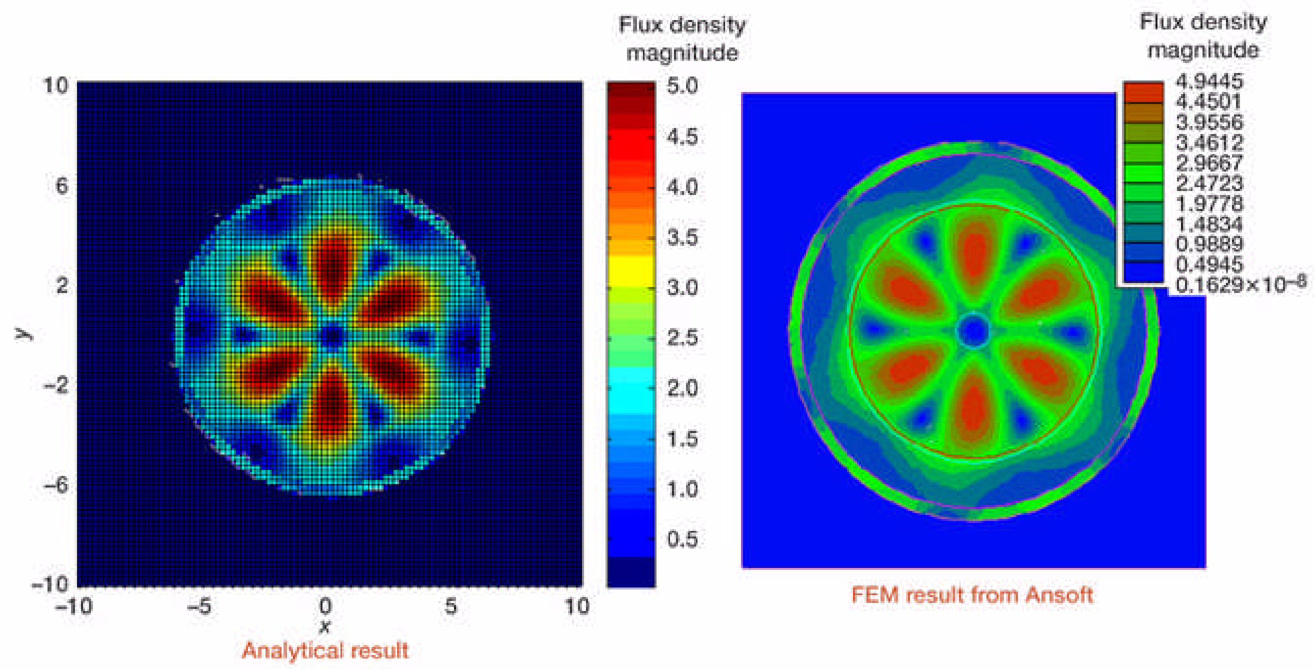
Ultra-High-Power-Density Motor Being Developed for Future Aircraft



Flux density magnitude of a six-pole analytical model with a 1-cm-thick back-iron[1] *(90° phase angle).*

Long description of figure 1 Analytical and finite element model plots with a stator back-iron are shaped a little differently around the back-iron. This is caused by an assumption made in the analytical model that the back-iron was fully saturated.

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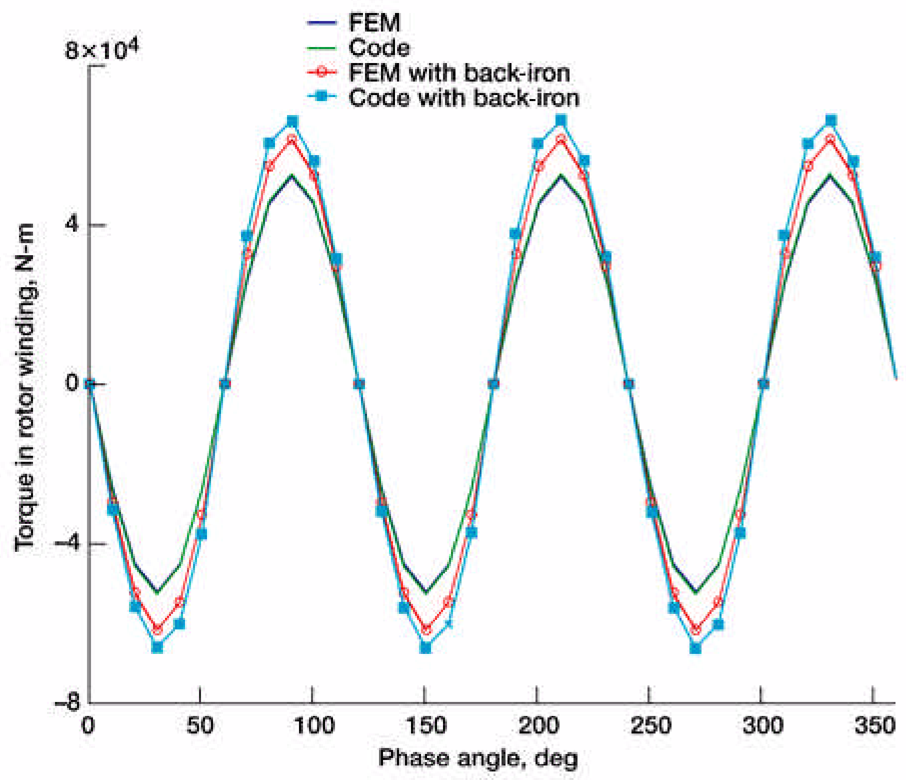

Torque in the six-pole synchronous motor with and without 1-cm-thick stator back-iron (10° increment).

Long description of figure 2 Analytical and finite element model results with no back-irons agree very well, whereas those with stator back-irons have some discrepancies. These results are caused by an assumption made in the analytical method that the bac- iron was fully saturated in the simpler analysis.

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To support the Revolutionary Aeropropulsion Concept Program, NASA Glenn Research Center’s Structural Mechanics and Dynamics Branch is developing a compact, nonpolluting, bearingless electric machine with electric power supplied by fuel cells for future more-electric aircraft. The use of such electric drives for propulsive fans or propellers depends on the successful development of ultra-high-power-density machines that can generate power densities of 50 hp/lb or more, whereas conventional electric machines generate usually 0.2 hp/lb.

One possible candidate for such ultra-high-power-density machines, a round-rotor synchronous machine with an engineering current density as high as 20 000 A/cm^2 was selected to investigate how much torque and power can be produced. A simple synchronous machine model that consists of rotor and stator windings and back-irons was considered first. The model had a sinusoidally distributed winding that produces a sinusoidal distribution of flux *P* poles. Excitation of the rotor winding produced *P* poles of rotor flux, which interacted with the *P* stator poles to produce torque.

This year we made significant contributions to this research:

1. We conducted a constant-tip-speed scaling study for synchronous round-rotor machines. To obtain the specified design and geometry of this high-power-density motor, we had to optimize the design. We analytically verified that Long’s contention, "Specific power is mainly a function of rotor surface speed," is approximately correct. At first, we kept the rotor surface speed constant for the scaled-up motors. Then, we increased the gap diameter by integer multiples of its initial value. It was proven that if surface speed, pole pitch, and electrical frequency are held constant, motors with different sizes develop the same power density.

2. We developed the Electromagnetic Analysis of Synchronous Machines code. This analytical tool and finite element model code uses AnSoft to analyze and optimize the performance of high-power-density synchronous machines (see the figures). This software gives us the basic tools to provide detailed quantitative results and the ability to determine optimal designs for the synchronous round-rotor machines. This work showed the feasibility of using this technology for a future more-electric engine, making advances on the Ultra-High Power Density Motor project.

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[1] Stack of thin iron layers to hold coil winding.