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A Novel Five-phase Double-Stator Tubular Fault-tolerant Flux-Modulation Permanent Magnet Motor

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Tubular permanent magnet (TPM) motors have been applied to many direct drive systems such as electromagnetic suspension. Double-stator structure can take best use of the motor space and increase the slot area. The flux-modulation structure is based on magnetic gear effect, which makes full use of effective harmonic components of magnetic field. Thus, this structure can increase the force density. Considering the motor reliability, which determines the stability of the electromagnetic suspension, the fault tolerant ability should be considered. A novel double-stator tubular fault-tolerant flux-modulation permanent magnet (DSTFT-FMPM) motor is proposed in this paper. The proposed five-phase DSTFT-FMPM motor is composed of outer stator, mover, and inner stator. The permanent magnets (PMs) are separated from the armature windings and located on the inner stator. The mover acts as modulation teeth to modulate the air gap magnetic field. The PM arrays have two magnetized directions, namely axially and radially. This improves the utilization of magnets as all PMs are used to produce the main flux, while the axial magnetized PMs reduce fringing leakage flux as compared with its counterparts. The main idea of the fault-tolerant teeth and single-layer concentrated winding is introduced to offer fault tolerance. The electromagnetic performances of the proposed motor are analyzed by using the finite-element method. The back electromotive force (EMF) is sinusoidal due to using PM arrays. The detent force is 30N after optimization. The thrust force is up to 840N with low trust force ripple while the phase current is equal to 10A. Finally, the ratio of the mutual-inductance to self-inductance is only 2.2%. That is to say, the proposed motor offers lower detent force, higher force density and excellent fault-tolerance. More detailed content will be discussed in the full paper.

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