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M2Or4A-05: [Invited] Motor configuration selection for a new technical challenge to develop a 5 MW cryogenic motor and drive

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Due to aviation’s appreciable and growing share of humanity’s impact on our environment and estimates that CO2 emissions only account for 34% of aviation’s total effective radiative forcing [1], there is a need to reach beyond climate goals that focus only on CO2 emissions, such as the US Aviation Climate Action Plan’s [2] goal to reach net-zero carbon emissions by 2050. There is motivation to develop technology that pushes toward future large transport aircraft with net zero climate impact that are highly electrified (i.e., have higher power electrical propulsion system components). This paper describes a new, 6-year technical challenge to address this need by developing a 5 MW superconducting motor and cryogenic drive. Section 1 will detail the motivation for this work. Section 2 will describe the technical challenge and the selected specifications for the motor. Section 3 will present the results of a motor configuration trade study and the down selection of one configuration to develop a detailed design for.

The technical challenge focuses on the design of a 5 MW superconducting motor and cryogenic drive and demonstration of it at a MW scale to achieve TRL 3. Both fully superconducting (superconducting stator and rotor) and fully cryogenic (superconducting rotor and cryogenic stator) machine configurations will be explored. An emphasis will be placed on addressing the key tall poles for high power superconducting machines. Further details will be included in the full paper.

The requirements and goals of the motor will be detailed. The rated speed (2,000 to 3,000 rpm) is defined to be appropriate for directly driving multi-MW fans or propellers. A range of rated speed is permitted because the motor is not designed for a specific aircraft and to provide design flexibility if AC losses in the stator winding are found to be a significant constraint (i.e., a lower speed can be selected to reduce electrical frequency). Relatively conservative requirements for efficiency (99%) and specific power (20 kW/kg) are defined, because TRL advancement and pushing toward flight readiness is emphasized over performance optimization. However, more aggressive efficiency and specific power goals are specified (99.9% and 40 kW/kg).

The 3rd section will present the results of a motor configuration trade study. The study started with a qualitative assessment of sixteen motor configurations based on geometric, mechanical, thermal, and electromagnetic criteria. This assessment has been completed with three evaluators scoring all nine criteria. A configuration down select was made by prioritizing the sixteen configurations into four tiers based on each configuration’ s total score and consideration of manufacturability, complexity, and support hardware (e.g., rotary vacuum seals, bearings). Configurations in priority A and B will be further evaluated through quantitative assessments, whereas those in priority C will only be further evaluated if time permits and priority D will not be further evaluated. Eight of the sixteen configurations were down selected for quantitative assessment, which will include analytical calculations and low- to moderate-fidelity finite element analysis to produce a preliminary Pareto front of efficiency versus specific power for each configuration. This assessment emphasizes the calculation of AC losses in the stator winding and an exploration of thermal management approaches to remove that heat and maintain cryogenic temperature.

The final paper will include a description of each motor configuration that was considered. The quantitative assessments are underway, and an assessment of one configuration is complete for multiple stator conductor options. The remaining assessments are scheduled to be completed by late March so that the final down select to one configuration can be included in this paper.

[1] D.S. Lee et al., “The contribution of global aviation to anthropo-genic climate forcing for 2000 to 2018,” Atmos. Environ. 244, 117834, 2021.
[2] Federal Aviation Administration, “United States 2021 Aviation Climate Action Plan,”2021.

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