
SESSION 17: Superconductor Applications

Paper 17.3

Thursday ORAL Session

3:15 PM

Parametric Design Study of Graded Heat Exchanger for Thermal Management of Superconducting and Other Devices on Liquid Hydrogen-Fueled Electric Aircraft

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Liquid hydrogen-fueled superconducting electric aircraft is under development to achieve emissions-free aviation. However, an effective, efficient, and safe cooling system for power devices operating at different temperature regimes and mission states poses a considerable challenge. The powertrain components require high power density to meet the aircraft's weight and space limitations, making efficient cooling crucial. Our NASA-funded Integrated Zero-Emissions Aircraft (IZEA) project focuses on liquid hydrogen fuel as a heat sink, enabling thermally optimal operation conditions for powertrain components. Gaseous helium has been selected as the cryogen in the secondary closed loops due to its broad temperature range without a phase change. A graded heat exchanger that provides helium gas at different temperatures is a vital element of the thermal management system. The graded heat exchanger is a modular design. This design supports multi-temperature secondary cooling loops that transfer heat to liquid hydrogen. Each module is optimized for the required heat loads of the devices operating at their optimal temperatures. The heat exchanger's efficiency and versatility in size and weight are critical for its successful implementation. The geometry, represented by a graded cylindrical heat exchanger with a cold cylindrical core cooled by liquid hydrogen, is analyzed using a 3D finite element model (FEM) for cryogenic thermal simulations. The heat exchanger concept is also suitable for cryocooler-based thermal management systems where the cold core is cooled and thermally anchored to the cold head. The simulation results provide insights into the pressure and temperature drops based on three main structural parameters: thickness of the module, channel diameter, and the number of channels. The analysis considers the interplay of these parameters and their influence on the heat exchanger performance. The paper recommends further research into exploring more complex cooling channel geometries for further optimization of the size and weight of the heat exchanger.