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C2Or4C-06: Modeling and Analysis of Graded Heat Exchangers for Cryogenic Power System of Electric Aircraft Using the AeroCryoX

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This paper presents a modeling approach for graded heat exchangers designed to support cryogenic power systems of hydrogen-fueled electric aircraft implemented within our comprehensive MATLAB/Simulink-based tool, AeroCryoX. The graded heat exchanger concept employs graded and partitioned to accomplish distinct temperature grades to provide multiple secondary cryogen flows to efficiently cool various superconducting and cryogenic components operating at different temperatures: high-temperature superconducting (HTS) generators (20-40 K), HTS cables (50-60 K), and cryogenic power conversion systems and motors (110-140 K). Using AeroCryoX, we develop comprehensive thermal models that model heat transfer and fluid dynamics within each temperature grade.

The paper focuses on two critical cooling loops: the primary loop utilizing liquid hydrogen as coolant and the secondary loop employing gaseous helium. The simulations account for various operational parameters including the cryogen mass flow rates, thermal loads of different components under varying aircraft flight profiles, and the performance characteristics of impellers used to establish fluid flows. Ee systematically evaluated the implementation of graded heat exchangers in aircraft applications. The models enable the determination of critical design parameters such as required hydrogen flow rates for each temperature grade, optimal sizing of cryogenic pumps, and helium flow requirements in the secondary loops.

Results from the models provided valuable insights into the practical implementation challenges and design considerations for graded heat exchangers in aircraft cryogenic systems. The simulation framework is a tool for optimizing cooling system design to predicting hydrogen consumption rates for next-generation electric aircraft. Additionally, the model helps establish operating parameters for the secondary helium loops, ensuring efficient thermal management while maintaining the system's stability across all temperature grades.

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