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Thermal Analysis Based Design of Hollow Shaft for Improved Cooling of Induction Motors

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ABSTRACT

The heat from the rotor and stator of an induction motor is accumulated in the air-gap, which causes secondary heating towards the stator windings. Due to the thermal interactions within the air-gap, it is important to reduce those secondary energy loss to improve motor performance. Although direct cooling of the rotor through its rotation can be difficult, introducing a cooling liquid in the hollow rotor shaft provides additional heat removal. In this study, a new method of rotor cooling is investigated, which consists of inducing forced liquid convection into the hollow shaft, acting as a counterflow heat exchanger for uniform cooling. The hollow shaft includes a stationary inner pipe, carrying cold fluid, and the area between the inner pipe and shaft wall, called the annulus gap, carrying a warmer fluid that is still colder than the rotor. The heat generated from the rotor is transferred into the annulus gap, then into the inner tube to be carried away from the system. The purpose of having the inner cold pipe is to ensure that the fluid closest to the rotor does not heat up and can steadily absorb the same amount of heat as it travels along the shaft. This study starts with applying the analytical approach. Using pre-existing stationary Nusselt number correlations, mass and energy equations, preliminary inlet parameters, and the shaft's outer wall heat flux boundary condition from the rotor, the Engineering Equation Solver software will aid in predicting the system's outlet flow temperatures and heat transfer coefficient. These results are used to validate the heat transfer coefficient taken from the numerical hollow shaft model created in the COMSOL Multiphysics software. The results find that the given shaft's length will not be sufficient for heat transfer to occur, but by adding in helical fins, it can achieve higher heat transfer compared to standard longitudinal fins, which will aid in reducing the heat losses occurring in the motor. With the added helical fins, the heat transfer coefficient in the annulus gap for a stationary model increased from approximately 3,000 to 6,000 W/m^2K. Other parameters, such as different fluids, inlet temperatures, velocities, and inner tube and fin materials will be investigated as well. The design overall reduces rotor losses and secondary losses at stator windings which will improve the efficiency and lifespan of the induction motor. This aids in creating an improved electric vehicle for consumers and promoting lower energy consumption.