Automation of Modeling and Data Transfer in Global-Intermediate-Local Analysis Based on ANSYS

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Abstract:

Due to the complication of stress distribution around the crack tips, it is hard to obtain the fracture parameters (Stress intensity factor, J-integral factor) in a 3-dimention model. According to this condition, some kinds of methods to simplify the model or calculation procedure are carried out. Basically for the crack in the thin shell structure, the parameters can be obtained finally from local models. This paper describes the hierarchical analysis strategy. It is a high efficient method for fracture mechanics analysis, which includes three main steps: model simplification, subregion extraction, and boundary condition transfer. A fracture parameter calculation system based on automated global-intermediate-local procedure to simulate cracked airplane panel tests was developed based on ANSYS. This system may create models of three stages, transfer boundary conditions, calculate and obtain fracture parameter automatically using APDL of ANSYS. New menus are made as well for these procedures in this system using UIDL of ANSYS.

Introduction

Fracture mechanics problems can have very serious consequences in aircraft structures. To analyze the local region of the aircraft containing the fracture, the global aircraft structure must be considered, which includes frame, stringer, joint members and fasteners. The traditional approach to this kind of problem is to use a large number of elements and embed local details using mesh refinement in the vicinity of the crack/damage. While the problem can be calculated in a single calculation, the approach needs a very powerful computer and takes a considerable time to produce a reasonable result.

As a more efficient alternative, the hierarchical method is extremely suited to solve this kind of problem, and this involves global-intermediate-local analysis (Reference 1). It needs three times calculation to get the final local result. Between these three kinds of models, there is data transfer including geometry, analysis results.

While a number of separate solutions are carried out, each is considerably simpler than a single global analysis.

Hierarchical Analysis Strategy

For fracture mechanics problems, a multistage hierarchical analysis is much more efficient than a single approach. A hierarchical analysis includes three steps: simplification of geometry, subregion extraction, and boundary condition transfer. There is a finite element model used in each step. Finite element models of these three steps have some common characteristics because they describe the same geometry configuration. However, they have much significant difference from each other in terms of level of detail, location and size of subregion, and boundary condition. Furthermore, not only the geometry-based analysis but also boundary condition transferring from a simplified model to a detailed model will be considered, such as conversion of displacement from beam element of global model to shell element of intermediate model.

The first step: Simplification of geometry

The aim of simplification of geometry is the whole way to reduce the number of degrees of freedom on the base of guarantee of the analysis accuracy of model. In this process, the detailed parts of geometry of realistic structure can be ignored because they almost do nothing with the stress analysis of model.

In the global model, the three-dimensional shell element and beam element are used. The many of the detail parts of the structure are simplified. For example, a beam element (BEAM188) is used to analyze the frames and stringers of aircraft when the fuselage is modeled using shell elements (SHELL181). Small parts such as clips and rivets are ignored and substituted to rigid connections among frame, stringer and fuselage (Reference 2).

The intermediate model is only a three-dimensional shell model (SHELL181). It is a part of global model containing crack. In the intermediate model, shell elements are used to simulate these frames and stringers so that a more detailed analysis can be carried out as we get closer to the crack. The clips are modeled using shell element as well when the rivets are modeled using spring element (COMBIN14). The rivet is placed at the exact position without its hole.

The local model is analyzed as a two-dimensional plane stress model. Only the region in the intermediate vicinity of the crack is modeled using two-dimensional plane element (PLANE2). The rivet force is also considered at the exact position without any simplification.

The second step: Subregion extraction

The second step for the hierarchical analysis is subregion extraction. Theoretically, the shape of the subregion can be any shape within the coarse model of the previous stage. Because the crack is in a fuselage, the subregion is typically a rectangle.

The third step: Boundary condition transfer

The analysis results from the previous stage are needed to be transferred to the next stage and are used as boundary conditions. So the data transfer among models is very important in hierarchical analysis. There are two times data transfers: from global to intermediate model; from intermediate to local model.

In global model, a beam structure is used for the frame, which is a shell structure in the intermediate model. Not only displacement analysis results from the beams are transferred to displacement boundary conditions of the shell in intermediate model but also displacement analysis result on the intersection point of the beam in global model are transferred to displacement boundary conditions along the intersection line sequence of the shell of intermediate model (Reference 3). APDL is used to output all these data to some files automatically.

In intermediate model, the three-dimensional shell element is used at this stage. The output files are read automatically into intermediate model as boundary conditions. Then the calculation results are outputted as the boundary condition of local model.

The two-dimensional plane element is used in the local model. Displacement boundary conditions along the boundary edges of the local model are obtained from displacement analysis results of intermediate model. The model of three-dimensional analyses is a part of a cylindrical shell in the case of an aircraft fuselage analysis. Conversion from analysis results of the three-dimensional shell to boundary conditions of the two-dimensional plane requires additional special treatments by APDL. The rivet forces from the intermediate model are also used as applied loads on the local model.

In general, the purpose of the global model is to capture global load flow; the intermediate model is performed to extract rivet forces in addition to more precise load flow around the local model, taking structural detail of stiffeners and joint configurations onto account, at last the local stage is performed to calculate fracture parameters (Reference 4).

System architecture of hierarchical strategy and automation:

The control flow of the hierarchical analysis is shown in figure 1. The local analysis of the last stage is performed and fracture mechanics parameters such as stress intensity factors are produced for each crack. The key three steps of hierarchical strategy (simplification geometry, subrigion extraction and boundary condition transfer) can be finished by the calculation system made by author automatically. The user just needs to modify the parameters of the input file according to the different model's character such as diameter, material, crack location etc.

Application to sample aircraft configuration

This hierarchical method is used here to simulate cracked aircraft panel tests and to calculate the fracture parameters.

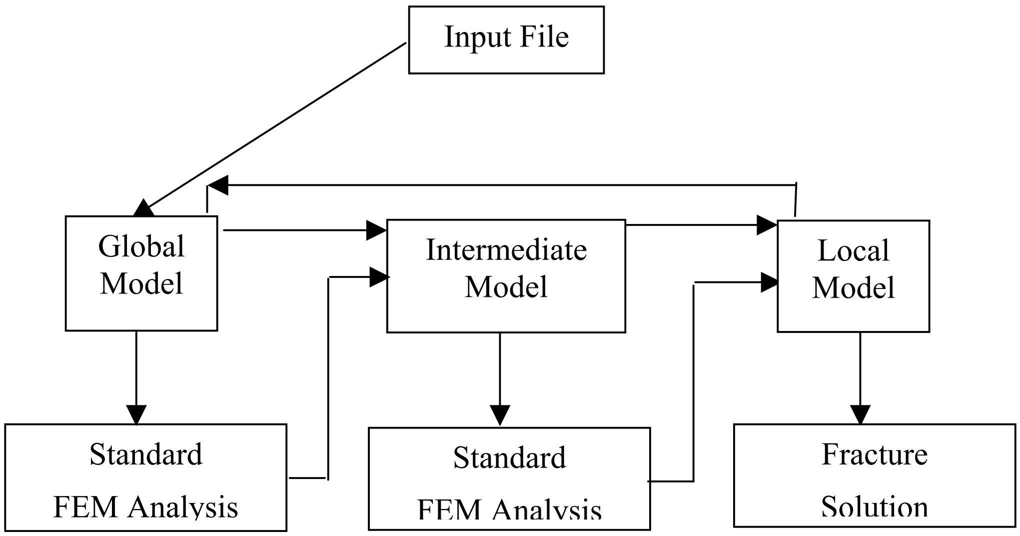
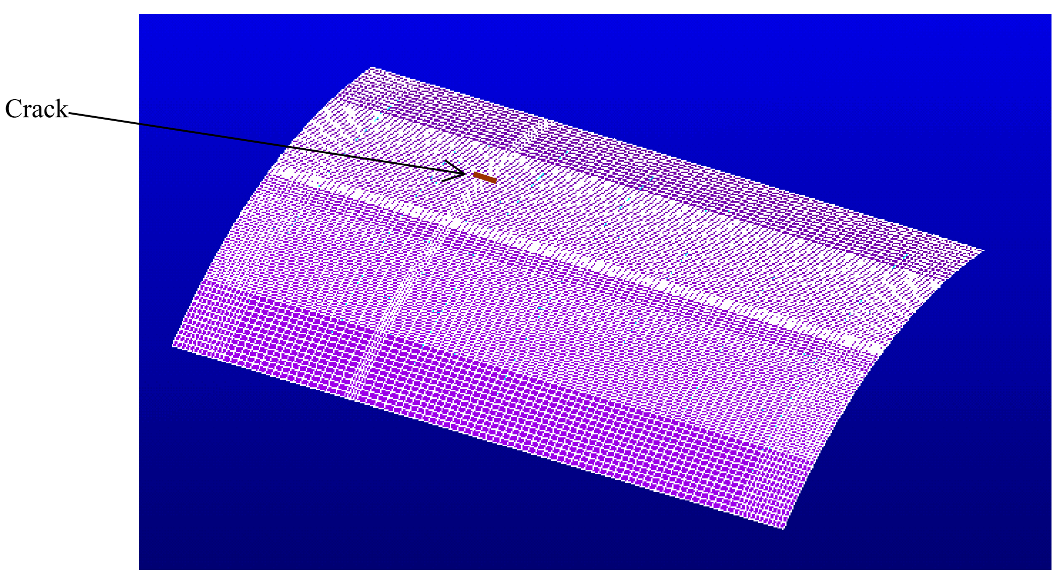


Figure 1. System architecture of hierarchical strategy

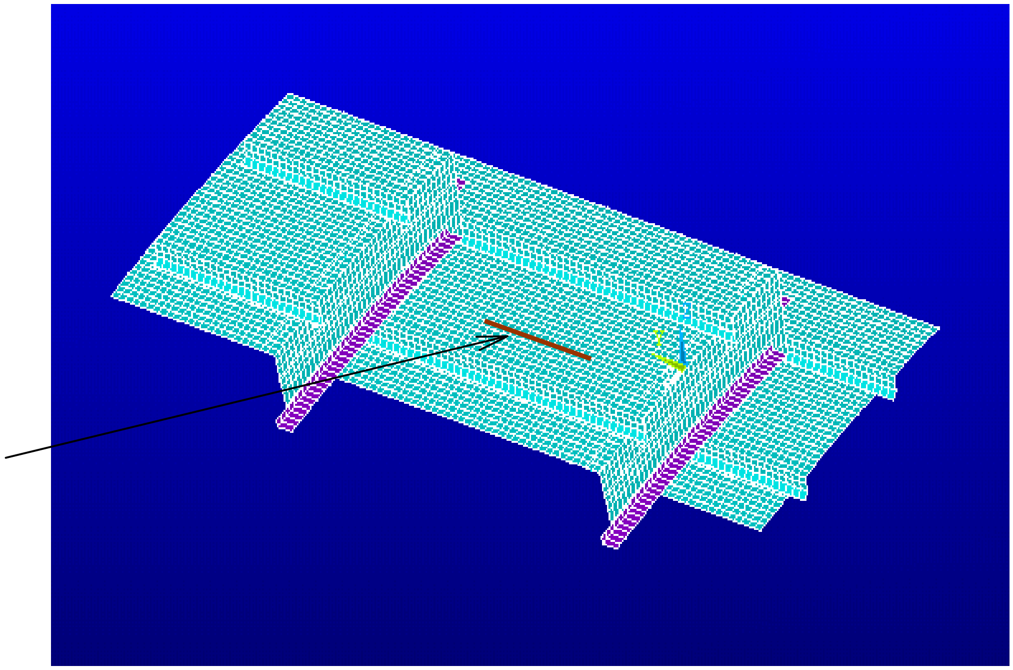
All the analysis adopt hierarchical analysis strategy; namely a global-intermediate-local analysis, shown in Figure 1. The crack is in the center of the bay of frame and stringer.

In the global model, the many of the detail parts of the structure such as clip and rivets are simplified. The beam element is used to analyze the frames and stringers of aircraft when the shell element is used for fuselage. (Shown in figure 2(a)) However, in the intermediate model, shell elements are also used to model these frames and stringers, clip and rivet are also modeled by shell elements and spring element. (Shown in figure 2(b)) The analysis results from the global model are transferred to the intermediate model and are used as boundary conditions.

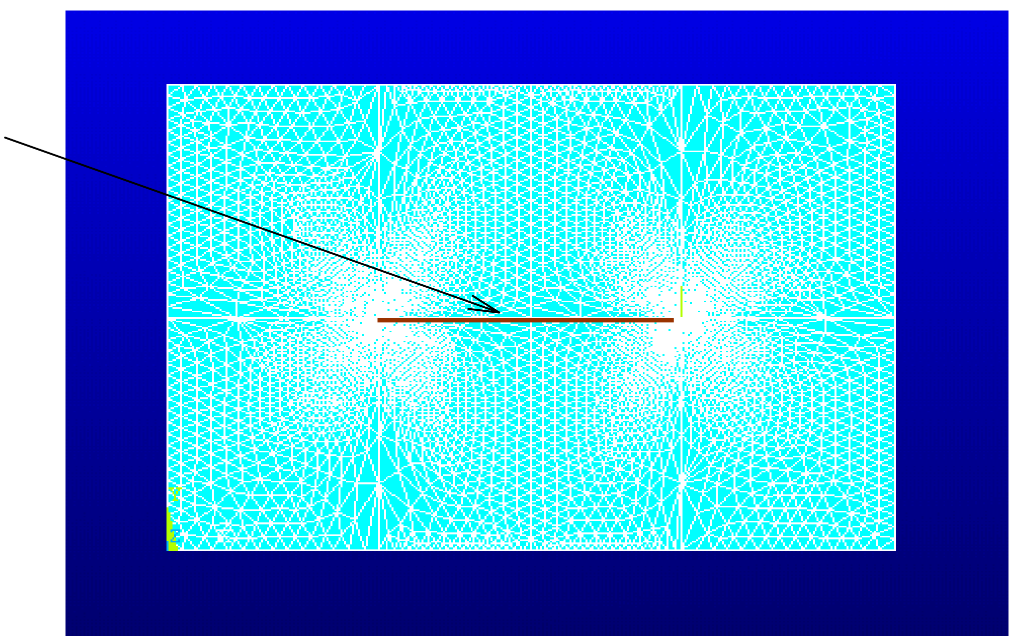
In the local model, we get closer to the crack region. It is sufficient to use two-dimensional plane elements to simulate the local model. The rivet forces from the intermediate model are also used as applied loads on the local model. The boundary condition from intermediate model treated as two-dimensional displacement is given to local model. (Shown in figure 2(c))



(a) Global model

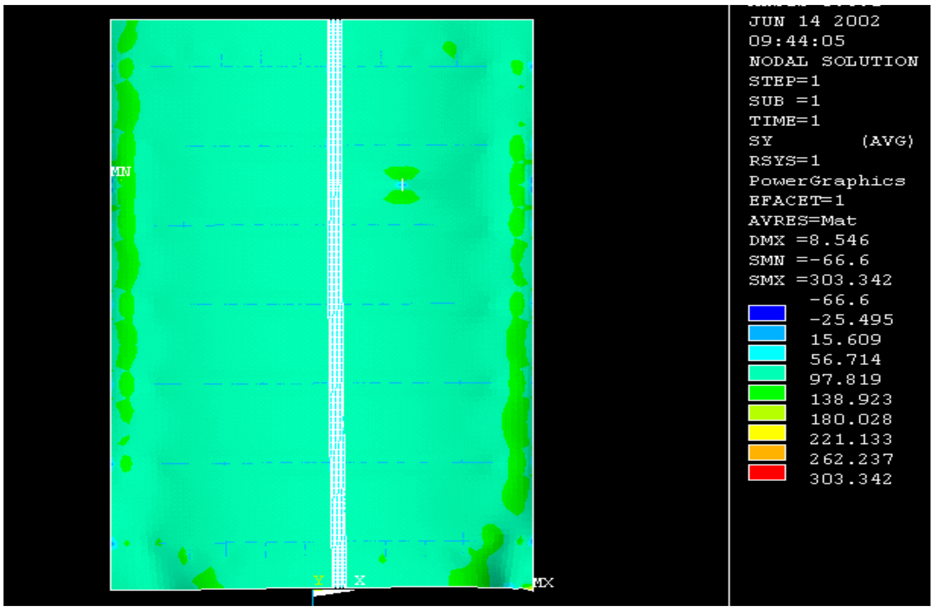


(b) Intermediate model

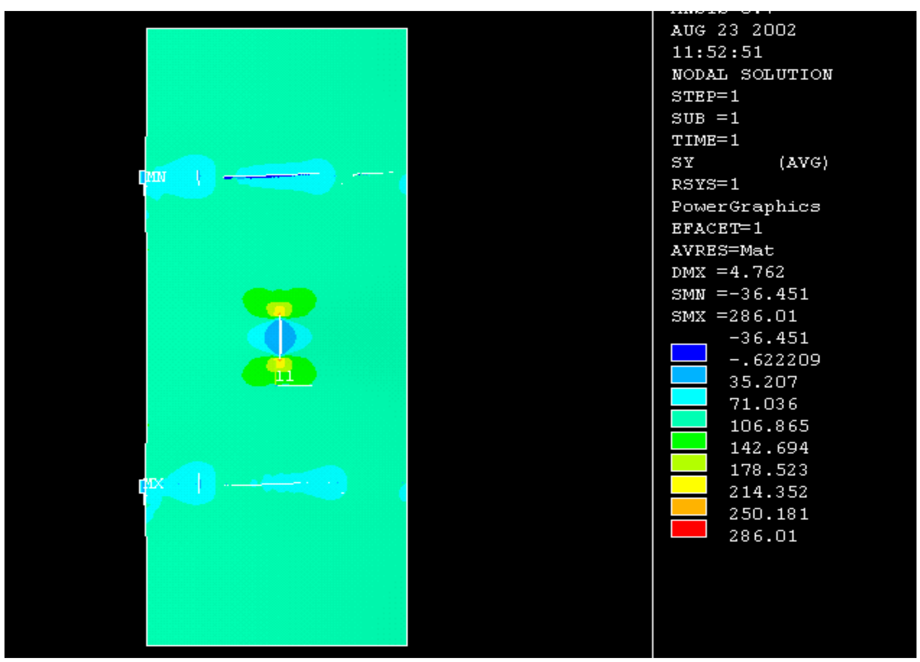


(c) Local model

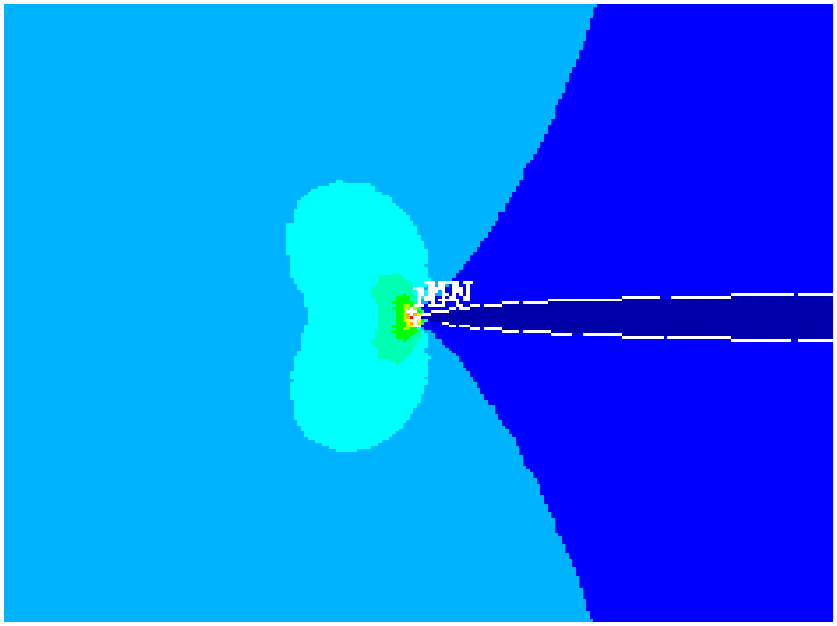
Figure 2. The meshes of models



(a) Global model



(b) Intermediate model



(c) Part of local model around the crack tip

Figure 3. The stress contour plot of three stages

The mesh models and the stress contour plots of crack are as shown in figure 2-3. From these figures, it can be seen that the more detailed the model is, the better stress contour is. In the coarse meshed global model, there are only half elements of that of intermediate model along crack. The mesh of local model is also much more detailed than that of intermediate model, which is composed by singularity elements (shown in figure 2). The stress contour is getting better and better from global, intermediate and local model (shown in figure 3).

In order to make input more convenient for analyst, the UIDL of ANSYS was used to create the new menus. There are four new menus for three stages models and post-process of local model. They are shown in figure 6 and figure 7. It can be seen that the analyst just needs to input some parameters for each model such as diameter, material, crack location, element number and element type etc. The model would be created automatically, the boundary condition data will be read from the former stage's output files and the calculation result would be outputted for next stage.

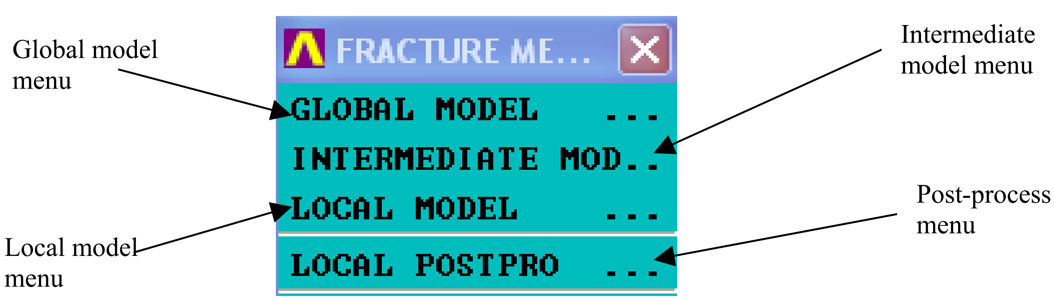


Figure 4. Menu for three stages and post-process of local model

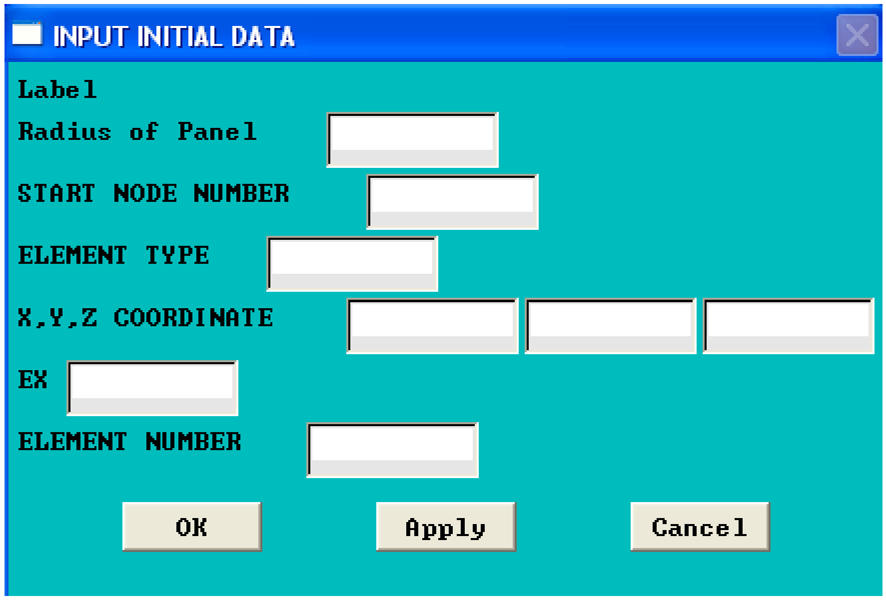


Figure 5. Input menu for global model initial data

Conclusion

An efficient automation system based on the hierarchical strategy is developed by APDL and UIDL of ANSYS. It was used to analyze the fracture parameters of the aircraft panel with damage. This system automates all the tasks necessary for the hierarchical analysis strategy, such as simplification, subregion extraction, and boundary condition transfer. This system allows analysts to obtain the fracture parameters high efficiently.

Reference

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