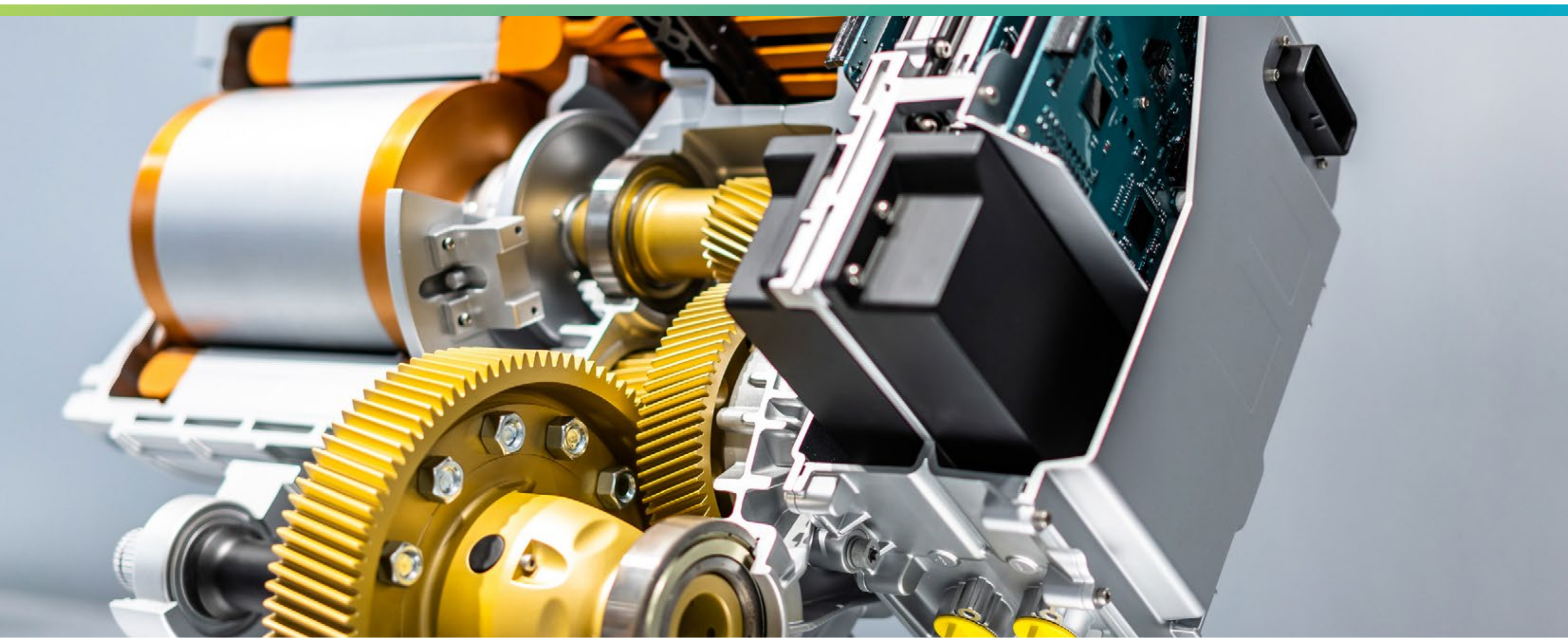
Case study

McMaster University

Actran induces optimization of electric motor drive design



Based on an interview with Dr. Berker Bilgin, research program manager and chief engineer of The Canada Excellence Research Chair

The transportation industry is facing various new technological changes. Among them, the replacement of traditional internal combustion engines by electric powertrains makes new vehicles quieter. Still, new challenges in noise and vibration are rising, in particular during the design of electric motors. In order to develop efficient architectures meeting the expectations both in terms of performance and acoustic comfort, engineers need to access new methods and tools.

Motor design generally starts with the torque as the main purpose of an electric motor is to deliver the required torque at a given speed range. Then, the dimensions of the motor start becoming apparent and efficiency analysis, radial force analysis, structural analysis, and acoustic analysis enter the loop.

“Acoustics analysis should be part of the process and not applied at the end of it” explains Dr. Berker Bilgin, Research Program Manager and Chief Engineer of Canada Excellence Research Chair in Hybrid Powertrain program at McMaster University. If not, it will become difficult to reduce acoustic noise from the motor once the motor design is finalized. Electric motor noise is mainly due to the impact of electromagnetic radial forces (see Figure 1) that excite the stator structure.

Depending on the stator mode shapes and frequencies, vibrations can create acoustic noise issues. However, not all acoustic noises are caused by structural resonances. Strong radial force harmonics may sometimes cause enough vibration to dominate the acoustic noise. Additionally, any modification of the stator or rotor structure or of the motor controls will have an impact on final electromagnetic forces and, hence, on on final electromagnetic forces and, hence, on electromagnetic and acoustic performances.

Consequently, "an efficient electric motor development process should be conducted with a mix of electromagnetic forces prediction, structural and acoustic analysis" insists Dr. Berker Bilgin.

MSC Solution

In the past, research institutes, the electric motor and the transportation industries were obliged to create multiple prototypes during the motor design process, increasing both the cost of the development and the time to market delivery. In addition, since today's motors are highly non-linear, predicting the radial forces through analytical calculations is not a practical solution as errors increase significantly – especially for complex geometries – and the acoustic noise reduction solutions may therefore not be efficient. An example of the acoustic noise modeling in Actran and the simulation results are presented in Figure 2 and Figure 3, respectively.

The use of simulation not only lowers the number of prototypes to be made, but also allows researchers to focus on prior extensive analysis before testing the final prototype.

Vibrations and acoustic noise over the complete frequency range

McMaster engineers use Actran to analyze vibrations and acoustic noise of electric motors over a wide variety of frequencies and motor speeds. McMaster engineers have relied on Actran to cover any frequency range.

Whatever the application and the rotation speed, from 2000-3000 rpm to 8000-10000 rpm, the accuracy of Actran results versus experimental ones convinced Dr. Bilgin's team to use Actran for predicting both the structural mode shapes and the acoustic response.

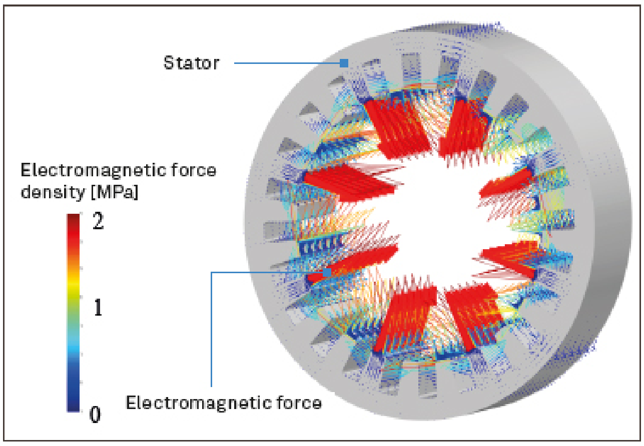


Figure 1 Electromagnetic forces in a 24/16 traction switched reluctance motor

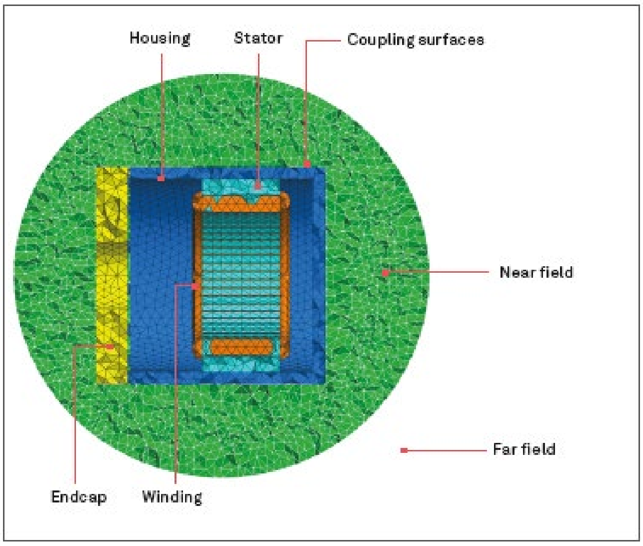


Figure 2 Vibro-acoustic model of a traction motor in Actran

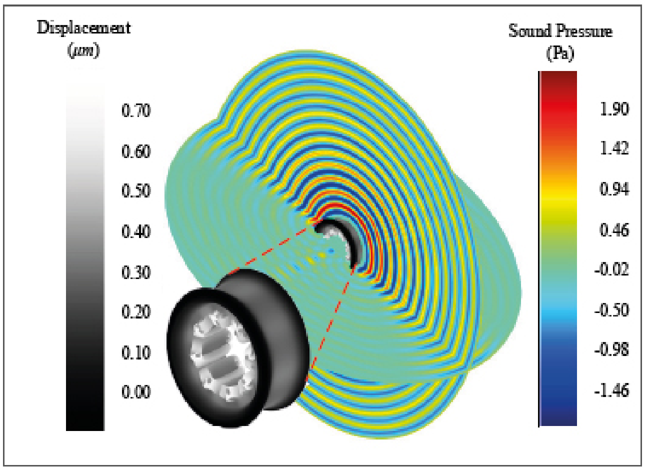


Figure 3 Simulation of vibration and acoustic field in Actran

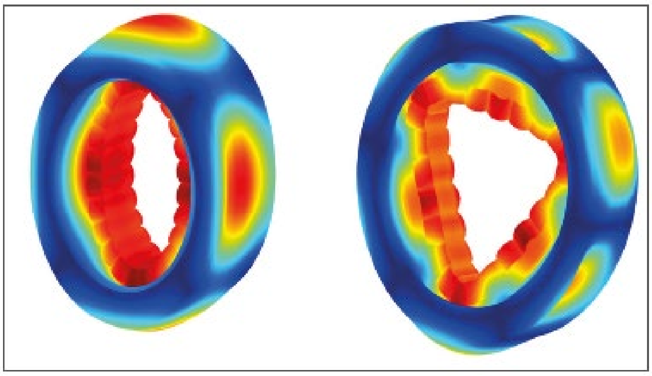


Figure 4 Simulation of mode shapes of a traction 24/16 switched reluctance motor in Actran

Figure 5 24/16 switched reluctance motor for a traction hybrid electric vehicle (HEV) application, designed by the researchers in the Canada Excellence Research Chair (CERC) in Hybrid Powertrain Programn

Capturing complex 3D geometries and their related dynamics

One important added value of Actran during the design process is the identification of the radial force harmonics which contribute the most to acoustic noise and to know whether they can be reduced without affecting the torque. Furthermore, it is able to deal with complex 3D geometries where it is more challenging to calculate mode shapes, especially for the analysis of axial mode shapes (see Figure 4.)

“Once the mode shapes of the motor and the natural frequencies are determined, we can predict which radial force harmonic is causing the most acoustic noise and go back to electromagnetic design to work on reducing that radial force harmonic.”

Results and correlation

By including Actran in their design process, McMaster researchers developed current control techniques to limit acoustic noise: “Without making any changes in the motor we can actually reduce the acoustic noise just by optimizing the current, because the radial forces are also related to stator excitation, and we experimentally verified drastic noise reduction in switch reluctance motors”, said Dr. Berker Bilgin.

The use of simulation tools has reduced significantly the cost of prototyping and allowed a more advanced analysis of the designed product. Another added value of simulation is of course the attention paid to details thanks to 3D acoustic modelling capabilities. In addition, Actran’s visualization capabilities offer a great possibility for students to train and dig deeper in their research.

In the future, CERC in Hybrid Powertrain team plan on working on how to modify the structural modes without affecting the torque performance of the motor, focusing on current controls of the motors, or modelling the damping ratio of the motor for accurate estimation and reduction of acoustic noise in electric motors.

Figure 5 24/16 switched reluctance motor for a traction hybrid electric vehicle (HEV) application, designed by the researchers in the Canada Excellence Research Chair (CERC) in Hybrid Powertrain Programn

Key highlights:
Product: Actran
Industry: Automotive
Challenge: To improve design of electric motors
Solution: Simulation with Actran helped researchers develop current control techniques to limit acoustic noise

About Canada Excellence Research Chair (CERC)

The Canada Excellence Research Chair (CERC) in Hybrid Powertrain Program is a research group at McMaster University, with around 80 people working on multidisciplinary projects, mostly with industry partners for transportation, electrified vehicles, e-bikes, e-mobility, and aerospace.

Dr. Berker Bilgin also manages the research program on the development of high-performance switched reluctance motor drives. Special thanks to Mr. Jianbin Liang, Ph.D. student at McMaster University, for providing the images in this article.

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