Electromagnetic Performance Analysis of an Axial Flux Partitioned Stator Hybrid-excited less-rare-earth PM synchronous Motor

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Mon-Mo-Po1.06-01 [63]

Session: 23 Sep 2019, 09:15

Posters Area: Motors I - Level 2 Posters 2

MT 26 International Conference on Magnet Technology

Vancouver, Canada | 2019

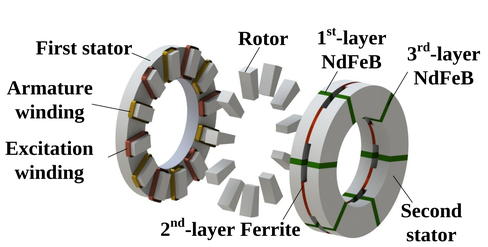
Abstract

In this paper, an axial flux partitioned stator hybrid-excited less-rare-earth permanent magnet (PM) synchronous motor(AFPSHL-PMSM) is proposed, in which the armature windings and excitation windings are placed on the first stator separated from the second stator having two types of less-rare-earth PMs embedded. The motor topology and operating principle are investigated firstly, and it is followed that the initial design of the motor is given. Based on the 3D finite element method (FEM), the optimized of the design parameters are conducted by the multi-objective optimization. The electromagnetic characteristics of the motor are analyzed and compared with that of the initial design. In addition, the flux regulation capabilities are evaluated under different field current in excitation windings. The results not only verify the effectiveness of the motor design but also reveal that the AFPHL-PMSM can exhibit high output torque as well as wide speed range.

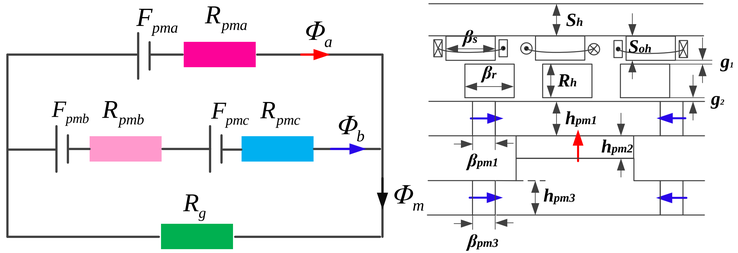
Conclusion

In this paper, a new AFPSHL-PMSM is proposed. Multiple PM combination forms and multiple excitation resources are concerned. The topology and operating principles of the motor are studied, and the effects of the PM design parameters are optimized based on the FEA method. In addition, the electromagnetic characteristics including the flux linkage, back-EMF, torque performances, and anti-demagnetization capability are analyzed. The demagnetization risk of the motor is evaluated, with the protection of the NdFeB PMs, the operating points of the ferrite PMs are well above the knee point, the results reveal that the proposed motor not only retains the high torque capability but also realizes the relatively low-cost design due to the composite magnetic resources of NdFeB and ferrite.

Motor structure



Topology of the proposed AFPSHL-PMSM

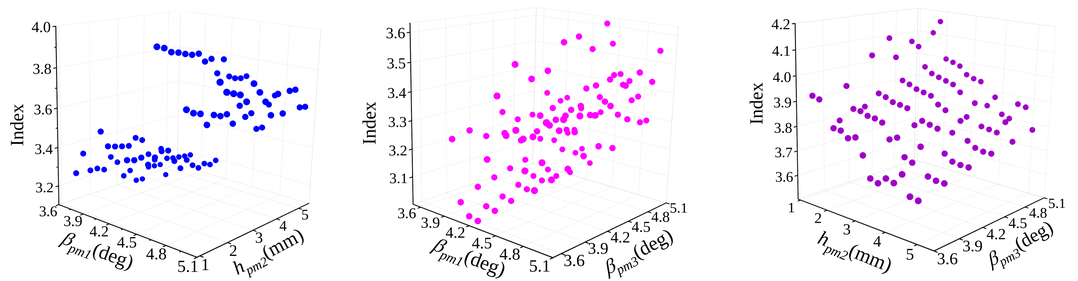


Equivalent magnetic circuit model

Design parameters

The proposed motor is composed of two stators and one rotor which is sandwiched between two stators. *Φa* is the magnetic flux generated from the 1st-layer PMs of the second stator, *Φb* is the series magnetic flux generated from the 2nd-layer and 3rd-layer PMs of the second stator, the magnetic flux *Φa* and *Φb* jointly constitute the main flux *Φm*

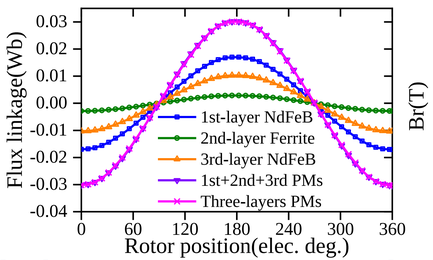
Multi-ojective optimiztion



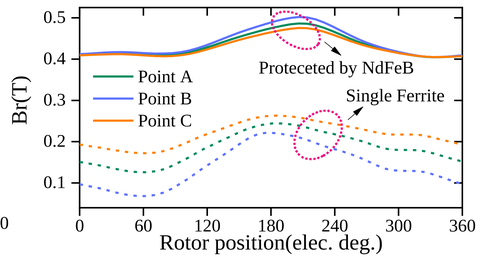
Variation of the comprehensive performance model with respect to the parameters

a multi-objective optimization method is applied to optimize the PM parameters *βpm1*, *βpm3*, *hpm2*, the output torque, torque ripple, and magnetic regulation coefficient *ξ* are selected as the design objectives

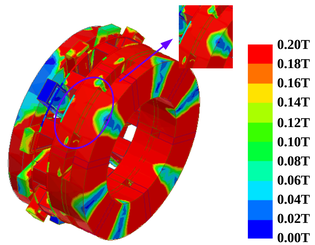
Results



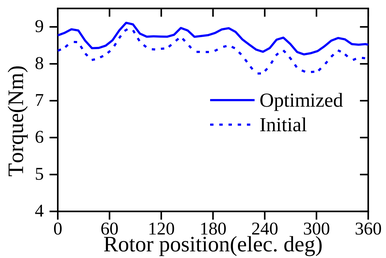
The electromagnetic performance under different PMs excitation conditions



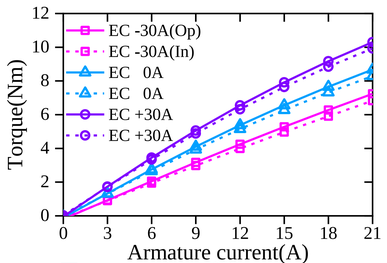
Working points of NdFeB and ferrite PMs



Magnetic flux density distributions



Analysis of output torque performance



Torque with different current in excitation windings

Based on the FEA method, the electromagnetic performances of the AFPSHL-PMSM are analyzed, including flux linkage, output torque, anti-demagnetization risk, and flux regulation capability.