Exposing the Myths of Design to Analysis Data Exchange

Joseph L. Walsh

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

Abstract

Design/Analysis integration is a major issue for most companies performing finite element analysis. This paper will outline some of the underlying issues and difficulties along with exposing the deficiencies of several attempts at Design/Analysis integration. This paper will also outline the approach and capabilities of data exchange based on IGES using MSC/XLfromCAD and FAM along with data exchange based on STEP.

Introduction

The concept of concurrent engineering has placed a renewed focus on efforts related to integration of Design and Analysis. This renewed interest has again raised the issue of Design to Analysis Data Exchange. Several attempts have been made related to Data Exchange from Design to Analysis with varying degrees of success and failure. Successful attempts at integration of Design/Analysis do exist for some limited cases but successful integration of Design/Analysis does not exist for the general case. This paper will attempt to outline some of the underlying issues related to Design/Analysis Data Exchange. This paper will also discuss why some of the current approaches and concepts fall short of meeting the needs for a general case and will discuss realistic capabilities available for Data Exchange from MSC and FEGS.

Geometry/Topology

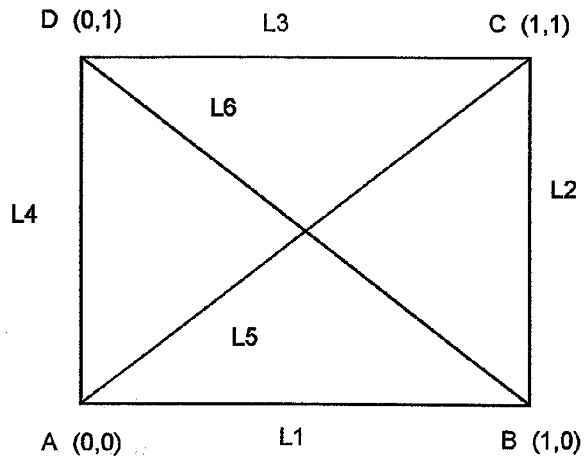
To understand some of the issues related to Design/Analysis Data Exchange it is first necessary to understand the difference between a geometry based data representation and a topology based data representation. The geometry based data representation stores geometric entities defined by entity type and location in space. The topology based data representation stores entities defined by entity type and connectivity. Topological entities usually have a geometric attribute assigned to control location in space. Figure 1 illustrates a simple example of the difference between a geometry based data representation and a topology based data representation.

Model Representations

It is also necessary to understand the different model representations used throughout the process. Aspects of the Design Model and the Analysis Model and the Idealized Model will be discussed in this section.

The Design Model is created for the purpose of enabling design decisions during the design process. This model may use a geometry based or topology based data representation. Most current CAD systems use a geometry based data representation. This model may also take a variety of forms related to dimensionality. Each form and therefore each Design Model is typically limited to a subset of dimensionality, often only one level.

The simplest form of a Design Model is a 2D CAD model. This form is almost always geometry based and typically contains only point and curve information.



Geometry Based

Point	A	0.0	0.0			
Point	B	1.0	0.0			
Point	C	1.0	1.0			
Point	D	0.0	1.0			
Line	L1	STR	0.0	0.0	1.0	0.0
Line	L2	STR	1.0	0.0	1.0	1.0
Line	L3	STR	1.0	1.0	0.0	0.0
Line	L4	STR	0.0	1.0	0.0	0.0
Line	L5	STR	0.0	0.0	1.0	1.0
Line	L6	STR	0.0	1.0	1.0	0.0

Topology Based

Point	A	0.0	0.0	
Point	B	1.0	0.0	
Point	C	1.0	1.0	
Point	D	0.0	1.0	
Line	L1	STR	A	B
Line	L2	STR	B	C
Line	L3	STR	C	D
Line	L4	STR	D	A
Line	L5	STR	A	C
Line	L6	STR	D	B

Figure 1

The next form of a Design Model is a 3D wireframe. This form contains 3D line data to describe the shape of a part. The 3D wireframe is almost always uses geometry based data representation. An example of a simple 3D wireframe is illustrated in Figure 2. The part in Figure 2 will be used throughout this paper as an example of the process of Design to Analysis Data Exchange.

The next available form of a Design Model is a 3D surface model. A 3D surface model contains information related to bounding curves and 3D surface definitions. These models typically use topology based data representations but some systems still use a geometry based data representation.

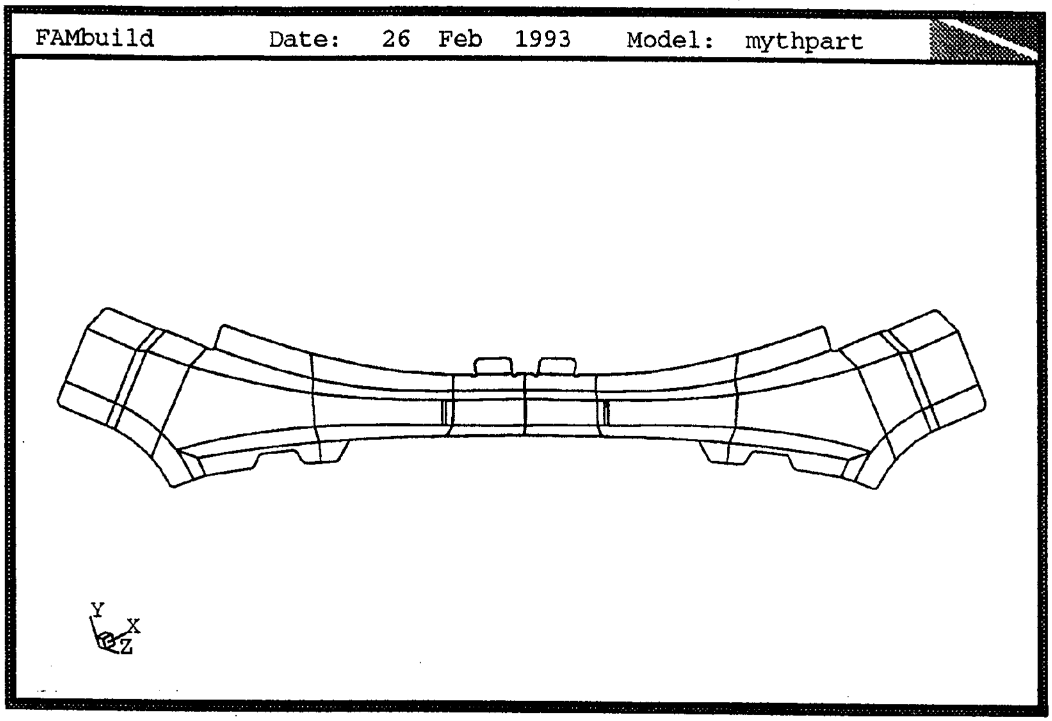


Figure 2: 3D Wireframe

The next available form of a Design Model is a solid model. Solid models contain a complete 3D representation of the part and come in two flavors; 1.) Constructive Solid Geometry (CSG), and 2.) Boundary representation (B-rep). Solid models almost always use a topology based data representation, but are usually restricted to manifold topologies. Solid models have recently begun to support non-manifold topologies.

Analysis Model

The purpose of the Analysis Model is to model the part behavior with a desired level of accuracy and efficiency. The Analysis Model consists of mesh data loading, boundary conditions, and properties. The Analysis Model uses a topological data representation. A grid defines a location in space and elements are defined by connectivity. The Analysis Model for our sample part is illustrated in Figure 3.

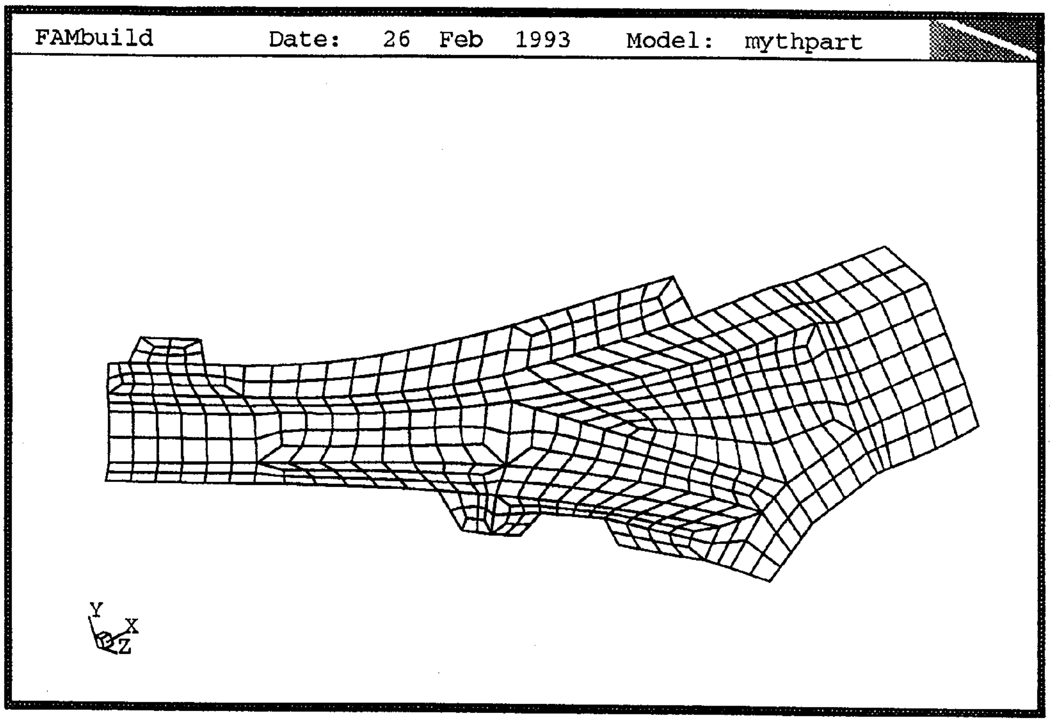


Figure 3: Sample Part Analysis Model

Idealized Model

The purpose of the Idealized Model is to create a data representation that can be used by mesh generation algorithms to generate mesh data. The Idealized Model uses a topology based model representation. Since all meshing algorithms available today require a topology based data representation, the Idealized Model also includes topology and geometry to control mesh flow. Control of mesh flow is required to control accuracy and produce results at desired locations.

The Idealized Model typically also uses several forms of non-manifold topology including multidimensionality and cellularity. Multidimensionality refers to portions of the same model may using different forms resulting in dangling faces, edges, etc.. Cellularity refers to the existence of common edges and faces between entities. Cellularity is required for multiple material models. The mapped meshing algorithms require the model to be defined in terms of meshable topologies. This imposes a requirement for cellularity to subdivide a part into meshable topologies. The definition of a meshable topology varies with every system.

Automatic or "free" meshing algorithms also typically work on a limited set of topologies. These sets are much broader than mapped meshing. One (1) common limit of these sets of topology is that of manifold topology.

The Idealized Model of our sample part is illustrated in Figure 4.

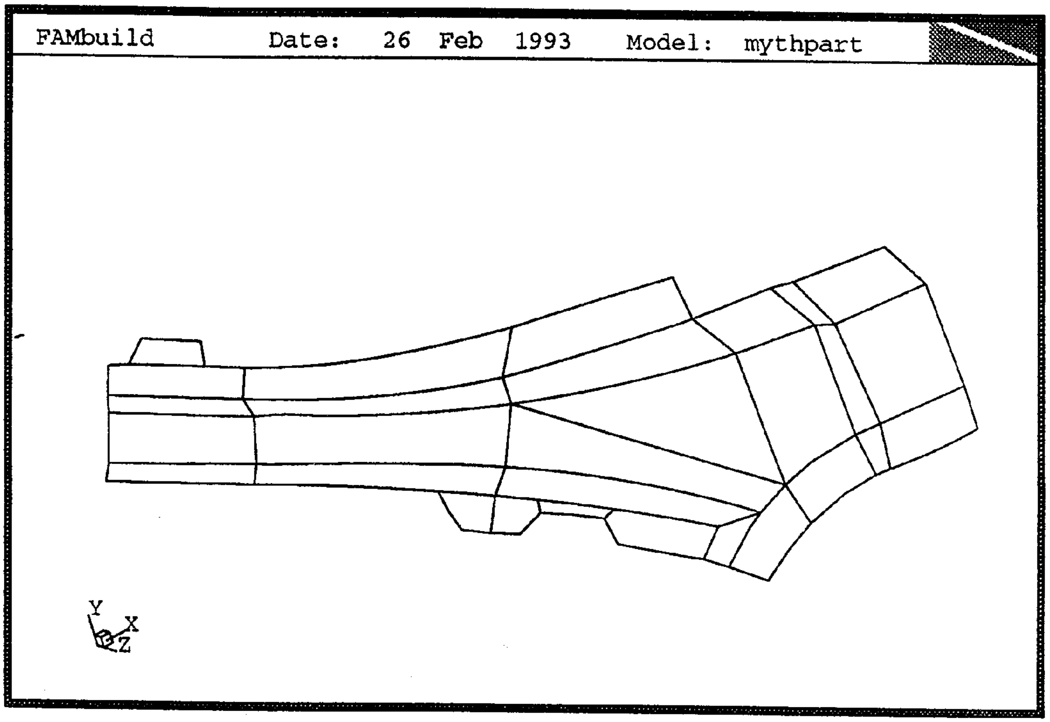


Figure 4: Sample Part Idealized Model

Data Exchange Process

The process of Data Exchange involves three(3) components of activity. The first component is Data Transfer. The second component is Model Abstraction. The third component is topology cleanup and building. These three (3) components may occur in any order. Figure 5 illustrates the typical data and activity flow for Design to Analysis Data Exchange.

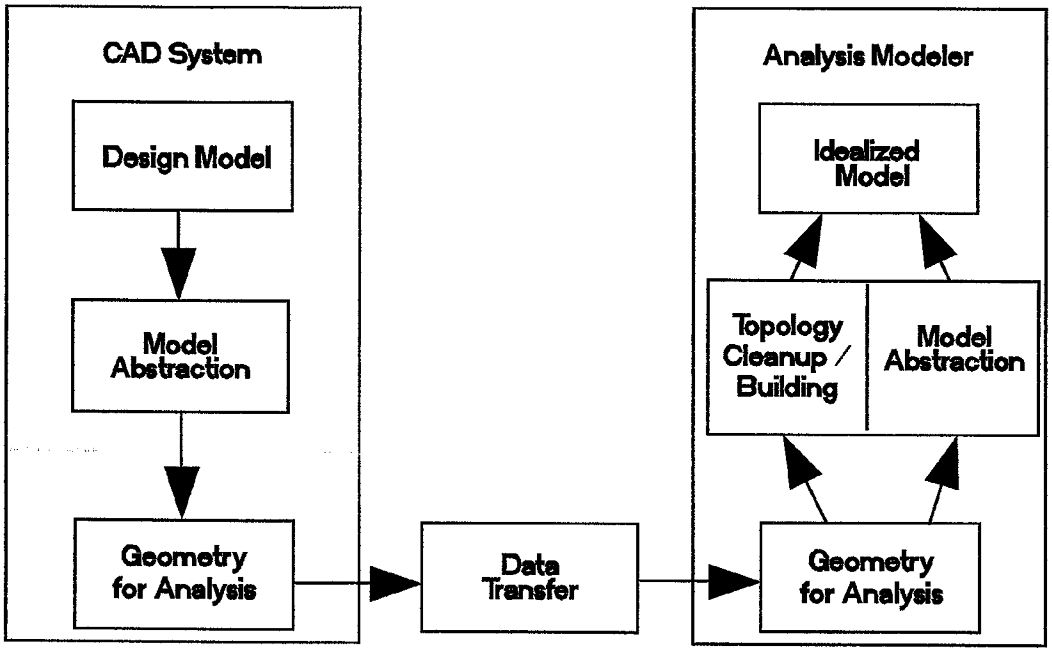


Figure 5: Data Exchange Process

Data Transfer

Data Transfer involves the actual movement of data from one system to another. Several methods are available for Data Transfer. Direct translators may be available between the CAD system and the Analysis Modeler or Data Transfer may be accomplished via standards or deFacto standards such as IGES, STEP, and ACIS .sat files.

The Iges file format supports 2D data, 3D wireframe, 3D surface models and solid models. Solid models were added to the IGES format in revision 5.0 while 3D surface models were added in revision 4.0. Most commercial CAD systems do not yet support IGES 4.0 or higher. The majority of data transferred in the IGES format is 3D wireframe data.

The IGES file format for 3D wireframe uses a geometry based data representation. Data Transfer based on IGES typically requires extensive topology cleanup and topology building in the Analysis Modeler.

STEP is the emerging ISO standard for Data Exchange and supports all model forms through application protocols for each model form. The initial release of the STEP standard is expected in 1993 with application protocols for 3D wireframe, 3D surfaces, B-rep solids, and CSG solids. The initial release will not support compound B-rep solids (cellularity). STEP will provide an excellent facility for data transfer retaining topological information wherever possible.

ACIS is rapidly becoming accepted as a geometry bus deFacto standard. ACIS uses a topological data representation and does support non-manifold topologies but not cellularity. Support of cellularity for ACIS is currently under development with an initial release expected late 1993. The ACIS .sat file provides an excellent facility for Data Transfer between two(2) ACIS based systems.

Direct data translators are available between some systems with varying degrees of effectiveness and are extremely costly to develop and maintain. Direct database access to the CAD system database removes the need for data transfer. It does raise the issue, however, of storage of new entities created or modifications to existing entities. If these new or modified entities are stored in the CAD system then the Idealized Model is actually stored in the CAD system along with the Design Model. Any storage method usually results in two (2) topological descriptions of the same part as it is very rare that a single geometry or topology definition would be acceptable for both the Design Model and the Idealized Model.

Topology Cleanup and Building

The Idealized Model requires a correct topological data representation for meshing. The use of IGES for data transfer of all model forms results in a loss of connectivity information which needs to be rebuilt. This topology cleanup involves activities such as: merging duplicate points, intersecting lines, unfaceting, simplifying, etc.. This problem also occurs for any method of Data Transfer or direct database access related to CAD systems which use a geometry based data representation.

3D wireframe and 2D CAD descriptions do not offer adequate information for surface or solid topology. 3D surface descriptions do not offer adequate information for solid topology and may not include adequate surface topology information. The creation of the required topological information is done as topology building activity.

Model Abstraction

The Model Abstraction activity is the most complex and least automated aspect of Design/Analysis Data Exchange. Automation of Model Abstraction is a research activity at FEGS and other organizations. Some of the various aspects of Model Abstraction will be discussed in this section.

The first aspect of Model Abstraction is symmetry recognition. The Idealized Model can be reduced in half for each plane of symmetry. Figure 6 illustrates our sample part after symmetry recognition.

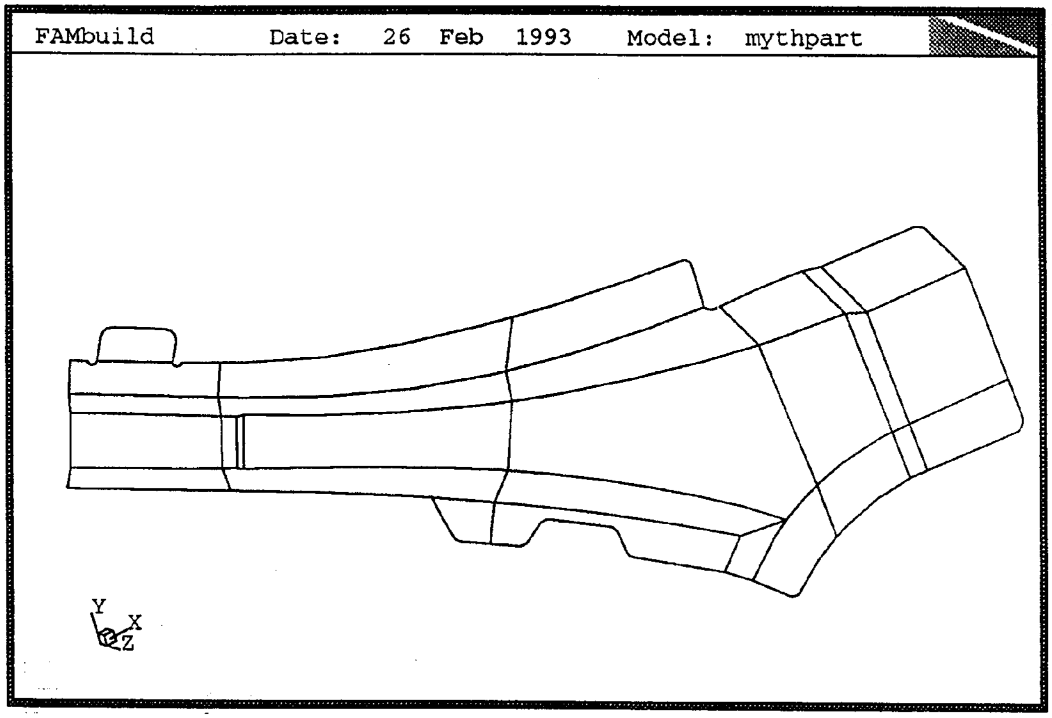


Figure 6: Sample Part Symmetry Recognition

The second aspect of Model Abstraction is that of dimensional reduction. Thin solids may be reduced to mid-plane surfaces or lines. Small surfaces and solids may be reduced to lines or points. This dimensional reduction not only allows for a minimal representation of topology for analysis but also allows for use of the best element formulations to capture the behavior. Shell elements provide a better representation of behavior than solid elements for a part which is "thin" in nature.

The third aspect of Model Abstraction is detail removal. The Design Model almost always contains a great deal more detail in geometry than is possible to create a reasonable mesh for. It is necessary to remove detail such as small holes, small fillet radii and unwanted features. Some solid model systems provide feature suppression facilities to assist in this aspect of Model Abstractions. Figure 7 depicts the sample part after detail removal.

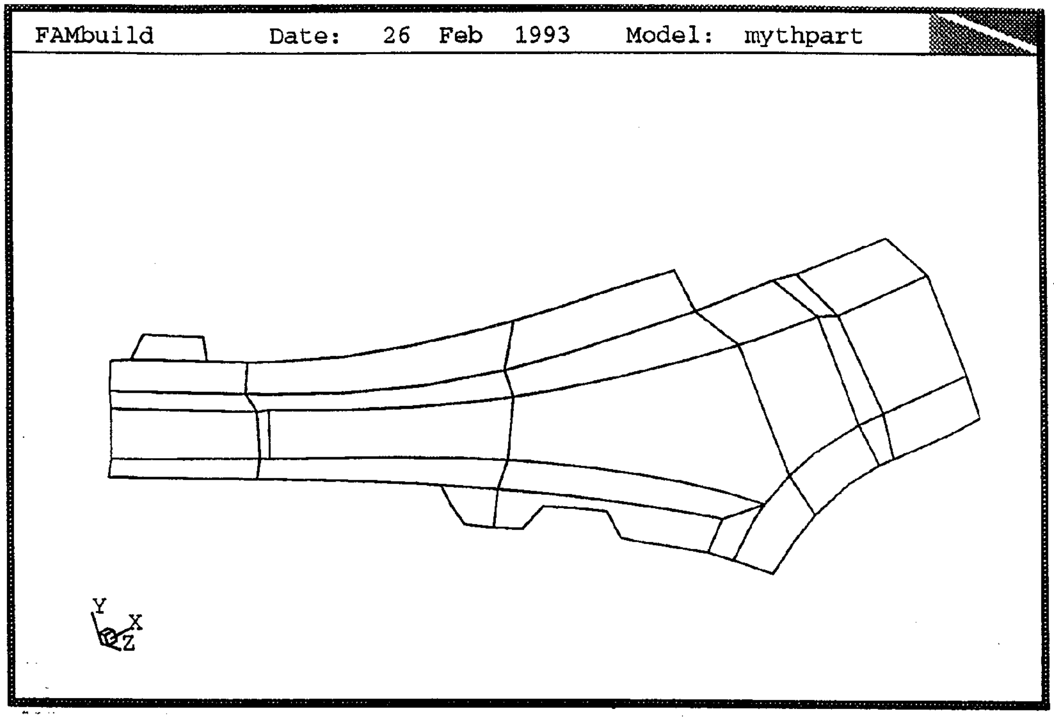


Figure 7: Sample Part Detail Removal

The fourth aspect of Model Abstraction is mesh flow control. The model must consist of regions which fit the acceptable topological complexity for the meshing algorithm to be used. This level of acceptable topological complexity is a function of the Analysis Modeler used and the meshing algorithm used. Additional entities may also be added to control mesh location and flow. The best analysis results are obtained when the mesh flow is consistent with the field behavior being analyzed. Figure 8 illustrates the sample model after mesh flow control considerations.

Current Data Exchange Myths

The background presented in the previous sections of this paper provides the information necessary to understand the fallacies of some of the common "myths" related to Data Exchange. This section will discuss six of these "myths" in more detail.

"It should be possible to mesh any data received from IGES file"

The IGES file format only provides a mechanism for Data Transfer and does not address any of the other issues related to Data Exchange. The IGES file format also

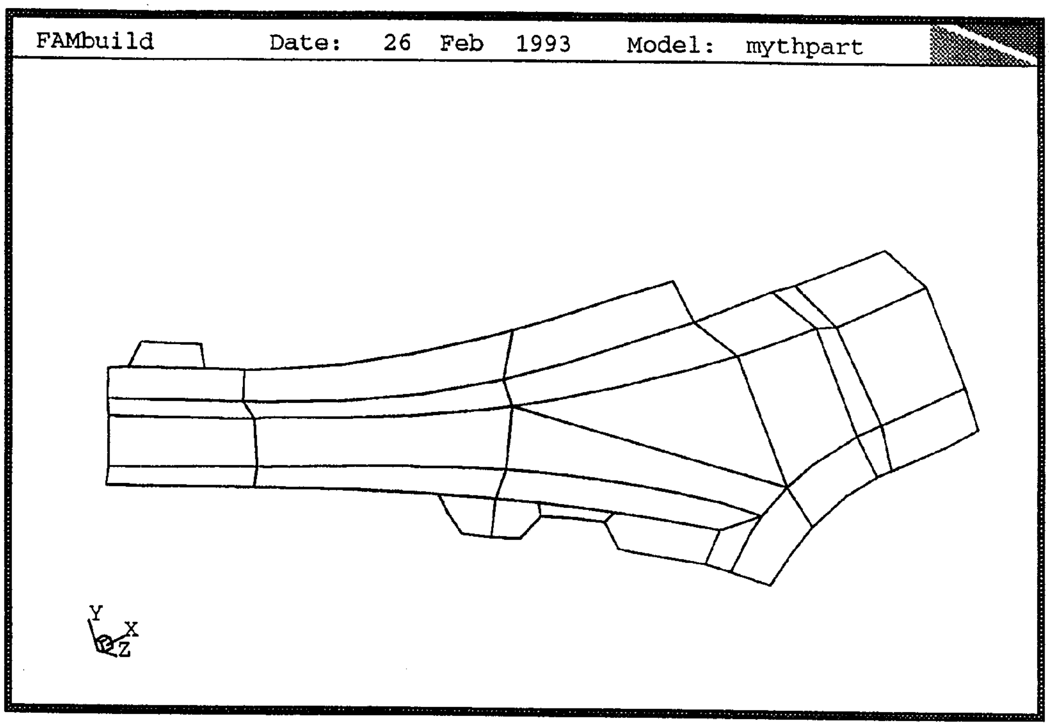


Figure 8: Mesh Flow Control

uses a geometry based data representation which needs to be converted to a topology based data representation. This conversion is a non-trivial data specific problem.

"PDES/STEP will remove all problems associated with Data Exchange"

PDES/STEP will provide for a better medium for Data Transfer retaining topological representations removing the need for the topology cleanup and building activity if the Design Model contains adequate topological definitions. PDES/STEP does not offer any utilities to assist with the Model Abstraction activity.

"Solid models with feature suppression remove the need for Model Abstraction"

Solid models with feature suppression may assist the Model Abstraction activity and for a small class of objects may provide all of the required abstraction facilities. The general case still requires Model Abstraction for symmetry recognition, dimensional reduction, and mesh flow control. The feature suppression typically only assists with detail removal.

"Automatic mesh generation removes the need for object subdivision."

Automatic mesh generation capabilities do reduce the need for object subdivision but do not remove this need. Most automatic mesh generation algorithms require a manifold topology. Subdivision may be required to achieve this if the Design Model contained non-manifold topology. Subdivision is also required for mesh flow control. Automatic mesh generation algorithms are typically limited by element type. This element type limit is often unacceptable for the analysis to be performed and results in the use of mapped meshing.

"A single geometry model may be used for analysis and design."

This is only true for the very small percentage of cases where the Design Model is the same as the Idealized Model. It is possible to remove the Data Transfer activity from the Data Exchange process through direct database access, but the topology cleanup and building and Model Abstraction activities are still required for most models. After either or both of these activities have taken place there exists two (2) topological/geometric models. The first is the Design Model and the second is the Idealized Model. These two (2) models may exist simultaneously in the same modeling system.

"Computers are fast enough today to ignore Model Abstraction."

Computers are fast today and are getting faster, however, it is not foreseeable that computer speeds would reach a level adequate to ignore Model Abstraction. The increasing computational requirements of non-linear analysis, mesh adaptivity, and geometry based design optimization would appear to exercise the increasingly available computing speed such that Model Abstraction will continue to be a requirement. It should also be remembered that dimension reduction can result in not only fewer elements but also more accurate results in many cases.

Data Exchange Capabilities

Since some of the common "myths" related to Data Exchange have been exposed the next few sections will discuss an overview of the actual capabilities and tools available for Data Transfer from MSC and FEGS.

MSC/XLfromCAD provides Data Transfer based on the IGES file format and supports 2D CAD models and 3D wireframe data. B-spline and NURBS curves are not currently supported. MSC/XLfromCAD also provides a set of facilities to assist with topology cleanup and building and Model Abstraction activities as follows:

1.) Connect duplicate points within tolerance

2.) Regenerate line data
   - delete duplicate lines
   - intersect lines
3.) Unfacet line data
4.) Build surfaces of a user specified topological complexity
5.) Build bodies of a user specified complexity.

FAMfromIGES provides Data Transfer based on the IGES file format and supports 2D CAD models, 3D wireframe data, and 3D surface models. FAMfromIGES supports NURBS curves and surfaces.

FAMsolid, which is scheduled for release in 1993, is an ACIS based modeler accepting and providing Data Transfer of solid models through ACIS .sat files.

FAMexchange, which is scheduled for release in 1993 is a STEP based system providing Data Transfer for the wireframe, surface model, B-rep solid model, and compound B-rep solid model.

FAM provides a set of utilities to assist with topology cleanup and building and Model Abstraction activities as listed below:
1.) Merge duplicate points within tolerance
2.) Simplify line definitions
3.) Merge duplicate lines
4.) Intersect lines
5.) Unfacet lines
6.) Remove free points and lines
7.) Project points and lines onto geometric entities
8.) Define lines at intersection of geometric entities
9.) Build surfaces of a user specified complexity
10.) Build bodies of a user specified complexity

Conclusions:

The following conclusions can be made based on the information provided in this paper:
1.) Additional research and development is necessary related to Design/Analysis Data Exchange.
2.) Most of the current "myths" related to Data Exchange are based on an oversimplification of the problem.
3.) PDES/STEP will provide an improved medium for Data Transfer.
4.) Model Abstraction is the most difficult aspect of Data Exchange.
5.) MSC and FEGS offer utilities to assist with the process of Design to Analysis Data Exchange.

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