

Topology Based Analysis Modeling and Parameter Driven Analysis Models in FEGS FAM 3.0

Joseph L.Walsh

**FEGS, Incorporated
P.O. Box 838
Duluth, GA 30136**

Abstract

Finite element analysis is being used more and more today to evaluate design alternatives and drive design decisions. The ability to quickly modify an Analysis Model based on design geometry parameters requires a Topology Based Analysis Model and may also require Parameter Driven Analysis Models. This paper will discuss the implementation of Topology Based Analysis Modeling in FEGS FAM3.0 Modeling System allowing for multiple geometric representations and assignment of analysis attributes to the topological entities. This paper will also discuss the application of parameter symbols and macros in FAM3.0 to achieve Parameter Driven Analysis Models along with user definable extensions to FAM3.0.

Introduction

The role of finite element analysis is rapidly changing from that of design verification to a role of driving decisions. This introduces a need in the Analysis Modeling environment to allow the analyst to quickly modify Analysis Models based on design parameters. This need is further exemplified by the growing interest in parameter based geometric shape optimization. Both of these applications require an Analysis Modeling environment which is topology based and provides programmability with support for parameters and extensibility. This paper will discuss the capabilities of FAM3.0 from FEGS related to these requirements.

Topology Based Data Structure

Central to the ability to modify an Analysis Model based on design parameters is a topology based data structure. FAM provides a topology based data structure. A topological entity is defined by its connectivity rather than its location in space. Five (5) topological entity types are supported by FAM3.0 as follows: point, line (covers all curves), side (a collection of lines to form a surface side), surface, and body. Each higher level entity is fully defined in its data structure by its connectivity to lower level entities. This data hierarchy is maintained in the data structure and may be queried in either direction. Figure 1 illustrates the underlying FAM3.0 data structure.

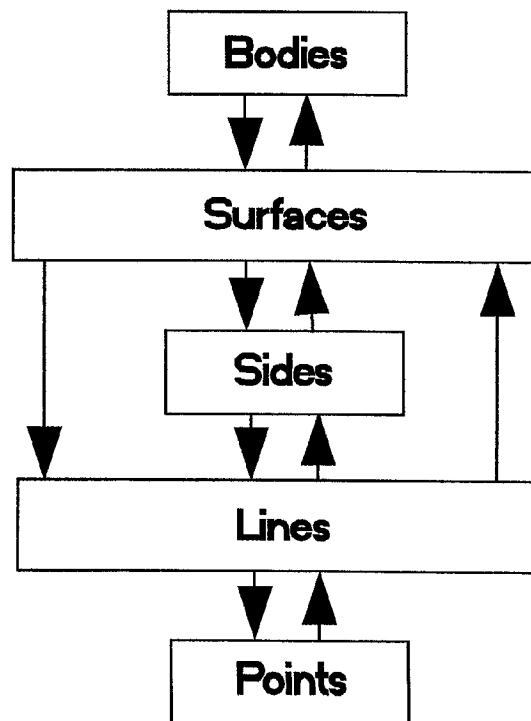


Figure 1: Topological Entities

It is important to note that in a topology based structure the topological entities do not have their own mathematics. This allows for flexibility of geometry representation and efficient data storage. Figure 2 illustrates this clearly.

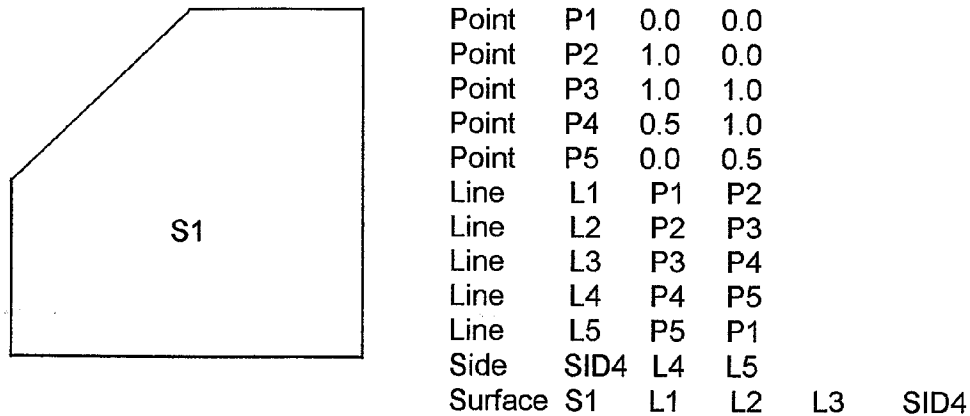
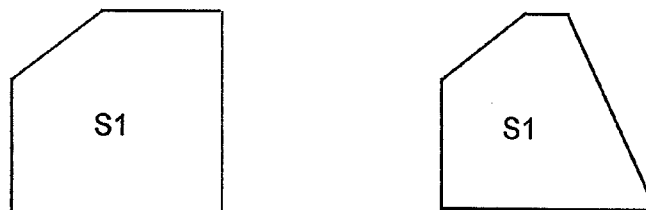


Figure 2: Topology Based Data Structure

This data structure retains connectivity and continuity of the model. Moving any entity retains the definition of all associate entities without redefinition. This is illustrated in Figure 3.



Move Point P3 Left

Figure 3: Moving an Entity

Geometric Attributes

FAM3.0 uses an object-oriented philosophy of entities and attributes. Geometric entities are created to define mathematics. These geometric entities include: straight lines, circular arcs, spiral arcs, cubic splines, NURBS curves, intersection curves, planes, cylinders, cones, spheres, ellipsoids, coons surface, and NURBS surfaces. These geometric entities are assigned to the line and surface topological

entities to define the mathematics within the topological entity. The geometric entities are then assigned as attributes to the topological entities. This is shown in Figure 4.

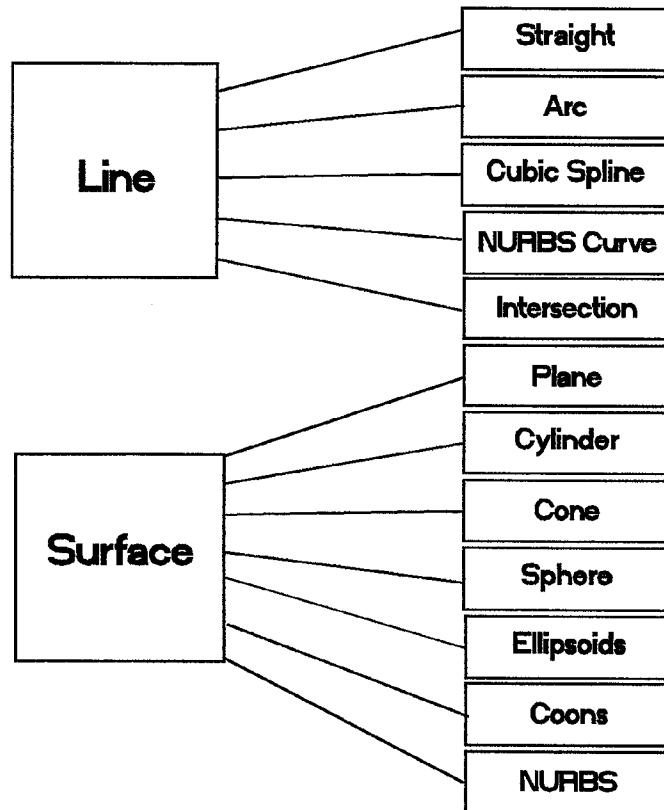


Figure 4: Geometric Entities as Attributes

This attribute assignment allows for multiple geometric representations within one model and provides for easy revision of geometry. Modifying the geometric entity automatically updates the topological entity referencing that piece of geometry. The internal geometry related to a topological entity can be easily modified by assigning a different geometric entity to control mathematics. This facilitates geometric modifications while retaining topological definitions.

Analysis Attributes

Additional attributes are required on the topological entities to generate all of the data required for a finite element analysis. These attributes are referred to as analysis attributes. The method of entity creation and assignment is used. These

analysis attributes are assigned to the topological entities and do not require a mesh to exist. Figure 5 illustrates the analysis attribute entity types available and their assignment to topological entities.

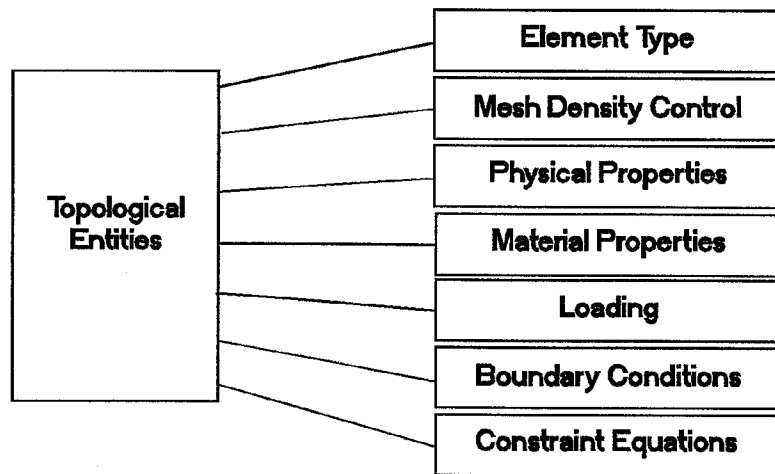


Figure 5: Analysis Attributes

Any change to one of these analysis attribute entities is automatically accounted for in all topological entities which have been assigned this analysis attribute.

Attribute Inheritance

Mesh entities are generated by the mesh operation and are considered as children of topological entities. Each mesh entity may have one or more parent topological entities. Typically mesh entities have single parents. Appropriate analysis attributes are automatically inherited by the mesh entities from its parents.

This mechanism of topology based data structure, geometric attributes, analysis attributes, and attribute inheritance allows the user to modify geometry, properties, loading, mesh flow, etc. and have FAM3.0 automatically create the new complete Analysis Model based on these revisions. This mechanism is referred to as Geometric Associativity. All assigned attributes are retained during revisions to any entities. This provides a facility to incorporate geometric design changes rapidly to create a new model.

Macro Capabilities

Creation of complex topological models and attribute assignments can be a cumbersome time consuming task. FAM3.0 provides an easy to use macro capability to contain repetitive commands or a complete process to create a model based on input values. Macros can be nested with macros calling other macros.

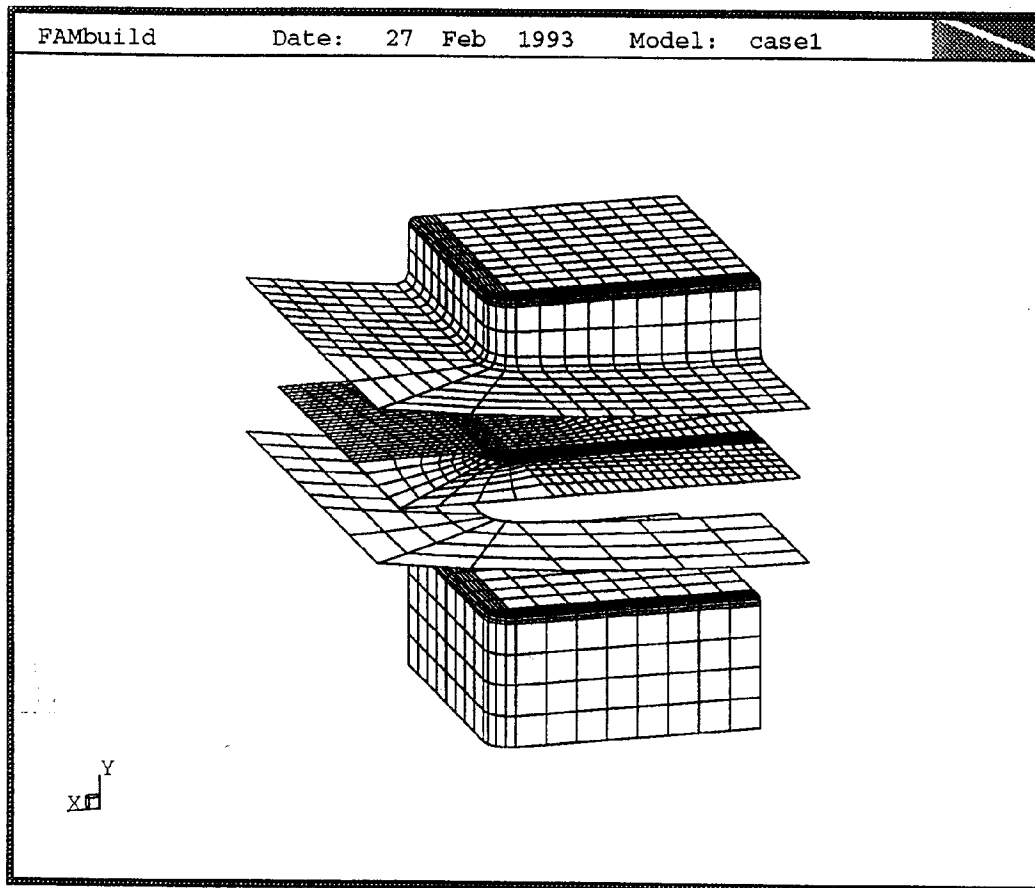


Figure 6: Macro Capabilities

Figure 6 illustrates the finite element mesh created by a macro for modeling metal forming of a sheet metal pan. The input to the macro was a series of key dimensions for the part. All topological, geometric, and analysis attribute entities were created by the macro with all appropriate assignments. This particular macro also created the required finite element mesh density control and mesh. Creation of a new model with different dimensions only requires the user to rerun the macro with new input values.

Parametric Symbols

The parametric symbol capabilities in FAM3.0 provide for definition of entities as a function of parameters and other entity definitions. Symbol creation capabilities are provided for integer values and operations, real values and operations (including distance and angles of existing points), character string values and operations, and truth values and operations. Symbols may be referenced by any entity definition or assignment merely by inputting the symbol name preceded by % in the appropriate command token. This is illustrated below.

Symbol	RAD1	10.0			
Symbol	RAD2	%RAD1	2.0	+	5.0
Point	P1	%RAD1	%RAD2		

The parametric symbols in FAM3.0 may be used in conjunction with the macro capabilities. This provides for an extremely powerful facility for defining Parameter Driven Analysis Models. When coupled with a topology based data structure and Geometric Associativity. The combination of these items provides the capability to modify Analysis Models as a function of design parameters. An example of this capability is illustrated in this section.

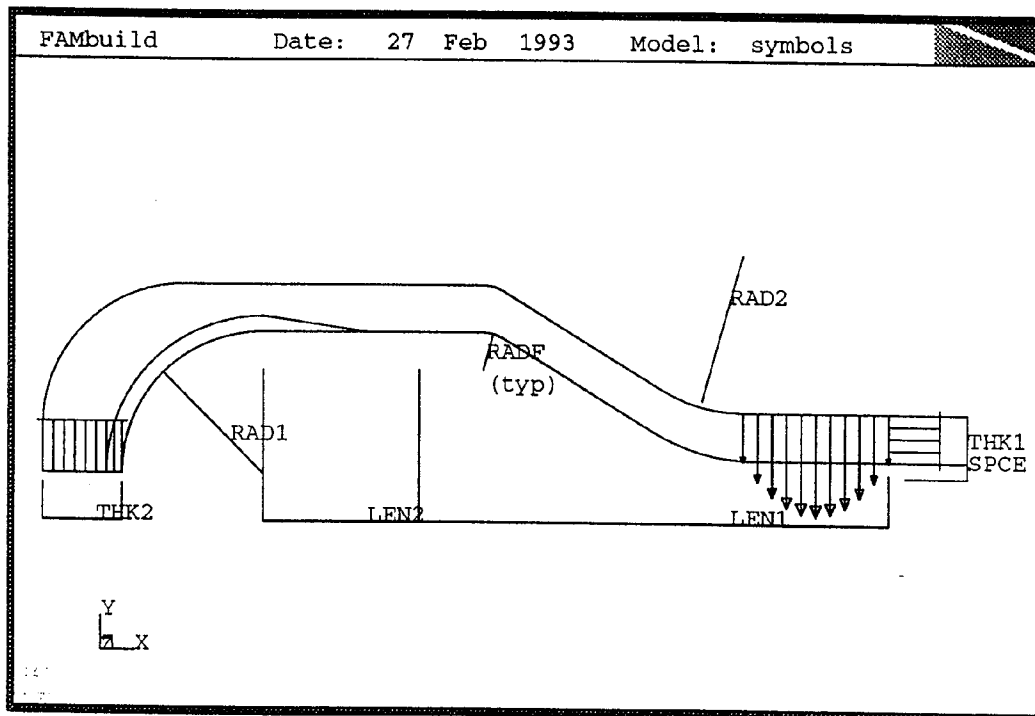


Figure 7: Topology and Attributes

Figure 7 illustrates the definition of topological entities and attributes with reference to a number of parametric symbols. These entities and their relationships to these parametric symbols are created automatically by a FAM3.0 macro. The macro defined initial symbol values and relationships as well as topological entity definitions in terms of these parametric symbols.

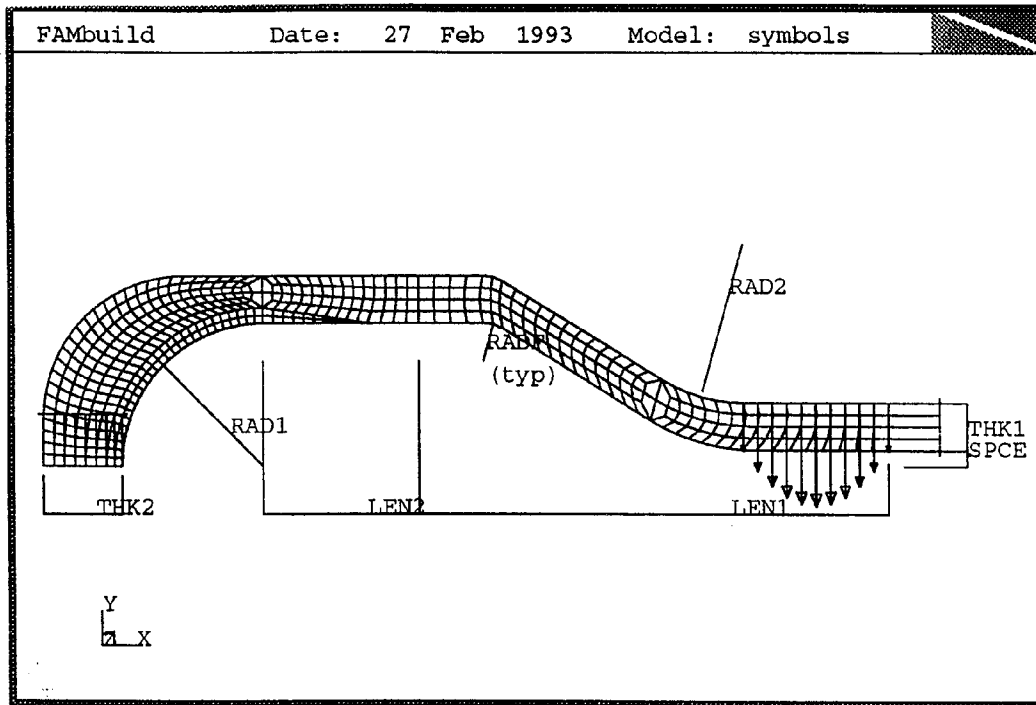


Figure 8: Mesh Entities Created

The macro used also created symbols for element sizes in various regions and assigned these symbols as mesh control attributes. The end result of running the macro was a fully meshed model, illustrated in Figure 8, ready for analysis.

Modification of some of the symbol values and update of entity definitions results in a new analysis model based on revisions to geometric parameters. The new analysis model is shown in Figure 9.

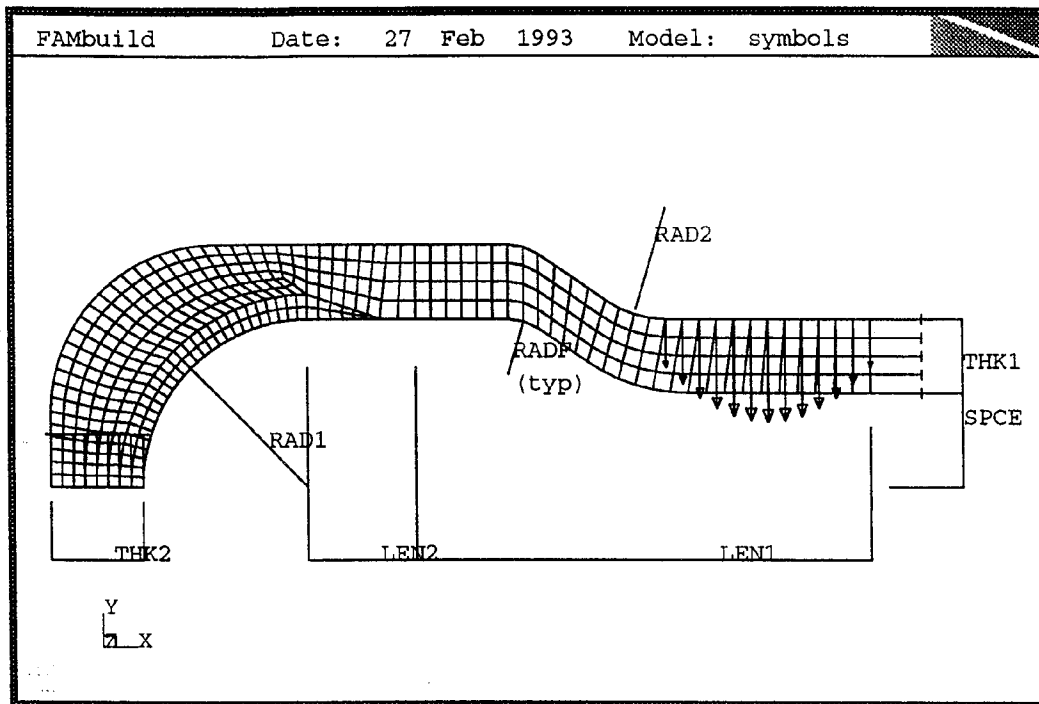


Figure 9: Parameter Driven Analysis Model

Process Executive

The parametric symbol and macro capabilities of FAM3.0 are further enhanced by the ability to access external programs, system functions, and UNIX shell scripts. The capability is provided through a facility referred to as the Process Executive. It is possible to activate external processes without leaving FAM. It is also possible for these processes to access the FAM database and to communicate with the FAM session. Macros, symbols and the Process Executive can all work in connection with each other providing an extremely flexible environment for development of parameter driven analysis models.

One example of the use of the Process Executive is shown in Figure 10 where the mesh control attributes of a simple model were adaptively modified to approach a target error. The Process Executive in this case included an external FORTRAN program, a collection of FAM macros, parametric symbols and a UNIX shell script. The entire procedure was activated by typing the name of one (1) parametric symbol while in a FAM3.0 session.

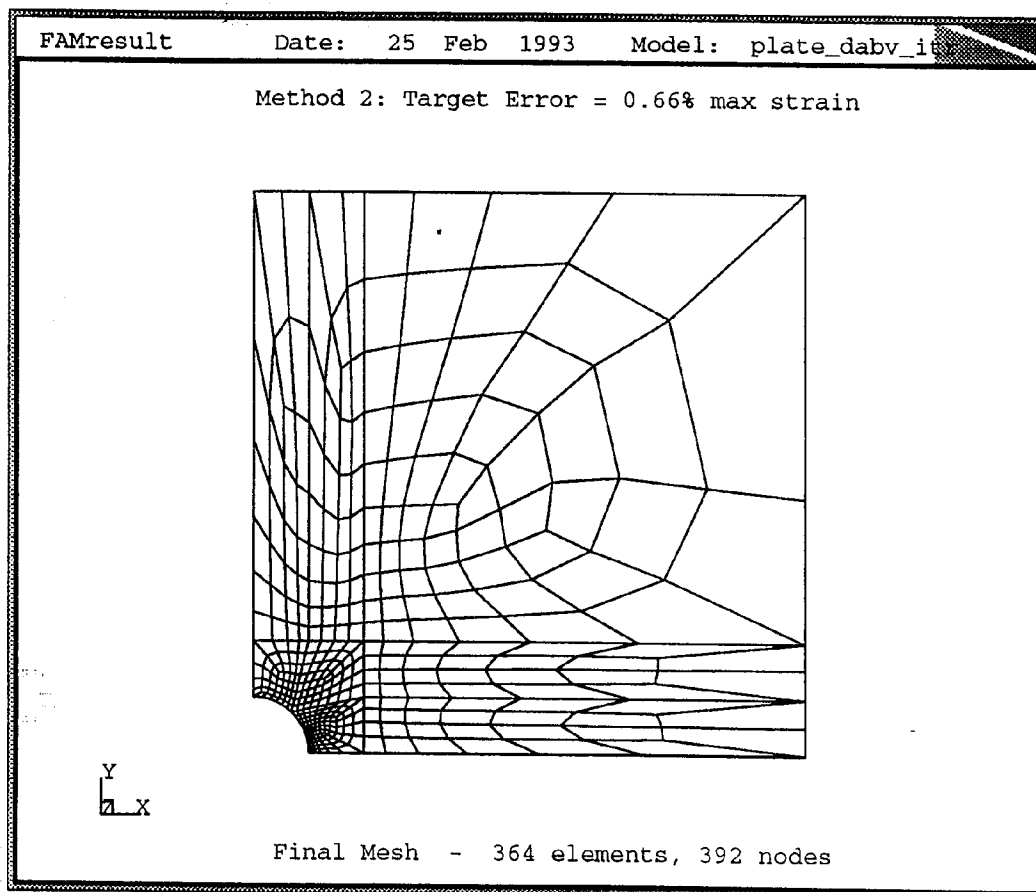
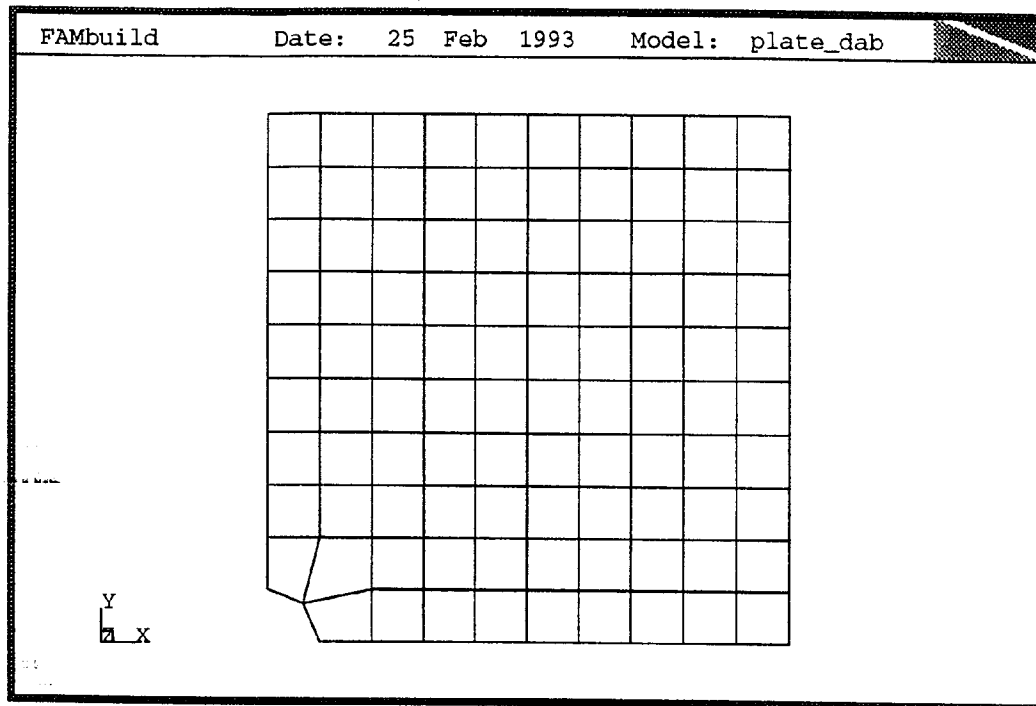


Figure 10: Adaptive Remeshing via Process Executive

Dialogue Boxes

FAM3.0 also provides for user-definable dialogue boxes, pop up and scroll menus to define symbols, activate macros, activate the Process Executive or issue any FAM command. These activities can then be accomplished by a single mouse click by the user.

Conclusions

Design being driven by analysis and geometry based shape optimization are two growing areas of interest which create requirements for geometric Parameter Driven Analysis Models.

Implementation of geometric Parameter Driven Analysis Models requires a topology based data structure, Geometric Associativity, macro functionality, and parametric definitions to be supported in the Analysis Modeler.

FAM3.0 provides a flexible environment for Parameter Driven Analysis Models based on an object-oriented philosophy using a topology based data structure, attribute assignment, macro capabilities, and parametric symbols.

FAM3.0 also provides for user extensibility through the Process Executive and user definable dialogue boxes.

References

Thompson, J. F., "The National Grid Project," *Computing Systems in Engineering*, Vol. 3, Nos 1-4, 1992, pp. 393-399.

Walsh, J. L., " Exposing the Myths of Design to Analysis Data Exchange," The MSC 1993 World Users' Conference Proceedings, May 1993.