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Design optimization of a slotless PM brushless motor with helical edge wound laminations for rim driven thrusters

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Abstract

This paper discusses the analysis and design of a very thin slotless permanent magnet (PM) brushless motor whose stator laminations are manufactured from a single strip of steel that is edge wound into a spiral (like a "Slinky") and then fitted over the windings that are preformed on the outside surface of a non-conducting former. Analytical and finite element analysis (FEA) are used to determine the constrained optimum dimensions of a motor used to drive a rim driven thruster in which the motor rotor is fitted onto the rim of the propeller and the stator is encapsulated in the thin Kort nozzle of the thruster. The paper describes the fabrication of a demonstrator motor and presents experimental results to validate the theoretical calculations. Experimental motor performance results are also reported and compared with those of a slotted motor that fits within the same active radial dimensions as the slotless motor. The slotless motor, which has longer active length and endwindings, and thicker magnets than the slotted motor, was found to be less efficient and more expensive (prototype cost) than the slotted machine.

Key words: slotless brushless permanent magnet (PM) motor, edge-wound laminations, rim driven thruster

0 Introduction

In rim or tip driven thrusters and marine turbine generators such as those illustrated in Fig.1 and Fig.2[1-14], the machine active components need to fit within the small space in the duct or Kort nozzle that surrounds the propeller. The duct ideally needs to be relatively thin to minimize hydrodynamic drag forces and achieve good thrust efficiency. Although demonstrator rim driven thrusters were built using induction[5] and switched reluctance machines[11], permanent magnet (PM) machines are bests suited to this application as they are more efficient and can be designed to have a large number of poles and hence be very thin. They are also tolerant of having a large airgap that is needed to accommodate stator and rotor encapsulation layers.

Fig.1 Photograph of a commercial rim-driven thruster (courtesy TSL Technology Ltd)

The manufacture of such radially thin machines poses several practical challenges. For example, the 50mm propeller diameter thruster shown in Fig.2[1] has a lamination yoke thickness of 1.25mm and teeth that are only 1.5mm wide. This makes lamination production and handling challenging and costly.

This paper investigates the design and performance of an alternative brusless PM motor topology that has the potential to overcome these difficulties. In this topology the stator laminations of the slotless motor are manufactured from a single strip of steel that is edge wound into a spiral like a "Slinky". The helical laminations are then fitted over the windings that are preformed on the outside of a non-conducting former. A brief description of the motor and preliminary performance results were published in

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