HEXAGON

Case study

Wikov

NVH optimisation for an eDrive tram gearbox

Using Romax Spectrum together with embedded capability from Actran, mechanical engineers at Wikov were able to assess their tram gearbox's radiated noise and make changes to the design to improve the NVH performance. By democratising such advanced airborne noise simulation capabilities and bringing them to non-expert users within the design phase of a project, valuable simulation insights can be fed back into the design to bring to market higher quality products more quickly.

Active in mechanical engineering for over 130 years, and specifically focused on gears and mechanical gearboxes for the last 100 years, Wikov have offices across the Czech Republic in Prague, Pilsen, Hronov and Zruč nad Sázavou. Combining state-of-the-art machinery with decades of experience, Wikov manufacture high-end products with progressive design solutions and robust parameters. They operate across multiple industries including rail, power generation, wind energy, marine and mining.

Wikov were working on a gearbox for a tram application, for a West European customer. The gearbox is part of an electro-mechanical system, consisting of an electric motor and a two-stage transmission. Wikov had performed some durability assessments on the tram gearbox, but were coming under pressure from their customer to do more NVH analyses. The customer had a rigid requirement that the gearbox must be no louder than 100 dB (A) in the air, across the whole operating range. Jan Křepela (Head of Research and Development, Wikov) comments: "Our customer told us they would not accept a design emitting more than 100 dB (A).

They were looking for confidence that we could meet this target, and reassurance that the gearbox was not going to be louder than expected in the real-life application."

Typically in Wikov's projects, durability and efficiency targets have higher priority than NVH, and their traditional simulation approach is well suited to optimise for these criteria. Therefore, although Wikov had a strong technical understanding, were fully aware of the NVH background, and had capability for testing, their existing simulation tools were not suitable for assessing NVH as part of a full system simulation. Having been long-term users of Hexagon's general finite element software tools including MSC Nastran and Patran, Wikov reached out to the team to discuss potentially also using Actran, Adams and Romax specifically for drivetrain NVH analysis. Romax was identified to be the tool which would meet Wikov's immediate need. Jan Křepela comments: "It was clear that Romax could offer the type of simulation that we needed. However, we also needed some expert help to support us in obtaining the NVH results against a very quick timeframe. Therefore, we engaged the Hexagon team in doing a consultancy project for us."

Consultancy for NVH optimisation

At the time that Hexagon were brought into the project, the detailed design for the tram gearbox was almost finalised. At this stage, the support that Wikov were looking for was to sign-off the prototype manufacturing, and to achieve confidence in the design's NVH performance. Jan Křepela comments: "Designing a tram gearbox follows quite a different process to automotive applications. It's very rare that we would start from scratch and design from the very early concept level. Typically we derive the topologies from what we have designed before, and make minor changes based on the specific application requirements. In this case, one of the problems we encountered was that we couldn't predict NVH from a vibration as well as from an airborne point of view. We wanted to have a process that would allow us to consider these two sources."

The scope of the project covered simulating the major gearbox components including shafts, gears and bearings and predicting the gear excitations and their impact on NVH. The Hexagon team created a baseline model of the system and provided baseline transmission error results. From this, they calculated the system vibration as well as airborne noise propagation, using the embedded Acoustic Analysis feature (powered by Actran) in Romax Spectrum. Jan Křepela comments: "We were able to relate the airborne noise radiation directly to the operating deflection shapes and the vibration analysis – in doing so, we could capture the motion of the drivetrain and understand what we could do to make actual improvements to the system."

As a result of insights obtained from the simulation, Hexagon sought to identify areas where design improvements could be made to improve the NVH performance, using Romax's in-built automation processes. While Hexagon took responsibility for the gear design mainly on the micro-geometry level, Wikov retained responsibility over the housing design and conducted manual structural optimisations in order to make improvements based on simulation insights. After the design had been updated, the transmission error was calculated again and the vibration, as well as the airborne noise analysis, was rerun. As a result of using the new gearbox housing and gear geometry, improvements were seen in the NVH results.

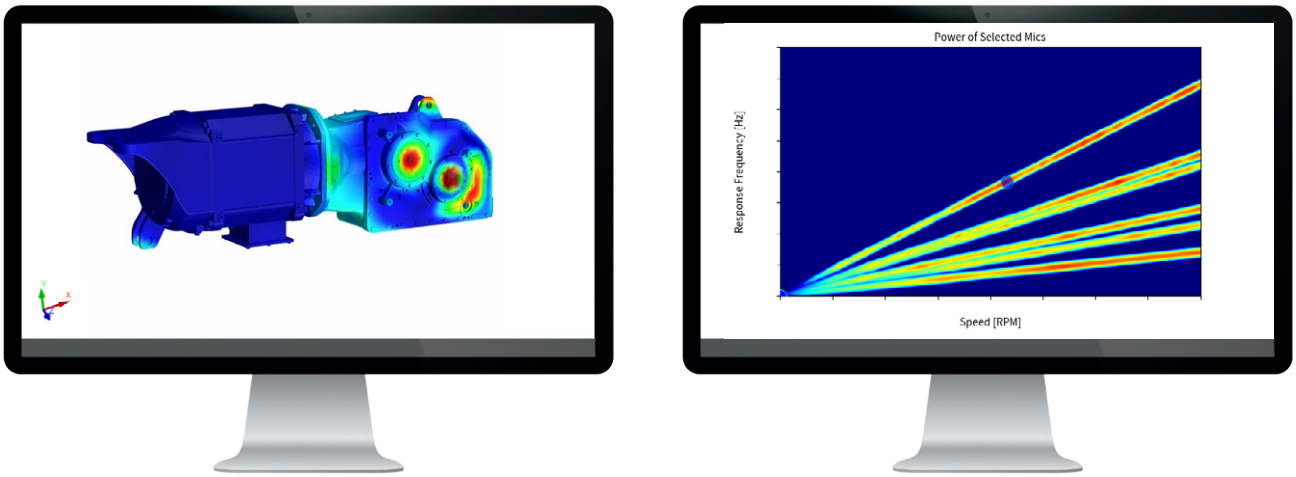

Figure 1. Operating Deflection Shape of Wikov model excited by order 51 at 2160rpm (left) and sound power Campbell diagram (right)

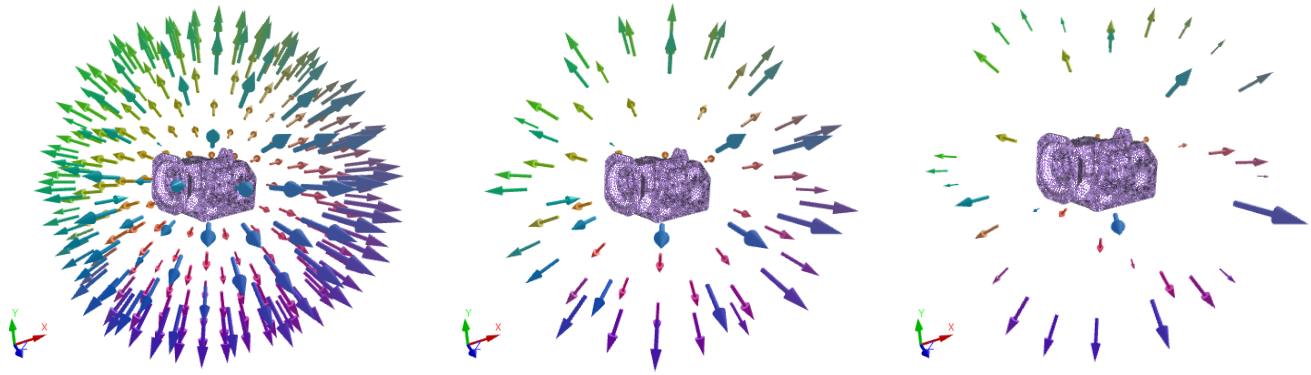

Figure 2. Peak sound power response interpolate 1 (left), interpolate 2 (middle), microphones (right)

As part of studies into the gear design and its impact on the NVH performance, Hexagon identified that the bevel gear set micro geometry design was not optimal. It was thought that resolving these issues could potentially result in NVH gains. Therefore, Hexagon performed a micro geometry optimisation using a combination of Romax tools and KIMoS software, benefitting from the direct data exchange available between the two products.

Jan Křepela comments: "We are very happy with the results of the optimisation. We were already a customer of KIMoS, and the interface between KIMoS and Romax tools was useful for us in terms of improving our processes and facilitating communication with other colleagues and partners. The Hexagon team helped us find improvements that we would not otherwise have found, had it not been for their software and their expert support."

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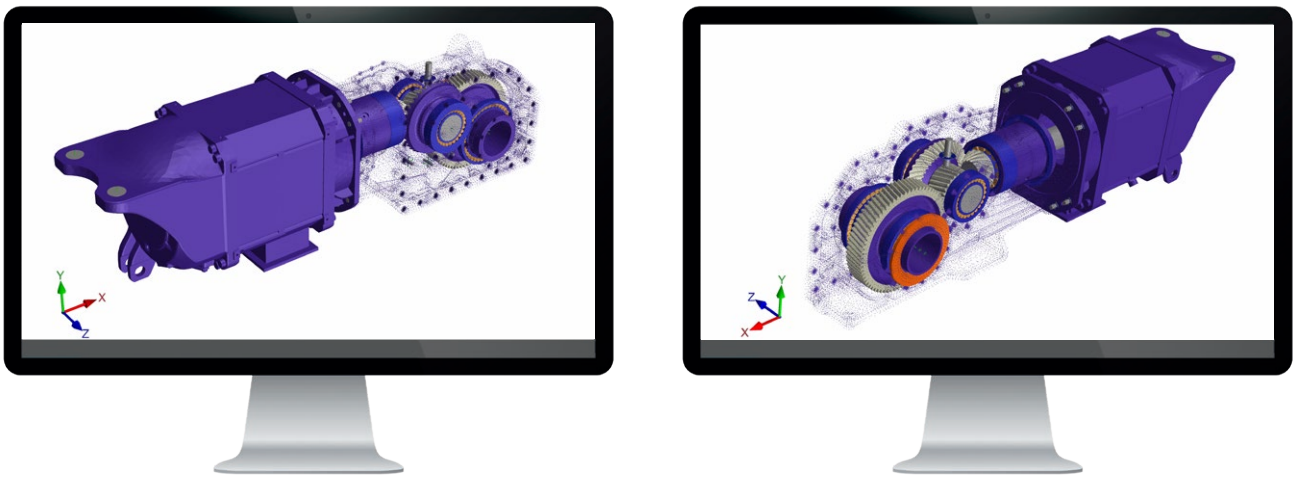

Figure 3. Wikov model in Romax

Correlating the simulation with test

After the project was completed, the next step was to perform testing. When comparing simulation and test, it is critical to take into account what has been considered in the simulation and how it differs from the conditions on the test setup. Particularly when simulating ePowertrain noise, understanding the different conditions and how they may affect the results is an important consideration. The test rig set up may apply different boundary conditions to those which the design will see in the real-life application, though this is not a hindrance since the Romax model can be designed to simulate either condition. In order to ensure differences between testing and simulation were understood and corrections were applied to the model if needed, it was important that Wikov were themselves exposed to the software tools during the consultancy project.

Very good correlation was seen between the physical test and simulation results, as can be seen in Figure 6. Average sound power results were calculated by Romax Spectrum's acoustic analysis tool (green line), and specific operating points were analysed and compared from the simulation and test. Simulation points (in yellow) were calculated through decimal addition of sound power results from 40 microphones distributed in a sphere with the results summed through decibel addition of the six harmonics (three harmonics for two gear sets). Results from the physical testing (in red) were measured using the same loading conditions from the simulation. The strong correlation between the physical test and simulation results increased Wikov's confidence in the accuracy of the simulation model.

“We were pleased to have the opportunity to trial Romax Spectrum and are considering how it will fit into our processes. We are particularly interested in the acoustic analysis capability, and potentially in using the full version of Actran as well. Being able to link together multiple Hexagon tools into a single process truly unlocks the value of this product portfolio. Having a single solution for multiple physics, for durability, efficiency, NVH - this would be an ideal set-up for us.”

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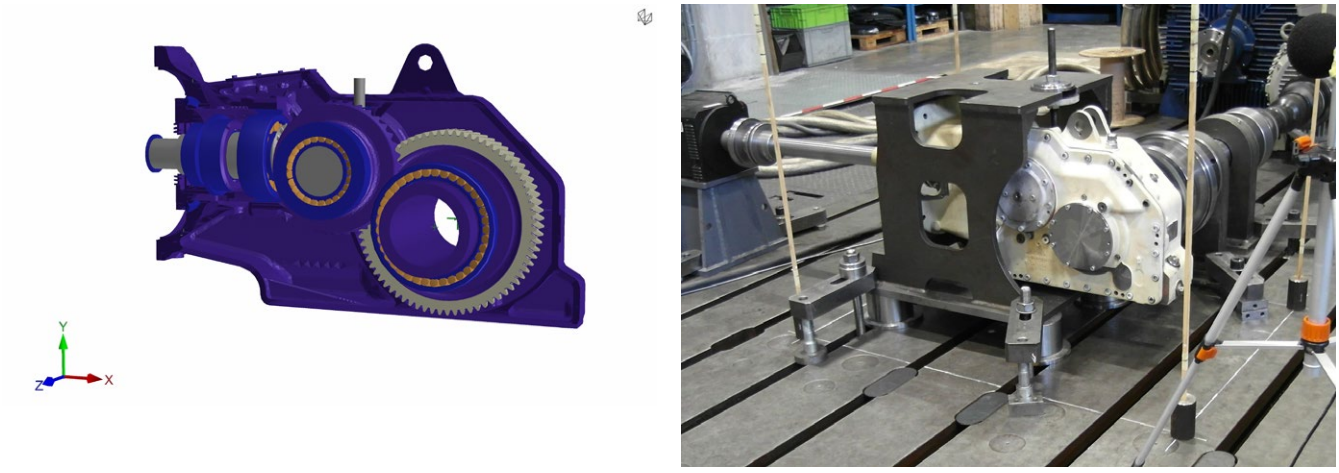

Figure 4. Wikov gearbox simulated in Romax (left) and produced and in test (right)

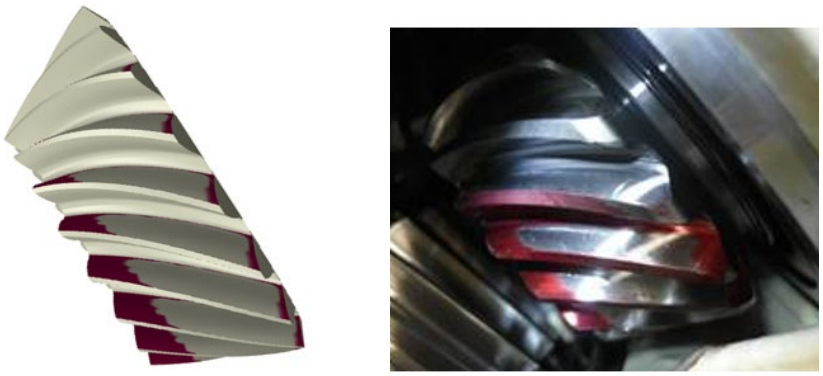

Figure 5. Contact pattern in simulation (left) and in test (right)

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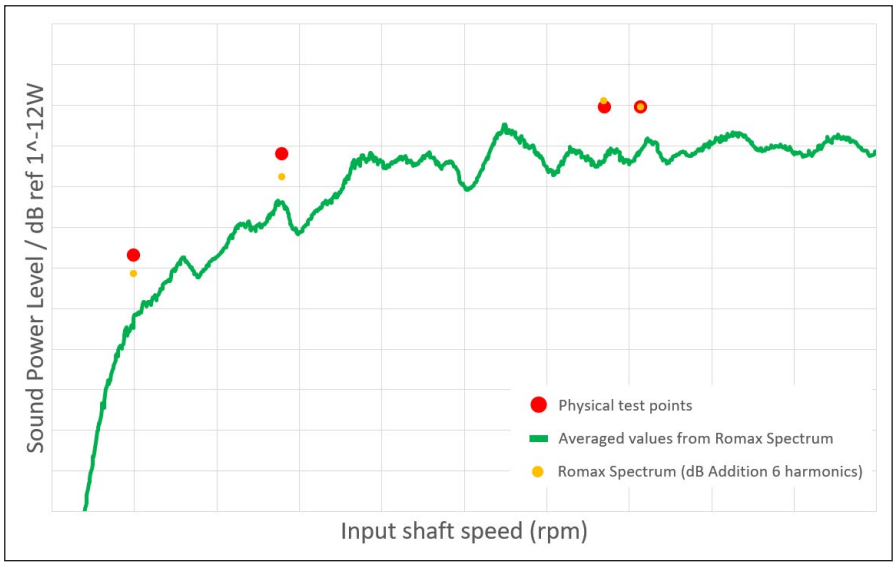

Figure 6. Average sound power results calculated by Romax Spectrum's acoustic analysis tool, showing good correlation with physical test

Future steps

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Following the success of this project, there is scope to perform a second phase, in which the eMotor excitation could be considered alongside the transmission error excitation. Analysing the system integration in such a way, work in which Hexagon have a lot of proven experience, enables engineers to gain a full understanding of noise source contributions to the vehicle, and to make improvements holistically, critical for engineering high-performance next generation drivelines.

Hexagon is a global leader in digital reality solutions, combining sensor, software and autonomous technologies. We are putting data to work to boost efficiency, productivity, quality and safety across industrial, manufacturing, infrastructure, public sector, and mobility applications.

Our technologies are shaping production and people-related ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

Hexagon's Manufacturing Intelligence division provides solutions that use data from design and engineering, production and metrology to make manufacturing smarter. For more information, visit hexagonmi.com.

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