transmission TECHNOLOGY INTERNATIONAL

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Final shift

As automatic transmissions go from strength to strength, is the end really nigh for the trusty manual?

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GEAR CHANGE
The time has come for high-tech EVs to move beyond rudimentary 1- and 2-speed architecture

VIRTUAL REALITY
Will advances in computing power mean that one day soon there will be no need for real-world transmissions testing?

EXCLUSIVE INTERVIEW
In one of his first media outings since leaving GM, FCA's new transmission VP, Jeff Lux, discusses future plans at Fiat-Chrysler

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Gear whine control

Controlling and fine-tuning gears in a virtual CAE environment is fundamental to making further advances in future transmissions

NVH is a key issue in the design and development of modern transmission systems, especially as a combination of regulations and consumer expectations drive demand for reduced noise in all drivetrain components. But how do these problems occur? How can they be controlled? And which CAE software can solve problems efficiently and to the precision required? These are common questions asked by transmission engineers the world over.

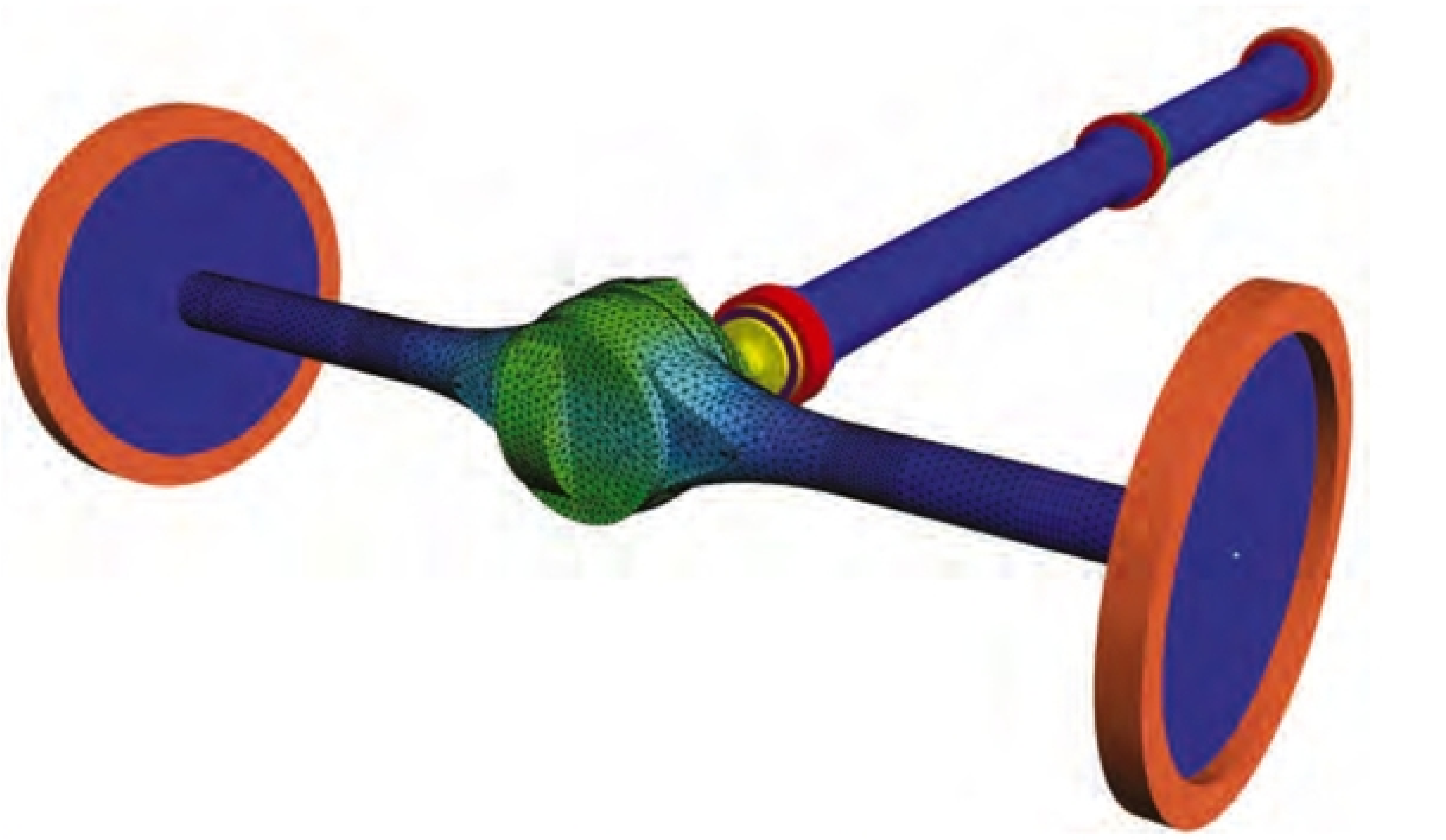
Gear whine is a particular NVH phenomenon that is generated from excitations in gearbox components – most commonly coming from transmission error at engaged gear meshes. In theory, a gear set with a perfect involute profile and totally rigid gears with no misalignment would transfer angular velocity and torque in perfect accordance with the designed ratio. But, in reality no gear is perfect and tooth bending and misalignments caused by system deflections contribute to real-life gear sets not performing ideally, to take one example.

Transmission error is a dynamic relative displacement at the mesh in the line of action caused by these non-ideal meshing conditions. The transmission error dynamically excites the gearbox through a path from the gear mesh, through the shafts and bearings, and on into the gearbox housing.

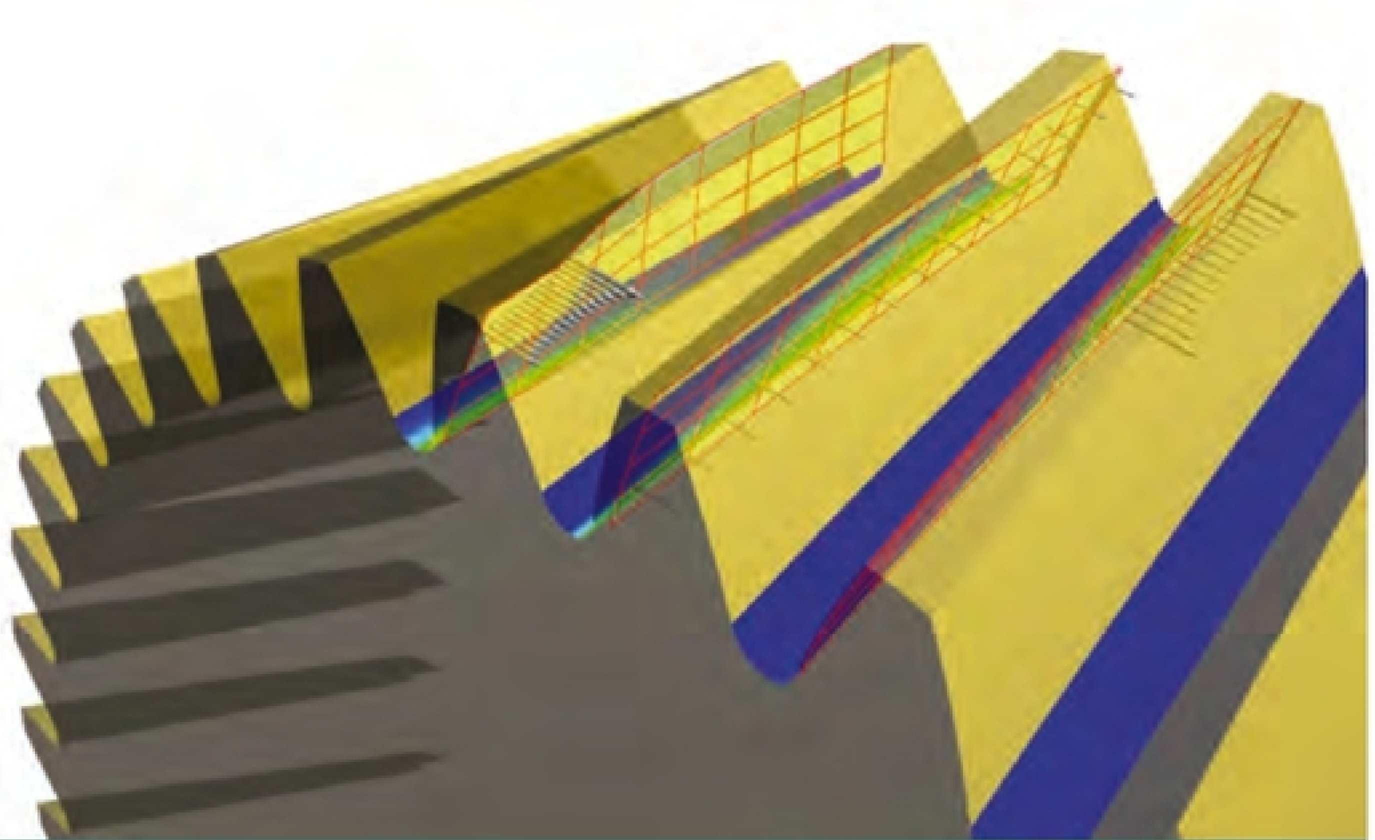
Although controlling transmission error will reduce gear whine, a gear mesh with minimal transmission error may still be a cause of gear whine if the rest of the system is highly sensitive to excitations at tooth passing frequencies.

Modern regulations and rising customer expectations for reduced noise make NVH a key issue for the design and development of new transmissions. As a result, reducing gear whine means controlling both transmission error at gear meshes and a system's susceptibility to excitations caused by such errors.

Transmission designers and engineers troubleshooting gear whine would therefore benefit greatly from tools that can not only predict transmission errors with accuracy, taking into account all contributions from the whole system, but could also predict the dynamic response of the system to excitation at the meshes by transmission error.



An automotive model with casing able to go through design iterations and NVH analysis in MASTA software



A 3D view of advanced loaded tooth contact analysis using the MASTA software

Standalone versus integrated

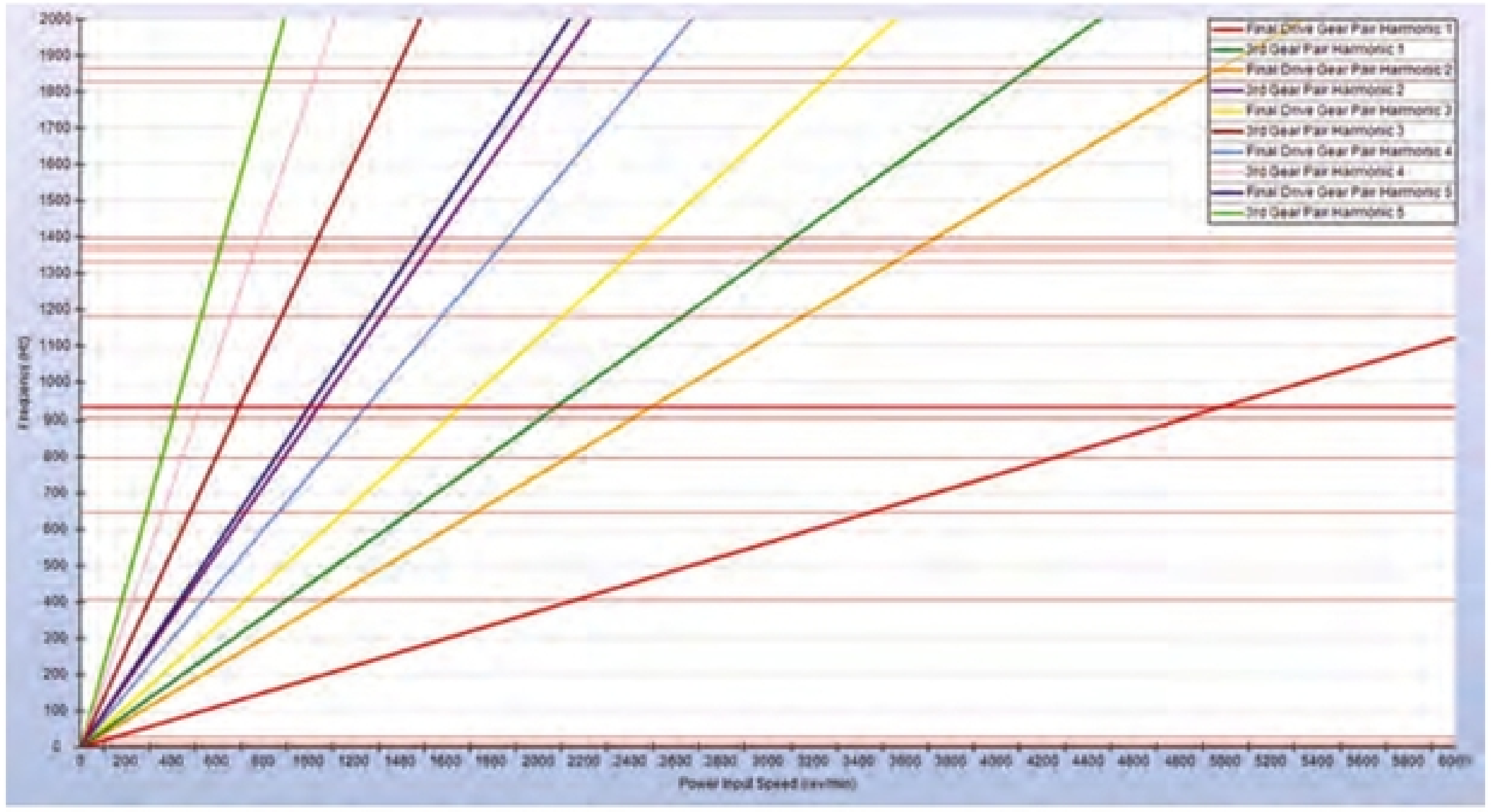
One method would be to perform the transmission error and dynamic analyses using a standalone commercial FEA package. This approach is problematic though, as it would usually require separate models with different levels of fidelity to calculate transmission error and the system's response to it. Further models are very difficult to set up and do not lend themselves well to analyzing the effect of design changes easily and quickly.

On the other hand, integrated CAE software can provide tools for transmission designers and engineers for assessing the potential of excitations across the entire system, while having the flexibility to make complex design changes on the fly and seeing immediate results within an integrated workflow.

A range of methods for analyzing potential noise issues can be used. This includes comprehensive calculation of transmission error, taking into account full system contributions; 3D visualization of system mode shapes that can be animated and contoured with strain/kinetic energy results; Campbell diagrams displaying mesh and shaft harmonics as well as modes in the system; the calculation of dynamic mesh force; and finally, Waterfall/order charts of the dynamic response of the system, such as at accelerometer locations on the transmission housing.

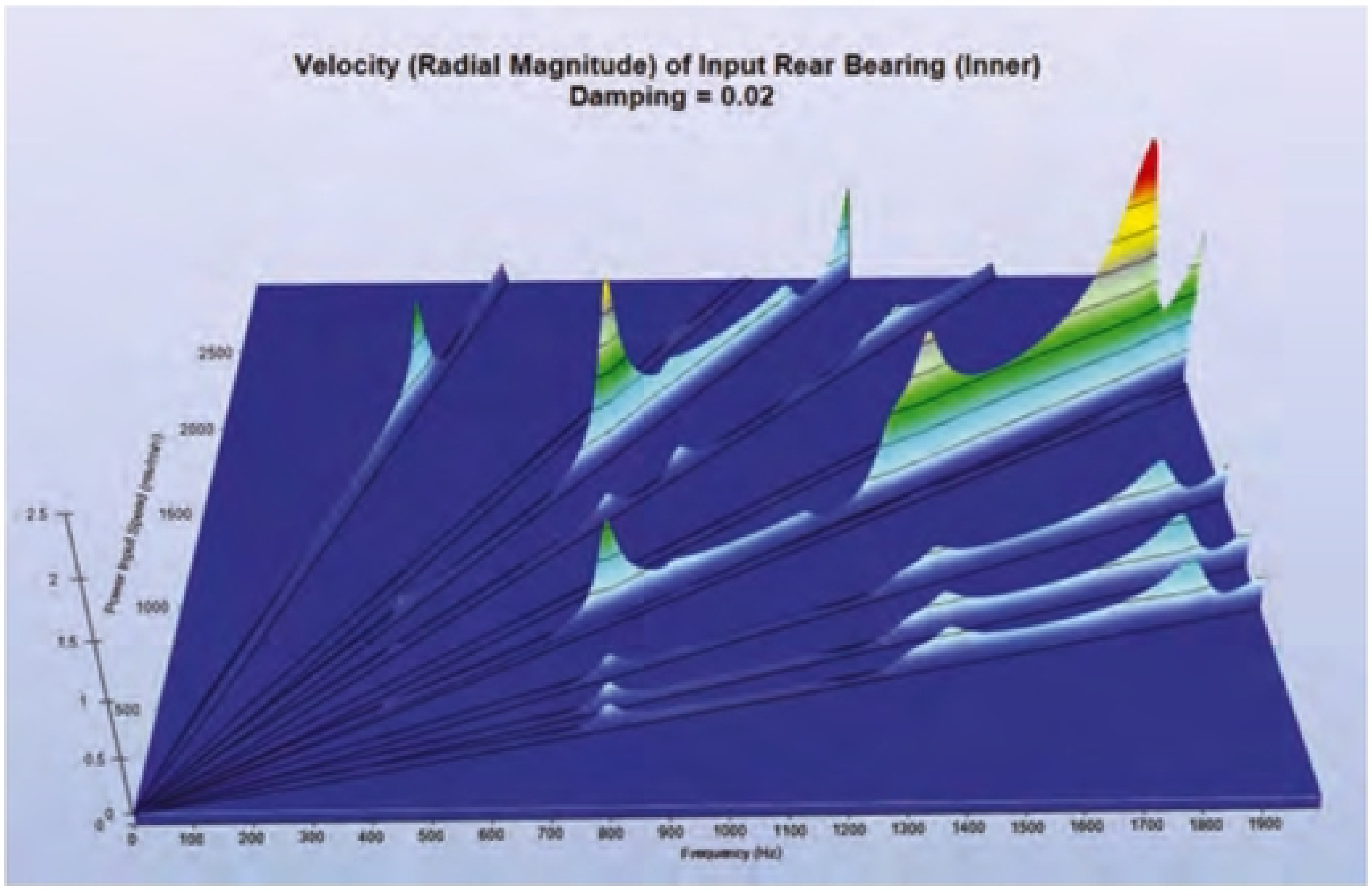
Calculation method

Full system-level models can be built with ease, including all relevant component geometry. Calculation of transmission error can be performed



Campbell diagram – comparison of natural frequencies and tooth passing frequencies within the operating speed range in MASTA

Waterfall chart – the dynamic response results available at many locations in the model in MASTA



using a hybrid FE and Hertzian contact solution for fast and accurate results. Misalignment at gear meshes can be calculated via the system level model before performing the transmission error analysis and assumed constant, or the system deflections and the tooth contact (transmission error) can all be calculated together in a coupled calculation.

The method that is used in calculating the system response to the transmission error is based on a well-known method by Steyer et al. at American Axle. The first stage is to calculate the dynamic force at the gear meshes, which leads to a relative displacement at the mesh given by the transmission error.

This force is known as the dynamic mesh force and is calculated from the dynamic compliances at each side of the gear meshes. The dynamic mesh force is then applied as an excitation to the system model to calculate the response at any point on the system to this excitation.

Applying results

Models built in CAE software can be tested against real-world examples. Accelerometer and/or microphone data can be correlated with the results given in software. Once a virtual model is created, contributing modes to problem frequencies can be identified with Waterfall charts and natural frequencies. The contributing components to the modes identified can then be found with mode shapes and energy contributions. With the results obtained, the design of these components can then be adjusted dynamically until the response of the analysis model is improved.

Once the desired results are obtained virtually, the design changes can be implemented on a prototype model and tested again with accelerometer and microphone data. There's no doubt that the development cycle of transmission systems is complex and costly. Finding new and better efficiencies can dramatically give the competitive edge that design engineers need to develop the groundbreaking innovations of tomorrow. With high market expectations in all aspects of drive quality, one of the most sensitive development areas is gear whine. Controlling and fine-tuning this quality in a virtual CAE environment, where design and simulation are integrated, accurately provides designers with the flexibility and freedom to achieve new levels of quality that would be too costly and time consuming to achieve through physical prototyping.

MASTA

Empowering engineers to achieve new levels of quality in a fraction of the time!

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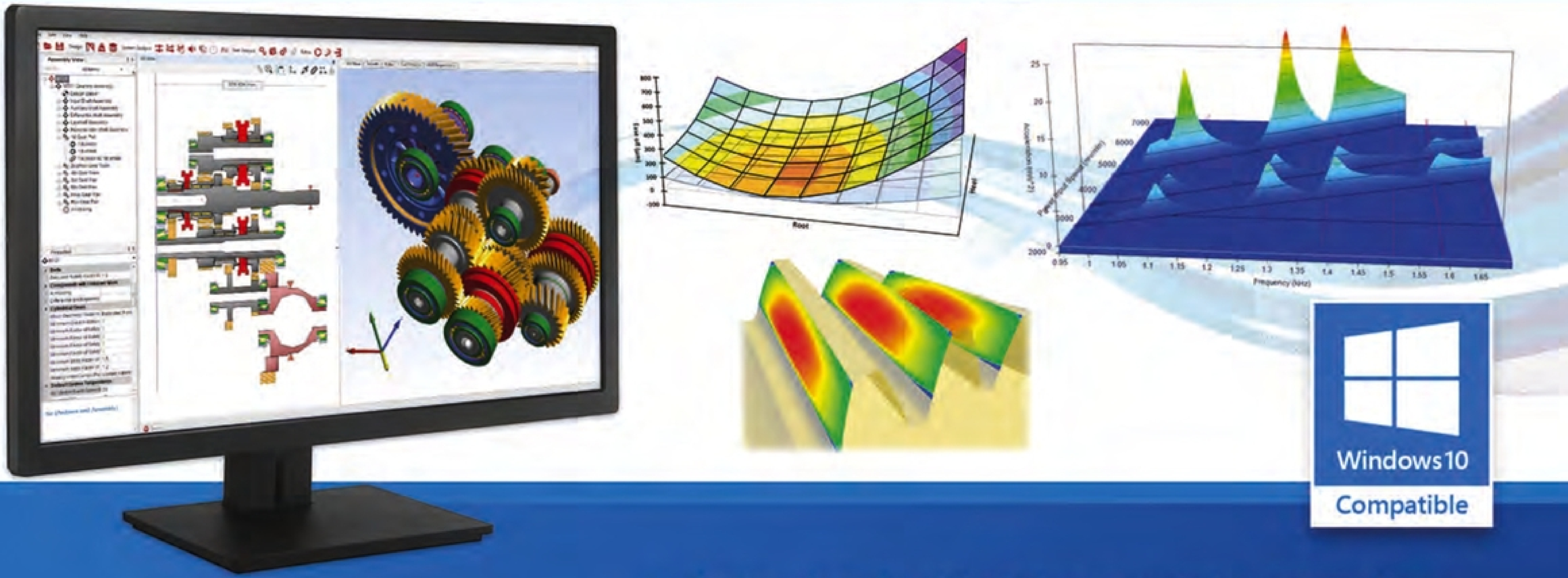

Windows 10
Compatible

- Accurately and rapidly design transmission systems from scratch or imported concepts
- Comprehensively understand the life of a mechanical part over the customer duty cycle
- Identify potential failure modes early in the product development cycle
- Rapidly predict key performance characteristics at the design stage
- Easily explore changes in transmission layout, component selection and/or design, materials and manufacturing processes in the convenience of a virtual environment
- Perform full system simulations for any transmission or driveline configuration
- Incorporate manufacturing simulation at the design stage to reduce process development time & cost

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