EDITORIAL

It's the System!

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I am quite certain that over the years, many experts have taken a run at communicating the importance of a "systems" approach to solving noise and vibration problems. The collection of words here is my own effort at this. I thought it would be helpful to recount a story that happened to me as a young noise and vibration engineer and had a profound impact on the way I subsequently viewed solving noise and vibration problems.

In 1997, an automotive OEM had developed a new model for introduction into the marketplace, and it was a major restyling of the previous model. The basic architecture of the vehicle was unchanged from the previous model, but the product managers decided that a much more aerodynamic look was appropriate. One of the many features of this new "aero look" was a very long and shallow sloped back window (or "backlight" as it's called at the OEMs). This change alone directly resulted in a most unexpected steering wheel vibration problem during idle conditions. I'll state that again: The change in the backlight design directly caused a vibration problem in the steering wheel. At first glance, this simply made no sense. Making the situation worse was that the problem was not discovered until prototype vehicles were built, at which point making major changes was nearly impossible.

The vibration problem was a steering wheel vibration at idle, especially while in gear and with a full accessory load (A/C, headlights, blower motor, etc.). This particular vehicle had a V6 engine which fires at three times the crank rotation speed (third order). With an engine idle speed of 650 RPM, this resulted in an excitation frequency of 30 Hz. This will become important later in the story.

When the vibration problem was first discovered on the prototypes, no one really understood how this could have happened, since the basic underbody and general architecture of the vehicle were the same as the previous model, which did not have this idle vibration problem. It was only after a lengthy investigation that the connection to the styling change in the rear backlight was discovered. The following is a basic explanation of the root cause of this vibration problem.

The styling change to the rear backlight created a much larger surface area that required a significantly higher number of backlight heating elements. The increased heat demand forced the alternator to put out much more power when the rear defroster was turned on compared to the previous model. This created a problem for the battery as explained below.

Automotive OEMs have a requirement regarding the vehicle charging system that forces the system to never allow the battery to discharge while the engine is running. This means that under no circumstances can the alternator output be allowed to drop below the demands of the electrical load in the vehicle. If this were to be allowed, the vehicle could theoretically drain the battery over time – even while the vehicle is running! The worst-case scenario for this is a vehicle sitting at idle with all major electrical systems on full – headlights on high beams, windshield wipers on high, HVAC blower motor on high, A/C compressor engaged, rear defroster on, and brake lights on. This is a common experience for those who live in a cold, wet climate.

Back to the vibration problem. It was discovered by the team responsible for the charging system that the additional load from the rear defroster's increased demand would exceed the alternator's output at idle and at full accessory load. They evaluated two options:

1. Change the alternator pulley diameter, effectively speeding up the alternator and creating more power for the same engine RPM.
2. Increasing the engine RPM.

Option 1 was ruled out due to durability concerns of the alternator at high engine speeds and also due to past experience with unacceptable alternator noise at high engine speeds.

Option 2 was chosen without much fanfare. The charging team tested and released an engine idle RPM increase from 600 RPM to 650 RPM. This decision occurred during the normal "engine calibration" phase of the vehicle program, which generally occurs late in the design phase so that design changes are not possible (and usually not needed). The idle speed change was accompanied by a myriad of other engine calibration tweaks that were routine in nature. What no one knew was that lurking in that idle speed change decision was a vibration problem just waiting to be unleashed!

Here is the final and critical connection: The new 650 RPM idle speed increased the excitation frequency of the engine at idle from 30 Hz to 32.5 Hz, which was the exact frequency at which a major bending mode of the body structure was found. This body bending resonance had a very specific mode shape that pivoted about the "cowl" (the structure at the base of the windshield) to which the steering column was attached. This pivoting motion acted like a crank on the steering column and drove the steering column into a vertical up/down motion as the body went through its bending mode, finally creating the steering vibration.

So in summary, a larger backlight:

- created the need for increased defrosting elements,
- which increased the load on the alternator,
- which drove an increase in idle speed,
- which lined up engine third-order idle excitation frequencies with the major bending mode of the body,
- which drove the steering column into unwanted vibration.

Who would have guessed?

The irony in this story is that body structure engineers are always trying to achieve higher and higher levels of stiffness (higher and higher modal frequencies), and during the development of the vehicle architecture, great effort and cost were put into achieving a body bending mode above 30 Hz. The body engineers were rightfully proud that they had achieved this (in fact they made it all the way to 32.5 Hz), but they had no idea that the larger backlight was going to bite them.

As a matter of interest, the solution to this problem was a tuned mass damper (chunk of lead on rubber springs) mounted behind the airbag module in the steering wheel, which was tuned to exactly 32.5 Hz. The effectiveness of this particular damper (and tuned mass dampers in general) is a subject for another story.

It seems to me that we "western-trained" engineers tend to view problem solving in a deep but sometimes narrow mindset. I know I was guilty of this in my early engineering career. It's an easy trap to fall into at that age, fresh out of school and armed with an arsenal of theoretical skills and a deep desire to compartmentalize everything. Nonetheless, I am sure many of you have heard references to the differences between "eastern" and "western" philosophies. They say that eastern thinking is more "holistic" and less compartmentalized then western thinking. I believe there is some truth to that, and I think it can be applied to our problem-solving mindset when working with noise and vibration solutions.

In fact, while reading a book recently by a famous "holistic" medical doctor (Dr. Andrew Weil), I came across this passage on the human body's healing system:

"The healing system is a functional system of the body, not a structural component like the nervous system or the musculoskeletal system. Western medicine focuses more on structure than on function, with the result that conventional doctors learn a great deal about the body's structural systems and less about functional ones.

Of course, in some cases – digestion and circulation, for example – structure and function are synonymous, but because the healing system does not correlate neatly with any one set of body structures, I cannot produce a line drawing of the healing system in a way that I could of the digestive system. The function of healing depends on the operation of all the systems known to Western medicine . . .”

Dr. Andrew Weil M.D.
Eight Weeks to Optimum Health
Alfred K. Knopf, New York, 1997

I was struck by the similarity between the medical and engineering worlds, especially the eastern/western mindset and how it applies to "systems" thinking. So I rewrote this section and inserted terminology normally used in the world of automotive noise and vibration:

"NVH is a functional system of the vehicle, not a structural component like the electrical system or the body structure. Conventional engineering focuses more on structure than on function, with the result that conventional engineers learn a great deal about the vehicle's structural systems and less about functional ones. Of course, in some cases – cooling and emissions, for example – structure and function are synonymous, but because NVH does not correlate neatly with any one set of vehicle structures, I cannot produce a line drawing of NVH in a way that I could of the cooling system. The function of NVH depends on the operation of all the systems known to conventional engineering . . ." Perfect! I couldn't have said it any better.

The moral of all this is that engineering solutions for complex systems requires the noise and vibration control engineer to be thinking "holistically" and looking for system interactions that lurk outside what is directly known. But thinking holistically does not mean that we should abandon our technical and organized approaches. On the contrary, methodical and compartmentalized solution methods are extremely valuable. Like most things in life, the best solutions come from a balanced approach where both methods are woven seamlessly throughout the engineering process. SV

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