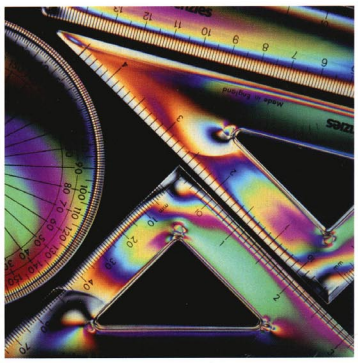

Stressed out

Finite element analysis packages may be easy to use – but some give dangerously wrong answers. They oversimplify the analysis of complex components, writes *Bob Johnson*

A crisis is looming in finite element analysis. There were concerns about the quality of FEA back in the 1970s and 80s because computing power was limited.

Back then, models were either under-meshed or engineers were forced to make invalid simplifications. But by the 1990s, the reliability of FEA had been demonstrated beyond doubt and the industry turned its attention to reducing project times. One of the most time-consuming tasks was the interpretation of drawings and the building of a "virtual" model of the component.

The breakthrough in model building came when 2D and 3D CAD data was used as the basic geometry model. Here the designer's draught was reused as the starting point for FEA.

Automatic mesh generators were developed to take a CAD-defined volume and fill it with tetrahedral elements. These enhancements enabled complicated solid models to be meshed quickly without simplification and reduction.

It is now common to see extensive use of CAD data – the model-building phase has been reduced to a simple matter of CAD-cleaning, preparation and automatic mesh generation. The trend today is to mesh everything in tetrahedral elements. Few people agonise over the reduction of the problem to, say, a collection of shells/plates, beams or some sort of 2D representative section.

Taken for granted

Where FEA used to mean a specialised package outside the design/CAD environment, now FEA is integral to, or embedded in, most CAD systems. The CAD-embedded FEA systems are certainly convenient – the user does not have to leave the CAD system to change the light-source shaded view of the 3D component into stress contours of the von Mises stress. Computing power has reduced the analysis time to just minutes. CAD-embedded systems have also concentrated on ease of use and this has led design engineers to carry out much more analysis.

The user of the typical embedded FEA system is rarely confronted with technical jargon – indeed many systems default to hide the resulting mesh. The part of interest is selected and meshed according to whether the user wants speed or accuracy. The user is not made aware that speed uses a four-noded tet mesh and accuracy a 10-noded mesh – industry accepts that results from the former are very suspect! Loads are applied as face pressures over a given area. Similarly, constraints are applied to a single face or patch of faces. Material properties are assigned to the model and the analysis can be submitted without leaving the CAD package. If something is wrong the system will shout up or, at worst, crash out. Stresses are ready for viewing in colour within minutes. What could be simpler?

But all is not as it seems. Discussions with designers and FEA analysts have revealed lots of flaws in the techniques, the models, and the thinking behind them. In providing ease of use, all problems have essentially been reduced to that of a cantilever beam – loads applied at one end and constraints at the other end. Invariably the constraint is a fully built-in condition, something that is impossible to achieve in practice and makes for unrealistic stresses where the elastic structure goes to ground. Some embedded systems will not report the loading totals generated by the various applied pressures. How can the user be sure of the magnitude of loading if no output is available? These are some of the basic problems – but there's more.

Further to the issue of realistic loading, in static stress analysis the structure of concern is in a state of balance or equilibrium – no net force or moment exists in any of the three co-ordinate directions. Engineers used to construct a so-called "free-body diagram" where all the forces and moments were drawn on a simple stick model. This specified all the loading. If we choose to use balanced loading (we put applied loading and reactions on our model) then we must use a minimum constraint pattern so as not to over-stiffen the model under investigation. Minimum constraint involves holding three points (say XYZ freedoms at one, YZ at another and Y at another) so that the structure is not stiffened by the method of constraint.

The problem with some embedded systems is that you can't apply minimum constraints – users are forced to apply constraints over a finite area or face and constraints at a point are often not available. So an alarming number of models have been poorly constrained such that the stresses are not conservative. Balanced loading is the key to good static stress analysis and many CAD-embedded FEA systems will simply not allow you to do this. Results that disguise the real level of stressing are dangerous.

However, a host of FEA systems can provide balanced loading and minimal constraint. If yours does not, then demand a fix from your supplier.

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