Overview of CADAM-MSC Interfaces, CADAM FEM Pre-processing, and Automatic Mesh Generation

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Abstract

CADAM, INC has been a CAD/CAM leader for more than 20 years with thousands of production users around the world. In the past, the emphasis has been on manufacturing applications. With the introduction of CADAM's new CIMCORE strategy, the integration of CAE applications with traditional CAD/CAM products has assumed central importance. Current FEM capabilities as they exist within CADAM's 3D MESH product will be briefly reviewed after which there follows a discussion of automatic mesh generation using CADAM's Interactive Solid Design (ISD) solid modeller.

CADAM-MSC Interfaces

The interactive MSC/NASTRAN interface simplifies the control of post-processing data recovery. Keying in an MSC/NASTRAN "result data base" name automatically returns the solution approach: be it static, transient or frequency repsonse, modal or non-linear analysis. Results are then interactively staged for display providing deformed shapes and color shaded stress contour plots. Since the "result data base" is dynamically allocated, multiple databases can be used to compare the behavior of the structure under various conditions.

The deformed shape and associated data can be permanently filed and later manipulated, plotted and viewed as a 3D object using CADAM's overlay function to allow comparison of the original mesh input with the deformed model.

The post-processing power gained by direct access of MSC/NASTRAN results data is enhanced by the many viewing options which are available to the user. CADAM's usual rapid and easy manipulation of geometry is carried over into 3D MESH models. Hidden line representations, shaded images, contour plots, cross-sections and more can be used singly or together to provide clear and accurate understanding of analysis results.

Using the 3D MESH neutral file the user can write his own interfaces to 3D MESH geometry. MSC/NASTRAN cards are generated from CADAM data to be used for analysis. Correspondingly, MSC/NASTRAN decks can be used to input FEM data into CADAM 3D MESH for modification or visualization.

CADAM FEM Pre-processing

CADAM 3D MESH has extensive construction and editing capabilities for 2D, 3D and mesh geometry. For example, the MAPMESH capability allows arbitrary 3D surfaces to be automatically meshed according to user specified boundary parameters and the PIERCE function allows the general projection of nodes on any CADAM surface. Extensive mesh element grouping allows the user to collect data into convenient chunks. These groups may be rotated, translated, mirrored or erased together. The user may provide his own element definitions or assign attributes using major, minor and material types. Definition and displacement coordinate systems may be explicitly assigned to all 3D MESH points. POINT/ELEMENT ID display, border shrink, no-show, tabular lists, isoparametric elements, copying (singly or by group), node propagation, layering by color, editing, gridpoint constraints and much more are supported by the 3D MESH product. Pre-processing users expect and receive the same response times as those who work in production manufacturing areas - no more than .5 seconds in most multiprocessing environments and usually considerably less. CADAM's extensive range of industry standard plotter interfaces ensure the availability of mesh data hardcopy.

Automatic Mesh Generation

Historically, up to 90% of the time required for FE analysis has been tied up in the construction of the FE mesh. Many users and vendors have been working to reduce this cost with limited success. Recent advances in solid modelling technology have now made "automatic" mesh generation achievable. With the addition of Interactive Solid Design (ISD) to CADAM's CIMCORE product line, sophisticated and robust automatic meshing techniques are now being developed. ISD itself is the result of 20 years of development. It is a CSG modeller which allows a whole range of geometric primitives including extrusions, revolutions, draft angle slabs (with fillets) and general sculptures. The product has been proven in practice to be robust and extremely efficient. These two qualities allow the accurate design of large and complicated parts and assemblies with minimal expenditure of resources.

Many CAD/CAE systems in the past have used "semi-automatic" methods for mesh construction, generally requiring the user to redefine geometry or select subregions which are acceptable to the system. CADAM, INC has chosen to emphasize the automation of the mesh generation process as the means for providing the largest analysis productivity gains. With these points in mind, a brief description of the process follows.

First, the user constructs his part using ISD. A mesh density is chosen and a job is interactively submitted from the scope. A mesh is constructed and placed in the current or separate model as desired. The elements created are triangular for surface meshes and tetrahedral for solid meshes. Midside nodes are a user selectable option in both cases. In general, simple tetrahedra do not provide the same quality of results as do simple HEX elements but there is a growing realization that well proportioned midside node tetrahedral elements perform comparably well to midside node HEX meshes. One of the main advantages of tetrahedra is that they are very flexible and can be used for graded meshes and awkward geometry where element blending can be difficult for HEXes. Another advantage is that local editing of tetrahedral meshes does not propagate through the mesh in the same way that it does for HEXes. A disadvantage of tetrahedral meshes is that they are hard to visualize. However, the goal here is for automatic realization of the mesh and this increase in visual complexity is a small price to pay.
The general approach to producing this sort of mesh will now be described. The basic ideas are similar to those used by Cavendish, Field and Frey of General Motors Research Labs in their Watson/Delaunay algorithms <1>. CADAM uses a highly modified version of this approach which avoids some of the serious degeneracy problems inherent to Watson/Delaunay for regularly spaced node points.

The first step is to obtain a polygonal representation of the solid part (ISD is a precise modeller and so this polyonal representation must be generated as an approximation to the part which, however, has all vertices residing on the true part surface). Nodes are now inserted along the boundaries of the polygons in accordance with the user's density specification. Points are now generated on the interior of each polygon in accordance with the density requirements. Finally, if a solid mesh is required, points are placed on the interior of the solid and the solid mesh generated. Any tetrahedron whose centroid lies outside the solid is discarded and all surface nodes not lying on the true surface of the part are pushed to the appropriate boundary. If midside nodes are requested, these are also pushed to the boundary. The algorithm proceeds until the density requirements are fulfilled while maintaining control over the aspect ratios of the triangles/tetrahedra. The same measure is used here as are used by Field, et al, namely the normalized ratio of the inradius to circumradius.

There are two critical tasks which are required of the solid modeller during this process: (1) To determine if a given point is in or out of the solid part and (2) to push a given point to the appropriate boundary of the solid part. ISD handles these problems exceptionally well allowing for a robust implementation of the above algorithm. Future enhancements include the use of parametric BREP data to aid mesh generation and more flexible user density specification options.

REFERENCES

<1> James C. Cavendish, David A. Field and William H. Frey, An Approac to Automatic Three-Dimensional Finite Element Mesh Generation, International Journal for Numerical Methods in Engineering, Vol. 21, 329-347 (1985)