The Modern Approach to Transmission System Design and Analysis

Jamie Pears

Over the last 15 years, there has been significant growth in the number of transmission types as well as their complexity: manual, conventional automatic, dual clutch, automated manual, continuously variable, split power and pure EV transmissions. Alongside this, most manufacturers are now simultaneously developing conventional, hybrid and all-electric vehicles, with each type requiring different driveline architectures.

A continuous drive to deliver optimal efficiency alongside reduced weight and cost also means that newer powertrains feature much closer integration of the gearbox, prime mover and energy recovery systems and rely on sophisticated control systems to ensure optimum performance and efficiency at all times.

This shift in technical complexity has occurred against a backdrop of increased competition and demands for great efficiency, as well as a need to comply with changing legislative and industry standards. More than ever, vehicle manufacturers must innovate and bring to market powertrains that are comparatively unproven.

For the engineering teams tasked with developing these new powertrains, resources are being pushed harder than ever, and development processes are now very much under scrutiny.

Typically, manufacturers have used a range of individual CAE software tools and methods to simulate and design separate components such as gears, meshes, gear microgeometry, shafts and bearings.

Whilst the sophistication and accuracy of these tools are not in question, the fact that many calculations are made without considering the effects of the entire system can lead to later problems during the manufacturing process, which in turn can prove incredibly time consuming and expensive to correct. For example, powertrain noise and vibration issues might go undetected until the first hardware prototypes have been tested.

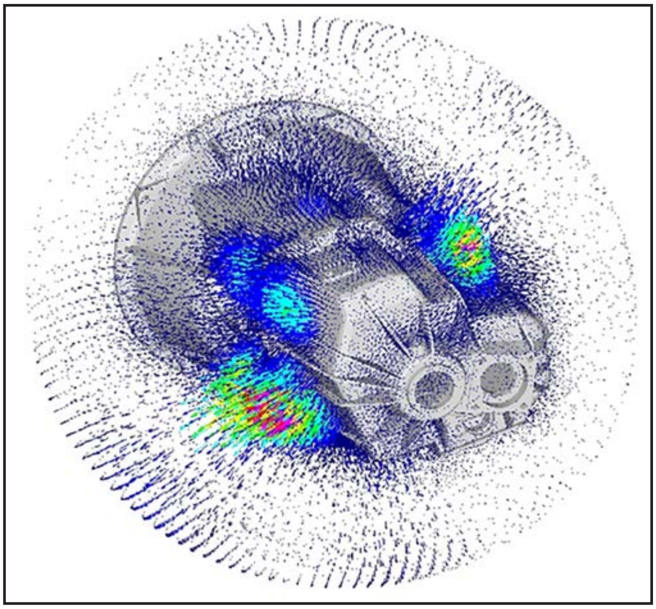

Figure 1 **Acoustic radiation predicted using results generated by RomaxDesigner.**

The transfer of data (or lack thereof) between different design and analysis tools can compound the problem. In some cases, basic concept design changes can take weeks to ripple through various departments, often requiring manual updating of models, which is both slow and error prone. This can be a major hindrance to the creation of optimal, cost-effective designs.

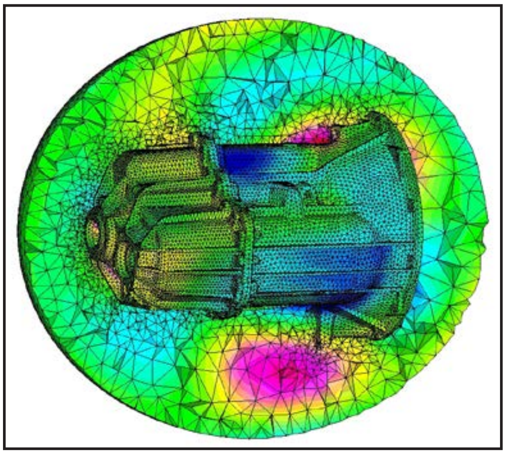

Figure 2 **Acoustic radiation predicted using results generated by RomaxDesigner.**

Component-level software tools have traditionally been unable to provide the over-arching system-level analysis needed within modern integrated design approaches. Many manufacturers recognize that this critical issue needs to be addressed, but when it comes to implementing a strategy to achieve this, it can be a case of "easier said than done."

Here are some examples of the actions you can take to address real-world challenges posed in the design and development process:

Pressure for Faster and Lower-Cost Development

Cost reduction and faster time-to-market are becoming the mantra for today's driveline engineers. Carmakers are requiring shorter and cheaper development cycles, meaning less time to work and a heightened pressure from senior management to get things right the first time. The fallout from this means design and analysis phases must be more efficient and more streamlined.

In order to address this, it is imperative that action is taken during the earliest parts of the design and analysis phase, widely identified as the key area in which process improvements can be made. Traditionally, the earliest stages of production are carried out in isolation with prototypes tested and problems fixed later during the production process. The fallout from this includes slow development cycles, high development costs, opportunity for miscommunication and errors, and limited opportunity for innovation.

Romax's Right First Time approach aims to update designs early on in the design process, where changes can be made with comparative ease, and in turn minimize late changes in the design and production process. In order to achieve this, the developers at Romax have identified six critical development stages:

- Educate & Evangelize: Senior management up to the highest levels need to understand the benefits provided by early analysis and its strategic importance in design and development
- Assess: Firms must complete a full audit of their design and development process – to understand the scale of the challenge and better target activity
- Identify: It's important to find the "quick win" areas where analysis can add immediate value
- Implement: Organizations must deploy appropriate analysis tools in the area(s) identified – and do so with commitment based on senior management buy-in and sponsorship
- Focus: Firms must ensure they have effective analysis tools at the concept design stage that are able to consider layout, center distance, gear and bearing sizing, loads, packaging, NVH, etc.
- Improve: Firms must be prepared to continuously monitor, update and develop their processes – continuous improvement will consolidate and extend the gains being made

Providing more focused analysis during the earliest planning stages enables comparisons to be made with previous designs and with competitive products more easily. For the manufacturers, this will help determine more realistic target setting as well as allowing them to ensure that any changes can be made quickly and efficiently with minimal long-term impact.

Addressing Demands for Improved Performance

Modern-day consumers are conditioned to constantly expect more power, better performance, more features, a smaller carbon footprint, and all for the same cost or less. The result is increased pressure to ensure that any potential design targets and product criteria do not clash.

Across an automotive transmission, engineers have to balance conflicting requirements of efficiency and noise, while reducing weight without compromising durability. All such requirements are interdependent, and therefore it's imperative that before any actions are taken, you are able to consider the impact on other components within the design chain.

One of the clearest examples of this can be demonstrated when looking at the hybrid and electric vehicle (HEV) markets. As the demand for hybrid and electric vehicles continues to grow, one of the main challenges that manufacturers struggle with is improving noise, vibration, and harshness (NVH).

While the automotive sector has made steps toward improving NVH — thanks to improvements across design, analysis, development and manufacturing processes — challenges still exist for the hybrid and electric vehicles sector. EV and HEV design is altogether a more complex process than designing traditional drivetrains; EVs do not benefit from the "masking" effect of the noise from internal combustion engines, while HEVs represent a particular challenge because vibrations from both the engine and the motor must be considered, along with the interactions between them.

In order to address this, simulation needs to be at the forefront when trying to reduce NVH. Many manufacturers work with finite element analysis and multibody dynamics tools that try to predict vibration response of the drivetrain system. However, these processes can prove to be so time-consuming that they're often only used too late in the design process for the problems to be resolved.

If manufacturers have access to software that can simulate different solutions in the earliest design phase before they are produced, organizations can save vast amounts of cost and time. To support this it is important to ensure companies have the right CAE tools and development processes in place.

Putting this into Practice – GKN Case Study

GKN Driveline has applied Romax Technology software and consulting to focus the optimization of gearbox efficiency in electric motor-driven transmissions without compromising noise and durability.

After identifying the main contributors to power loss, investigating how changes to macro- and micro-geometry would affect efficiency, and optimizing the geared system in *RomaxDesigner*, GKN Driveline manufactured the resulting gears and evaluated experimentally the driveline efficiency. Results showed improvements across the speed and torque range of interest of up to 2 percent without compromising on durability and NVH. This provided valuable insights into how GKN Driveline continuously initiates performance improvements in its customer applications.

Hybrids and EVs: a Market Opportunity

GKN Driveline develops the latest driveshaft and geared component technologies. "During first hype of electrifica-

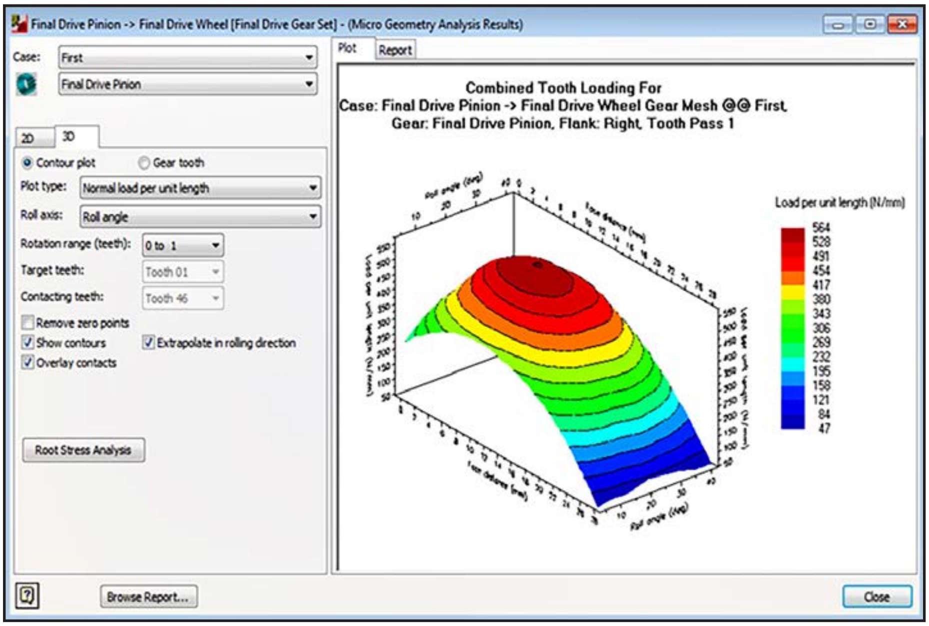

Figure 3 Tooth contact in RomaxDesigner.

tion four to five years ago, everyone talked about quick introduction of battery-electric vehicles," says Theo Gassmann, vice president of Advanced Engineering. "The reality was that the technology wasn't ready — for instance, battery technology is too expensive — and customers aren't ready, particularly regarding range limitations. So the EV market experienced a slow start." He says this led companies to change strategy, embracing a hybrid approach to develop the marketplace.

"GKN Driveline, as market leader in driveline technology, is growing fast in conventional and electrified driveline systems. Coming from AWD systems, we successfully launched transmissions for hybrid and electric vehicles in the last years. Transmission has not been our core business but we utilized our driveline expertise and technologies to expand our portfolio successfully."

Gassmann says transmission issues for EV and HEV are broadly similar to non-electric applications: "Powertrain efficiency, durability and NVH. Differences come regarding the duty cycle and loads, between coast and drive. The driveline is different. And when you have to invest in battery capacity, you don't want to waste energy in the transmission. The biggest challenge is arguably NVH. Missing masking noise from combustion engine and lightweight-design leads to an early focus on NVH improvements."

The Value of the Right Analysis System

Conventional methods to increase transmission efficiency can have adverse effects on durability and quiet running; lack of engine noise in EVs renders current design practices unacceptable. In addition, the pressure to improve efficiency of the eDrive gearbox in GKN Driveline's all-wheel drive hybrids required a new approach. "We've worked with Romax for several years, in a step-by-step process that started in Japan then moved into Germany and Sweden," says Dr. Artur Grunwald, supervisor of Advanced Geared Systems Calculations.

"We saw the value of analyzing the whole system, to identify where the greatest benefits could be gained, then working to balance efficiency, durability and NVH across the entire system.

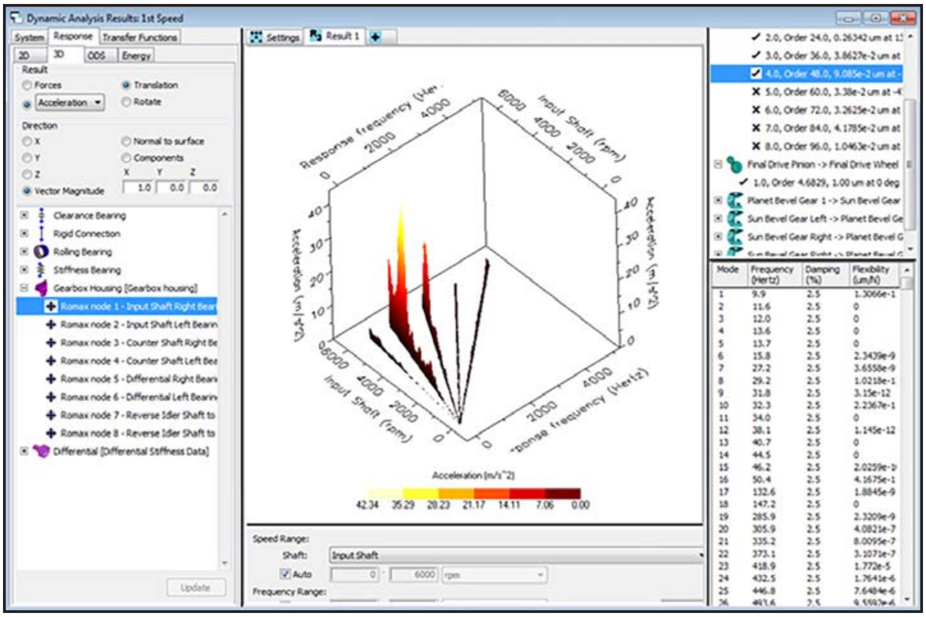

Figure 4 Vibration response calculation in RomaxDesigner.

RomaxDesigner provided the accuracy in modeling and analysis, and we worked with Romax people on a project and consulting basis to learn how to best use the software and apply our engineering expertise.

"We use *RomaxDesigner* for problem solving and for system optimization from concept to production design. Perfect components don't always equal a perfect system when combined. That's why we use *RomaxDesigner*: it shows where you can have the most impact and where the benefits lie. It's one of the few software systems capable of this type of system analysis. Our goal is, systematically, to separate the useful parameters from the possible in order to enable the biggest benefit at acceptable cost level."

Taking a Whole System Approach to Optimize Design

Romax's abilities to improve efficiency were tested in a project that saw an eDrive gearbox connecting an electric drive to the rear axle of a PSA Peugeot Citroen passenger car, with a conventional internal combustion drive connected to the front wheels. The original gearbox was analyzed using *RomaxDesigner*, which explored potential improvements to gear geometries, comparing predicted NVH and durability with the original design.

GKN Driveline manufactured a redesigned set of gears, with extensive tests confirming overall efficiency improvements and, in the all-important coast condition that determines energy recuperation performance, the 1–2 percent gain across the speed and torque range required. "The efficiency of the gearbox was assessed by calculation of the component losses from gears, bearings, seals and oil churning," Dr. Grunwald says.

"Efficiency results from the simulation are compared against frictional torque measurements taken during testing under a range of torques and speeds. The methodology used allows advanced parametric studies to be carried out in an all-in-one approach with *RomaxDesigner* to consider the effect of a wide range of design changes on efficiency at the same time as durability and NVH performance."

He adds, "We also have several years' experience of working with Romax people, who have been extremely reliable and professional. We clearly benefit from that valuable experience. As a business, we want to develop a common understanding of simulation issues and use consistent methodologies from concept to production. Our requirement to take a whole-system approach will increase with future projects and applications, and across different regions and product ranges. The way *RomaxDesigner* integrates with other software packages also saves us time. Its ability to provide interfaces and to share results for interpretation by our engineers is another reason we use it internationally."

Gassmann adds, "We're moving into a new era of hybrids and electric cars. Genuinely high-performance products demand the effective application of system know-how from concept to production, so you can find the best possible balance."

Meeting the Demands of a New World

Calls for innovation can be triggered by a variety of factors. It could be from a demand to keep up with competition, a demand to incorporate technology enhancements, or even a demand to satisfy compliance and legislative changes.

In line with this, it is important to understand the impact on not just the internal design process, but also the need to account for external variables.

Probably the best example of this can currently be seen in Europe, notably the EU's plans for addressing growing carbon emissions amongst all passenger vehicles. Currently, the EU has put in place a comprehensive legal framework designed to reduce CO_2 emissions from new light-duty vehicles as part of efforts to ensure it meets greenhouse gas emission reduction targets under the Kyoto Protocol and beyond. Car manufacturers are obliged to ensure that new fleet cars do not emit more than an average of 130 grams of CO_2 per kilometre (g CO_2/Km) by 2015 and 95g by 2021.

The fallout of this has seen major OEMs, led by some of the industry's biggest car manufacturers, actively developing low-carbon, electro-mechanical drivelines and vehicle technologies to address consumer demands while still meeting the requirements of the EU.

While it is reassuring to see positive actions being taken, what often isn't considered is the impact of real-world variables on those early design phases. Earlier this year, a study carried out by Romax in collaboration with Loughborough University in the U.K. revealed that fuel consumption in the automotive industry can differ by as much as 20 percent when comparing real-world drive cycles to that of rig and simulated tests based on legislative drive cycles. This demonstrates the significant variances which exist when it comes to fuel efficiency.

The findings, which stemmed from the impending EU legislations, were part of a three-year investigation into the factors that influence energy consumption across hybrid electric vehicles, and how real-world driving differs from legislative test cycles. The interesting point of note is that the findings clearly demonstrate that while traditional design tools used by manufacturers tend to focus on efficiency against a single drive cycle, they don't account for the robustness of a vehicle's performance against a set of drive cycles or against external factors such as locational influence.

Tests are carried out in a very regimented environment and rarely account for outside influences and as a result, the data achieved from this is rarely put to effective use. In light of this, it is imperative that organizations start to make the most of data streams available to them, and doing so at the earliest points of the concept design stages. Embracing this would dramatically smooth the transition from one drive cycle to another, with significant cost reductions being seen through greater fuel efficiencies.

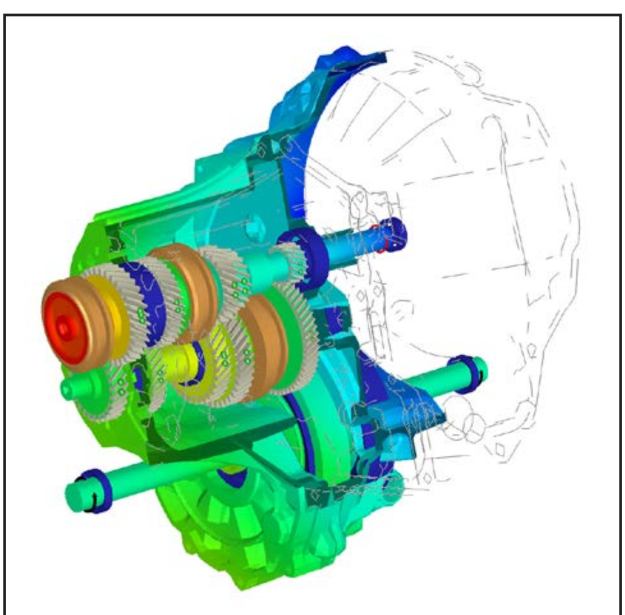

Figure 5 **Mode shape analysis in RomaxDesigner.**

As a final thought, it is important to recognize

that OEMs have and will continue to use a wide array of individual software tools and methods to simulate and design driveline components. The problem that arises is that no matter how good these standalone tools or individual analysis processes are, they often fail to account for unforeseen problems or external variables, when combining components into the complete system.

As demand for faster, smarter and more cost-effective design increases, so does the need to provide innovative simulation tools, which can encapsulate the entire driveline system, allowing for it to be modeled and simulated quickly, accurately, repeatedly and as early in the process as you want.

As a company, this is what we at Romax are committed to providing our customers. Our solutions are designed with the intentions of being integrated into the overall design and development process, with end-to-end tools designed to address all elements from product planning to manufacturing.

This quarter, Romax is announcing its new comprehensive gear design tool, embedded into its *Concept* product. This will enable gear design to be part of a fully integrated system-level design and development process which includes system durability, efficiency and NVH, rather than being the standalone activity which it often is today. See Romax at booth #1402 at Gear Expo 2015, October 20–22 in Detroit.

For more information:
www.romaxtech.com

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