

NVH-ORIENTED TOPOLOGY OPTIMIZATION OF A PERMANENT MAGNET SYNCHRONOUS MOTOR FOR AUTOMOTIVE TRACTION

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Abstract

Noise Vibration and Harshness (NVH) plays a crucial role in the design of efficient electric traction motors for electrified vehicles. In particular, mechanical vibrations induced by the magneto-motive forces acting at the airgap are acknowledged to be the main source of sound emission of these machines.

In the paper, magneto-mechanical topology optimization is employed to design the internal rotor of a 6 poles/36 slots Permanent Magnet Synchronous Motor (PMSM) for automotive traction. Starting from a reference design of the electric machine, a 2D plane finite element model is developed by means of Altair Flux software. The layout of the internal rotor lamination is optimized by accounting for both electromagnetic and mechanical requirements. In particular, the amplitude of the 6th and 12th harmonic time orders of the output torque are minimised for reducing torque ripple and noise emission of the electric machine over the entire range of rotational speeds. Constraints on the minimum delivered torque and structural safety of the rotor (i.e. maximum stress and radial deformation) are included in the optimization. A SIMP-based material interpolation scheme is adopted to penalise the relative permeability of the rotor lamination stack.

A simplified analytical model of the external stator of the motor is employed to assess the NVH performances of the optimized design. In the model, the stator, windings and external housing of the motor are modelled as an equivalent curved beam with equivalent mass and structural properties. The model receives as input the time- and space-harmonic decomposition of the electromagnetic force density distribution resulting from the magnetic interaction between stator and rotor occurring in the airgap. The resulting distribution is applied as a field of distributed forces acting on the internal radius of the curved beam. Closed-form analytical expressions of the natural frequencies and vibration amplitude of the external surface of the stator are obtained. From the computed radial velocity field of the surface, the radiated sound pressure is calculated by assuming an infinite cylindrical surface radiator model.

The optimized solution is finally compared with the reference design in terms of output torque, structural response and acoustic emission.