A Cryogenic Cooling System for a Fully Superconducting Aircraft Propulsion Motor

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Abstract
The Cryogenic Hydrogen-Energy Electric Transport Aircraft (CHEETA) study involves the design of a fully electric hydrogen-powered airplane, and its assessment through component-level tests. Fans driven by fully superconducting 2.5 MW motors, made with MgB2 wires, will propel the aircraft. The plane’s supply of 20 K liquid hydrogen fuel will serve a dual purpose as the cryogen for the motor cooling. The dominant heat load in these motors will be AC losses produced in the stationary armature coils. Approximately 3,000 W of AC losses are expected per motor. A conceptual cryogenic cooling system for these motors will be presented, with supporting analysis.

Feasibility Study on Superconducting Motor Topologies for a Hydrogen-Powered All-Electric Commercial Aircraft

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Abstract
The Center for Cryogenic High-Efficiency Electrical Technologies for Aircraft (CHEETA) is a NASA-funded project that aims to design an ultra-efficient (99%) electrical system with high specific power (>25 kW/kg) required for commercial electric aircraft. The system uses liquid hydrogen not only as the energy source for the fuel cells but also as the cryogen for the electrical system. This eliminates the additional cryogenic system weight and opens up the propulsion system design space to consider various motor topologies which leverage superconducting (SC) technologies. Furthermore, operating the electrical system under the cryogenic system also enables various advantages, such as low resistivity of “conventional” conductors like copper or aluminum.

This paper considers a 40 MW regional airplane for 6 hours of operation and analyzes the feasibility of three motor topologies for its electric propulsion: (1) fully superconducting machine with active shield and iron shield configuration, (2) cryocooled partially superconducting machine with active shield and iron shield configuration, and (3) PM machine with SC armature coils. Pros and cons of each topology at the required power level are analyzed, and the optimal motor topology for enabling commercial electric aircraft is identified. Efficiency and specific power are used as the metrics to compare the motor topologies. To obtain a fair comparison, each motor is optimized to maximize its efficiency and specific power.