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MODELING AND NONLINEAR CONTROL OF A TOOTHLESS SELF-BEARING MOTOR

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ABSTRACT

Self-bearing motors (SBMs) are an emerging technology that integrates the functionality of active magnetic bearings and conventional electric motors. Generally, the benefits are a more compact design, higher power density, and reduced rotordynamic effects. This paper explores a special type of SBM- the slotless permanent magnet synchronous machine (PMSM). This design has the additional advantage of eliminating cogging torque due to its slotless construction. As a result, it is suitable as a high performance servomotor capable of eccentric rotor positioning (i.e., rotor tilting). However, eccentric rotor positioning introduces destabilizing unbalanced magnetic pull forces and is a considerable modeling challenge. Magnetic field analysis is the key to obtaining a dynamic model. Much of the existing SBM modeling is based on simplifying assumptions such as a current sheet approximation to the stator windings, decoupled reluctance circuit models, and ignoring armature reaction. With an eye towards developing model-based motion tracking control strategies, we derive a reluctance network-based dynamic model which offers several improvements. Specifically, we derive a ring stator reluctance network model to obtain analytical expressions for air gap flux density due to both the permanent magnets and the stator windings. Using insight obtained from a PDE solution to the air gap flux density, we incorporate higher order harmonics to better approximate the flux density waveform shape. Finite element analysis is performed to validate the analytical field solutions, and radial force and torque expressions are derived using a Maxwell stress-tensor.

Keywords: self-bearing motor, magnetic levitation, permanent magnet synchronous motor, finite element analysis, slotless