SPECIAL APPLICATIONS OF GLOBAL-LOCAL ANALYSIS

BY
DARA SABAHI and TED ROSE
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ABSTRACT:

Local regions of a structure may require more detailed analysis due to higher stress levels or gradients than can be accurately modelled by the overall finite element model (called the global superelement model in this paper). These local regions, as long as they are contained completely within a superelement, can be analyzed independently with a finer mesh by using "Global-Local" analysis. Global-Local techniques can be used to apply the forces and displacements resulting from the global model to the boundaries of the detailed local model.
These Global-Local methods have been presented in an MSC/NASTRAN Application Note entitled "Applications of Superelements in Global-Local Analysis," dated September, 1987. However, certain types of detailed local analysis cannot be readily performed using standard Global-Local techniques. Boundaries of two or more superelements, local analysis that involves multiple superelements, superelements with partitioned databases, and solving for local buckling are typical examples. This paper outlines Global-Local methods which can be utilized in performing these analysis.

INTRODUCTION:

As outlined in the Application Note, there are three methods available for Global-Local analysis: The first method is called the Force-Method, where a DMAP alter is used to retrieve the boundary forces acting on any superelement as a DMIG matrix with one column for each loading condition. The advantage of this technique is that the local model can be completely separated from the global model and it is not necessary to use the global database in the analysis of the local model. Since the adjoining structure is not modelled, it should be noted that the local model may not reflect the proper displacements and stiffness at its boundaries and therefore, the results at the boundaries may not be accurate if any change in loading or stiffness occurs.

The second method is the Displacement Method, where it is necessary to use the global database to retrieve the displacements at the boundary of the local model resulting from the global analysis. Again, since the forces and displacements at the boundaries of the model assumed not to change, the results may be inaccurate at the boundaries if the load is changed.

The third method is the Force-and-Displacement Method where essentially all the boundary properties of the local model are accurately retrieved from the global database by replacing the existing superelement with a new superelement with the desired mesh.

The standard methods are effective if the local area of interest for analysis is completely contained within one superelement and does not encroach upon the boundaries of other superelements. These methods provide a clean, self-contained package that is optimal for Global-Local analysis.

It is not always easy or convenient to plan ahead for these optimal conditions when creating a model. Often, after detailed superelement partitioning, major changes in the structure or unforeseen areas of critical stress concentration lead to a requirement for local models of structural regions that either contain more than one superelement or are located at the boundaries of superelements. This type of problem may require expensive repartitioning and reduction of the original global model.

This paper outlines some techniques that allow the analyst to solve awkward Global-Local problems using standard techniques. These techniques can also be applied to nonstandard problems, such as buckling of shells and plates, which may require finer meshes than the original static analysis.

DISCUSSION:

A. LOCAL MODELS LOCATED AT THE BOUNDARIES OF SUPERELEMENTS:

A typical example of this type of problem is the transition stiffener between a sphere and a cylinder in a pressure vessel. This type of stiffener is normally quite stiff and bulky compared to the shell and can be modelled using only a ring of CBARs at the junction of the sphere and cylinder. If the superelement boundaries are also located at this junction, the local analysis of the stiffener can become difficult if standard superelement and Global-Local techniques are used.

A faster and more economical solution to this problem is to isolate the local region of interest (in this case the stiffener) from the global model and database. The easiest way to accomplish this separation (and also apply the globally induced forces to the local region) is to use the Global-Local Force Method.

In order to apply the Force Method to this problem, data recovery runs that include the Force Method DMAP alter should be run for all of the superelements that have nodes of the boundary in question as their external nodes. This will produce a set of DMIG cards for the external forces applied to the boundaries of each superelement attached to the boundary. the next step is to manually edit these DMIG cards and remove the forces acting at shared boundaries of the superelements (these are redundant forces that will balance at the boundaries of the superelements) while retaining the forces acting at all remaining boundaries of these superelements. These DMIG cards then should be combined into one set (the continuation cards will need to be edited to avoid multiple continuation numbers).

The next step is to create a new model containing the data for the superelements (along with all appplied loads) which attach to the boundary in question. The DMIG cards prepared earlier can now be added to the new model creating an isolated model that has all the external forces that are applied to it by the global structure. A superelement tree is not necessary for this model and all the GRID points can be placed in the residual structure. The mesh for the local area of interest (the original superelement boundary) can now be refined as desired without any impact on the global superelement model. Since there is no longer a superelement boundary at this location (the isolated model has been transformed into an all residual model), the mesh refinement is greatly simplified.

The major problem faced in this type of problem is balancing the internal and external forces and boundary conditions. Theoretically, if the internal forces are not changed, the internal and external forces should balance exactly, giving an OLOAD RESULTANT of 0.0. This is not always the case in practice. If there are geometry changes, especially in pressure vessel type models, internal and external force differentials may be experienced. Also it should be noted that any forces applied to the external free boundaries of the superelements involved should be eliminated from the isolated local model since they are already reflected in the DMIG global force input cards.

If it is possible to balance the internal and external forces, the boundary condition problem may be solved by attaching a set of soft grounded CELAS elements to one of the nodes of the local model and then analyzing the model using SOL 61. If the internal/external force imbalance is great enough to make the structure unbalanced for this type of analysis, then SOL 91 may be used without the CELAS elements but with the addition of a SUPORT card for all the six degrees of freedom. The latter solution is often more reliable.

B. LOCAL MODELS CONTAINING MORE THAN ONE SUPERELEMENT:

Occasionally, a large section of a model may need to be remodeled either with a finer mesh or to account for various structural changes such as multiple penetrations and/or access hatches in a pressure vessel. These types of structural changes may often involve more than one superelement. Since it may be required to perform multiple iterations to achieve these modifications, it may be desired to handle this region as an all residual structure local model using the Force Method and avoid tampering with the global database. This approach has two advantages: first, the area to be changed can be modified easily once the superelement partitions in the local model have been eliminated, and second, if the global database is very large and possibly partitioned to accommodate limited disk space, this approach avoids the time-consuming effort of constantly loading the databases from tape to disk and vice versa.

Two approaches can be used to apply the Force-Method in isolating the local region to be remodeled. The first method is exactly as outlined in the previous section where the Force-Method is applied individually to all the superelements and then the resulting DMIG cards are edited to eliminate the forces at the mutual boundaries.

The second approach is easier and has less chance for error, but it requires that the analyst know the extent of the region which may require remodeling (local analysis) early in the analysis. If the superelements that will be included in the local model are known, the superelement tree may be set up so that the superelements in question will reduce to a superelement called a collector and then the collector can be reduced to the residual structure. The external non-mutual boundary nodes of the superelements can be placed in the collector to produce an envelope encasing these superelements.

This superelement tree structure will allow the analyst to apply the Force-Method to the collector superelement and avoid the requirement for editing the forces applied to the mutual boundaries of the superelements, since only the forces on the collector will be retrieved by the Force-Method. Afterwards, the local model can be separated and its superelement partitioning eliminated as described in the previous section.

BUCKLING ANALYSIS USING A LOCAL MODEL:

Buckling analysis, especially for cylindrical and spherical shells, may require a much finer mesh than is necessary for static analysis only. Also, in most structures, the areas of critical buckling can be determined beforehand based on the geometry and loading of the structure by an experienced analyst.

In large superelement models, performing overall system buckling analysis of the structure can be both expensive and cumbersome. All the GRID points in the critical regions for buckling should be placed in the residual structure. This can result in a large, expensive residual structure.

In order to avoid having a large fine mesh global model which is used for both static and buckling analysis, the Global-Local Force Method can be used on local models of the regions which may be critical for buckling. Depending on the size of the critical buckling region, it may contain one or more superelements, in which case either the standard Global-Local Force Method or one of the techniques described earlier may be used to apply the boundary global forces to the local buckling model. It should be noted that this method only accounts for the external forces on the boundaries of the local model and not the stiffness. Therefore, if the unconstrained boundaries of the local model are too flexible, it is advisable to stiffen them by adding elements or springs. Also, care must be taken to select the local model such that the boundaries are far enough from the critical buckling region to avoid any impact from the artificial boundary conditions on the buckling eigenvalues.

The local model can now be solved by first using SOL 61 or 91 for reduction as described earlier followed by solution 65 for buckling analysis. In MSC/NASTRAN version 64, SOL 91 may cause problems since SOL 65 cannot be run if a support card has been used in SOL 91. This can be avoided with a simple DMAP alter.

GLOBAL-LOCAL ANALYSIS WITH PARTITIONED DATABASES:

If segmented databases are used in the superelement analysis of the global structure, it is recommended that individual databases be allocated for each superelement. This not only facilitates maintaining and manipulating the databases but it also greatly simplifies local analysis. Using database partitioning, the local model of any superelement (as long as it is approximately equivalent in stiffness to the original superelement) may be reduced to its own database. This database can then be used instead of the original superelement database in the data recovery phase of the analysis. This solution method is displacement compatible for the boundaries of the local model, is easy to use, and avoids the need for the superelement to be reduced all the way to the residual structure and then resolved for multiple iterations.

CONCLUSION:

Global-Local techniques and their applications as described in this paper are versatile and useful tools for the analyst when dealing with large structures that may require local mesh refinement or buckling analysis. These methods not only allow a great deal of flexibility in the initial modeling of the global model, but also in the subsequent requirements for refinement and analysis to conform to changes in the structure.