Electric Vehicles Need Quieter Gears

Mark Findlay

For Mark Findlay of UK specialist driveline consultancy Drive System Design, reducing gear noise to suit the low noise levels in an electric vehicle cabin has meant throwing away the rule book.

The high-speed electric motor in an electric vehicle (EV) usually requires a train of reduction gears to achieve suitable road wheel speeds, while the most efficient EVs also have multi-speed, geared transmissions. With no combustion engine to mask the sound, it has become critical for customer acceptance that these gears achieve new standards of silent operation, and that has meant applying new design approaches.

Traditional Methods Prove Inadequate

Historically, designers have selected the gear macro geometry to provide the required durability with a specified duty cycle, and then looked to the micro geometry to deliver satisfactory refinement. Old rules-of-thumb — such as choosing overlap ratios and total contact ratios with values just higher than integer numbers — are still touted as "safe" guidelines for low-noise designs in some quarters. The inadequacy of this method has been thoroughly exposed by the demands of the EV industry where a modern, systems approach is delivering a promising combination of operational refinement and robustness to manufacturing tolerances.

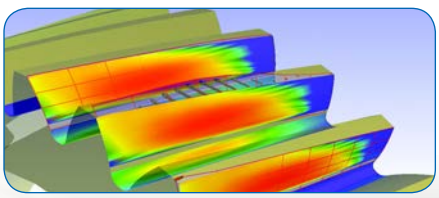
The systems approach considers the component, not in isolation, but as an integral part of a wider system in which it interacts with other parts. It generates a more complete understanding of the issues, and prompts solutions that may sometimes be counter-intuitive. For example, reducing the helix angle on a gear can, by reducing thrust at the mesh, lead to better alignment through reduced deflection, imparting better noise performance despite the apparent loss of contact ratio. Effective management of misalignment and deflection makes possible highly successful designs using contact ratios below the traditional norms for helical gears in mainstream automotive applications.

By correctly specifying the macro geometry — and thus satisfying the requirements for durability, good NVH and high efficiency — the need for sophisticated or complex micro geometry can be eliminated, making the gears much more forgiving in manufacture. The challenge is to identify the appropriate macro geometry.

Whatever the geometry — as the teeth deflect, any meshing pair will generate excitation from transmission error under load. The response of the system to this excitation, including its harmonic content, is just as important as the gear geometry in achieving a refined product. A systems approach can also help address this aspect of the design.

System-Level Interactions

At Drive System Design, when a noise issue in a transmission or axle is investigated, we model the whole system as far as the points where it mounts to the vehicle in order to identify whether the



problem is caused by the response of the casings or mountings to the excitation coming from the gear mesh. This explains why gear noise can be so difficult to eradicate by changes to the gear geometry; i.e. — the real culprit is a system -level interaction — not a component-level "defect."

Every element of a system has a number of potential modes of vibration, each at a characteristic frequen-

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cy. By the time we include all the gears, shafts, bearings, casings and mountings in a typical system, we have a huge potential for interaction where different modes align with each other. The use of sophisticated analytical tools, such as *MASTA* software, allows us to identify potential issues and separate the system modes to avoid undesirable responses, detected as unwanted noise by the observer.

In practice, this often means that a noise concern that the client perceives as a gear mesh issue is actually eliminated by measures such as adding stiffening ribs to a transmission casing or re-specifying the mounting bush characteristics of an axle assembly. The effect on production costs is usually insignificant, and the investigation may even uncover the potential to use a more economical manufacturing route. (A recent project for a client investigated the prospects for replacing helical gears with spur gears, so great had been the noise reduction.)

Though it has taken the particular needs of EV manufacturers to compel the automotive industry to take note of the value of using a systems approach to gear design, the benefits can be applied to many other applications.

Keep in mind that specifying increasingly high gear quality or complex micro geometry in order to address a noise concern will not only add cost, it may not work. So the next time a customer tells you your gears are too noisy, and asks for suggestions, it may be time for them to take a systems approach to the problem. **PTE**

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