EDITORIAL

Knowledge & Understanding – NVH in the Automotive Industry

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My involvement in NVH began in 1979 in a research lab at Ford. Most of the work was in the area of vehicle body acoustics, including the measurement of structural modes. We had a state-of-the art two channel analyzer that could perform tests not only with swept sine inputs but also with random noise. We used the latest and greatest curve fitting techniques to find mode shapes, but somehow we could not get satisfactory results. So I traveled to Cincinnatti to attend a course given by the gurus of modal analysis, which helped, but we still had a long way to go. Now, after 22 years of NVH work in the auto industry, I have developed some strong, and possibly heretical, ideas for the path to enlightenment, knowledge and understanding.

One source of constant problems is a lack of "nuts & bolts" training. Because engineers circulate frequently between positions, it is hard to provide suitable training in a timely fashion, or to know who has appropriate training. As a result, all too often one meets situations such as an engineer wondering why his measured road noise sound pressure is always positive. How was the engineer to know that the sound level meter output labeled 'DC' was not "DC-coupled," but "rectified and time averaged?" Perish the thought he should read the somewhat ambiguous documentation!

These problems can exist at a quite sophisticated level. For example, how can an engineer estimate how well different accelerometers perform in practice? A group of consultants (experts?) once visited our lab to show us how their new test technology could deal with a difficult problem. However, the signal to noise ratio of their accelerometers was not good enough for the task. They solved their problem by borrowing ours! Consequently, when we re-equipped our labs, we devised a bench test to determine relative performance under our typical operating conditions. We even went as far as to check the effect of thermal shock by blowing hot air on the accelerometers. The results were very revealing. Similarly, the documentation for analyzers is typically so obscure that it is hard to be sure of the effect of any given operation. My advice is to always check new analyzers with known signals.

Here is my suggested solution to the nuts & bolts training issue – training on a disc. Each vendor of test and analysis equipment should provide computer-aided training on a CD, complete with user self-tests and a printed certificate of completion! Further, the sales department should work with experienced NVH engineers to customize the training and focus it on the users' needs. For example, in the case of sound level meters for NVH measurements, the material should cover (in part) basic acoustic theory, operation of microphones, calibration and use of meters (what does 'DC' mean?) and introductory psychoacoustics theory. Subjects such as airport noise would be skipped, but a special section might be provided on vehicle pass-by tests. Training for digital data acquisition should emphasize NVH conventions and point out what might be considered unexpected quirks. For example, does the displayed spectrum include a frequency region strongly impacted by the anti-aliasing filter? (This varies from vendor to vendor.)

For many years it was very difficult to transfer data electronically. I remember well our first successful effort to use the Kermit protocol to transfer modal data from the lab to an FEA computer. Today this is relatively simple, but we still run into problems with 'proprietary' file formats and a general lack of standardization. Even the Universal File Format (UFF) has not turned out to be universal. Randy Allemang, in a recent editorial, described some efforts to fix the problem. I hope they are successful. One point worth mentioning here is that we have frequently run into scaling issues when data are downloaded to spreadsheets. Is the spectrum amplitude or energy normalized? Analyzer software will switch between scaling conventions depending, for example, on whether one or two cursors are used. Ultimately this problem, like many others, needs to be addressed by better documentation and training.

Our early experience with modal analysis led us to the conclusion that experimental technique was as important, perhaps even more important, than software. We thought that bodies-in-prime (welded sheet metal body with fixed glass) should be simple to test and analyze. However, we found that getting good results required various improvements in technique such as mass-loading planned accelerometer locations and carefully removing all rattles. Experience taught us that all unitized vehicle bodies have essentially the same modes but at different frequencies. This enabled us to optimize force input locations and to develop checks to ensure we had all the relevant modes. Finally we had a standard test, complete with data and analysis quality checks (reciprocity, modal mass, MAC, etc.). We were even able to relate dynamic modes to the usual auto industry bending and torsion tests. Curiously, analysis software improvements did not improve analysis quality, but did dramatically cut analysis time.

With this success under our belts we took on the more difficult task of determining the modes of the "trimmed body," i.e., the complete body with doors, seats, etc. These modes directly affect vehicle NVH evaluations. Some important local modes, such as those of the steering column, are easily found, but good definition of the important 'overall' bending and torsion modes proved difficult due to the large number of 'local' modes at neighboring frequencies. As a result, measurement and simulation will usually produce several overall bending and torsion modes. The problem is more in experimental technique and interpretation than in analysis. Improved modal analysis software only results in our faster confusion.

How can we improve the test and analysis of complex systems? I think that we need improved understanding of particular systems such as vehicle bodies, which could result from combined test and FEA studies. For example, an FEA body model could be simplified by representing local structure (such as doors) as distributed mass and stiffness. The underlying overall modes would then be clearly seen. The complexity of the 'real' structure could be re-introduced piecemeal to clarify its effects. Finally the model could be used to generate transfer functions to be analyzed using the laboratory software (of course noise should be added). Since we know the modes that produced the data, we could thus validate the software performance, understand the results and ultimately achieve modal enlightenment.

Try these ideas in your own workplace and on your own problems. SV

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