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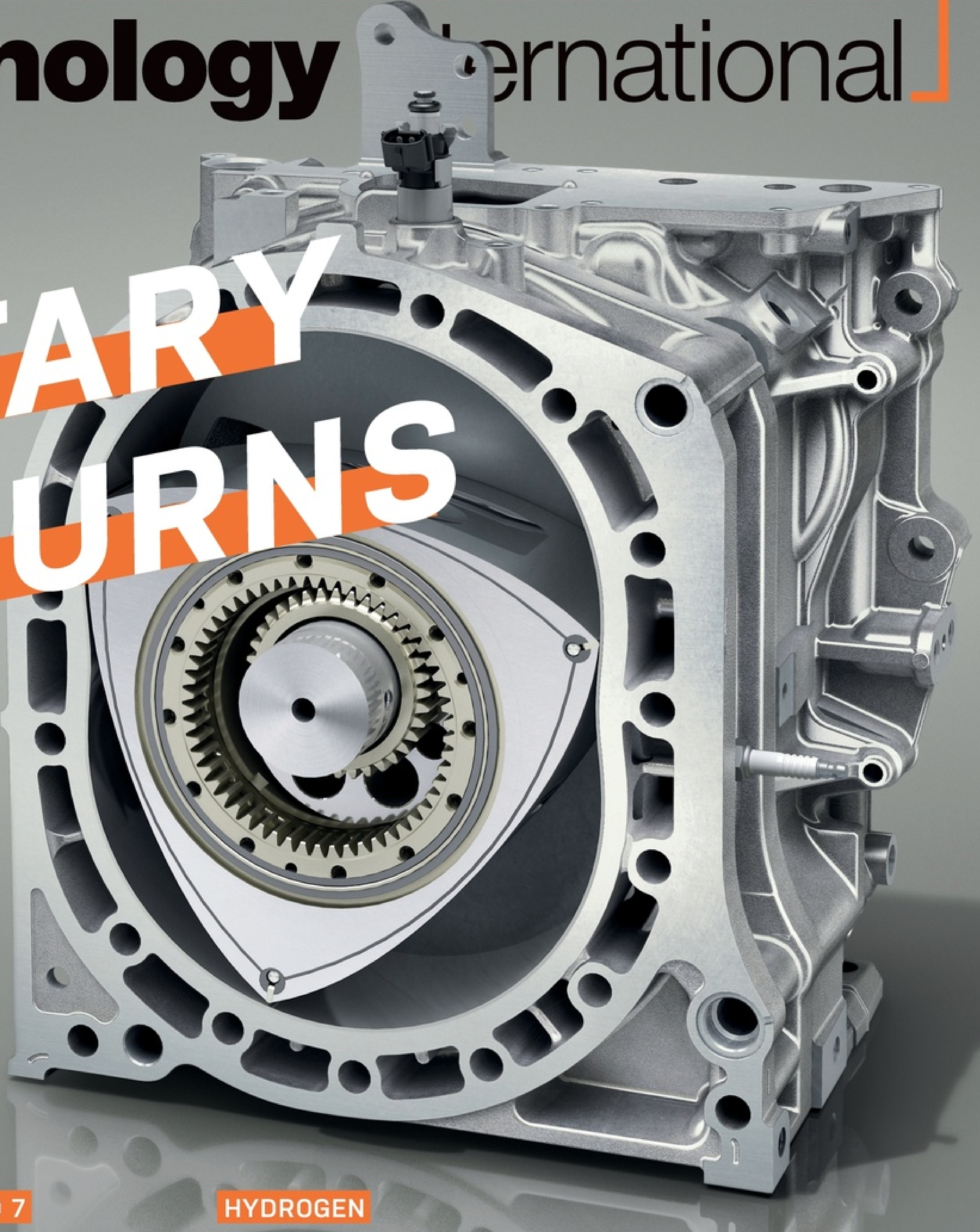
ROTARY RETURNS

Mazda has resurrected the Wankel. Is it the perfect BEV range-extender solution?



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Modeling electrified powertrains

Advanced e-motor electromagnetic and mechanical design tools are becoming indispensable

The trend toward electrified powertrains in the automotive industry continues. While offering numerous benefits to society in terms of reduced emissions and decarbonization, electrification has also introduced many new challenges for automotive engineers. Specifically, the design and integration of electric machines into automotive powertrains requires an increasingly systems-based approach to achieve good efficiency, durability and noise and vibration performance.

Design tools, therefore, must reflect this systems-based approach and afford easy integration of analysis between different domains: mechanical, electromagnetic and thermal.

With this systems approach in mind, SMT recently released MASTA 12, which now includes an electric machines module in addition to its existing drivetrain modeling and analysis capabilities. This new module allows engineers to model, analyze and design electric machines from first principles. Machine geometry can be designed using template models of existing machine topologies or imported from CAD files using MASTA's Geometry Modeler.

Winding topology can then be specified, and the stator, rotor, magnet and conductor materials selected from a vast database provided with the software. Finite element analysis is used to solve the electromagnetic behavior of the machine. The results can be presented graphically – such as magnetic flux density distribution within the machine – and numerically, in charts and tables of quantities such as voltages, flux linkages and torque. The finite element model can also generate D- and Q-axis flux maps, used to quickly calculate torque-speed curves, efficiency maps and current and phase angles required to generate a desired torque at a specified speed.

Given that this new module is fully integrated into MASTA, the system performance of the electrified powertrain and all its constituent components (gears, shafts, bearings, casings, electric machine) can be evaluated using a single tool. For example, powertrain noise and vibration characteristics are a function of excitation forces from the gears and the electric machine, which are then transferred through shafts, bearings and casings to the vehicle via the mounts, or perceived directly as casing vibration noise. Within a single tool, MASTA, it is possible to optimize the gear and electric machine design to reduce the excitation forces, understand and optimize transfer paths throughout the system and assess and evaluate casing design to mitigate any noise and vibration produced by these forces.

Design tools such as this will become increasingly important as engineers seek solutions to design problems that may only be discovered when understanding behavior and performance at the system level.

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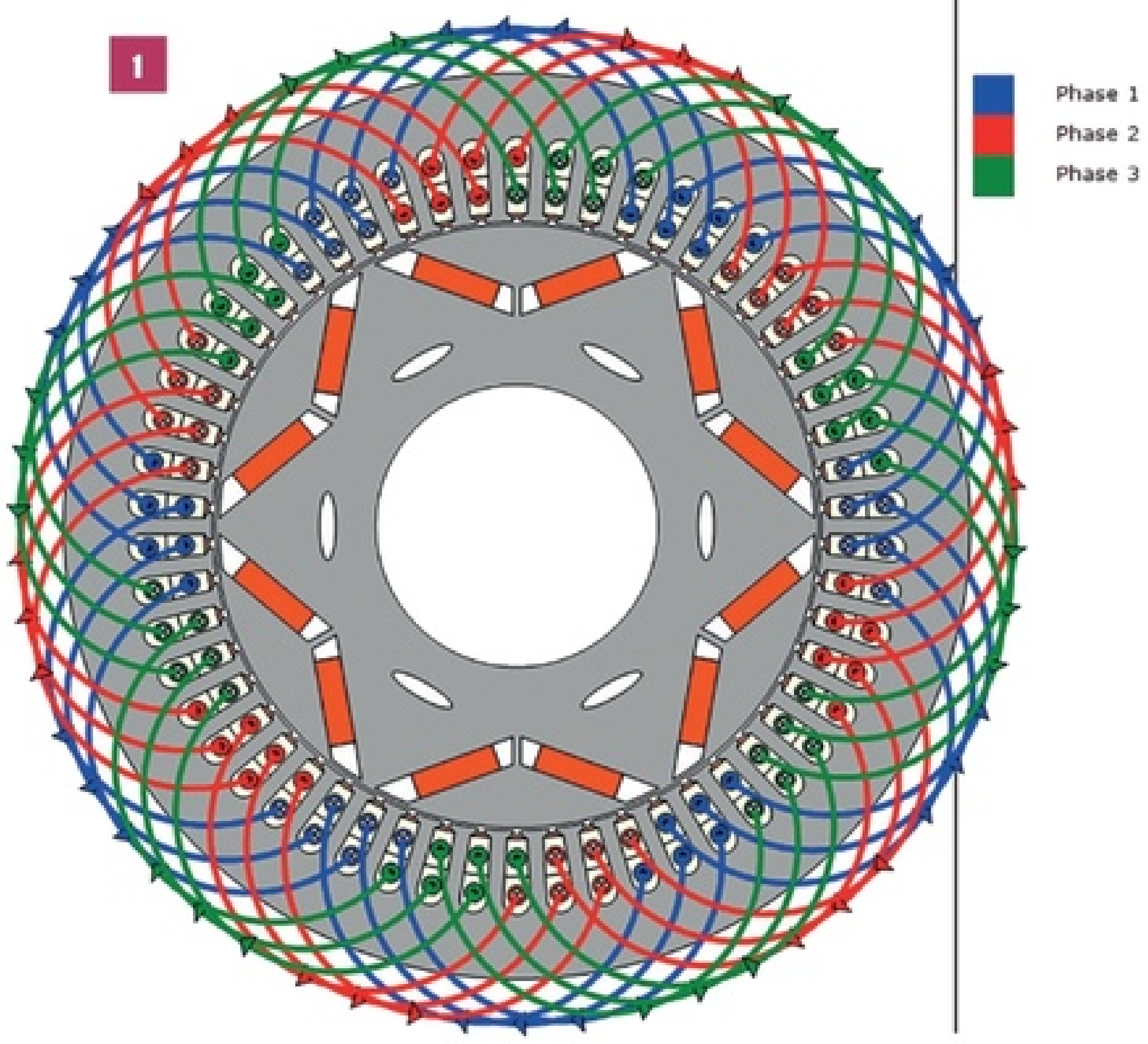


1. Even highly complex winding arrangements can be accommodated by MASTA 12

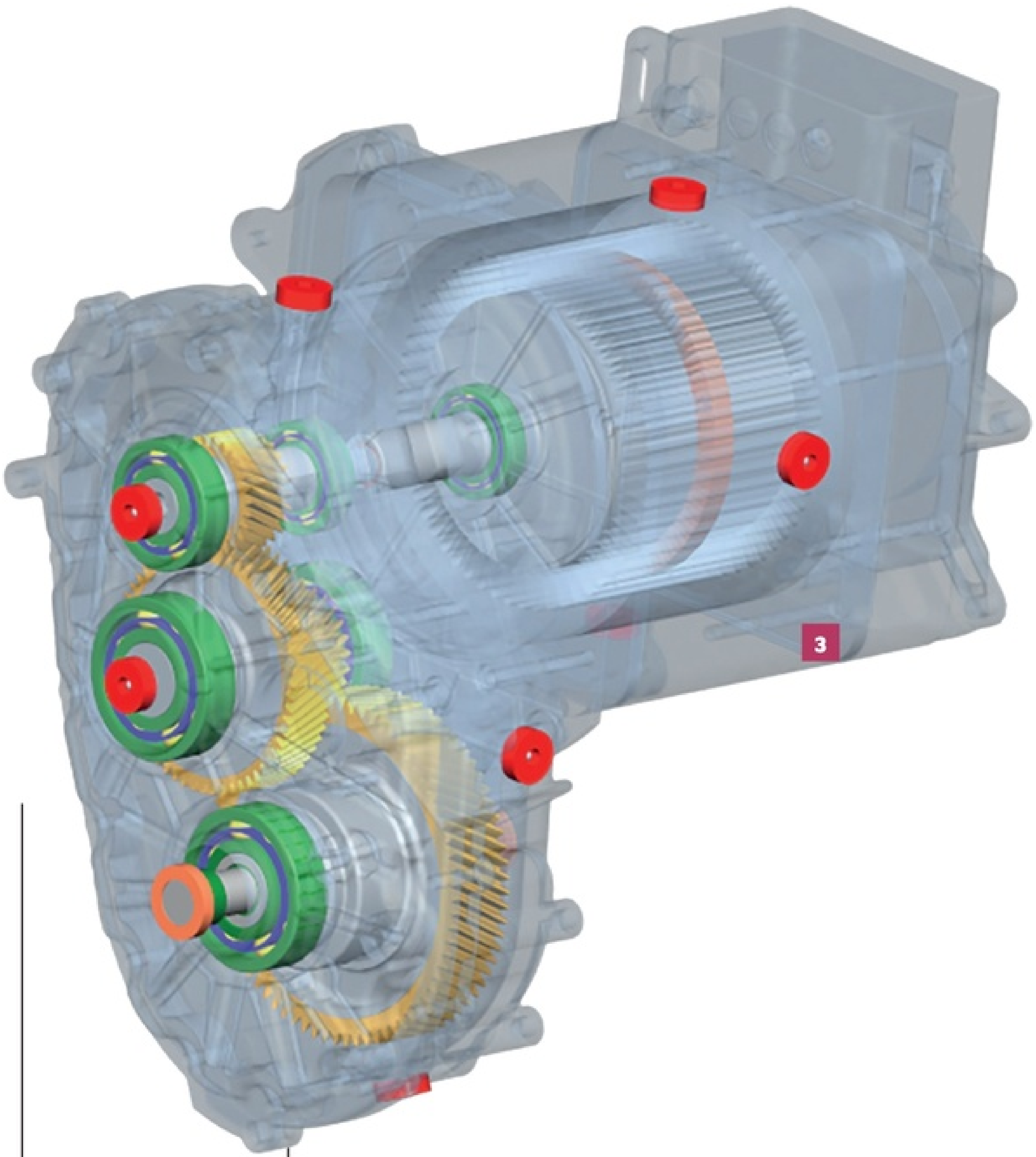
HIGH-SPEED BEARINGS

Higher speeds are becoming increasingly common in modern transmission designs. Ball bearings are better equipped than roller bearings to deal with the effects of increased speed, thanks in part to smaller contacts with the raceways. This results in less heat generation and hence power loss, but at the cost of higher stresses.

For many years, ball-bearing analysis models have generally used an approach that originated in the 1960s and was first detailed by A B Jones*, where the gyroscopic moment on the ball is assumed to be reacted by a 'controlling' raceway. Although this has worked well in the past and at lower speeds, higher-fidelity approaches to calculating bearing forces, moments and power losses are now required.

In MASTA 12, a new higher-fidelity ball bearing model is available for performing these calculations at higher rotational speeds. As well as the ball deflections, the ball orbital speed, ball rotational speeds and ball rotational axis are all considered as degrees of freedom that must be taken into account when balancing the forces on each ball.

To achieve this, frictional forces on the ball from each contact patch must be considered. In turn, this requires calculating the sliding speed distribution, the coefficient of friction and the pressure distribution at each contact. This information is then



used to calculate frictional forces on the ball, which are further combined with normal loads, gyroscopic moment, centrifugal force and other lubricant-related forces. The calculation of the coefficient of friction is important to the qualitative and quantitative behavior of the model, which is why MASTA uses an advanced lubricant model, accounting for different lubricant regimes and asperity effects.

As a result of this analysis, a detailed breakdown of power losses can be produced, and changes in bearing internal geometry, temperature and lubricant properties can be investigated. It is also possible to predict the risk of damage from smearing, a type of failure more likely with higher speeds.

CUSTOMER FOCUS

Now entering its third decade in business, SMT has established itself as a trusted global provider of engineering solutions and services that enable engineers to deliver highly innovative driveline technology solutions.

Its flagship software, MASTA, is a powerful finite element and multibody dynamics software application developed specifically for the detailed design, simulation and analysis of transmissions, electric machines and electrified powertrains and used by many high-profile automotive OEMs and Tier 1 suppliers.

Software functionality ranges from initial concept design to detailed design, analysis and manufacturing simulation. SMT continually adds to and enhances the functionality of MASTA to ensure it keeps pace with industry trends and enables users to explore cutting-edge designs as they seek to make technological advances and improvements in several areas, including efficiency and NVH.

2. Drivetrain casing in MASTA, implemented as one finite element mechanical model of the entire casing around the gearbox and motor

3. High-speed bearings in modern transmissions place a greater onus on calculating factors such as friction coefficients

A recent survey of users confirms the company is achieving its commitment to delivering a first-class service with an overall customer satisfaction rating of 95%. A net promoter score (NPS) of 69 also indicates a very strong willingness to recommend SMT and MASTA to other colleagues or industry contacts.

The company is working hard to provide software simulation tools for transmission, driveline and powertrain electrification engineers. Rob Forrest, SMT's customer support manager, summarizes, "Through a close working relationship and by understanding our customers' challenges, we both have a higher chance of being successful – if our customers achieve their aims and objectives, SMT will succeed in ours." ⦿

* A B Jones, *A General Theory for Elastically Constrained Ball and Radial Roller Bearing under Arbitrary Load and Speed Conditions*, Journal of Basic Engineering, Vol. 82, No. 2, 1960, pp 309-320