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Thermal Analysis and Optimization of a High-Speed Permanent Magnet Synchronous Motor with Toroidal Windings

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Abstract : Toroidal windings were taken advantage of to reduce of axial length of the motor, so as to match the applications that have severe restrictions on the axial length. But slotting in the out edge of the stator will decrease the heat-dissipation capacity of the water cooling of the housing. Besides, the windings in the outer slots will increase the copper loss, which will further increase the difficult for heat dissipation of the motor. At present, carbon-fiber composite retaining sleeve are increasingly used to be mounted over the magnets to ensure the rotor strength at high speeds. Due to the poor thermal conductivity of carbon-fiber sleeve, the cooling of the rotor becomes very difficult, which may result in the irreversible demagnetization of magnets for the excessively high temperature. So it is necessary to analyze the temperature rise of such motor. This paper builds a computational fluid dynamic (CFD) model of a toroidal-winding high-speed permanent magnet synchronous motor (PMSM) with water cooling of housing and forced air cooling of rotor. Thermal analysis was carried out based on the model and the factors that affects the temperature rise were investigated. Then thermal optimization for the prototype was achieved. Finally, a small-size prototype was manufactured and the thermal analysis results were verified.

Keywords : thermal analysis, temperature rise, toroidal windings, high-speed PMSM, CFD
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