Design Of An Axial Flux Motor With Innovative Permanent Magnets

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Abstract

Surface mounted sintered magnets are commonly used in axial flux motors and offer strong magnetic flux but generally suffer from high cogging torque and increased vibration. To overcome these drawbacks Halbach arrays can be used as a replacement as they create a more sinusoidal field along with a concentrated field in the air gap, thus leading to a smooth operation. However, Halbach arrays are complex to manufacture and assemble leading to higher costs and therefore are not widely used in commercial electrical machines. An innovative method to make Halbach array permanent magnets with continuously varying magnetization patterns was developed at Advanced Magnet Lab and the process provides ease of assembly along with cost-effective manufacturing. This technology is called the PM-360 which is enabled by the PM-Wire manufacturing process, a powder-in-tube process.

This work presents a comprehensive evaluation of an axial flux permanent magnet motor featuring a 36-slot, 16-pole configuration that utilizes non-sintered NdFeB PM360 permanent magnets. The objective of the study is to assess the performance of the machine—focusing on torque output, back electromotive force (EMF), torque ripple, and demagnetization field using finite element analysis using COMSOL Multiphysics and also to validate the simulation results by comparing them with magnetic field maps obtained from a fabricated PM360 rotor.

Nonlinear magnetic properties were assigned to both the PM360 magnets and the soft magnetic laminations, using measured B-H curves to reflect saturation effects and coercivity thresholds. Temperature effects and field-dependent permeability were also accounted when simulating the magnet's demagnetization field. Simulations also provided insight into the internal demagnetization field in the PM360 magnets, allowing identification of vulnerable regions where the local magnetic field strength approaches the coercive threshold. The torque is computed as a function of rotor angle to compute peak torque and torque ripple was quantified by analyzing harmonic content and periodic variation due to slot-pole interaction.

Field maps of magnetic flux density and magnetic vector potential were recorded across multiple air gaps. These maps were used as a reference in the testing phase, where a prototype PM360 rotor was constructed and magnetic field measurements using 3-axis Hall sensors were compared against simulated data which showed good agreement with minor deviations that can be attributed to tolerances and assembly conditions. The analysis validated the modeling approach of PM360 magnets in a motor application and provided valuable insight into the demagnetization behavior of PM360, offering a good foundation for future motor development using different magnet materials in a PM360 configuration.

Figures used in the abstract

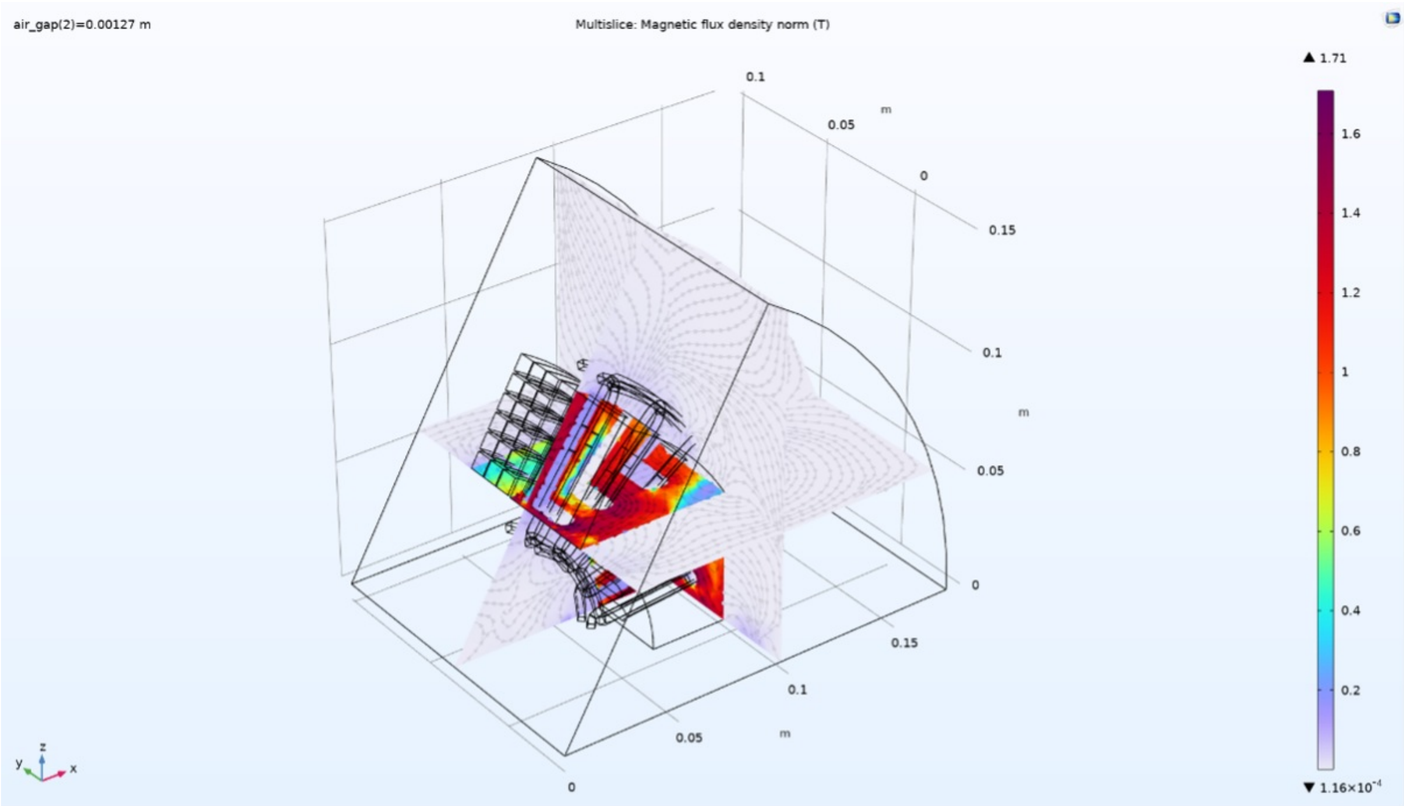

Figure 1 : Magnetic flux Density Contour

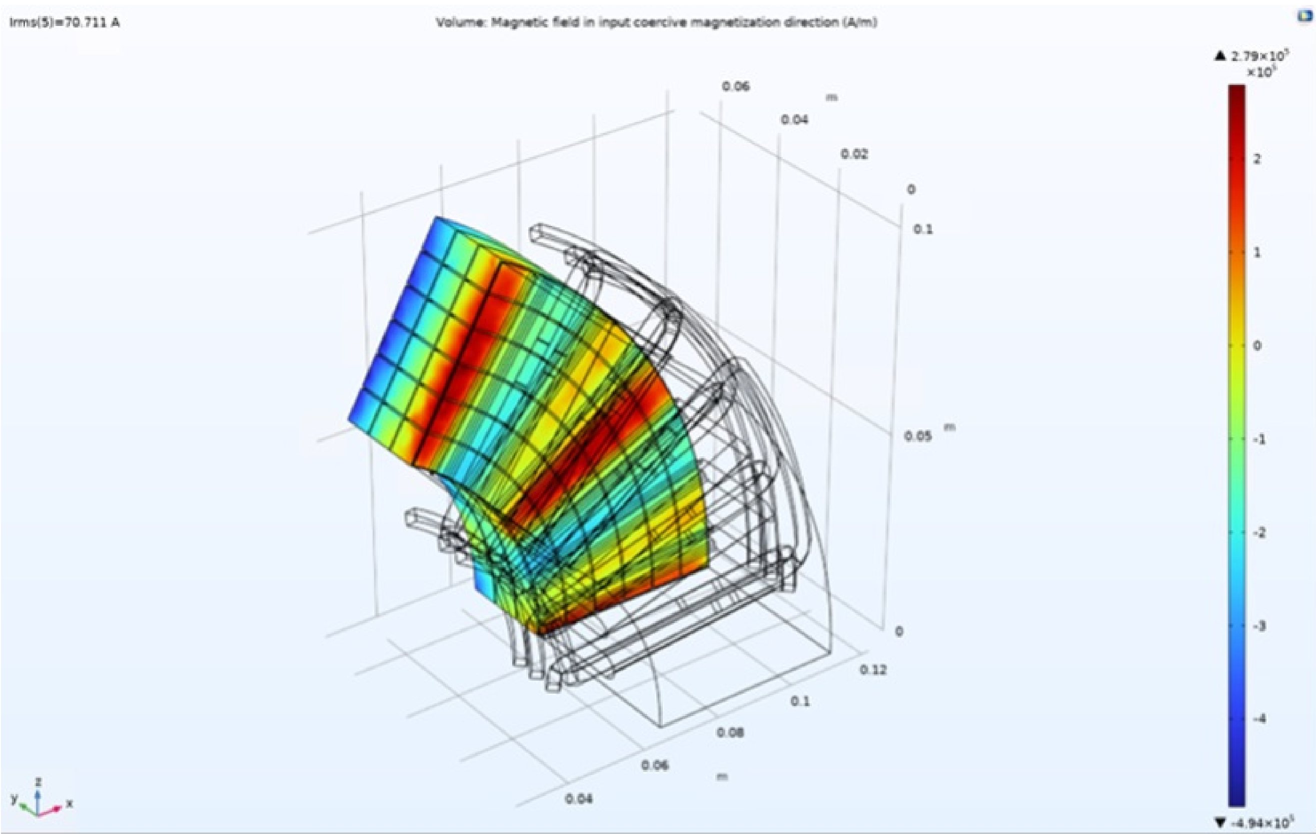

Figure 2 : PM360 Demagnetization field (input coercive magnetization direction)