CAD BEAT

Integrating design with analysis

by Paul Kurowski

Despite years of efforts to merge design and analysis software, there are still two separate applications in the design process: CAD, used for designing, and separate software for analysis of that design.

To understand the difficulties in integrating design and analysis, one must first look at the evolution of CAD and analysis tools over the last 30 years.

CAD started out as an electronic drafting board in the 1970s. One decade later, came 3-D wireframe tools. Solid modeling arrived in the late 1980's and to this day rules high-end CAD, allowing designers to create and manipulate geometries of unprecedented difficulty.

The analysis tools, mostly different varieties of Finite Element Analysis (FEA), were evolving parallel to, but not in sync with, CAD. The h-method of FEA became available in the early 1970's and was well suited for handling simple geometries of that time. In the early 1990's, the p-method brought a significant improvement in analysis of more complex designs being created by increasingly powerful solid modelers.

Eliminating the problem

One could expect that CAD and analysis tools would have merged into one by now, and the need for interfacing between the two of them would have been eliminated. This has not happened due to irreconcilable differences in the requirements of CAD and FEA geometries. CAD geometry must be fully featured, as needed for manufacturing. FEA geometry must be defeatured, idealized and cleaned up to make it meshable, since meshing is a pre-requisite to finite element analysis.

Using modern CAD and FEA tools, design and analysis can be preformed at the same time. However, the need to differentiate between two geometries remains the major stumbling block on the road towards Integrated Analysis, which uses the same geometry for design and analysis and eliminates the need for interfacing.

The recently introduced new analysis technology, Precise Solids Method (PSM), does not require meshing. Consequently, it does not require the differentiation between CAD specific and analysis specific geometry. It works directly on solid geometry of any complexity, with no need for simplifications, defeaturing or cleanup. By eliminating meshing, the PSM also eliminates many secondary problems facing the FEA user, like selecting the right element type, dealing with a large number of elements, unintentional creation of degenerated elements, inability to mesh complicated details or difficulties when meshing thin features and "dirty" geometry. On contrary to FEA, which provides results pending successful meshing, PSM will always deliver results because the solution is not dependent on the ability to create a mesh. Eliminating problems of the FEA technology, the PSM makes integrated analysis finally possible.

PSM is similar to the finite element method. PSM approximates the global behaviour of field variables with functions of polynomial type, similar to those used in the FEA. It also uses specialized, non-algebraic functions to model stress concentrations. Unlike simple shapes of h or p elements, the PSM allows for modeling of field variables in complex 3-D shapes. Splitting facilitates description of field variables in each subpart with reasonably similar functions.

The iterative solution process, in which the complexity of approximation function increases with every repetition, enables the analysis of both relative convergence errors (p-method of the FEA) and absolute boundary conditions (BC) errors, informing the user how well the displacement and traction boundary conditions are satisfied. Those BC errors are called "absolute" because the target value and the actual value are both known. The PSM exactly satisfies the equilibrium equations in each subpart while displacement and traction boundary conditions are satisfied approximately, with user-controlled accuracy.

PSM allows for discontinuity of displacements along split surfaces and for approximate fulfillment of displacement BC. The allowed magnitude of discontinuities and the allowed approximation of displacement BC are user controlled and can be analyzed along with results.

Finding the solution

On the loaded surfaces, tractions should equal the applied load. On surfaces where supports are defined, they should equal reactions. On all free surfaces tractions should equal zero. All of the above requirements are fulfilled only approximately, the user will decide how much traction BC error is allowed.

The PSM has been implemented in the commercial software, Procision (www.procision.com), developed by Canadian company, Procision Analysis Inc. based in Mississauga, Ont.

Procision is the only implementation of PSM that offers unprecedented capabilities of error analysis. It also has a stand alone, free of charge postprocessor that can be included with reports for active analyzing of results in place of the typical, passive review of printouts. The entire code compresses down to 3.5 MB, and can be easily distributed over the Internet (www.engineering.com).

Unlike the FEA, the PSM is able to deal with CAD created geometries of any complexity and without any need for modification. It also offers significantly shorter solution time. Catching up with progress of CAD tools, PSM can be seen as the next step in the evolution of analysis.

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