEX
37120	PIHEX
37130	PIHEX
37200	PWEDGE
41320	PTRIA2
43110	PTRSHL
44100	PTRIA2
44200	PQUAD2

Subroutine PNDOF

Subroutine PNDOF processes constraint data stored in PAFEC BS module 2. Each degree of freedom is examined for constraint codes. Any constrained degree of freedom generates an appropriate COSMIC/NASTRAN SPC data card. PAFEC REPEATED.FREEDOMS are output as COSMIC/NASTRAN MPC data cards for the repeated degrees of freedom.

Subroutine PGCMP

If GENERALIZED.CONSTRAINTS are defined via PAFEC BS module 143, then subroutine PGCMP generates appropriate COSMIC/NASTRAN data cards for each generalized constraint. An arbitrary limitation of three independent nodes for any dependent node has been set in subroutine PGCMP. Unique continuation card mnemonics are generated as necessary.

INTEGRATION OF THE PAFEC SOFTWARE INTERFACE INTO THE PAFEC MACRO DICTIONARY

Minor additions to the PAFEC MACRO dictionary were all that was necessary to completely implement the PAFEC software into the PAFEC PHASE execution scheme. The PAFEC MACRO dictionary is used by the PAFEC driving program to create FORTRAN and job control information for a particular PAFEC PHASE. Within each PAFEC user data file there exists a control module and possibly several sets of data modules. (The PAFEC control module is analogous to the executive and case control cards of a COSMIC/NASTRAN data deck.) Based upon the user-specified PAFEC control directives, the PAFEC driver program determines which PHASE and what subroutine within the PHASE should be executed. In order to permit a user-friendly interface between the PAFEC system and the PAFEC software, a single new control directive, appropriately named COSMIC/NASTRAN, was added to the PAFEC MACRO dictionary.

PHASE 4 was chosen as the appropriate PHASE to create a COSMIC/NASTRAN NBD, due to finite element model generation completeness. The MACRO dictionary was modified to conditionally include a call to subroutine PAFNBD (the driver for the PAFEC software) in the PHASE 4 FORTRAN, based upon the presence or absence of the COSMIC/NASTRAN control directive. Similarly, an instruction was inserted to conditionally include the precompiled PAFEC relocatable object module in the linkage edit step of the PHASE 4 job control. Therefore, to access the PAFEC software all the user must do is to simply insert the phrase COSMIC/NASTRAN following the PHASE=4 PAFEC control directive somewhere within his control module. For example, the following few lines represent a valid PAFEC control module that would invoke the PAFEC software:

```
CONTROL
NAME.ABCD
PHASE=4
COSMIC/NASTRAN
STOP
CONTROL.END
```

AN ILLUSTRATIVE EXAMPLE

This rather academic example demonstrates most of the capabilities of the PAFEC software. It is intentionally brief so that a very small COSMIC/NASTRAN bulk data deck is created. The following listing is a copy of the PAFEC data deck that generates the small three-dimensional plate finite element model shown in figure 1.

```
TITLE PAFEC TEST
CONTROL
SAVE.RESULTS
```


CONCATENATE.OUTPUT
 SAVE.PLOTS
 NAME.T
 PHASE=4
 COSMIC/NASTRAN
 STOP

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CONTROL.END
 NODES
 NODE.NO X.IN Y.IN Z.IN
 1
 2 1.5 0 0.8
 3 3.0
 4 0 5.0
 5 0.75 5 0.4
 6 1.5 5.0
 PAFBLOCKS
 ELEMENT=44200
 N1 N2 TOPOLOGY.OF.BLOCK
 1 2 1 3 4 6 2 0 0 5
 MESH
 REFER SPACING
 1 2
 2 2 1.5 1
 PLATES.AND.SHELLS
 MATERIAL THICKNESS.IN
 1 0.81
 MATERIALS
 MATERIAL E NU RO
 1 27E6 .27 7.7
 RESTRAINTS
 NODE PLANE DIRECTION
 1 2 0
 MODES.AND.FREQ
 AUTOMATIC.MASTERS MODES
 10 4
 END.OF.DATA

After successful execution of PHASE 4 on an ORNL DECsystem-10 computer using the above PAFEC data, a file, T04.NBD, is created containing the COSMIC/NASTRAN bulk data deck. For completeness this data deck is listed below:

GRID	1	0.000	0.000	0.000	0
GRID	2	1.500	0.000	0.800	0
GRID	3	3.000	0.000	0.000	0
GRID	4	0.000	5.000	0.000	0
GRID	5	0.750	5.000	0.400	0
GRID	6	1.500	5.000	0.000	0
GRID	7	0.000	2.222	-0.000	0
GRID	8	1.167	2.222	0.622	0
GRID	9	2.333	2.222	0.000	0
GRID	10	-0.000	3.889	-0.000	0
GRID	11	0.917	3.889	0.489	0
GRID	12	1.833	3.889	0.000	0
MAT1		12.70E+07	1.06E+07	2.707.70E+00	.00E+00

+MAT001

SPC	10000	1	123456						
SPC	10000	2	123456						
SPC	10000	3	123456						
SPC	10000	4	6						
SPC	10000	6	6						
SPC	10000	7	6						
SPC	10000	9	6						
SPC	10000	10	6						
SPC	10000	12	6						
CORD2R	1	0	0.0	0.0	0.0	0.0	0.0	0.0	1.0+C2R001
+C2R001	1.0	0.0	0.0						
CORD2C	2	0	0.0	0.0	0.0	0.0	0.0	0.0	1.0+C2C002
+C2C002	1.0	0.0	0.0						
CORD2S	3	0	0.0	0.0	0.0	0.0	0.0	0.0	1.0+C2S003
+C2S003	1.0	0.0	0.0						
CQUAD2	1	1	1	2	8	7			
CQUAD2	2	1	2	3	9	8			
CQUAD2	3	1	7	8	11	10			
CQUAD2	4	1	8	9	12	11			
CQUAD2	5	1	10	11	5	4			
CQUAD2	6	1	11	12	6	5			
PQUAD2	1	1	0.81						

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All that remains for the user to do is to merge the above file with the IBM JCL procedure for executing COSMIC/NASTRAN at ORNL, add an executive and case control deck, and then submit the job.

CONCLUDING REMARKS

For production problems, using PAFEC and the PAFCOS software as a preprocessor for COSMIC/NASTRAN eliminates a large majority of the cards necessary for a finite element analysis. This software has been used to preprocess several large magnet structural analysis problems at ORNL and has demonstrated an over 95% reduction in the total number of cards typed for these problems. Future improvements are planned to convert and/or create even more of the data.

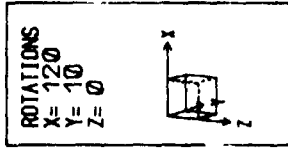
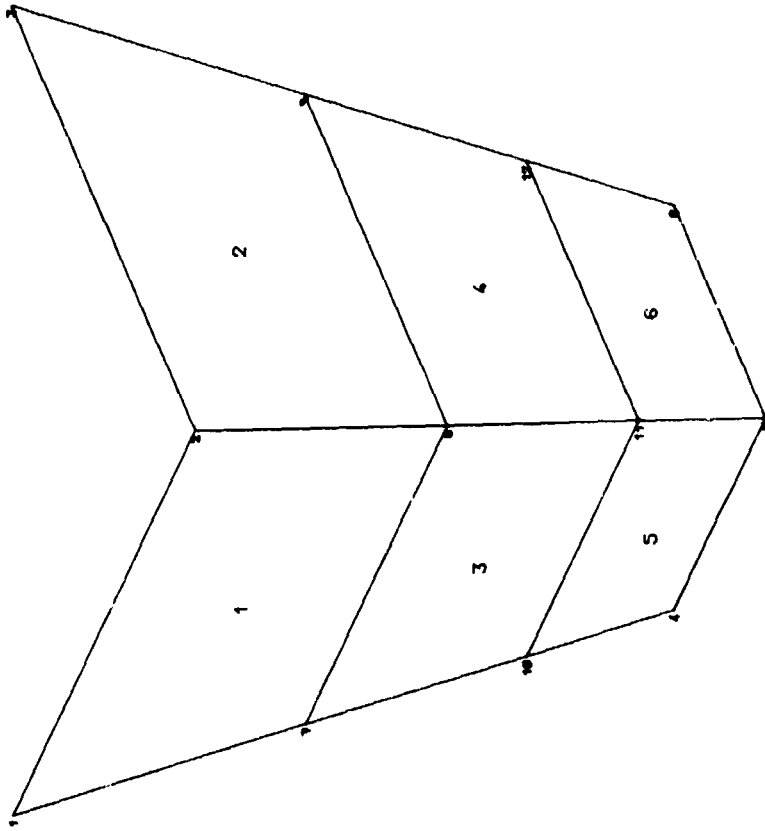
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3. Hirt, E. F. and Fox, G. L.: Recent Developments of NASTRAN Pre- and Post-processors: Response Spectrum Analysis (RESPAN) and Interactive Graphics (GIFTS). Tenth NASTRAN Users' Colloquium, NASA CP-2249, May 1982, pp. 18-44.

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4. The first implementation of this software was called PAFNAS and was documented in the following reference: Baudry, T. V. and Gray, W. H.: PAFNAS, A PAFEC to COSMIC/NASTRAN Conversion. First U. S. A. PAFEC Users' Conference, June 1981.
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PAFEC-PIGS-PLOT

TEST OF PAFECOS



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Figure 1. The finite element mesh for the example problem showing the element and nodal numbers.