SIZE MATTERS

The ANSYS Application Customization Toolkit is put to use to more accurately size welds by taking existing standards into account.

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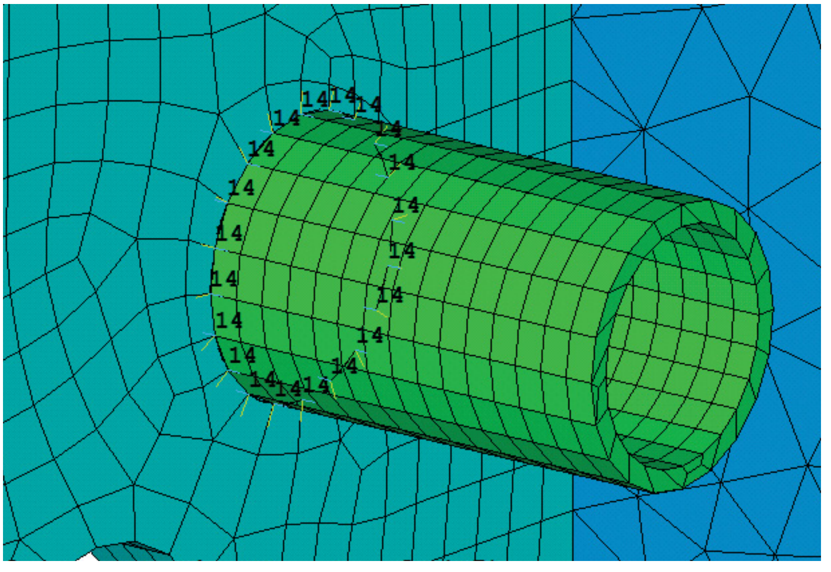
The sizing of welds is often controlled by standards, such as those developed by the American Institute of Steel Construction (AISC) and the American Welding Society (AWS). These standards were written with the expectation that hand calculations would be used to determine generalized loads for structures with relatively simple geometries. While finite element analysis (FEA) more accurately simulates complex geometries, it normally requires a laborious manual process to transform localized stresses (as determined by FEA) into the generalized loads needed to size welds that meet standards. By creating an extension using the ANSYS Application Customization Toolkit (ACT), Epsilon FEA has made it easier for the company's engineers to automate the process. The improved accuracy this approach offers provides significant cost savings while ensuring full compliance with relevant codes.

▲ Weld manufacturing costs are often nontrivial.

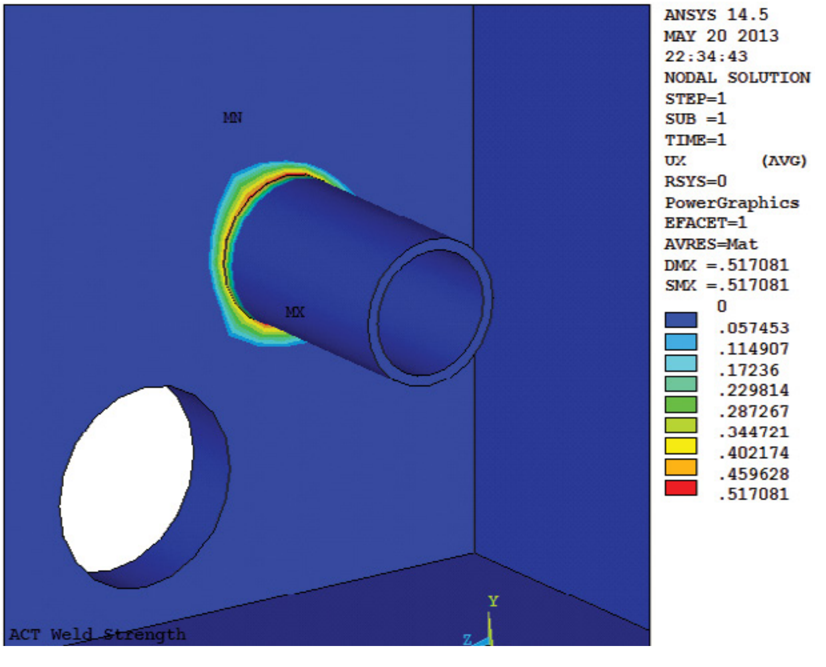
STANDARDS BASED ON HAND CALCULATIONS

Welds today are frequently sized based on decades-old standards founded on the use of free-body diagrams to hand-calculate loads based on forces and moments. Hand calculations have diminished accuracy when predicting statically indeterminate and complex structures. Even a fairly simple structure, such as a gusset with a large hole, can't be assessed reliably with hand calculations. Judgment calls are typically used in these situations — relying on the standards' large safety margins. The downside is that for some geometries and loadings, welds are sized considerably larger than necessary, which tends to drive up the manufacturing cost of structures. While structural analysis tools and methods such as FEA have rapidly advanced, the standards have failed to keep pace, in part because the weight and cost of welding are only minor factors in many structures. But for some industries, the labor-intensive nature of the welding process and part volume has sufficiently driven up costs to warrant a more thorough analysis. In many cases, companies have already created an FEA model of the structure as part of the development process, which can be leveraged to minimize additional effort.

Most welds are sized considerably larger than necessary, driving up the manufacturing cost of structures.



▲ Script determines normal thickness.



▲ Stresses averaged along a length four times thickness

FEA WELD SIZING

Around 1950, engineers began using FEA to size welds. Many approaches were developed using different specifications and methods involving meshing the weld bead and relying on localized stresses. Using existing commercial tools for evaluating welds with FEA may require substantial amounts of pre-processing, large computing resources and correlation with extensive test data for prediction of performance. The more recently developed Verity method (Batelle, 2006) accommodates virtually any geometry and provides impressive accuracy in predictive results that enable welds to be sized more accurately than ever before. The cost of this approach can be considerable, given the need to geometrically model each weld bead and continually update the model as the required weld sizes are determined iteratively.

But because these methods approach the problem from completely different directions, the resulting weld sizes will usually not comply to a standard such as those of the AISC.

For cases in which a standard based on hand calculations must be met and when an FEA model is either cost-justified or already available, the analyst must convert the very localized FEA results to the load-based approach of the standard.

EXTENSION AUTOMATES STRESS AVERAGING

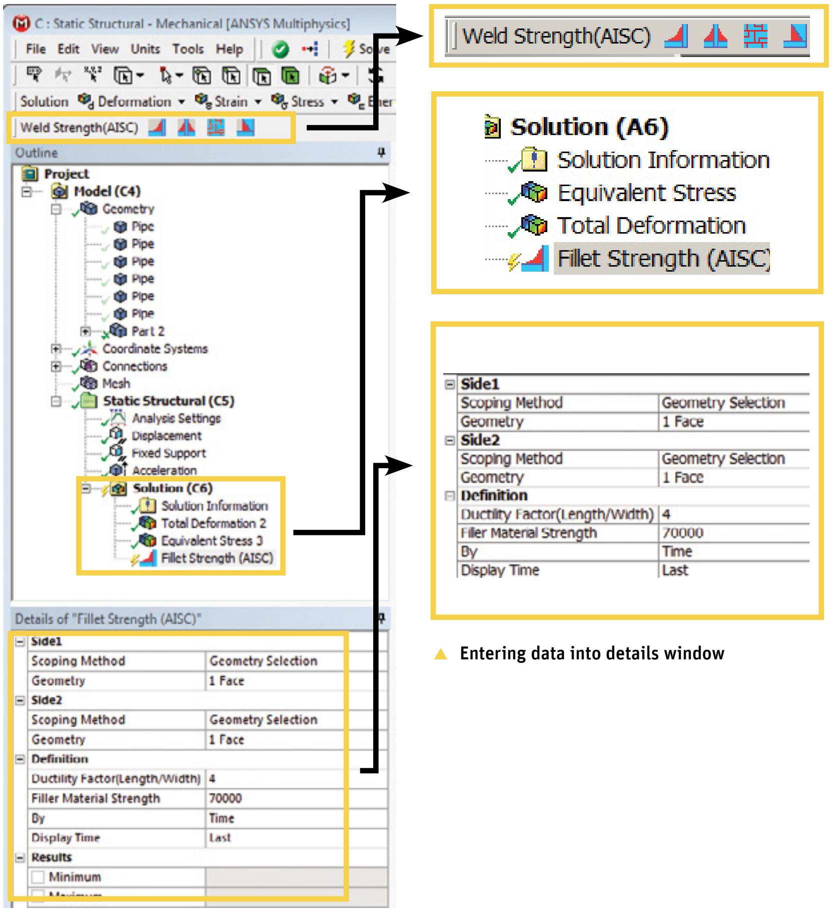
Converting the localized FEA results to a form applicable to a given standard is a manual process that becomes costly and error-prone (even tedious) on an assembly with many welds. ANSYS ACT offers a powerful object-oriented programming environment that provides the ability to fully access and manipulate the model, scope to selections, run custom calculations and plot contour results. ACT also can encapsulate legacy ANSYS Parametric Design Language (APDL) scripts to leverage the investment in legacy code.

Epsilon developed an extension that leverages ACT to automate the process of sizing welds using ANSYS Mechanical in accordance with existing standards. The first step is that the engineer selects the surfaces to be welded and invokes the ACT extension. The extension prompts the user to enter a few items into the details window, such as weld type and filler material strength. Then the engineer plots the required weld size per the specified standard. Different calculations are performed for each specified weld type, such as double fillet or partial joint penetration (PJP). For further investigation, the user examines the weld stresses in local coordinates to plot tensile and shear loads. Behind the scenes, the extension calls a 150-line APDL script that determines the normal thickness of parent materials at each shared node. The extension's flexibility accommodates curved welds and varying material thicknesses along the joint. By querying normal and shear stresses on both parent materials on the front and back of solids, engineers calculate average stresses and input loads. These results can be plotted or used in calculating required weld size using a known standard, such as that from AISC or a custom criterion per internal design practices. Finally, the node-by-node results are listed in an ASCII text for reference or use in an external weld evaluation tool.

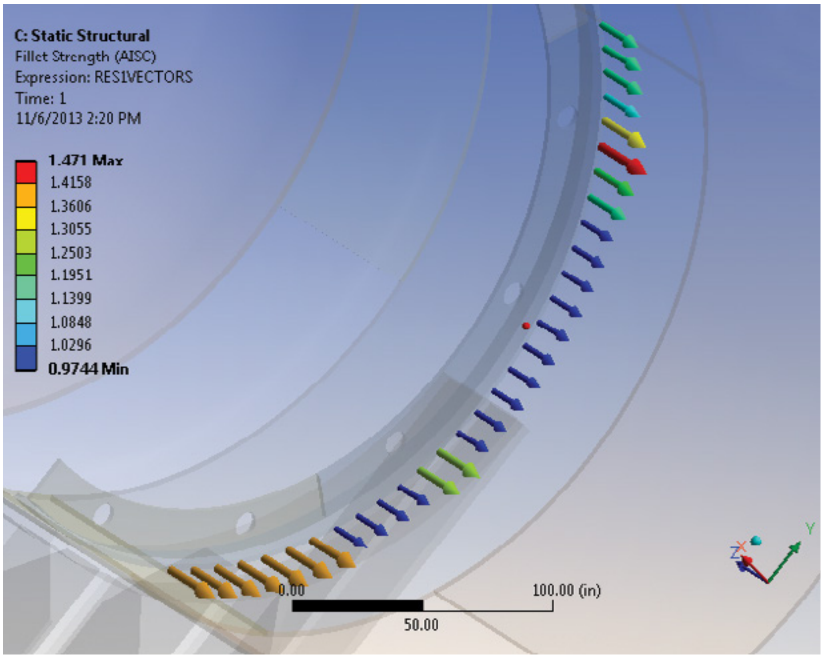
To meet a particular customer methodology, another APDL macro script with 100 lines converted the localized stresses to generalized ones by averaging the localized stresses along a welded length four times the thickness of the parent material to account for the ductility. These generalized stresses were then used to determine the minimum weld size in another APDL script with 25 lines based on the AISC method (Chapter J, Table J2.5). The object-oriented scripting within ANSYS Workbench combines with legacy APDL code into a seamless tool that is operated through the user interface and transferable as a single add-on extension. This successful automation and codification of a design process demonstrates the future path for advanced customization and automation within the Workbench environment.

POTENTIAL COST SAVINGS

Epsilon FEA's weld ACT extension can provide significant welding cost reductions while still delivering complete compliance with relevant standards, by identifying regions where smaller fillets or PJP welds are acceptable. In the example, a wind turbine tower was analyzed using structural simulation for modal, vibration and seismic conditions. The geometry consisted of tapered cylindrical sections. The wind load varied in a nonlinear manner from the top to bottom of the structure; wind load

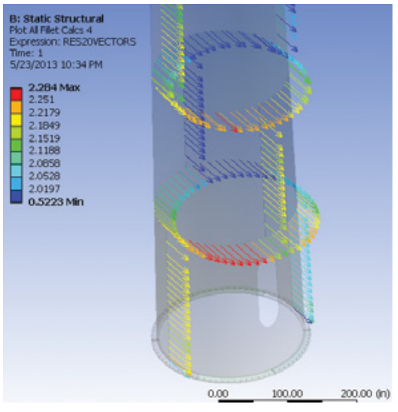


▲ Entering data into details window



▲ Results plotted in vector style

This application is a good example of how using ACT extensions can save money through more accurate weld sizing.



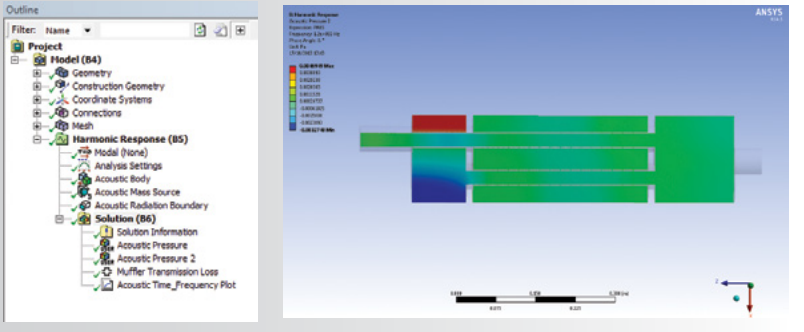
▲ Cost savings achieved on wind tunnel tower by using PJP welds; blue vectors indicate potential PJP welds.

also varied circumferentially due to drag. It would have been very difficult to determine the varying weld size requirement using hand calculations. Relying on conventional hand calculations for the 2-inch-thick material likely would have resulted in complete joint penetration (CJP) welds being used throughout the structure. The FEA results, however, showed that the top third of the structure can be manufactured with PJP welds while still complying with the standard, saving significant assembly cost for each tower. This application is a good example of how the ACT extension approach can save money through more-accurate weld sizing.

ADDITIONAL RESOURCES

APPLICATION CUSTOMIZATION TOOLKIT (ACT) IN ANSYS MECHANICAL
ansys.com/81size

ACT Improves Productivity Through Customization



▲ The ACT acoustics extension facilitates performing vibro-acoustics modeling with ANSYS Mechanical software. This extension expedites defining acoustic properties, applying acoustic boundary conditions and loads, and performing post-processing results. An example of a muffler is shown.

Many product development organizations improve productivity by customizing engineering simulation tools to local workflow requirements. Customizing can take the form of introducing unique capabilities to enhance what's already available within the base product — capabilities that are uniquely different from a simple automation of existing features and functionality. Through customization, engineering simulation activity becomes integral to a firm's product development process, resulting in improved overall productivity for the engineering staff. At the same time, customization provides the opportunity to involve a broad cross section of the product creation team in engineering simulation activities.

ANSYS launched the Application Customization Toolkit (ACT) as part of the new ANSYS Customization Suite. ACT introduces new customization capabilities for the ANSYS Mechanical environment, allowing users to:

- Encapsulate APDL scripts cleanly through GUI buttons and menus
- Introduce new loads and boundary conditions
- Create custom results
- Integrate third-party tools

An introductory course, Introduction to Application Customization Toolkit, is available for download by ANSYS customers in the Knowledge Resources area of the ANSYS Customer Portal. In the Extensions Library at the Customer Portal, ACT extensions can be downloaded to facilitate training and improve the performance of ANSYS Mechanical for various tasks, including vibro-acoustics simulation.

— Shane Moeykens, Democratization of Simulation Program Manager, ANSYS, Inc.