Advanced Analytical Multiphysics Methodology for time-domain NVH Prediction of a high-speed PMSM

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The rapid electrification of the automotive industry has led to substantial research and subsequent development of lighter, more power-dense electric traction motors that can maintain performance standards at operating speeds in excess of 10,000 rev/min. Nonetheless, an equally important criterion in the development of electric vehicle (EV) powertrains, is Noise, Vibration and Harshness (NVH) behaviour, as increased operating loads and speeds, can result in the amplification or introduction of new noise contributions at higher frequencies. The use of traditional Finite Element (FE) based methodologies for the prediction of electric motor NVH (e-NVH) may therefore become prohibitive due to the higher computational costs when considering large speed and frequency ranges. This is especially true at pre-design optimisation stages, where fast decision-making can provide a competitive advantage. In our work, we are presenting a reduced order multi-physics methodology for the electromagnetic and vibroacoustic resolution of a typical EV Permanent Magnet Synchronous Machine (PMSM). A two-dimensional (2D) analytical electromagnetic technique was implemented for the fast calculation of the electromagnetic stresses acting on the stator and rotor structures. In contrast to typical reduced-order methodologies utilising 2D structural models to predict the vibroacoustic response of the stator in the frequency domain, a novel thick cylindrical shell approximation was employed, allowing for the dynamic time domain response of the system to be computed using analytical expressions. The ability to represent the system's boundary conditions more accurately, as well as to predict the temporal response of the system with consideration of axial and torsional vibrations can be of crucial significance to the NVH engineer. However, most importantly the developed methodology can provide direct insight into the root causes of the main

NVH components, while simulation times remain orders of magnitude faster than in conventional 3D FE methods. Such an approach, combining analytical electromagnetic modelling with analytical thick cylindrical models for the NVH estimation of EV motors has hitherto not been reported in literature.