Shake, Rattle and Roll

Software Providers Examine the Dynamic Behavior of Gear Noise

Matthew Jaster, Senior Editor

Some truth about gear noise: Electric motors compared to combustion engines are close to inaudible. For both electric and hybrid vehicles the engine noise that is covering the gear noise is gone, therefore, in low-speeds when tires and wind noise are low, the demands to the gears are much higher concerning noise.

In pure electric cars, gear speeds are typically higher (10,000 rpm vs. 2,000 rpm), which increases the problems with noise, according to Dr. Michael Platten, senior product manager and NVH specialist at Romax Technology. The pressure is on manufacturers to placate gear noise by analyzing data, optimizing gear systems and testing results.

"After decades of optimizing noise of wind turbines and kitchen appliances, the focus switched to electric cars lately. There is now a significant market for battery electric cars, with much higher demands on low-noise gearboxes. In addition, there is always pressure on price in automotive. So, we now need low-cost, low-noise gearboxes," said Dr. Stefan Beermann, CEO at KISSsoft AG.

Meeting Gear Noise Challenges Today

Platten believes there are essentially four main challenges today when looking at gear noise:

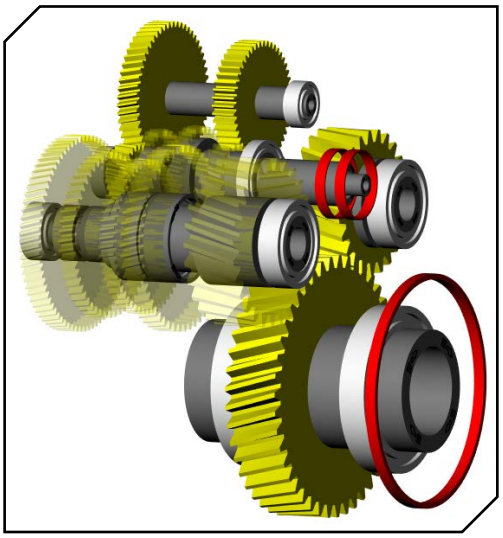
The challenge of reducing product development times and costs while simultaneously meeting the demands of improved noise and vibration quality.

The challenges of electrification in the transportation industry with new powertrain designs and aggressive noise targets.

The challenge of understanding the effects of production variability on gear noise and vibration performance.

The challenge to make everything lightweight in automotive and aerospace sectors which is driven by efficiency concerns, but has a significant impact on gear noise and vibration.

As software solutions continue to increase, gear noise can be better evaluated through virtual, predictive and efficiency coverage of the physics in the overall system, according to Christoph Schweiger, team leader of structural dynamics simulation at AVL.

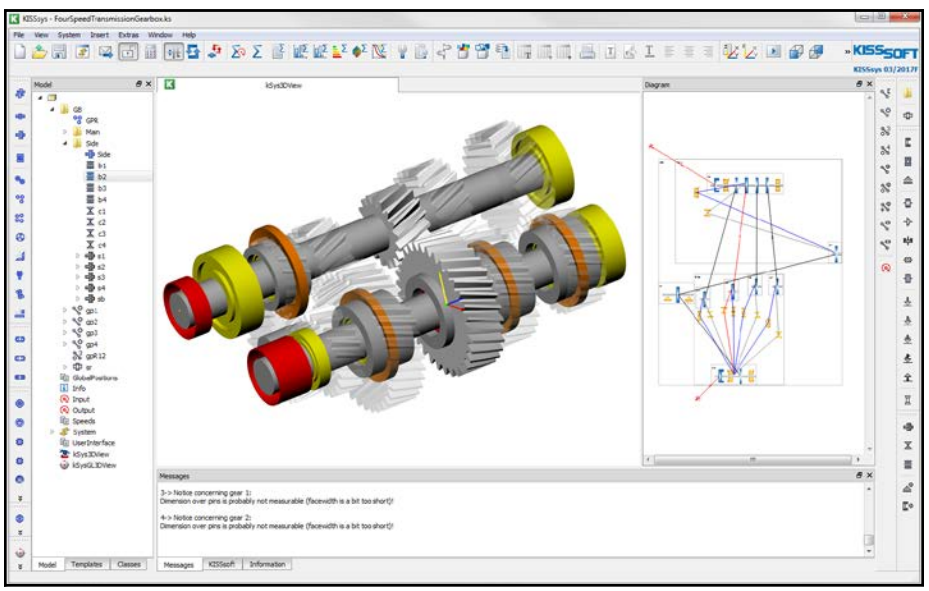


KISSsoft examines the reliability of the system with its software tools.

"You're looking at a variety of things happening inside the transmission, for example, when studying gear rattle," Schweiger said in a recent webinar titled Efficiency and NVH Simulations for Transmissions. "There are repeated impacts caused by the movement of free parts (loose gears, synchronizer rings) within their active backlash. Another important driver is the torque fluctuation from the engine. You need to have a gear contact model, study oil resistance, the roller bearings, shaft flexibility and housing flexibility. All of these things must be considered in detail when calculating gear rattle."

KISSsys, for example, is a gearbox design software. Integrated into the software are assessment functions that evaluate the relevant properties of gear meshes, the most important feature being the contact analysis under load which simulates the flank contact over the whole meshing cycle.

"The important influence factors like all involved stiffnesses (tooth, gear body, shaft, bearing, housing), the exact tooth shape, misalignments and tolerances, are taken into account. Based on these assessment functions, optimizations are



KISSsys includes assessment functions that evaluate the relevant properties of gear meshes which lead engineers to the best solutions.

automated and lead the engineer to the best solutions for their current problems," Beermann said.

To meet the challenge of modelling and simulating the combined electric machine and transmission system, Romax software lets the user build a complete structural model of the full system and analyze the complete dynamic behavior.

"Gear mesh excitation forces are calculated directly in the software and close partnerships with electric machine modelling tools like *MDL Motor-CAD* and *Cobham Opera* allow seamless integration of the electric machine structural model and electromagnetic excitation forces with the transmission model. In this way the effects of the electric machine structure on gear noise can be considered and likewise the effects of the transmission dynamics on the electric machine noise are taken into account," said Platten.

To address the issue of balancing durability and efficiency with noise and vibration performance in the high speed, high duty environment of electric drivelines, Romax's simulation tools provide the ability to analyze and automatically optimize all these performance targets simultaneously. Romax customers like GKN use this within a *Right First Time* development environment to maximize performance and quality of their EV solutions.

"We're moving into a new era of hybrids and electric cars. Genuinely high-performance products demand the effective application of system knowhow from concept to production, so you can find the best possible balance," said Theo Gassmann, vice president, advanced engineering at GKN Driveline.

"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," added Dr. Artur Grunwald, supervisor, advanced geared systems calculations, GKN Driveline.

For understanding the role of gear noise within the context of today's new EV chassis designs and the seemingly infinite range of proposed hybrid and EV layouts, Romax works closely not just with gear and transmission engineers, but also with driveline integration and vehicle NVH teams. By linking to other tools like multibody dynamics and whole-vehicle NVH simulators Romax tools are being used by customers to look at gear whine and rattle under dynamic torque loading and predicting directly how designs sound and feel at the driver's ear.

Schweiger at AVL explained the process of determining gear whine and gear rattle in transmissions.

"The NVH Generation and Transfer process typically begins with an excitation mechanism followed by amplification, damping, transfer and then the response, result and assessment. Our research looks at whine and rattle in everything from passenger cars, trucks and tractors to industrial machinery, wind turbines and aircraft transmissions," said Schweiger.

Simulation & Testing

Testing and simulation play an important part of the process even though many interviewed believe that this data is highly subjective and not always guaranteed.

"With simulations the number of prototype tests is reduced. So, there is a huge gain in speed and cost reduction, if the number of tests can be minimized," Beermann said. "Still, noise is a complicated enough issue, that no simulation can give a 100% guarantee that the predicted noise behavior is true. This means that the final step in the development must be a prototype test."

Simulation is critical to ensure the best noise quality from the start. For too long noise and vibration has been considered as "something you do at the end to make it quiet". Continuous simulation during all stages of the design allows engineers to iron out problems before they become problems.

"It is also the main driver in reducing development time and costs by speeding up design time and reducing prototyping cycles. It avoids the need for major remedial noise treatment late in the design when the opportunities for significant design changes are limited," Platten said.

Platten continues, "Of course, testing still plays a role — we can never eliminate prototyping completely — and in the electric vehicle world, we need to be sure that the simulations we are doing actually work by comparing them with real-world noise and vibration tests. Once engineers have the confidence provided by correlation test, then simulation-led design becomes the norm."

Ultimately the "digital twin" concept is what Romax is aiming for, where almost all of the engineering design process for transmissions and drivelines is test-free and the prototyping phase becomes merely a verification exercise. To achieve this, you need to have engineering design processes — not just for noise and vibration — that work across CAE tools, across departments and even between different organizations (OEMs and suppliers, for example).

"Our strategy is to concentrate our efforts as much on streamlining and automating the process as we do on providing simulation technology," Platten added.

A Systematic Approach

Beerman said that during the design phase, a systematic approach asks for a definition of macro parameters first (for gears that would be parameters such as module, number of teeth, pressure angle) and then a refinement by applying micro modifications, like lead and profile modifications for gears.

"Going to the second step too early means blanking out a large field of potentially much better solutions," Beerman said. "For strength, this is often not so critical, but for the higher demands on low noise gears this might cause insurmountable issues."

At Romax, Platten mentioned the "Right First Time" as a philosophy for CAE-led design.

"Nowhere is this more important than in the consideration of noise and vibration. Design decisions made right at the start — like tooth numbers and contact ratios - have the most impact on noise in the end while details like micro-geometry design that are considered later can only really fine-tune what is already set in stone. It is therefore critical that consideration of gear noise is considered systematically from beginning to end," he said.

When dealing with gear noise in transmissions, Schweiger believes there are always tradeoffs. "Areas such as performance, fuel consumption and emissions, temperature and thermal management, packaging, durability and costs can be affected."

It's essentially a balancing act to get the gearbox to run smoothly, quietly and efficiently while reducing costs and energy consumption. You can't focus on one single area to get the best results. The vibration of the entire system comes into play when evaluating noise and performance, according to Schweiger.

So how can you best identify and analyze noise issues when you may be utilizing different people in different departments that are responsible for NVH and durability?

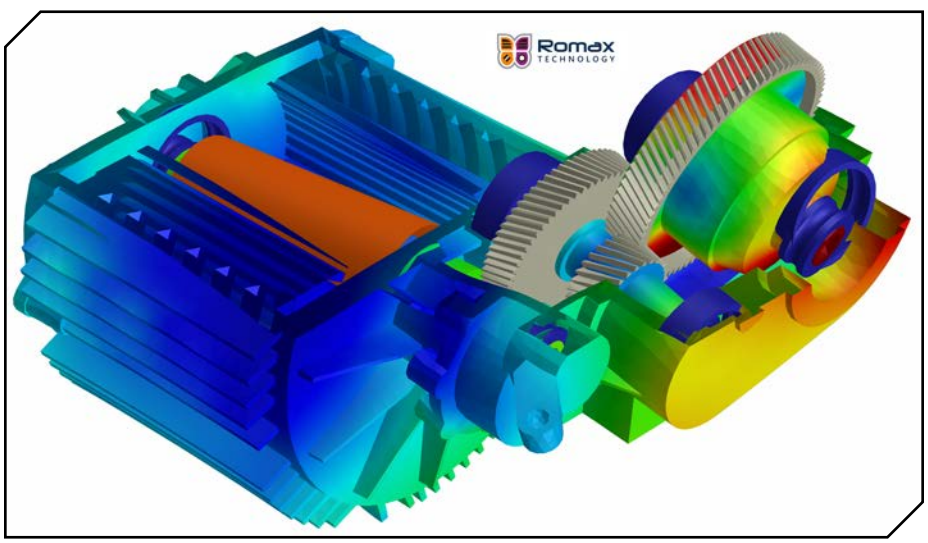
"Those people need to be educated in each other's areas and be provided with the tools that help them to make sure they do no harm to each other's aspects of the design," Platten added. "We must ensure that the processes for modelling and analysis are fast and robustly repeatable."

Selecting the Right Tools

So, the take away here is that it helps if the software toolbox is diverse and the staff is properly trained to utilize it to examine potential noise issues.

KISSsoft, for example, offers public and individual training about methods on how to tackle noise problems with gears.

"And we do noise optimizations for gears ourselves, using these methods. However, it is important to understand, that there is not one optimal way to low noise gears that always works. It is more like an optimization process that might go through several loops. The important part is to understand the mechanisms that generate noise and to know the influence of the parameters controlled by the engineer," Beermann said.



Romax follows a "Right First Time" philosophy for CAE-led design, according to Dr. Michael Platten.

"In KISSsoft, we have integrated tools and algorithms that help with the assessment of gear noise. In addition, we offer interfaces to dedicated vibration software, for deeper analysis. With this, the user gets the best of two worlds, an easy to use gear design software and a software that is specialized on vibrations, but not on gears," he added.

Working alongside the Romax tools for gear whine analysis and electric machine noise, the company also provides interfaces and links to a number of other tools which support design for gear noise and help customers to create integrated and automated CAE processes:

Interfaces for gear contact analysis and transmission error calculation which support our own contact simulations: *OSU Gearlab LDP* for helical gears. *Ansol*, *Gleason CAGE* and *Klinelnberg KIMoS* for bevel and hypoid gears.

Interfaces to FE tools like *MSC Nastran*, *Altair Optistruct*, *Ansys* and *NX Nastran* for pre- and post-processing of components like housings and complex shafts for dynamic simulation of gear noise

Interfaces to acoustic radiation tools like *LMS Virtual.Lab Acoustics*, *MSC Actran* and *Ansol Coustyx*

AVL offers software suites such as *AVL Excite*, software for the simulation of rigid and flexible multi-body dynamics of powertrains. It is a specialized tool that calculates the dynamics, strength, vibration and acoustics of combustion engines, transmissions and conventional or electrified powertrains.

AVL Fire is a CFD simulation tool in the field of combustion analysis. It specializes in the accurate prediction of all IC Engine relevant processes including injection nozzle flow, fuel injection, combustion, emission and exhaust gas aftertreatment. The software also supports the development of electrified powertrains and drivelines.

Collaborate and Innovate

"The best way to meet the multitude of challenges discussed in this article is to tackle issues such as fundamental validation of the methods for simulating gear noise, which have worked previously for conventional drivelines, but which are now being pushed due to increased speed, and the subsequent impact on, for example, gear contact through interactions with tribological factors," Platten said.

Additionally, work is needed to simulate vibration and noise of structures at very high frequencies, where the FE starts to break down, to investigate energy methods which give less detail but provide better ability to make engineering decisions about high frequency behavior and which take into account inherent variabilities at high frequencies.

"For gear noise, Romax has worked with the Gear and Power Transmission Research Laboratory for over 10 years. Researchers at Politecnico di Torino and TU Darmstadt have both also published work on their use of Romax software for simulation of gears in novel applications: the former on optimization methodologies for lightweight gears produced by additive manufacturing techniques using *RomaxDESIGNER* simulation, and the latter on investigating novel concepts for range-extended electric vehicles," Platten said.

The outcome of projects with institutions such as Ohio State's Gear Lab or the FZG in Munich often are the basis for standards and also go into commercial software such as *KISSsoft*.

"In the gear world, the topics of strength, efficiency and noise will always benefit from close cooperation between industry and universities," said Beermann.

All in all, gear noise is just one of many design challenges that pop-up in a variety of industrial applications. The automotive industry is a focal point today as we discuss electric vehicles, mobility and new transmission and efficiency requirements. In a few years, there will be another area where software providers will need to develop new innovative, solutions.

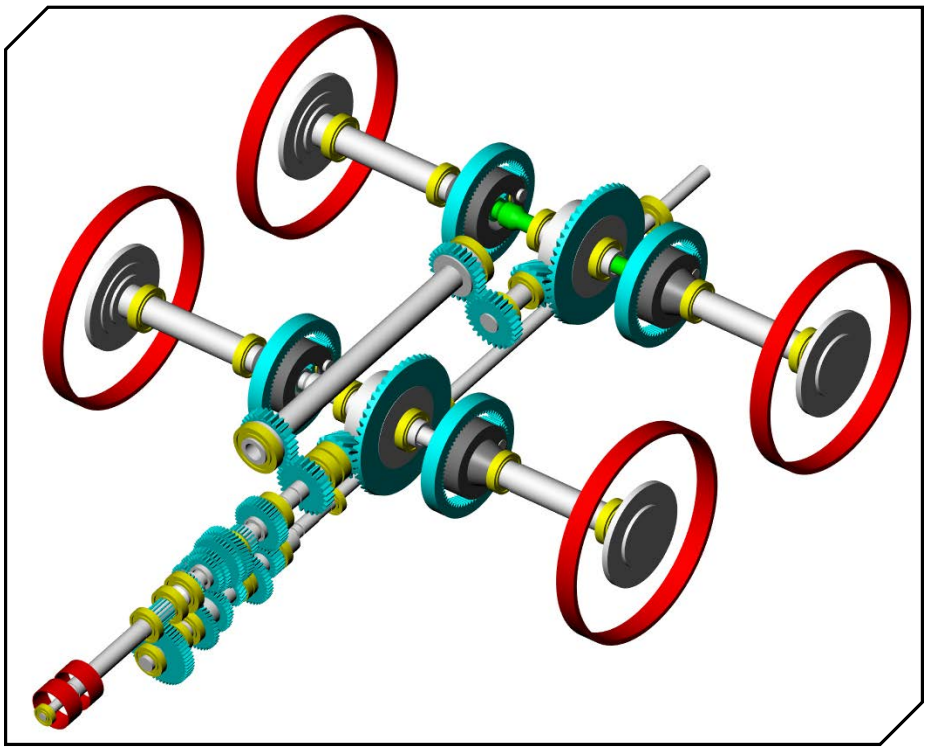
Who knew that being quiet could be quite so complicated?

For more information:

AVL North America
Phone: (734) 459-3426
www.avl.com

KISSsoft AG (Gleason Corporation)
Phone: +41 55 254 20 50
www.kisssoft.ag

Romax Technology
Phone: (248) 220-1201
www.romaxtech.com



After decades of focusing on gear noise in wind turbines and kitchen appliances, the focus has switched to automotive and vehicle applications, according to Dr. Stefan Beermann at KISSsoft.

For Related Articles Search
software
at www.geartechnology.com