COMPOSITE BLADE DESIGN FOR BIRDSTRIKES USING MSC/DYTRAN

AN AUTOMATED APPROACH TO ENABLE RAPID SCREENING OF COMPOSITE LAY-UPS

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Abstract

As the aerospace industry continues to strive for lighter weight, more cost effective solutions, the emphasis on composite fan blades has become intense. Composite blades must be designed to meet tough, FAA, foreign object damage requirements. In order to meet these goals, the design engineer must intelligently manage the variation of large numbers of lay-up parameters. This requires an analysis system that couples the Aerodynamic, Design and Structural disciplines and proves rapid evaluation of composite lay-up changes. Hamilton Standard and the MacNeal-Scwendler Corp. have developed a shell element based, composite blade analysis system, to evaluate composite blade bird strikes. Using this rule based, MSC/DYTRAN analysis system, Hamilton Standard can provide same day, blade impact screening, starting from an aerodynamic blade definition and ending with stresses & strains for a fully prestressed plate model.

INTRODUCTION

As part of a continuous effort to reduce in-flight operating costs, gas turbine engine manufacturers are always looking for ways to decrease engine weight. In recent years, composite fan blades have received a great deal of attention. Their low weight coupled with great flexibility in terms of adhering to optimized aerodynamic airfoil shapes makes their use attractive. To take advantage of these potential advantages, certain complex design issues must be addressed.

Bird strike impacts are among the most challenging loads composite blades must accommodate. In order to effectively manipulate the numerous design variables associated with composite blades and maintain reasonable cycle times, Hamilton Standard needed to develop an analysis system by which bird strikes can be rapidly simulated. The thrust of this system would be rapid blade screening for the purposes of guiding the design direction.

Hamilton Standard has, in conjunction with MSC, developed a coupled rule based/DYTRAN system that allows rapid screening of birdstrike events. Analysis turnaround time, starting from aerodynamic airfoil definition to post-processed fully prestressed birdstrike strains, can be less than eight hours.

PROBLEM DEFINITION

During the design of composite fan blades it is important to maintain, as closely as possible, the blade shape as specified by the aerodynamics people. This shape must be maintained while designing the blade to withstand steady, vibratory and impact loads caused by birdstrike and other foreign objects that might strike the blade. While fashioning the internal structure of the blade, the design engineer has many variables to adjust. He may vary the laminate stacking order, individual layer orientations, individual layer materials, layer thickness' as well as the laminate thickness when absolutely necessary. With such a great number of design variables on the table, one must establish a means by which variations in laminate definition can be quickly evaluated. Such a tool must accurately simulate both the steady and transient loads imparted during an foreign object damage (FOD) event while providing strain information throughout the composite structure.

ANALYSIS

MSC/DYTRAN was chosen as the tool of choice to analytically simulate this event. In order to establish a system that would allow rapid analysis turnaround time, one day or less per iteration, a plate model formulation was chosen. Figure 1 shows an example of a blade plate model with a bird. This model is surrounded by an eulerian mesh through which the fluid bird model could travel. Once the model was created, the birdstrike analysis can be run.

The full bird strike analysis was conducted in two steps. The first step was prestressing the blade. The second step being a restart in which the bird impact was modeled. For this step, an ICAD based blade/eulerian mesh generator was written; see Figures 2 through 4. This pre-processor interfaces with Hamilton Standard's rule based blade design system and automatically submits the necessary MSC/DYTRAN runs. The results from the bird strike run were evaluated using both fringe plots of surface strains and special FORTRAN based post processors; see Figure 5. The results from these analyses were evaluated to establish trends for the laminate design. The turnaround time, starting from an aerodynamic blade definition and ending in birdhit strains can be within eight hours. When a final blade configuration has been arrived at the next phase of the analysis can be conducted.

The final phase of this analytical scheme is to conduct a full 3D solid brick analysis of the final blade. This method will account for non-linearities that might occur in thick portions of the laminate. These through the thickness strain variations are importunate as they may result in surface strains lower than those obtained by the plate model.

DISCUSSION

During development of the composite laminate shell methodology the MSC/DYTRAN development team added significant capability to DYTRAN in order to support our analytical direction. The support was both timely and accurate. This effort was key to the success of this project.

The project began with the development of a thin shell, PCOMP model that use the Belytschko-Tsay formulation. Each element has its own PCOMP card that defined the lay-up over that particular part of the blade. After removal of limits on the number of PCOMP cards, it was found that these elements exhibited a zero-stiffness "hourglass" mode for bending under the birdstrike loads. As a result, MSC enabled the Key-Hoff element to handle PCOMP cards. With the use of this element, the zero stiffness bending behavior exhibited by the Belytschko-Tsay element was corrected. Until recently, due to the inability of DYTRAN to use a spring mounted root for a pre-stress run, the base of this blade was held rigidly. The base was then rotated at the appropriate blade rotational velocity. Next, an eulerian mesh was created around the top 40% of the blade; see Figures 2 through 4. Arbitrary Lagrangian/Eulerian (ALE) coupling was used to model the interaction between the fluid bird and the blade. This represents the basic model. Next the analysis was conducted.

The analysis was conducted in two parts. Part one consisted of prestressing the bird directly in MSC/DYTRAN. This capability was also added to support our analytical effort. Blade loading was achieved using an RFORCE card. During the prestress run, a Lagrangian restart deck is written at a specified time and the deformed eulerian mesh is output to a separate files. The eulerian mesh must be read into a postprocessor and the deformed grids written out and hand merged into the birdstrike deck. The Lagrangian part of the solution is read directly into the restarted bird strike deck. The bird is initialized in the prestress run but not given any initial velocity.

Part two of the analysis consists of restarting the prestress run and actually conducting the bird hit. In this run, the bird is assigned physical properties and given an initial size, orientation and velocity. The blade is physically rotated in this run and the birdstrike takes place. The analysis is run for one complete revolution and strains are recovered. Post processing is conducted in I-DEAS and also by some in-house FORTRAN codes. Surface strains are evaluated and modifications are made to the laminate. At this point a new set of runs are made.

Once the analytical procedure was established the long pole because preparation of the models. A rule based system was created that automatically prepared the blade lay-up directly from the aerodynamic input file. At this point the complete blade mesh and Euler mesh were created. The prestress deck was then automatically prepared and submitted. The birdhit deck is also partially prepared and made ready once the prestress run is complete. Turnaround time using this system can be within eight hours.

CONCLUSION

The use of MSC/DYTRAN has proved to be an effective tool to screen composite blades for correct design trends and preliminary strain screening. The tool, combined with MSC's support and Hamilton Standard's rule based system, provides a fast turnaround design tool for composite design under bird strike loading. This tool is currently being expanded for the automation of blade FOD analysis using solid brick elements. This new method will provide a means by which more accurate strain predictions can be made. In addition, follow-on development needs to be made in the area of post-processing and interpretation of the analytical results.

FIGURE 1: MSC/DYTRAN FAN BLADE PLATE MODEL

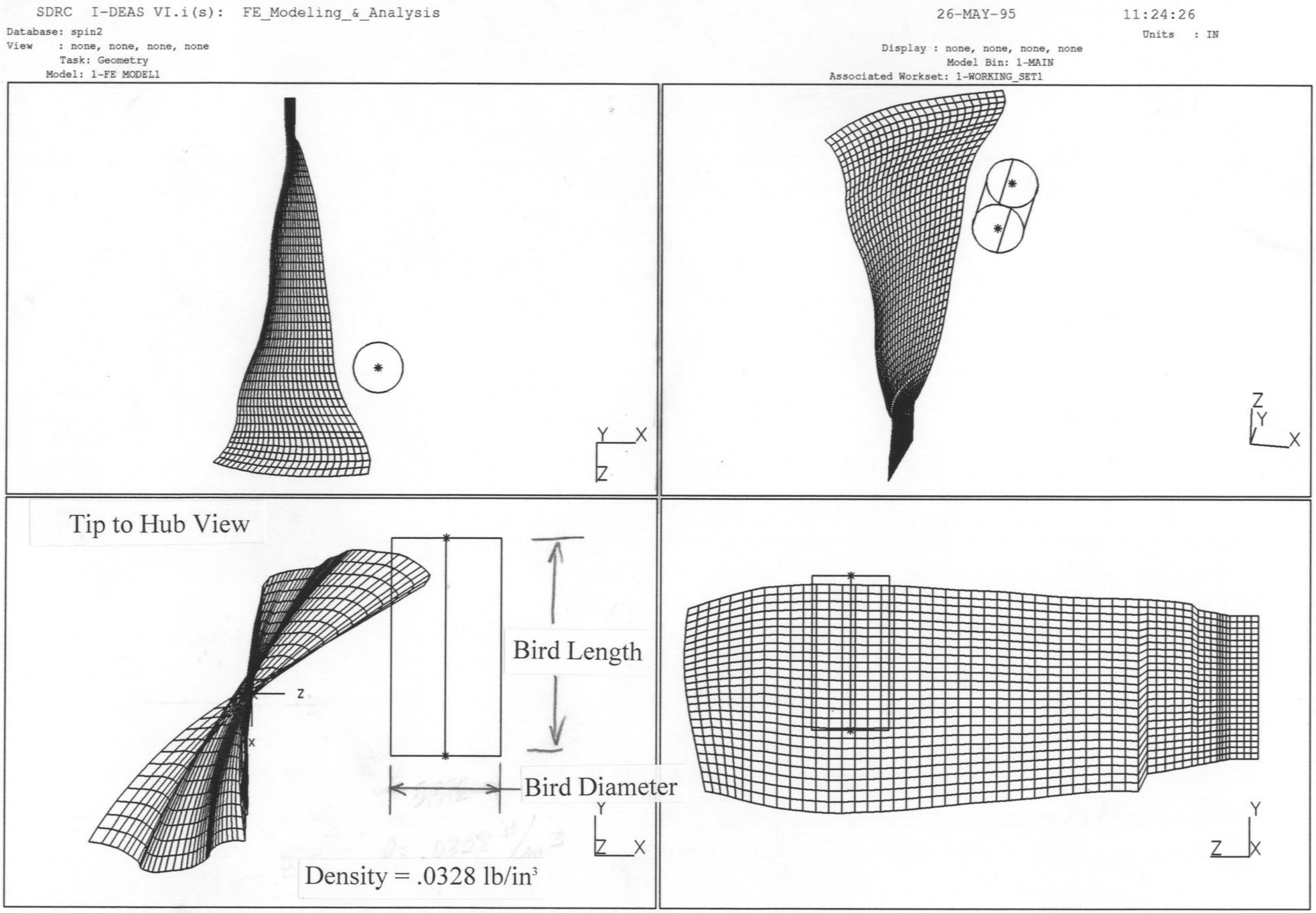


FIGURE 2: BLADE RULE BASED SYSTEM

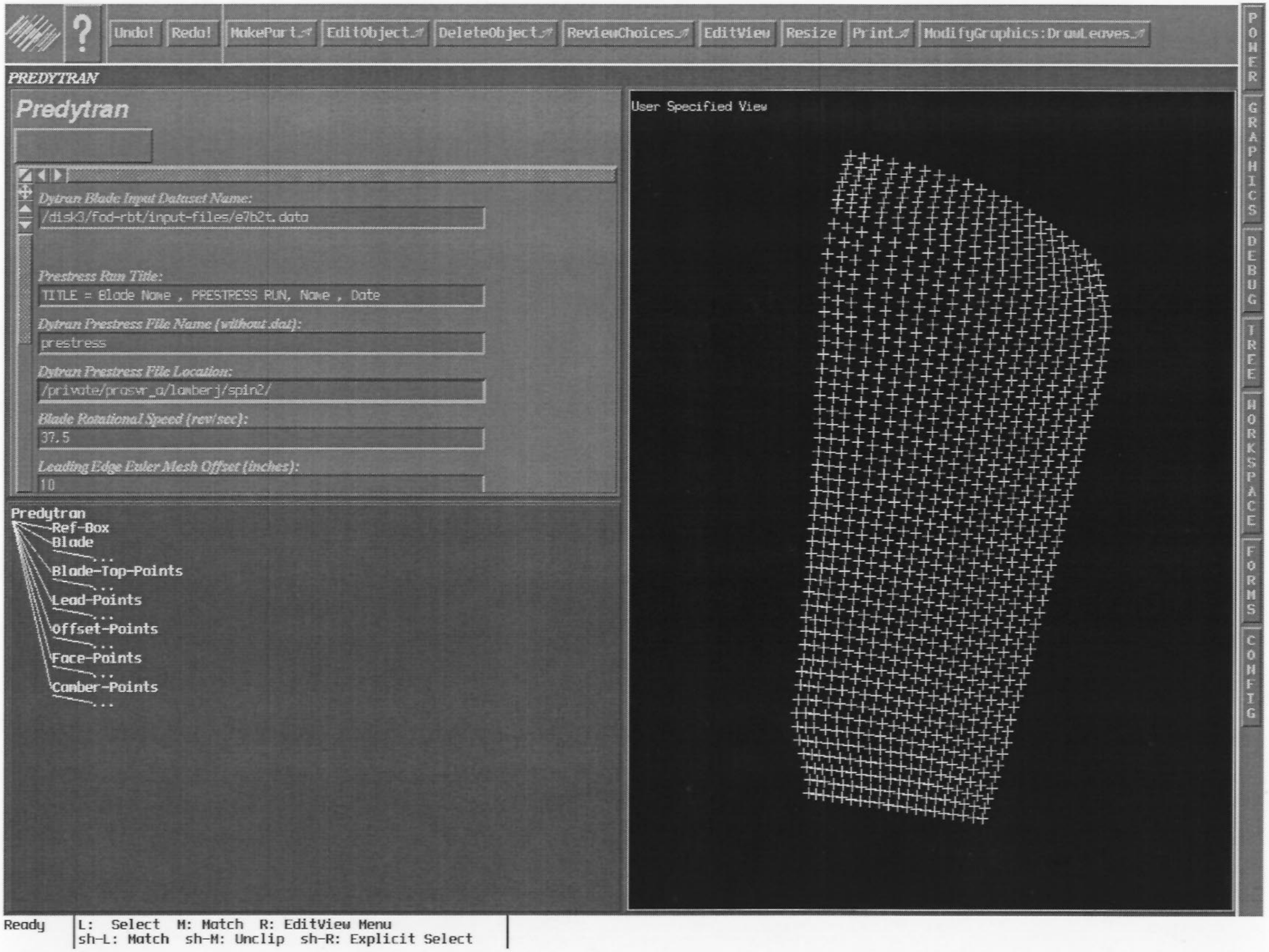


FIGURE 3: BLADE RULE BASED SYSTEM

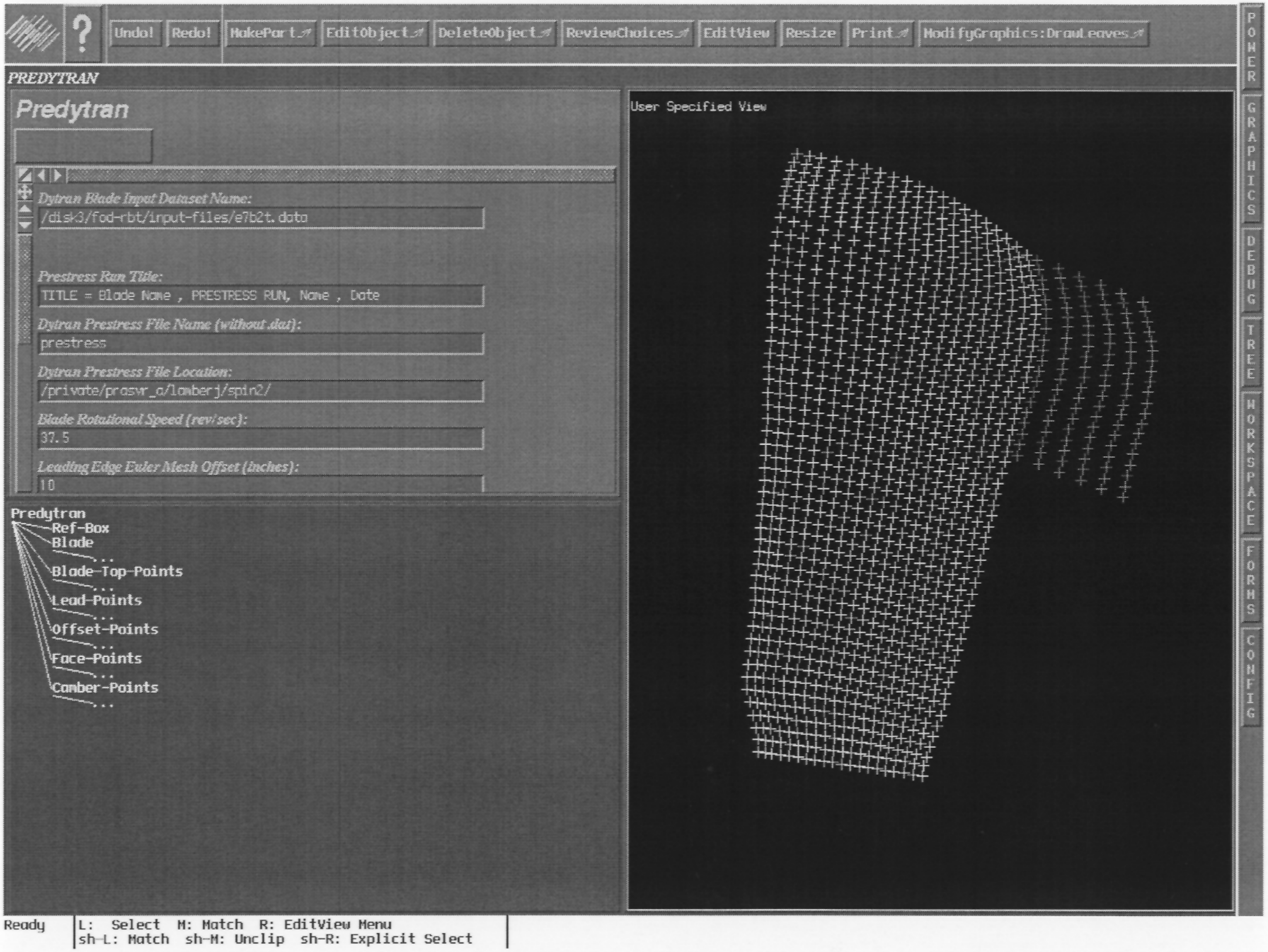
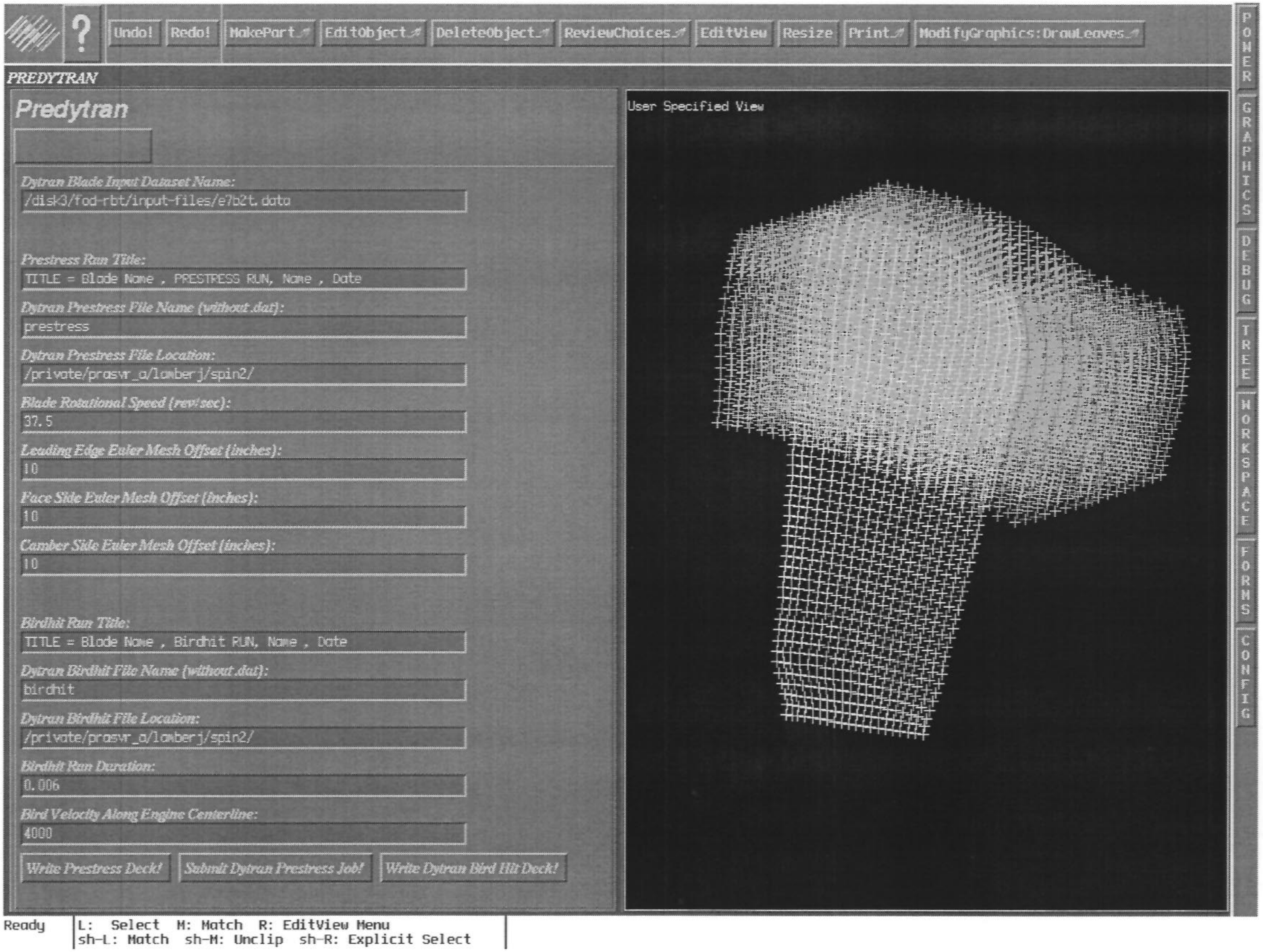


FIGURE 4: BLADE RULE BASED SYSTEM



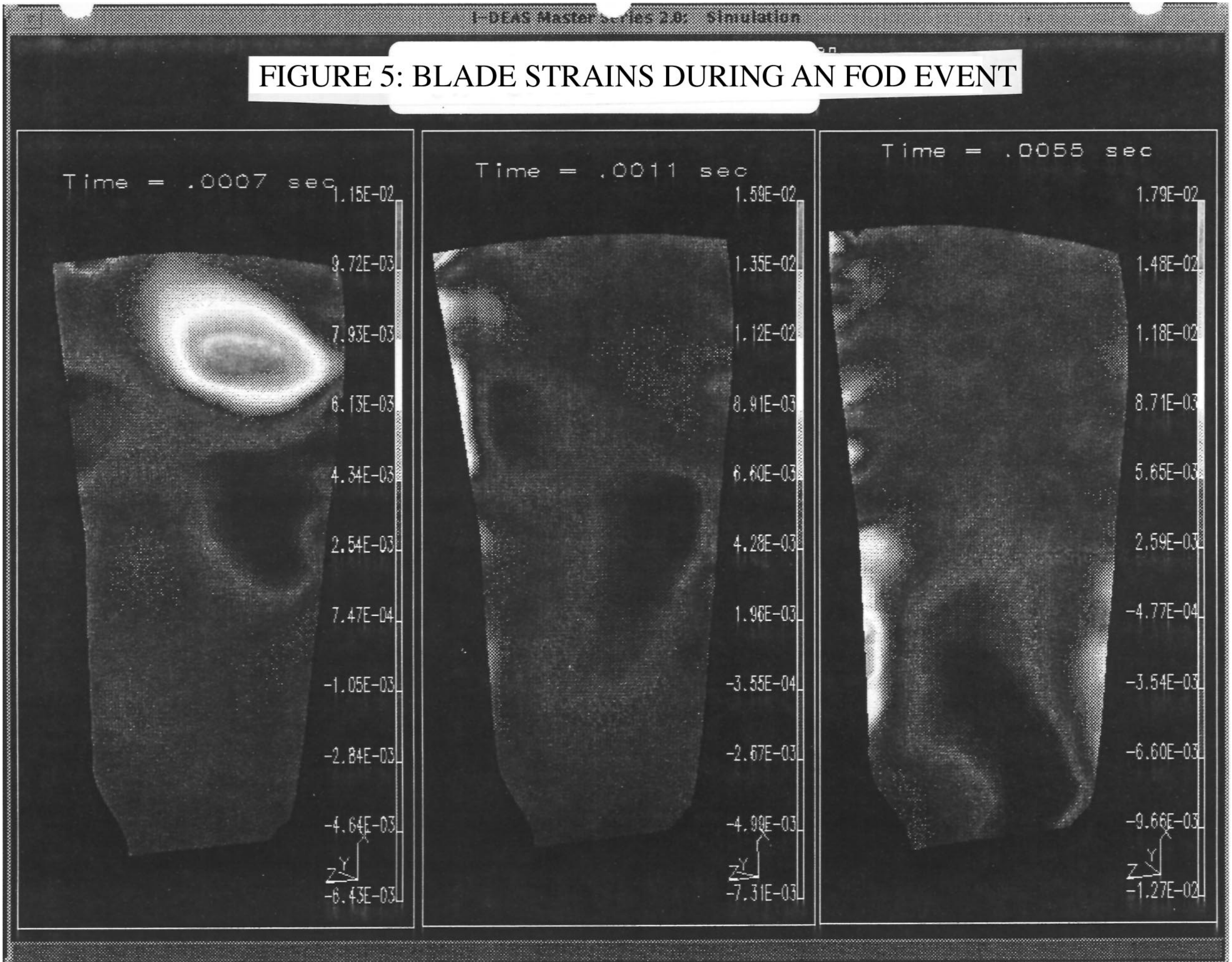


FIGURE 5: BLADE STRAINS DURING AN FOD EVENT