Paper

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Integrating ANSYS with Modern Numerical Optimization Technologies

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Design automation with finite element analysis as a simulation and evaluation tool is becoming more and more desired. The ability to do automatic design iteration has constantly been a popular research and engineering topic. In this article, we will show how Honeywell Engines & Systems took advantage of the flexible environment of ANSYS to achieve this goal. Honeywell Engines & Systems, Phoenix, has automated the design process by integrating numerical optimization programs with ANSYS. The effort has been proved to be both time and cost-effective. Here we will show some technical considerations as well as some examples.

Mesh Perturbation for CAD-independent Parametric Model

It has been the common experience of the analysts that parametric modeling is not easy to accomplish. De-featuring the original solid model takes a large amount of time which typically slows program completion. Building a parametric model especially for FEA purposes has proven to be very time-consuming. Even after a parametric model is made, consistency of mesh pattern cannot be guaranteed. If the mesh pattern cannot be kept, there may be unexpected variation of stress in addition to that caused by parametric changes. This is sometimes called the "stress oscillation" phenomena. It will usually cause problems in the optimization process. At Honeywell Engines & Systems we have overcome this difficulty by utilizing a CAD-Independent parametric modeling technique called the "Contour Natural Shape Function". The idea is, when there is only FE mesh available, the user should still be able to make parametric changes on the model, without changing the existing mesh connectivity and pattern.

To illustrate this concept, first consider a given mesh like Figure 1. The user first divides the "contour" of a FE mesh into segments of controlling curves, without any CAD model information. The user input is not intensive since these segments are controlled by only a few key points. The user then specifies the points to be moved and the magnitude of movement. Using the parameters in ANSYS, this information can be saved and written out for external programs. The external program then reads the data and decides the new distribution of all nodes, and writes an ANSYS macro for defining the new coordinates. Finally ANSYS reads in the macro created by the external program and produce a new mesh shown in Figure 2.

The above procedure can all be executed in one macro by using the flexible APDL (ANSYS Parametric Design Language). This model is indeed parametric since all modifications to the model can be defined and saved as named parameters in ANSYS.

Design-Oriented Analysis

Parametric modeling is crucial and necessary for numerical design optimization. However, being able to do parametric modeling does not mean you can use it for optimization. Numerical optimization does have its limitation and assumptions. Our experience has shown that blindly coupling a parametric model together with optimization routine will usually cause serious problems. This is why the above-stated methodology was developed.

Numerical design optimization and automation requires consideration of several other issues. Some of these issues include the data structure of the model, the communication interface between ANSYS and the optimization algorithms being used, and, of course, a parametric modeling scheme more suitable for numerical optimization purpose. Other issues like numerical stability, computational efficiency and selection of optimization algorithms have also been a popular research topics for decades.

The concept of organizing and planning the global design process for the purpose of design automation is often referred to as Design-Oriented Analysis. With the concept of Design by Analysis at Honeywell

Engines & Systems, we are stepping forward to advance the analysis module so that it can be easily fitted into the design automation loop in the future.

Isolating the Design Parameters, Modeling Batch File and Responses

For the purpose of modularizing the FEA process, ADPL can be utilized to separate the parameters from the modeling file into another file. Other desired responses can be separated into different files as well. This input-analysis-response model can immediately be fed into many stand-alone optimization programs. For efficiency consideration, an in-house optimization code integrated with ANSYS was developed instead of using the stand-alone optimization packages. This architecture ensures independent maintenance for both modules. Using the named parameters in ANSYS as the interface and the APDL (ANSYS Parametric Design Language) for model manipulation, the user can do as much number crunching as desired within ANSYS. In other words, the analysis procedure itself is programmable. This is almost impossible for most of the optimization packages available today.

Multidisciplinary Analysis and Optimization

Another advantage of using ANSYS as a FEA solver in optimization is that it is multidisciplinary. With the architecture mentioned above, the optimization program does not need changes when additional analysis discipline is added. If the users have a lot of in-house codes supporting ANSYS, with the right communication protocol, the in-house code can be added onto the optimization loop without additional programming or frustrating data transferring. One example is the mesh perturbation module in the previous section. The module developed at Honeywell Engines & Systems can be used either as a separate parametric modeling tool through a macro, or in combination with optimization loop by inserting this macro command into the ANSYS modeling batch file. This implies that it is possible to use ANSYS as an analysis platform rather than just as a module.

Reducing Engineering Cost by the Leading Edge Technology

Finally, using the leading-edge numerical optimization technology provides the missing link from analysis response into a fast and optimum design. The immediate impact is the potential savings in engineering cost since the iteration can be done in an automatic process. For example, Figure 3 shows the FE mesh and the boundary conditions of a model. The goal was to minimize the weight with the equivalent stress under certain allowable value. The parameters for mesh perturbation took only a few minutes to set up. An ANSYS batch file was then put into the optimization program and after about 5 minutes the optimum configuration was obtained as shown in Figure 4 (with the HP C3000 workstation, 2GB RAM). Without the design automation tool, the same example would have taken more than one day to achieve the same result lacking any prior knowledge of the physical significance.

Looking into the Future

Currently we have the plan of incorporating an even more flexible optimization algorithm, called the Genetic Algorithm, into the in-house package. With this algorithm the package will provide more flexibility for the problems to be solved. Although this algorithm is computationally more expensive, the growth of computing power is making it more and more practical. In the future, it can be expected that the user will be more tolerant to these kinds of algorithms for being able to handle complicate design requirements. This kind of non-gradient based algorithms is only made possible with today's ever-growing computing power and a robust analysis package like ANSYS.

These examples illustrate the potential of reducing engineering cost by integrating and automating the design process. Although it is still too early to expect a fully automatic design environment at this time, local automation is possible with a flexible analysis platform. Surprisingly, such technologies have been around for decades, but questions of reliability had kept experienced engineers from investigating this tool. However, since 1995 there has been a significant increase in acceptance among engineering communities. With proper education and effort, we will see more and more successful design automation stories in the future.

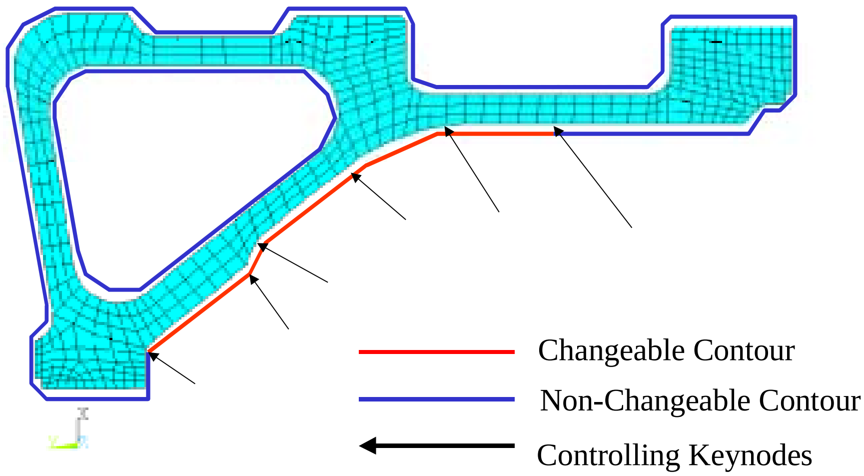

Figure 1 Finite Element Mesh and the Contour Controlling Net

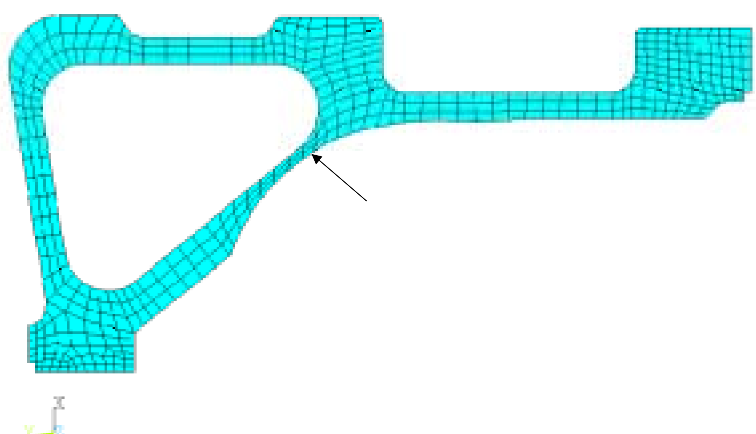

Figure 2 Perturbed Mesh After Moving the Controlling Node

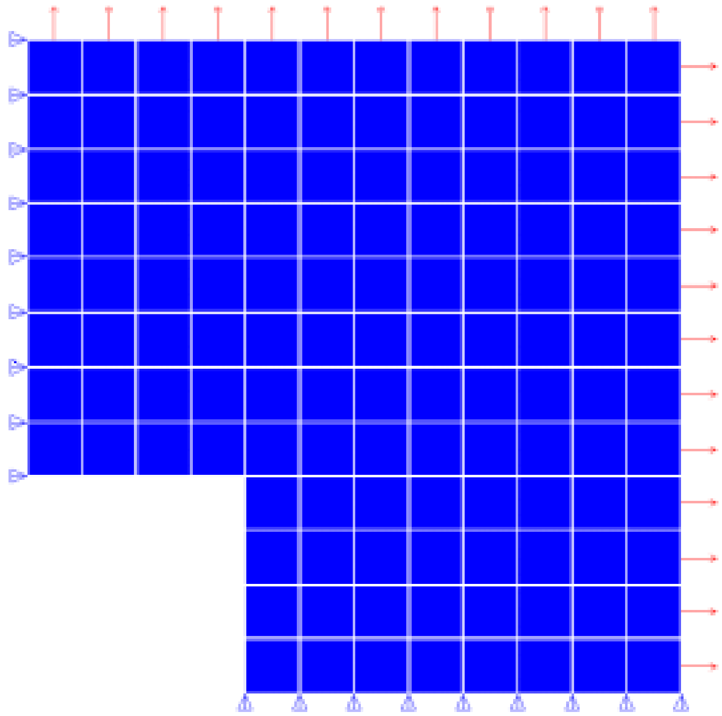

Figure 3 Finite Element Mesh and Boundary Conditions of the Original Geometry

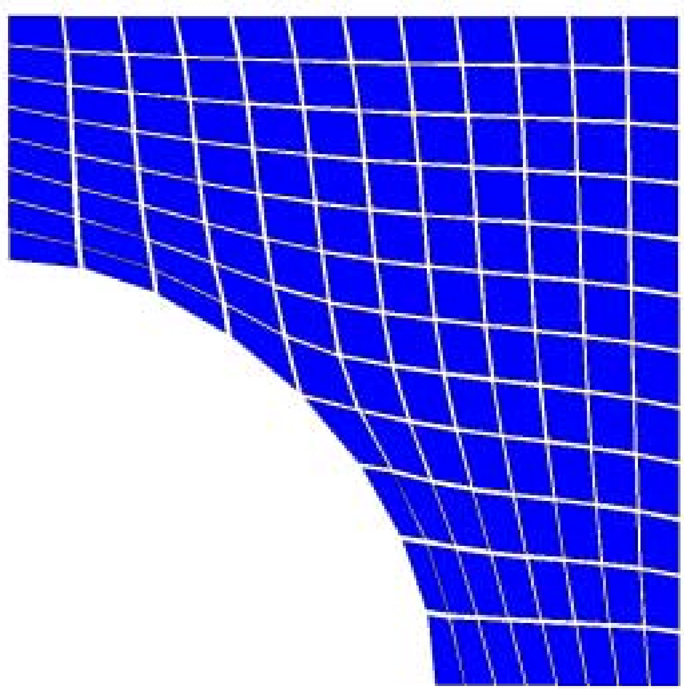

Figure 4 Optimal Design and the Final Mesh