PRE- AND POSTPROCESSING LARGE DETAILED MSC/NASTRAN MODELS

by

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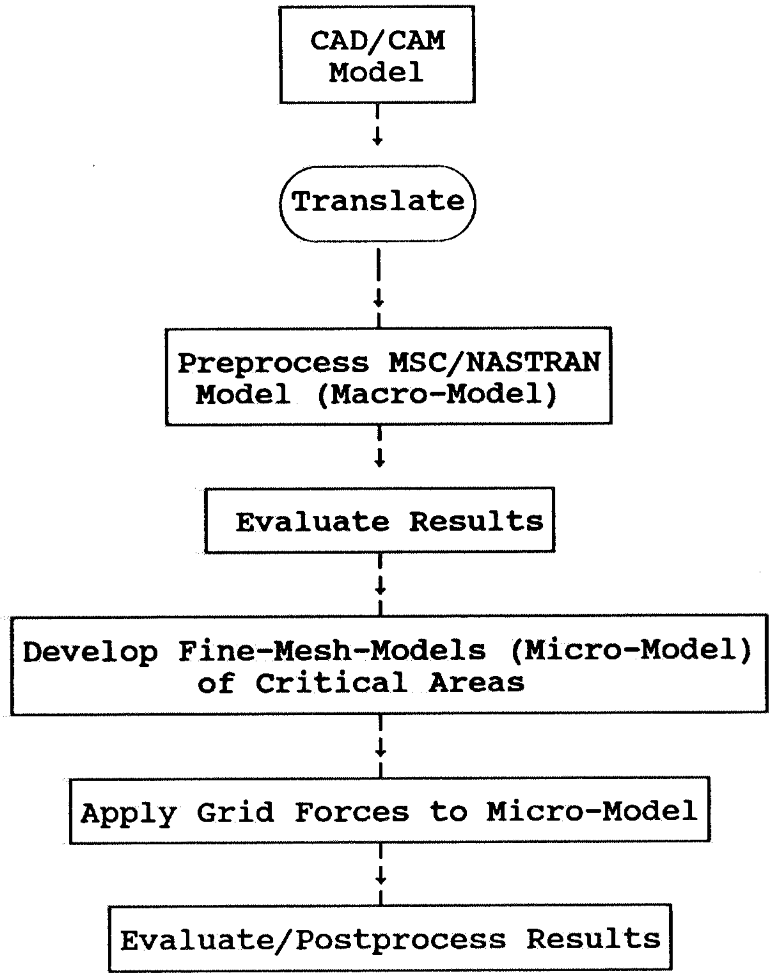
The advent of advanced pre and postprocessing techniques makes MSC/NASTRAN more viable in evaluating large detailed structures with unique geometry and characteristics. Discrete areas can be modeled in detail to evaluate effects such as stress concentrations. Shell element analysis of laminated composite structure on a ply basis can be performed and the results postprocessed. The large output generally associated with PCOMP and MAT8 card images of such an analysis can be easily managed. Three dimensional ply representations, using solid HEX8 elements to evaluate interlaminar tension is practical.

The technique of evaluating and postprocessing large detailed MSC/NASTRAN models is the topic of this paper.

Evaluating discrete areas within finite element models requires sufficient geometry definition to effectively characterize the effects experienced in that location. Such detail in local areas could place a burden on the model as a whole. The following figure illustrates the technique used to evaluate critical areas with unique characteristics within MSC/NASTRAN models.



The geometry of structural components are graphically represented in a CAD/CAM system during the design phase. The CAD/CAM files contain loft surfaces and other viable geometry. These files are thus translated and used as initial geometry in preprocessing sessions of the finite element model (macro-model). This model maintains the proper geometry and stiffness of the component structure. The macro-model can be relied upon to develop correct internal loads within the structure. Internal loads "build up" towards the boundaries of discrete areas of interest within the finite element model. These internal loads are recovered through grid point forces from the bounding adjacent elements. The recovered grid point forces are thus applied to a fine-mesh-models (micro-model) that describes the bounded area of interest. The micro-model describes in accurate detail the geometry of such critical areas in MSC/NASTRAN models. These models are developed externally to the macro-model. Thus allowing for greater detail meshing of critical areas without adversely effecting the mesh fidelity of the original macro-model.

Applying the recovered grid point forces from the macro-model to the micro-model will result is an unbalanced structure. This imbalance can be reacted by applying the average of the resultant imbalance to the extremities of micro-model. A token SPC may be necessary to take out any slight residual imbalance that may still exist.

Figure 1 illustrates the relationship of the control slot cutouts in the tailboom to the micro-model. This model's function is to characterize the state of stress and strain at this location of the tailboom. The micro-model determined a stress concentration of nearly 5.0. This information is particularly useful in the assessment of manufacturing defects and repairs in this area of the composite tailboom. Figure 2 is a micro-model for the bridge section of the tailboom.

This model was used to predict the effects at the radius of the bridge where strain gage data is not reliable. Stress analysis by the photostress method was performed on this area of the tailboom, and used a standard of comparison. The micro-model correlated very well with the photostress results.

There are other programs designed for this type of analysis. However this technique employing MSC/NASTRAN coupled with a preprocessor is an effective means to characterize local effects.

Figure 1

Control Slot Micro-Model

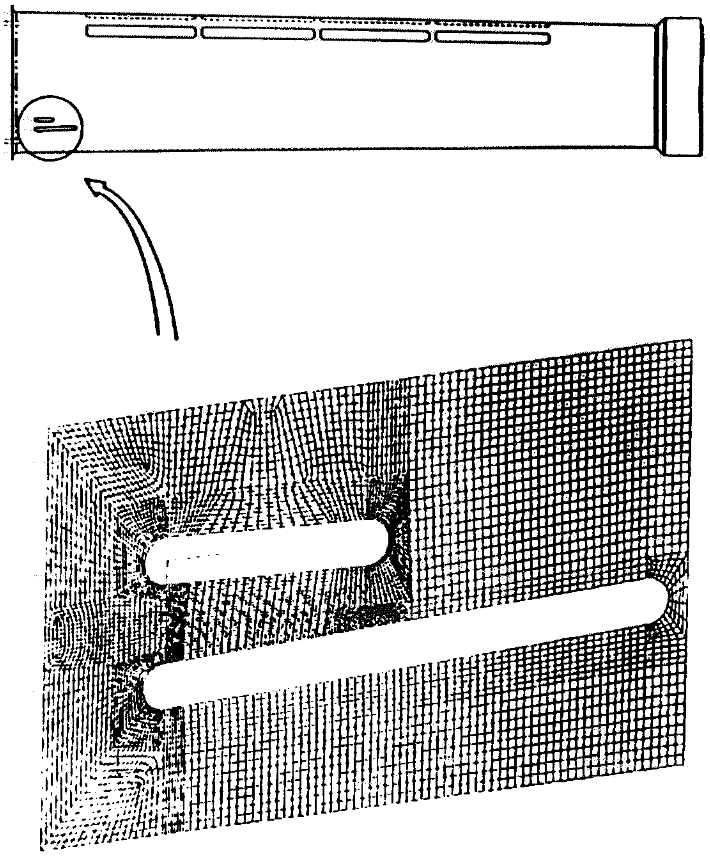
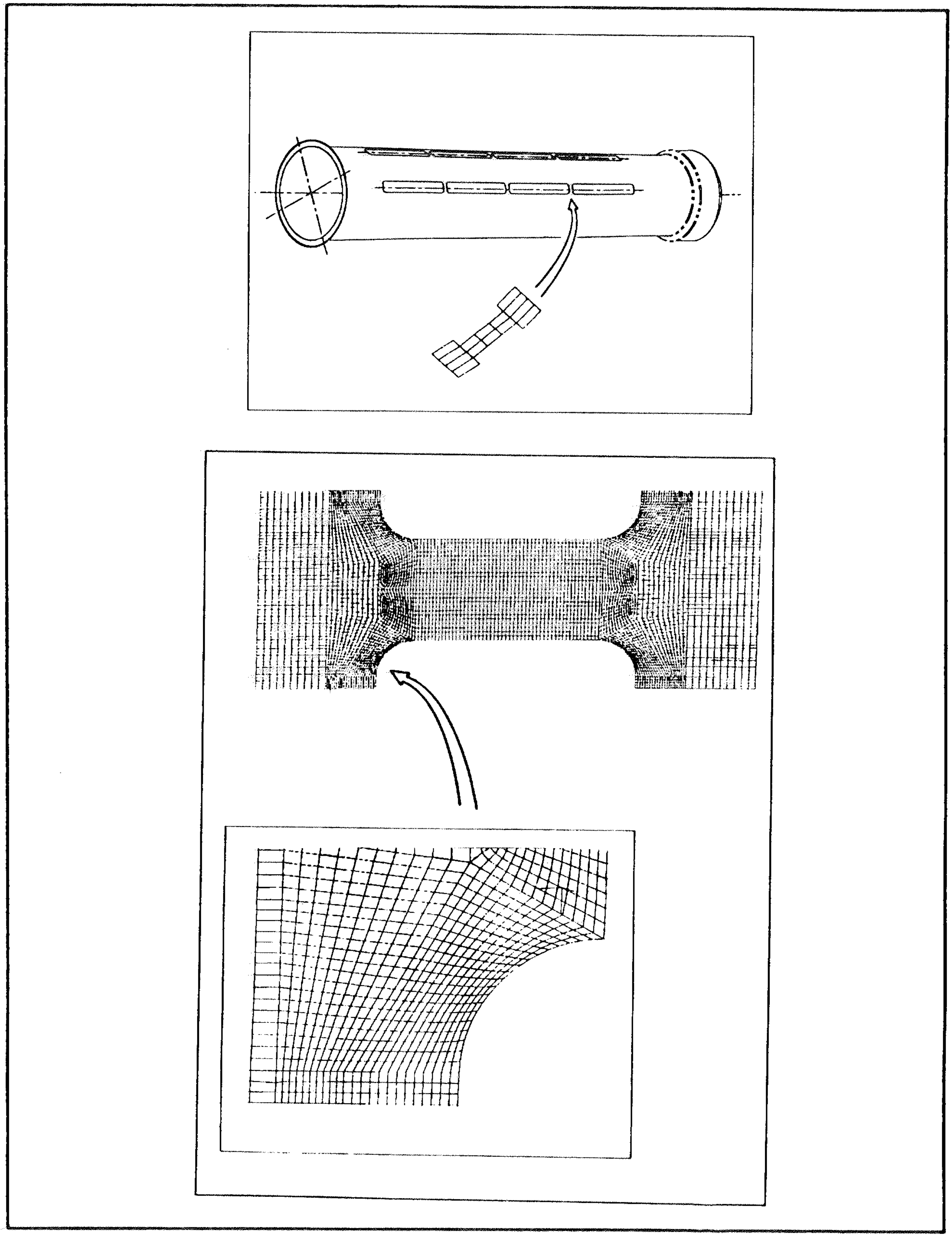


Figure 2

Bridge Micro-Model



3-D REPRESENTATION
OF LAMINATED COMPOSITES

The analysis structure considered is an angle lug. This lug consists of a thick stacking sequence of composite material and tight radius. The function of the lug is to react tension and compression loading. The lug's ability to carry load is reduced by the thick stacking and geometry. In carrying tensile or compressive loading, a bending moment is reacted across the radius of the lug. In the case of tension, such a bending moment will tend to "open" the radii (see figure 3). This circumstance can produce the condition known as interlaminar tension. The effects of interlaminar tension can produce premature failure. To assess the effects of interlaminar tension on the angle lug, each ply was represented 3-dimensionally in MSC/NASTRAN. Ply definition employed the use of solid HEX8 elements. 3-dimensional representation of ply material is essential, since classical laminate theory does not consider σ_z, τ_{zx}, τ_{zy}. Also correct geometry is maintained through the radius of the lug with solid ply representation. Maintaining correct 3-dimensional geometry is an important factor in evaluating interlaminar stresses.

The time and effort involved in representing plies of laminate composite structures 3-dimensionally in finite element models can be formidable indeed. Simply maintaining correct mesh interfaces between layers of solid HEX elements alone in most cases is preclusive. The development of solid models is greatly enhanced by using advanced automated meshing techniques. The technique of isoparametric meshing enables the analyst to mesh intricate 2 and 3 dimensional geometry with very few commands. Viable mesh transitional from small to large areas is performed automatically during preprocessing. In fact if Phase I geometry (PATRAN's patches and hyperpatches) is topologically congruent, isoparametric meshing can mesh the entire model with one command. Employing the use of isoparametric solid meshing enabled the completion of the lug model in less than sixteen person hours.

ANALYSIS

The micro-model for the lug consists of three primary sections, a mid-section and two outer-sections. The mid-section represents the 30 degree section at the center of the radius of the lug. In the evaluation of interlaminar tension of such a component, the mid-section of the radius is most critical; thus the mid-section consists of greater detail, sub-micro-model of sorts. For efficiency and practicality only this section of the Micro-model is considered during postprocessing and results evaluation. The two outside sections of the model require less detail. Their function is to provide the correct geometry and stiffness of the lug, thus developing the correct internal loads to distribute into the mid-section Micro-model. Figure 5 illustrates the cross-section view of the lug with actual number of plies included in the radius of the lug. The geometry and stacking sequence is maintained and shown in a cross-sectional view of the finite element model (figure 4). The micro-models correlated well with the results of the photoelastic stress analysis. Interlaminar tension failure was not predicted by the MSC/NASTRAN model. Posprocessed results are not included in this report. The detail of micro-models do not lend themselves well to stress contours in black and white. Brilliant color graphics of each model described in this paper will be shown during the presentation.

Figure 3
Radius Section Reacting Moment

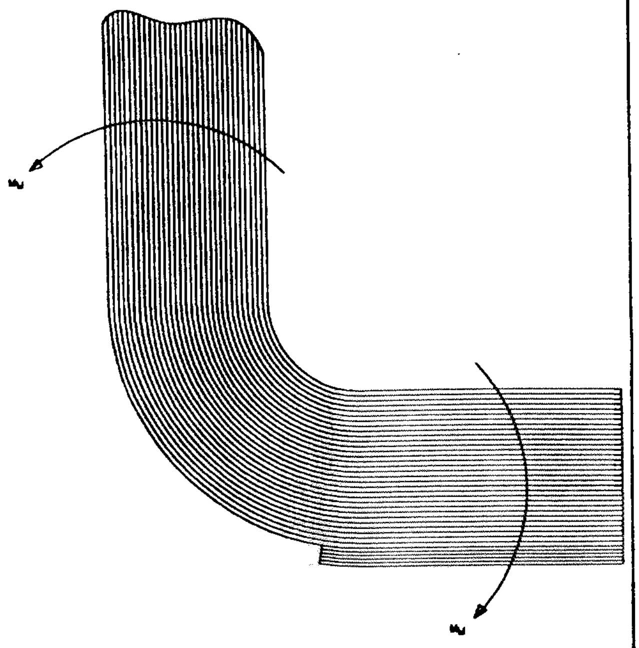


Figure 4
Cross-Section of Solid Model

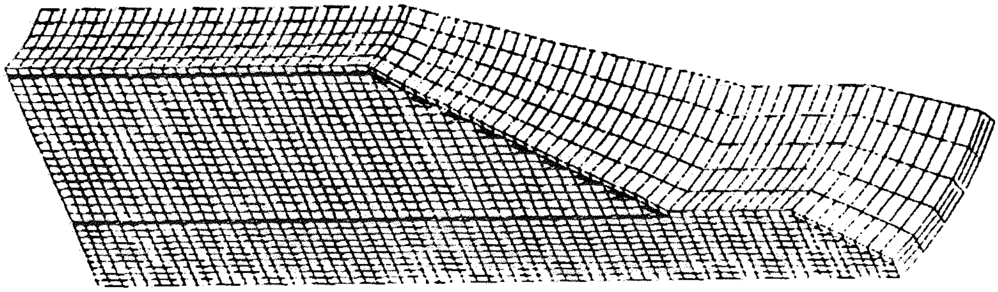
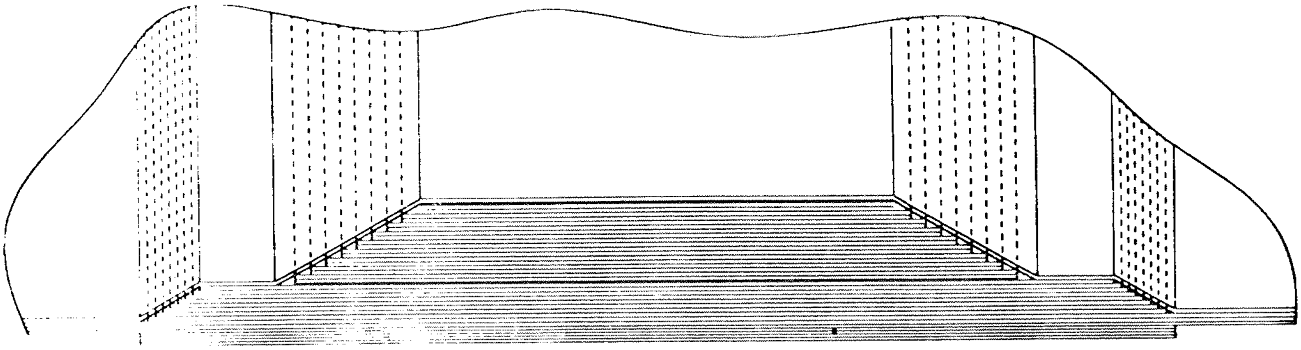


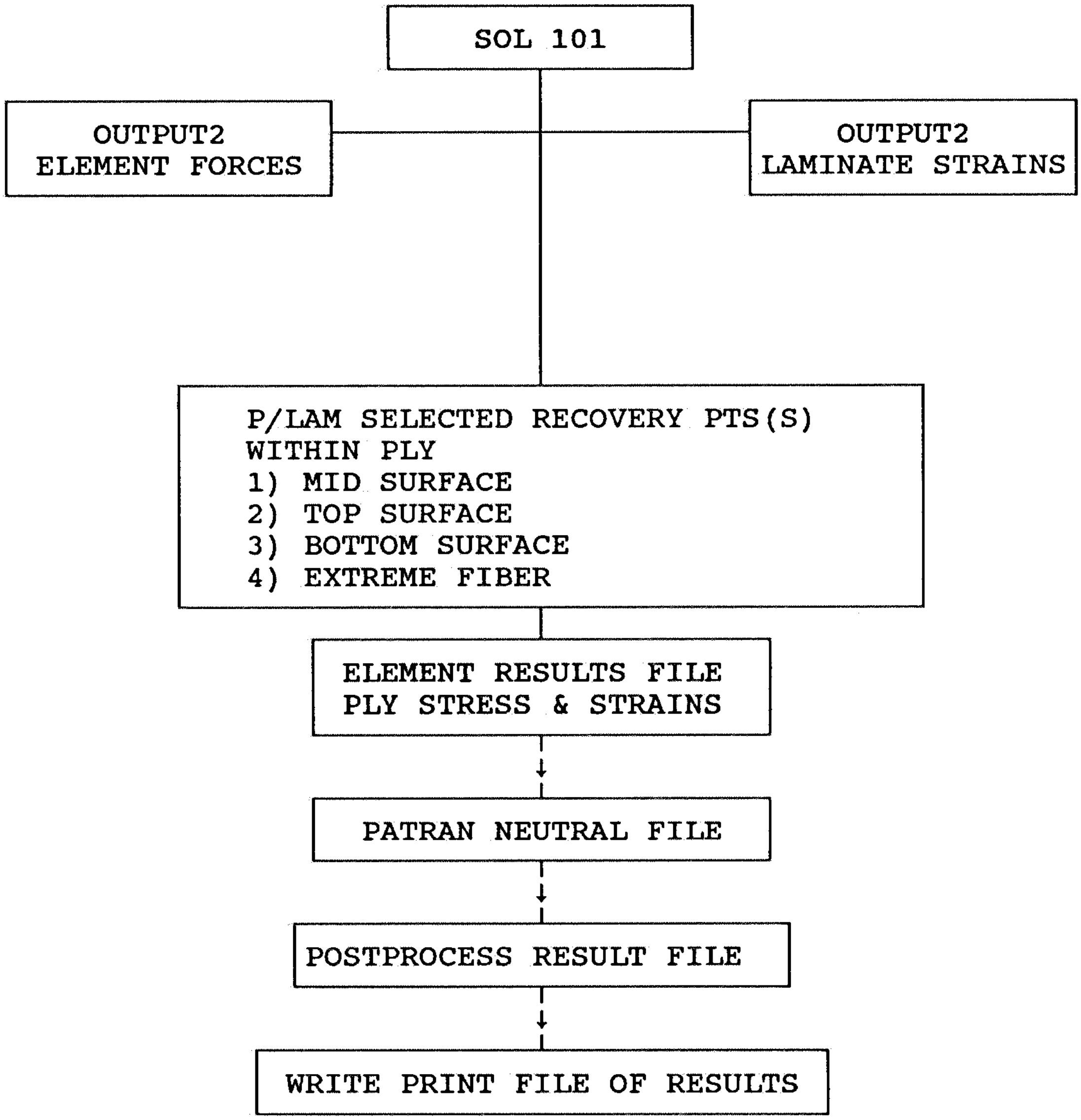
Figure 5

Cross Section of Lug



SHELL ELEMENT ANALYSIS OF LAMINATES

The technique of defining and analyzing laminated composite structure on a ply bases can be a formidable task. Shell element analysis of a laminate structure with MSC/NASTRAN is greatly enhanced through the use of postprocessors. Large complex composite structures can be developed in considerable detail employing the use of PCOMP and MAT8 cards. The results of such an analysis is easily managed via advanced postprocessing techniques. The following figure illustrates the analysis process used to evaluate the interlaminar stresses and strains experience, within a laminate structure.



Plies within each laminate are described individually with PCOMP and MAT8 card images. The static solution sequence 101 writes the laminate stresses and strains, as well as element forces to an output2 file. The results from this file are integral to the ply evaluation of the laminate. The element forces developed in the model from the solution 101 run, are used to compute the interlaminar shear results. The original element strains and curvatures are used to determine the ply stresses and strains of each laminate. The material properties and ply orientation provided on MAT8 and PCOMP card images are read into a neutral file of the model. PATRAN's P/LAM module formulates the rotation matrices from the element to material coordinate frame and processes the ply stresses and strains. The results from the MSC/NASTRAN model is thus evaluated on the ply basis. The P/LAM module allows the analyst to select the recovery points within the ply. The following selection are offered:

1. Mid-surface
2. Top-surface
3. Bottom-surface
4. Extreme fiber
5. MSC/NASTRAN PCOMP recovery convention

The results of the analyst's selection is written to a PATRAN results file. Postprocessing this results file will illustrate graphically the stresses and strains experienced on the ply level.

The P/LAM module writes a print file of the selected laminate results developed from MSC/NASTRAN and the postprocessing session. Based on the selected recovery points and laminate, a summary of individual ply and laminate results are included in the results file. The results of the layered composite elements are written in standard MSC/NASTRAN format. Review of this file will eliminate the need to pore over extensive ply data generated from a standard run.

A summary of layered composite results developed during a typical P/LAM session is presented in Table I.

ADVANTAGES

1) Develop and evaluate MSC/NASTRAN composite models without compromise.

2) Graphical representation of individual ply results.

3) Eliminate the need for external composite programs.

4) Perform sensitivity studies of laminates.

TABLE I

P/LAM SESSION SUMMARY

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                         #### SUMMARY OF PLY RESULTS ####

                                                  MINIMUM

                                                LAMINATE   PLY
          QUANTITY                    ELEMENT      ID       ID        VALUE
 -------------------------------     ---------  --------  -----   ------------
 FIBER STRESS          ( NORMAL-1 )    7642        13        1     -1.04195E+04
 TRANSVERSE STRESS     ( NORMAL-2 )    8206        21        1     -1.50273E+04
 IN-PLANE SHEAR STRESS ( SHEAR-12 )    8442        13        1     -1.49639E+03
 INTERLAMINAR STRESS   ( SHEAR-23 )    4456         1        1     -5.49539E+01
 INTERLAMINAR STRESS   ( SHEAR-31 )    7923        13        1     -5.71100E+01
 PRINCIPAL STRESS - MAJOR              4432         3        1     -2.33282E+03
 PRINCIPAL STRESS - MINOR              8206        21        1     -1.50275E+04
 MAXIMUM SHEAR STRESS                  5978         2        1      1.61865E+00

                                                  MINIMUM

                                                LAMINATE   PLY
          QUANTITY                    ELEMENT      ID       ID        VALUE
 -------------------------------     ---------  --------  -----   ------------
 FIBER STRAIN          ( NORMAL-1 )    7642        13        1     -1.17344E-03
 TRANSVERSE STRAIN     ( NORMAL-2 )    8206        21        1     -1.73877E-03
 IN-PLANE SHEAR STRAIN ( SHEAR-12 )    8442        13        1     -1.87048E-03
 INTERLAMINAR STRAIN   ( SHEAR-23 )    4456         1        1     -6.86923E-05
 INTERLAMINAR STRAIN   ( SHEAR-31 )    7923        13        1     -7.13875E-05
 PRINCIPAL STRAIN - MAJOR              4632         3        1     -1.53013E-04
 PRINCIPAL STRAIN - MINOR              8206        21        1     -1.73941E-03
 MAXIMUM SHEAR STRAIN                  5978         2        1      4.25670E-07

      SUMMARY OF PLY RESULTS FOR LAMINATE        1 PLY NUMBER       1

                                          MINIMUM                 MAXIMUM
         QUANTITY                    ELEMENT     VALUE        ELEMENT     VALUE
 ------------------------------      -------  ------------   --------  -----------

 FIBER STRESS          (NORMAL-1)    4629     -4.03160E+03     4646     3.04798E+03

 TRANSVERSE STRESS     (NORMAL-1)    4434     -7.59810E+03     4457     8.27994E+03
 IN-PLANE SHEAR STRESS (SHEAR-12)    4456     -7.74933E+02     4463     3.33437E+02
 INTERLAMINAR STRESS   (SHEAR-23)    4456     -5.49539E+01     4637     1.83466E+01
 INTERLAMINAR STRESS   (SHEAR-31)    4456     -7.82174E+00     4629     1.09542E+01
 PRINCIPAL STRESS - MAJOR            4565     -2.00442E+03     4457     8.34305E+03
 PRINCIPAL STRESS - MINOR            4434     -7.63029E+03     4643     2.24425E+03
 MAXIMUM SHEAR STRESS                4676      7.94731E+01     4434     4.11345E+03

                                          MINIMUM                 MAXIMUM
         QUANTITY                    ELEMENT     VALUE        ELEMENT     VALUE
 ------------------------------      -------  ------------   --------  -----------
 FIBER STRAIN          (NORMAL-1)    4629     -4.33906E-04     4646     3.25169E-04
 TRANSVERSE STRAIN     (NORMAL-2)    4434     -8.38057E-04     4457     9.08464E-04
 IN-PLANE SHEAR STRAIN (SHEAR-12)    4456     -9.68666E-04     4463     4.16796E-04
 INTERLAMINAR STRAIN   (SHEAR-23)    4456     -6.86923E-05     4637     2.29332E-05
 INTERLAMINAR STRAIN   (SHEAR-31)    4456     -9.77718E-06     4629     1.36928E-05
 PRINCIPAL STRAIN - MAJOR            4632     -1.53013E-04     4457     1.07802E-03
 PRINCIPAL STRAIN - MINOR            4434     -9.37066E-04     4643     1.19445E-04
 MAXIMUM SHEAR STRAIN                4651      2.06441E-05     4456     6.64351E-04
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BENCHMARK

A static test was performed on a tailboom. The test article was subjected to a critical limit load condition. Strain gages were located at areas of interest. The results of the static test were correlated with results predicted by the MSC/NASTRAN model of the structure. Figure 8 illustrates the close correlation between test and analysis.

A stability analysis was performed on the composite tailboom MSC/NASTRAN model to determine the buckling failure mode. The first mode determined by MSC/NASTRAN model was considerably less than the test results. Employing the postprocessor to graphically display this mode shape showed this buckling mode to be extremely local. Further evaluation of this results substantiated this mode as non critical. Ultimately the buckling failure mode predicted by the MSC/NASTRAN model was within 6% of the actual test values.

The postprocessed buckled mode shape of the MSC/NASTRAN model very closely characterized the failure mode of the test article. Figure 7 illustrates this failure mode, as compared with the undeformed shape of Figure 6. A portion of the model has been removed for visual clarity.

SUMMARY

The pre and post processor makes viable the representation and evaluation of large complex composite structures in considerable detail. MSC/NASTRAN's PCOMP and MAT8 representation of composite structures provide additional information and accuracy to an analysis. The large quantity of output generally associated with PCOMP ply definitions is easily managed through PATRAN's P/LAM postprocessing routine.

Figure 6

Undeformed Shape of Tailboom

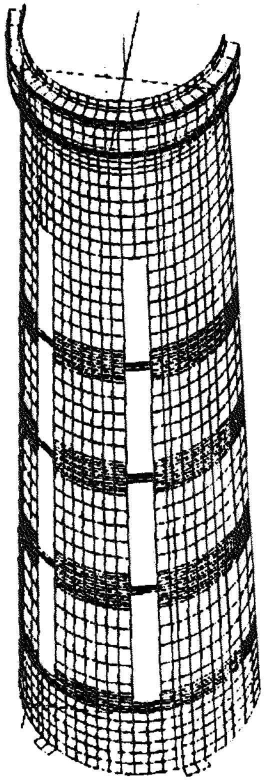


Figure 7

Buckling Failure Mode of Tailboom

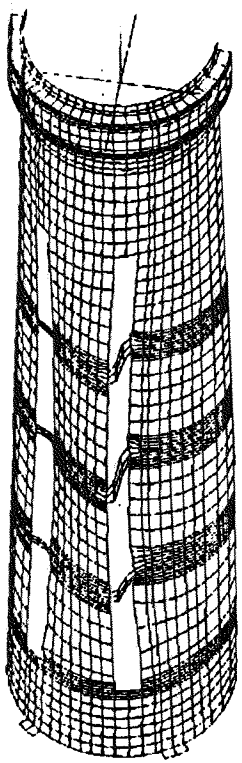
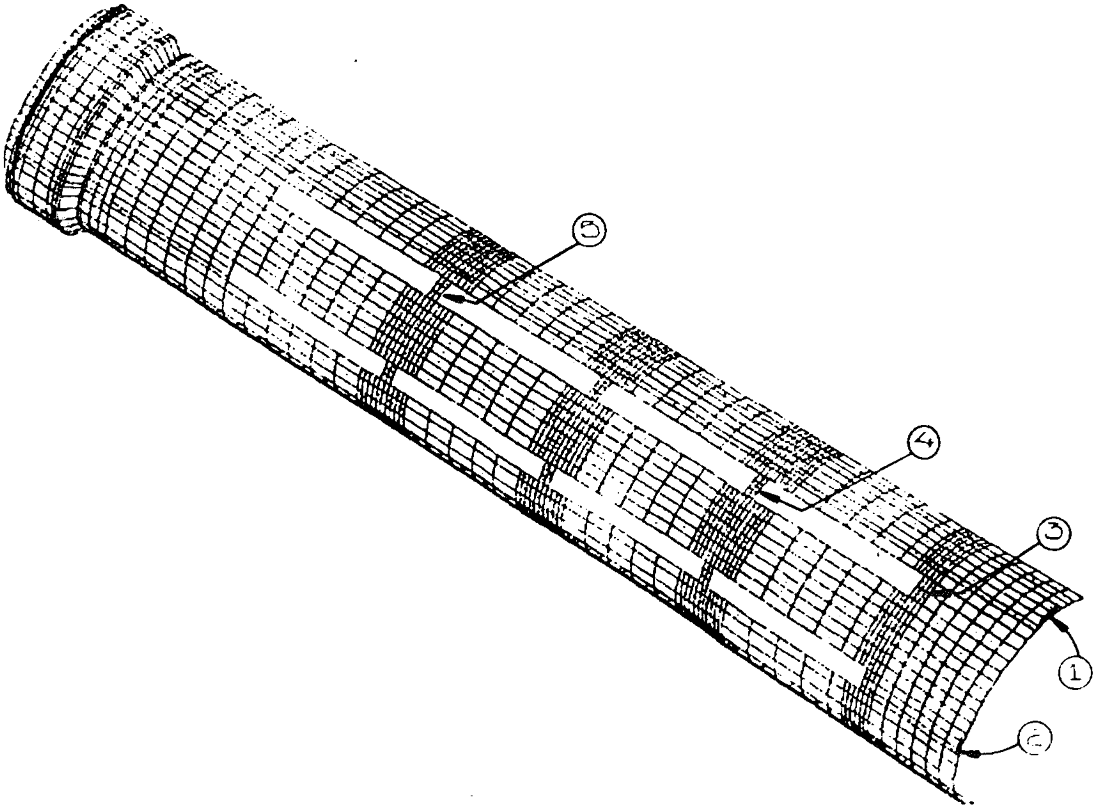


FIGURE 8
TAILBOOM RESULTS

	Location	Static Test	MCS/NASTRAN Model
1.	Upper right lug	-3932	-3772
2.	Lower right lug	-4104	-4231
3.	Fwd upper slot	2788	2624
4.	Outside fwd bridge	3772	3739
	Inside fwd bridge	-3928	-3968
5.	Outside aft bridge	-621	-984
	Inside aft bridge	616	615



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