EDITORIAL

Coordinated Test and Analysis in the Design Process

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Most of us have heard the old adage that "Everyone believes the test data except the engineer who took it, but no one believes the computer model except the engineer who built it."

This may imply something about how entrenched in reality test and analysis engineers may be, but more importantly, the adage speaks volumes about how the general engineering community looks at the value of test and analysis. The skepticism about analytical results is surprising in this day and age when contemporary computer tools are so incredibly powerful. It has become almost routine to perform analyses of all kinds – static or dynamic; linear or nonlinear; solid mechanics, fluid mechanics, or an interaction of both – in the context of very complex geometries. Surely an analyst can get all the "right answers" with such a vast offering of tools at his disposal? In the event that he cannot, testing can be used to help fill in the gaps, and this coordinated use of test and analysis can serve as a powerful means of enhancing structural designs.

Analysis is just one of the disciplines that an engineer needs to bring to bear in a design situation. The solid modeling tools that are generally used in day-to-day design work have also realized vast improvements in recent years. These have been accompanied by the availability of data management systems that overlay the design software to help the designer work within a larger program or organization. In addition to making the designer's job easier, these tools also assist the analyst in his work, enabling the analyst to impact the design in a more effective and coordinated way.

The analyst, armed with a set of powerful software tools, is typically able to negotiate through the design space to provide incremental improvements to the design. Analysis-driven design has progressed smoothly along these lines in recent times. However, there are some pitfalls in this process, not the least of which is the need to directly address the right design challenges. All too often a finite-element model is built without the realization that the type of model being used implies a set of approximations that may not always be appropriate. A simple example would be the use of shell elements to model a moderately thick plate that has a sudden thickness change. This model would shed no insight into peak stress at the transition. Such occurrences of implied approximations are pervasive in the analysis world, although they are usually more subtle than in this simple example.

Testing can provide an avenue for helping avoid analytical challenges. Perhaps the challenges confronted by the analyst that are the most difficult to address without ambiguity relate to the analysis boundary conditions – displacement restraints and loads. The degree of boundary fixity that is generally assumed is unlikely to be truly representative of actual conditions. This uncertainty is generally ignored with the assumption being that the analytical results are insensitive to any possible discrepancy. Regardless of the importance of boundary fixity, the loads are always critically important. This situation brings to mind another adage – "If you are going to assume the input, you might as well assume the output." This is also known as GIGO – garbage in, garbage out.

So the analyst must rely on loading information from some reliable source, with testing being the most likely in the majority of cases. This is but one way that testing is critical to the success of the design process.

In what other ways can testing contribute to the design process? At first glance it would appear that testing can't be used in the early stages of the design, because typically no hardware has been built yet. But this is the ideal time to collect data on existing designs, including those of competitors, to help build a design specification that will help lead the program in the right direction. This testing can identify critical design issues early on so that the analyst is able to focus on the real design drivers and quickly engage in meaningful and productive trade studies.

Once the analyst gets into some meaningful investigations, there is a real need to work with simplified models to cover the entire design space as quickly as possible. The need for a comprehensive analytical model that can answer all the design questions (if this is ever possible) should be pushed back to later in the development program. But the simple models that are needed early must be convincing and avoid the skepticism mentioned previously. This is another area where testing meshes well with analysis by providing insight into the key issues that the analyst must address. The testing done at this stage can also eliminate issues that are only of secondary importance, thus helping simplify the models needed for analysis.

The complementary roles of test and analysis should likewise continue through the entire design process. Analysis can help make the tests more effective by guiding sensor placement and helping define data acquisition requirements, and as the design matures, testing can be used progressively to qualify components long before the entire system is subject to a final qualification test.

The coordinated use of testing and analysis during the design stage often relies on model correlation technology to aid the process. This is another area where significant gains have been realized in recent years, where partially or even completely automated methods have been developed to assist the analyst in making sure the model's response is consistent with performance measured in a particular type of test. Most attention in the aerospace vehicle industries has been placed on structural modal properties as measured during low-level vibratory loading. The article by Brillhart, *et al.*, on ground vehicle testing (GVT) in this issue of S&V is a good example of the type of testing that is generally required for accurate correlation studies. This kind of correlation work generally leads to a much more reliable and accurate analytical model.

There is one caution worth raising in regard to the usefulness of correlation technology: it is not able to increase model reliability in all circumstances. In the GVT example cited, the model would be correlated for low levels of vibratory response, but this correlated model may or may not be particularly useful for assessing the structural response in extreme loading events. A crash would be an example of such a situation. In all cases, the correlated model is most applicable for the type of loading used in the correlation testing. Stress predictions for the modally correlated model may well be better than for an uncorrelated model but could probably be improved further if strains were included as correlation variables in the testing program.

In summary, the correlation effort should be undertaken with full recognition of how the correlated model is to be used in the design process.

Regardless of whether formal correlation work is undertaken, it is clear that test and analysis can be used together in a coordinated way to help the design process. Testing should not be thought of only as a pass/fail gate during qualification but instead as a means to provide input and support to a series of focused analyses used to proceed progressively through the design space.

This methodology generally leads to a superior design.

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