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Design and Analysis of Cryogenic Cooling System for Superconducting Motor

Content

Superconducting (SC) motors are electromechanical Alternating Current (AC) synchronous machines that use superconducting windings where conventional machines would use copper coils. These machines provide numerous advantages such as reduced size and losses in the rotor, yielding better weight to power capacity ratios when the cooling system is neglected. However, a dedicated, high-power density cooling system is essential to compensate for heat losses and to maintain a superconducting state. A superconductor operates in a conductor stabilized matrix defined by limits on the current, temperature, and magnetic field. A SC AC motor can revert to a "normal" phase, losing its superconducting state, when one of these limits is exceeded. To keep the motor superconducting, the windings must operate at temperatures well below the critical field, thereby providing a reasonable safety margin. One way of effectively cooling a superconducting motor, therefore, is to utilize a cryogenic cooling system.

The Center for High-Efficiency Electrical Technologies for Aircraft (CHEETA) aims to utilize Superconducting Motors with electrically-driven propulsors for aircraft applications. To meet the cooling requirement of the superconducting motors, CHEETA proposes using a Cryogenic Liquid Hydrogen (LH2) Cooling system. This paper briefly discusses the design of such a cooling system. The design is analyzed by developing multi-domain models using the Modelica modeling language in the Dymola software tool, where the thermal behavior is modeled and interfaced with its electromechanical model. These models allow to simulate the flow of LH2 coolant through the designed helical heat exchanger. The paper aims to study pressure drops in the bends of the helical tubes, the heat transfer potential of such a design, and the phase change from LH2 to 2-phase H2 (forced-flow boiling) while the coolant moves from the inlet of the cooling circuit towards the exit. This paper aims to validate the design of the cooling system through this endeavor.

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