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Challenges in Optimising System NVH Performance of Electrified Powertrains through Developing Correlated Component Models

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Despite significant improvements in the NVH performance of electrified powertrains and an improved understanding of behaviour in certain areas of NVH, costly and late emerging NVH issues are still commonplace within the industry. Targets and requirements are constantly evolving, with expectations from vehicle manufacturers, consumers and regulators becoming increasingly challenging.

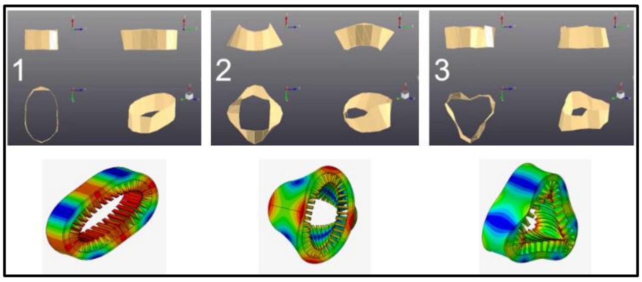

Fig. 1 Stator Mode Shapes Test vs Simulation

The noise issues that are commonly seen in electric vehicles arise most often due to the complex interactions between components. Due to the highly integrated nature of Electric Drive Units (EDU), with shared structures between the motor, transmission and inverter, each generating excitation sources, a system level approach is required. Including these key components within a single model, usually up to the isolation mounts, enables their interactions to be captured. This behaviour would otherwise be missed if individual component models were analysed. Key risks and complexities at a component level must be understood. This allows for NVH issues at system level to be more easily traceable, allowing identification of components and joints which could be modified to mitigate the issue.

Simplifications in the modelling of complex components and the joints between them, such as isotropic materials, are not sufficient to accurately capture certain NVH issues. An improved understanding of how these components behave and interact is required. Component correlation is used in order to achieve this, by optimising finite element (FE) modal simulation models against physical modal tests of the components. FE modal simulation correctly predicted the mode shapes as seen in the physical testing, however the frequency that these modes occur at must be accurately correlated too. Optimisation of the stator lamination stack material properties found best correlation occured when the shear modulus between the laminations was around 13% of the shear modulus in the radial direction. In comparison to a stator modelled as isotropic, the #2 bending mode was found to be up to 90% higher frequency, showing the significance of capturing the othotropic nature of stator lamination stacks.

This paper has demonstrated that using isotropic materials and joint simplifications is not adequate for system NVH modelling of EDUs. Significant NVH issues may be missed, leading to costly rectifications required after hardware testing. Determining how to model anisotropic components and complex joints is key to capturing these NVH issues during pre-hardware simulation. The methods demonstrated in the paper show the importance of accurate component and sub-system level modelling to understand and correlate NVH behaviour. This subsequently contributes to improved system level correlation, and through substantial experience, allows potential issues to be identified and rectified prior to the costly procurement and testing of hardware. The example used in this paper shows that stator behaviour and mode shapes propagate throughout the various assembly stages, as shown during system response tests, and that modelling the stator with accurate orthotropic material properties is crucial in order to identify responses through motor and EDU assemblies.

Although this understanding has yielded significant benefits, there are still many challenges in the optimisation of NVH performance in electric vehicles. Advances in FE techniques, particularly joining methods such as representing transient contact conditions and integrating these within system NVH models, will enable the next phase of complex development within electrified vehicles. Sound quality targets and psychoacoustic metrics are quickly advancing, and using simulation to aid sound quality target definition, and sound quality verification is of great importance to the industry and consumers alike. This allows the industry to not only improve perceived quality of vehicles, but also reduce time to market.

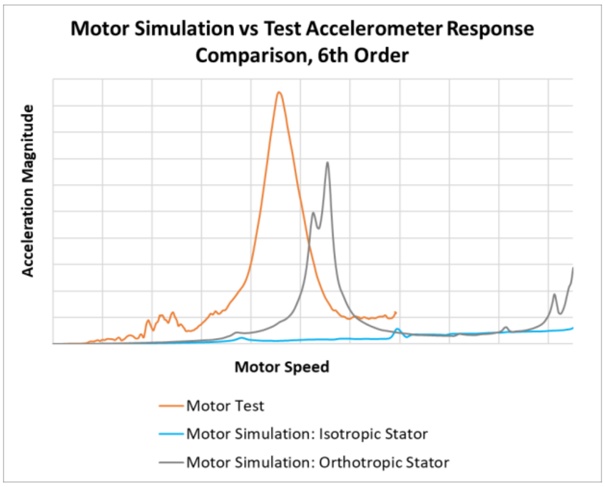

Fig. 2 Comparison of Motor Test vs EDU Test Response