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M3Or2G-03: [Invited] Superconducting electric machines for electric propulsion –CHEETA motor, HEMM motor, and CRUISE motor, a comparison.

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Superconducting electrical machines have emerged as an enabling technology for electric propulsion applications, and there are several ongoing efforts to develop these machines. The NASA High-Efficiency Megawatt Motor (HEMM), Center for High-Efficiency Electrical Technologies for Aircraft (CHEETA), and Cryogen Free Ultra-High Field Superconducting Motor (CRUISE-motor) are at the forefront of superconducting electric propulsion motor development, and this paper provides an in-depth comparison of these machines.

The CHEETA motor is specifically designed for use in a hydrogen-powered electric aircraft. It is a fully superconducting electric machine with a power output of 2.5 MW and a specific power greater than 25 kW/kg, achieving an impressive efficiency of 99.9%. To take advantage of the available liquid hydrogen, the machine is designed to be cooled by the hydrogen flow to the fuel cells.

NASA's HEMM is a partially superconducting motor with an HTS field winding and copper armature winding. It is a 1.4 MW electric machine that aims to achieve a specific power of 16 kW/kg with 99% efficiency. To cool the field windings, a rotating cryocooler is integrated with the rotor, which eliminates the need for external cooling to the rotor.

Hinetics is developing a Cryogen Free Ultra-High Field Superconducting Motor (CRUISE-motor) for large-scale electric airplanes. The aim is to develop a 10-MW partially SC electric machine with a specific power of 40 kW/kg and 99.4% efficiency. The machine features an integrated cryocooler on the rotor that provides cooling to the field windings. It also has a novel spork-supported rotor architecture that eliminates the conduction heat from the torque tube, minimizing the cooling load on the cryocooler. The air-core stator with exceptional thermal performance results in a modest armature temperature. These features enable Hinetics to develop a practical partially SC machine for electric propulsion applications.

This paper presents a detailed comparison of the key performance metrics of these three machines and provides updates on their development and testing. In addition to this, the full paper includes EM optimization, EM analysis, mechanical design and analysis, thermal analysis, and updates on risk reduction experiments of the CHEETA and CRUISE motors.

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