Predicting the **Acoustic Signature** of Electric Vehicle Powertrains

By **Yijun Fan, Global Automotive Application Manager & Romain Baudson, Actran Product Marketing Manager, MSC Software**

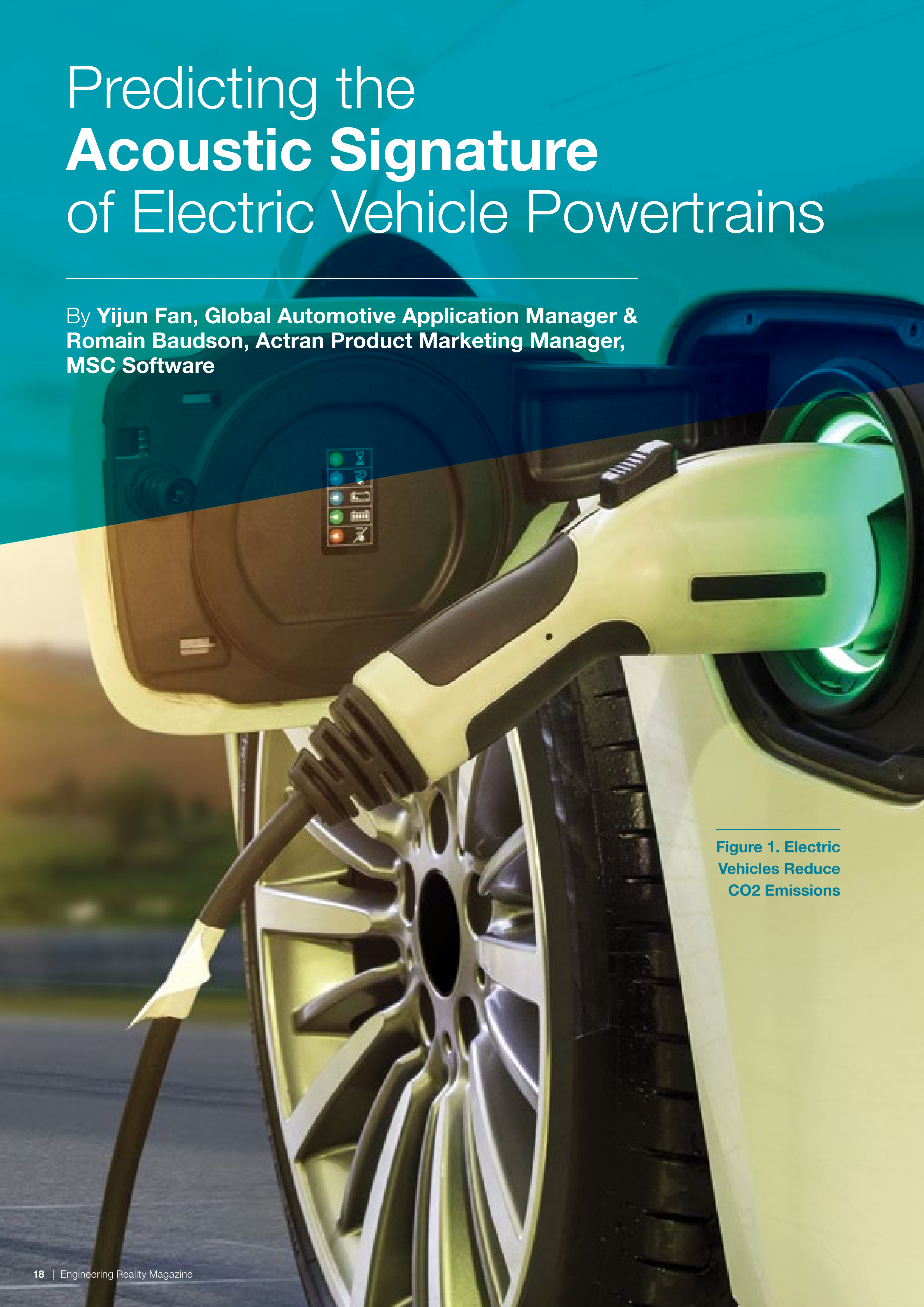

Figure 1. Electric Vehicles Reduce CO2 Emissions

“With the emergence of hybrid and electric vehicles, the automotive industry is also facing new Noise, Vibration and Harshness challenges.”

Since 2010 the global Electric Vehicle (EV) market has been growing rapidly. Different electrical vehicle technologies have been introduced, from the Hybrid Electric Vehicle (HEV) to the Fuel Cell Vehicle (FCV). According to projections, BEV and PHEV will be the dominant technologies in the coming years, with a larger proportion of BE Vehicles in the field. In other words, we will face a complete change of landscape in the way passenger cars will be powered with a removal of Internal Combustion Engine (ICE) technologies. To understand this growth, one needs to look at government and state regulations. Indeed, all major automotive markets in the world do have emissions regulations in place aiming at reducing CO_2 emissions and improving vehicle fuel economy. Taking a closer look at the European CO_2 regulation for instance, it can be seen that the year 2020 will be affected by the entrance of a new $C0_2$ emission target together with an excess emissions premium being applied to manufacturers failing to meet it. This new regulation will actually demand a 27% emission reduction from all OEMs, which will be achievable only by changing the technology that powers passenger cars and by moving to the electrification of powertrains (Figure 1).

With the emergence of hybrid and electric vehicles, the automotive industry is also facing new Noise, Vibration and Harshness (NVH) challenges. The removal of both engine and transmission when compared to conventional internal combustion engine cars will make the vehicle a lot quieter. However, previously hidden noise sources will then become more dominant with a potentially annoying effect on customers, for example, HVAC noise and Tire/Road noises. Besides these traditional types of noise, electric vehicles also show new noise types originating from the electric powertrain which includes the electric motor and the gear reduction system. It is more challenging to accurately predict these new types of noise because they are usually generated at a higher frequency level than before, plus other non-traditional powertrain physics types like electromagnetics need to be captured during the computer engineering simulation analyses.

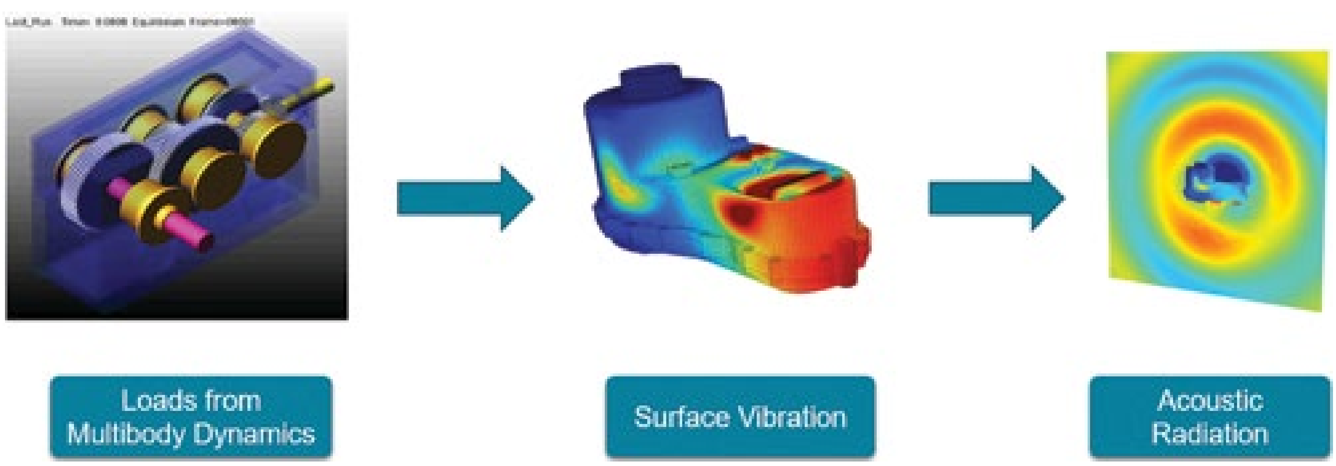

Figure 2: Noise Prediction in an Internal Combustion Engine Car

Workflow Solution: EV Powertrain Acoustic Analysis

Electric Vehicle powertrains usually consist of an electric motor and a gear reduction system (Reference 1). In order to accurately predict the noise generated by the entire electric powertrain, dynamics performance and acoustic behavior need to be studied together for both the electric motor and the gear reducer.

1. Gear Reducer: Assessing Gear Rattle and Gear Whine Noise

Both gear rattle and gear whine noises are the result of specific forces being applied on the gear mechanism. While rattling noise is an impact-induced noise generated by the unloaded gear pairs, whine noise can stem from different factors that include the change in tooth stiffness, tooth surface imperfection, or the transmission error resulting from the tooth deformation. In order to capture these physics behaviors in a systems model, engineers need the correct tool to predict dynamic loads generation, structural vibration and the acoustic radiation of the gear mechanism. The traditional engineering simulation workflow (Figure 2) for such analysis involves a sequential application of a multi-body dynamics (MBD) tool, a finite element analysis (FEA) tool, and finally acoustic software, which could be fairly time-consuming especially when dealing with multiple changes in the design.

A co-simulation methodology developed at MSC Software allows engineers to perform modeling within an MBD interface (Adams) to get initial results and impressions of the acoustic behavior without manually exporting the results into acoustics software. Typical acoustic results are computed in the background via an acoustics solver (Actran), and displayed in the MBD interface, including the acoustic pressure evolution at selected positions and the creation of audible acoustic wave files for listening to the sound. Such relatively new workflows can greatly reduce the time and cost to conduct acoustic analysis on moving mechanisms like a gearbox, allowing for more iterations in the same time than with conventional methods. Indeed, the methodology fully automates this workflow into a single simulation environment by embedding an acoustic solver into an MBD tool (Figure 3). If deemed necessary, acoustic engineers can also perform a more detailed analysis by investigating acoustic maps or further post-process results and analyze the acoustic frequency content of their results.

2. Electric Motor Noise

Noise radiation from an electro-magnetic motor is driven by the structure of the motor that vibrates due to the internal electro-magnetic forces in the air gap between the rotor and stator of the motor. Indeed, if the frequency of the radial forces on the stator teeth are close to, or equal to, any of the natural

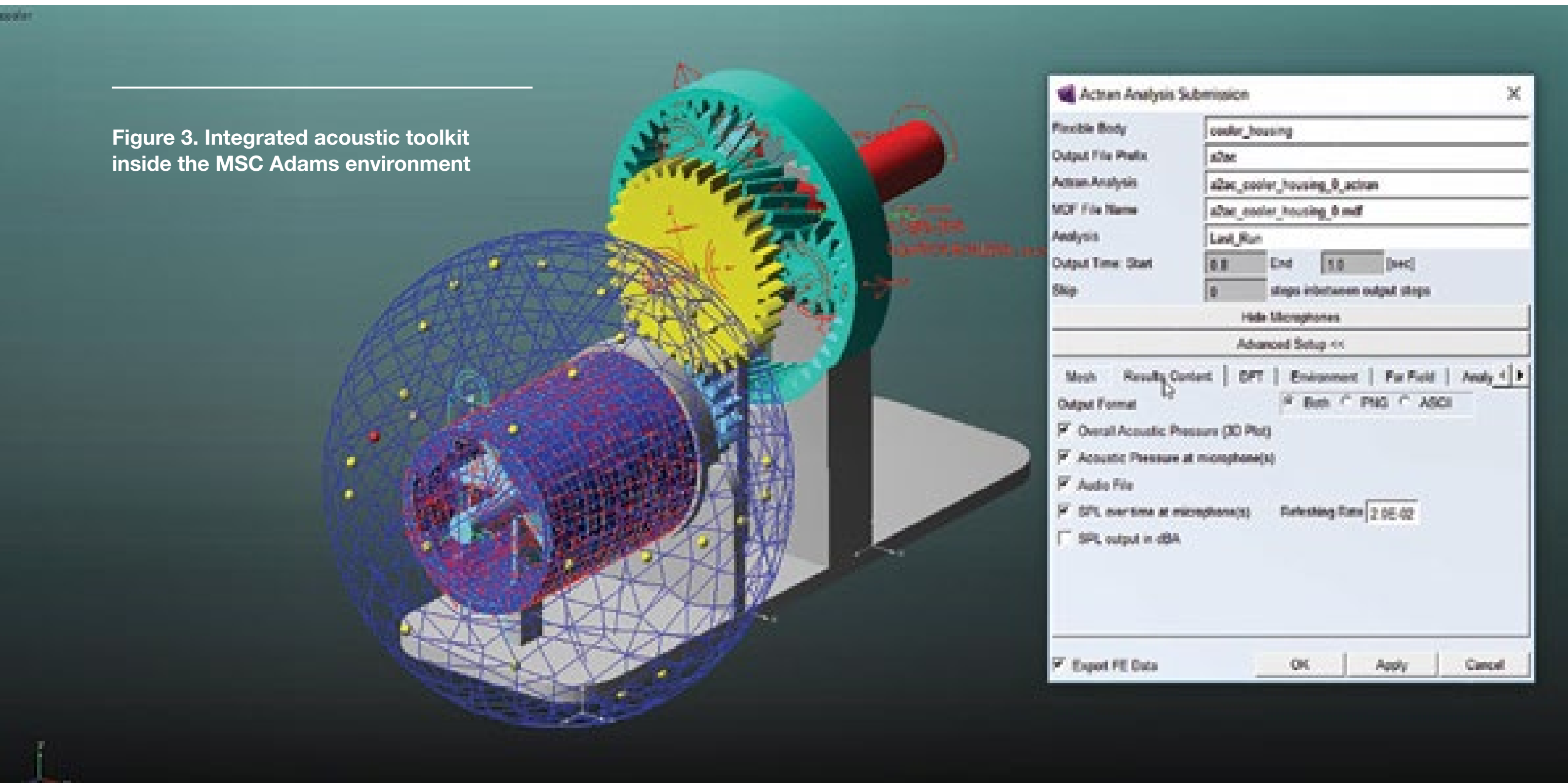

Figure 3. Integrated acoustic toolkit inside the MSC Adams environment

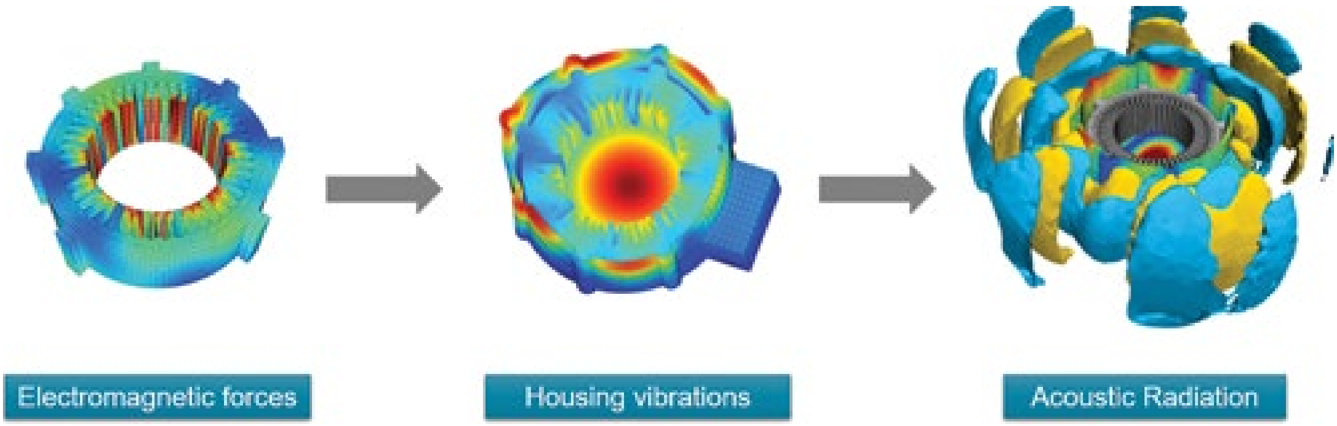

Figure 4. Electric Motor Noise Prediction Workflow

frequencies of the stator frame, resonance of the stator will occur. This leads to deformation of the stator which ultimately causes vibrations and generates the noise. Assessing the noise radiated by an electric powertrain therefore requires co-simulation analysis of structural vibrations induced by the electromagnetic forces (Figure 4).

A hybrid engineering simulation methodology (see Figure 5) for predicting electric motor noise has been created by Renault in France (Reference 1) that relies on a weak coupling between the three steps of the process; respectively the predictive computation of electromagnetic forces, structural vibrations and acoustic radiation. This multiphysics workflow has been used to validate electric vehicle electrical powertrain designs at Renault. It relies on the integration between 2D electro-magnetic simulation software, structural deformation in MSC Nastran, and then Actran for the acoustic prediction. This workflow permits the Renault NVH team to simulate the acoustic radiated power of an EV powertrain at different RPMs up to 10kHz in order to validate the design of their electric motor.

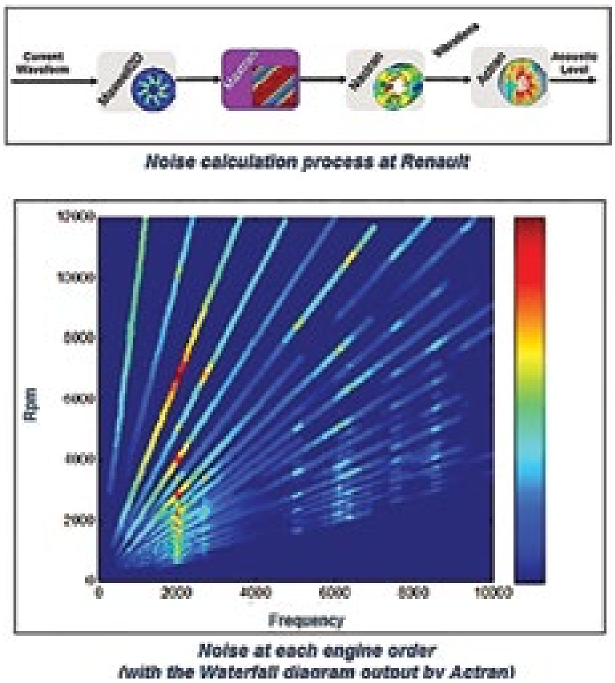

Figure 5. Workflow for Electric Motor Noise prediction by Renault

Summary

Car buyers generally have a very high expectation of low noise levels for electric vehicles. Predicting the acoustic behavior of their electric powertrain involves the study of the noise generation mechanisms for both the electric motor and the gear reduction system. This article illustrates a very clear workflow for engineers to analyze the noise generated by both the electric motor and also the gear reducer, leveraging multidisciplinary computer-aided engineering analyses using MSC Software tools. The expertise generated helps auto OEMs and suppliers improve the acoustic signature of their electric vehicle powertrains.

Reference

1. "Numerical methodologies to address electromagnetic noise at each phase of development of electric machines" by G. Fritz and H. Mechmeche, SIA International Conference, Automotive NVH Comfort, 2014