EDITORIAL

Mathematical Modeling

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If you have a few minutes, I would like you to join me on a small, thought-experiment journey. These are always the most cost-effective and sometimes even useful moments engineers can spend. I don't promise you anything concrete as a result, but perhaps some may find it diverting.

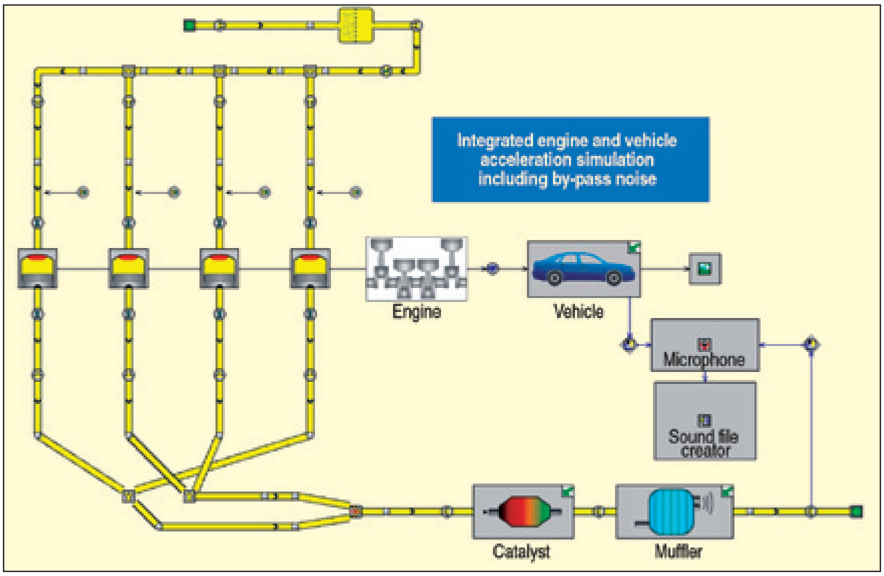
It is an old saying in our profession (told to me many years ago when I was starting out on practical engineering work) that we should learn from mistakes – preferably those made by other people. This has been confirmed by nearly 50 years of personal activity involved with research, design, development and some manufacturing, mostly in the automotive arena.

Part of the excitement of engineering is creating new solutions but it is still nearly always true that there is little really new under the sun. So what we are doing, most of the time, is finding new ways of doing the same thing, with a different stress on various parts of the equation. How we do this with some new materials and new techniques is the material that makes life interesting. With that as a starting point, I want to look at one aspect that has been the largest change in my career – *mathematical modelling*.

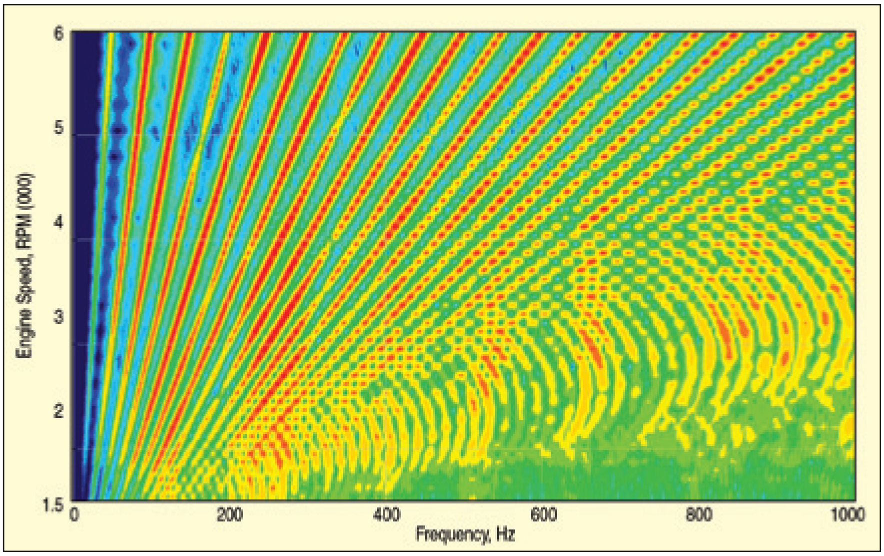
It was the thought that when I started out in engine design initially, there were hardly any tools that were in common use, other than intelligent examination of what had been done before and imaginative use of possible alternatives. One of the main design tools at the start of the 1970s was a set of guides that were jealously guarded and applied with care, mostly based on the size ratios of various components. Known as the "design bible," these pages were the composite distilled wisdom of many years' experience from many people, both designers and test engineers, together with practical results of what worked in practice and what did not.

There were indeed some calculations that could be done on some elements in a design, but the overall complexity of a complete engine system was far beyond the scope and time available for a design. Despite this, or maybe because of it, there were many adventurous steps taken. Statistically, it was true that the majority of the designs failed – in that they did not reach a production stage. This would be seen as a scandalous waste of effort and resources today. But at the time. there was little alternative and the economic balance of many things, including engineering design, was very different. (A review of that would be a very different matter.)

As an illustration of where mathematical modelling was in the acoustics space, some of the first systematic engine exhaust system studies were starting in the late '60s, and a few doctorate studies resulted in some predictive code that was available for license in the early '70s. Although it proved to be a useful tool in some ways, it was far from being a reliable design aid.



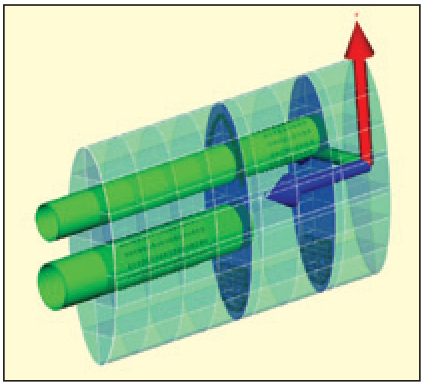
An integrated model of engine, vehicle and exhaust system in GT-POWER/GT-SUITE that predicts the transient acceleration of the vehicle along with the pass-by noise that emanates from the exhaust pipe. In addition to typical output, like Campbell diagrams, a sound file in WAV format is created so one can listen to the sound of the vehicle before it is built.



A contour plot (commonly known as a Campbell diagram) of exhaust system noise produced by GT-POWER/GT-SUITE using the same format of plots produced in test cells.

Similarly, we were scratching the surface of understanding engine noise radiation in terms of driving sources and vibration response. By the 1980s, we had the beginnings of some useful analysis tools and a sight of what would be needed for actual design for structural components. Life began to get "interesting" in the choppy waters at the confluence of both time/cost pressures mixed with reliable predictive codes. A cynic might observe that we are still at a stage where the waters are not yet entirely suitable for safe navigation.

On to the thought experiment, then, having set out the history. What if we had a set of mathematical modelling tools that enabled us to feel our way through the tangled undergrowth of power train (real engine and transmission) design features and to obtain reliable noise and vibration predictions? How would we best use such tools?



Model of a muffler with three chambers discretized in GEM-3D using a mesh of quasi-3D flow elements to predict the multi-dimensional acoustic attenuation of engine exhaust noise as it passes through the muffler. Modeling elements are designated by white outlines in the shells.

The engineering approach can be separated into the conservative approach, extending gradually from known territory and the innovative, where we might examine entirely novel mechanical options.

The questions that start off our journey are such as the reliability of the projections, the range of applicability and the time involved in setting up both the initial design and the checking of results.

What is the main priority in our modelling project? Is it the production of a design that meets the specification in all areas or maybe it is a range of answers that the designer then has to examine to make a selection of that which meets the maximum number of selection criteria.

Wait, who said anything about criteria? Who has to specify both a primary set of requirements and then an additional set of desirable features? Is this a different way of designing, or is it merely bringing out to the bright light of day those previously hidden working processes that designers did internally, often without any conscious mention or even awareness of them?

It seems clear that today we have a range of analysis and modelling tools that are capable of sufficient accuracy to provide a different approach to the old model of "design," where a specification is drawn up and a solution eventually emerges. We can now extend the design process in both directions, so that specification process is more complete and also the design that emerges can be tailored more closely to the optimum.

The current state of the art in acoustic modelling makes virtual experimentation both fast and reliable. Even the optimization of complex volumes used for intake systems is now accomplished, as these Gamma Technologies results illustrate.

In some areas of engineering, it was once an objective to have a design with a target production volume of one unit allowing the ultimate in customization. In the automotive mass-market, this may not be an appropriate methodology, but some aspects of the abilities we have to design, rather than guess at a solution, allow us to have confidence in a useful output.

Pass-by noise requirements creep down inexorably, and we face the challenges of electrified vehicles, as well as those with internal combustion engines achieving very high fuel economy. The need to use the best tools and the best imagination becomes clearer each day. It is just what to do that remains a challenge! S/V

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