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M2Or3A-01 [Invited]: A fully superconducting air-core machine for aircraft propulsion

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High-speed fully superconducting (SC) machines for aerospace applications need to achieve high power density while reducing losses. To increase the power density and eliminate core losses, an inside out synchronous machine is proposed with the iron yoke replaced with actively shielded coils. The additional coils are placed radially outward to contain the flux within the machine. Since core saturation is eliminated, higher flux density design can be achieved with this topology. Initial studies have shown that flux density up to 3 to 5 times of conventional iron core design is possible, and more compact machine designs can be attained compared to conventional designs. Previous studies indicated that with a 5 T air gap flux density, 35% volume reduction can be attained with only a 17% increase in superconductor usage.

Converting this machine to a fully SC design can potentially offer further performance improvements. However, ac losses in the armature winding in fully SC machine designs introduce a limitation on the achievable air-gap field strength and frequency. This paper explores fully superconducting actively shield machine design for aircraft electric propulsion. A 12-MW, 8000-rpm MgB2 based fully SC machine design is investigated. A feasibility study of this topology for electric propulsion is studied considering efficiency, weight, cryogenic design, mechanical performance and cost. Special attention is given to the ac losses in the machine. An optimal design is targeted which reduces the SC usage and weight while constraining the total ac loss in the machine below a practical limit. A pole count study will be conducted to identify the optimal frequency which balances tolerable ac losses with high power density. The results are compared against a traditional iron core machine to evaluate the benefits.

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