The University of Manchester

Design and Performance of AC Superconducting Motors for Aerospace Electric Propulsion Systems

Introduction

Hybrid electric distributed propulsion (HEDP) has been identified as a potential solution to the ambitious environmental emissions and noise targets of the aerospace industry. Conventional electrical motors have been considered too heavy for use in aircraft propulsion so to reduce weight and volume a fully or partially superconducting HEDP system has been proposed. A power dense and high efficiency superconducting motor is the key component of this promising architecture and the development of such a machine designed for aircraft propulsion systems would enable the hybrid electric aero-propulsion concept.

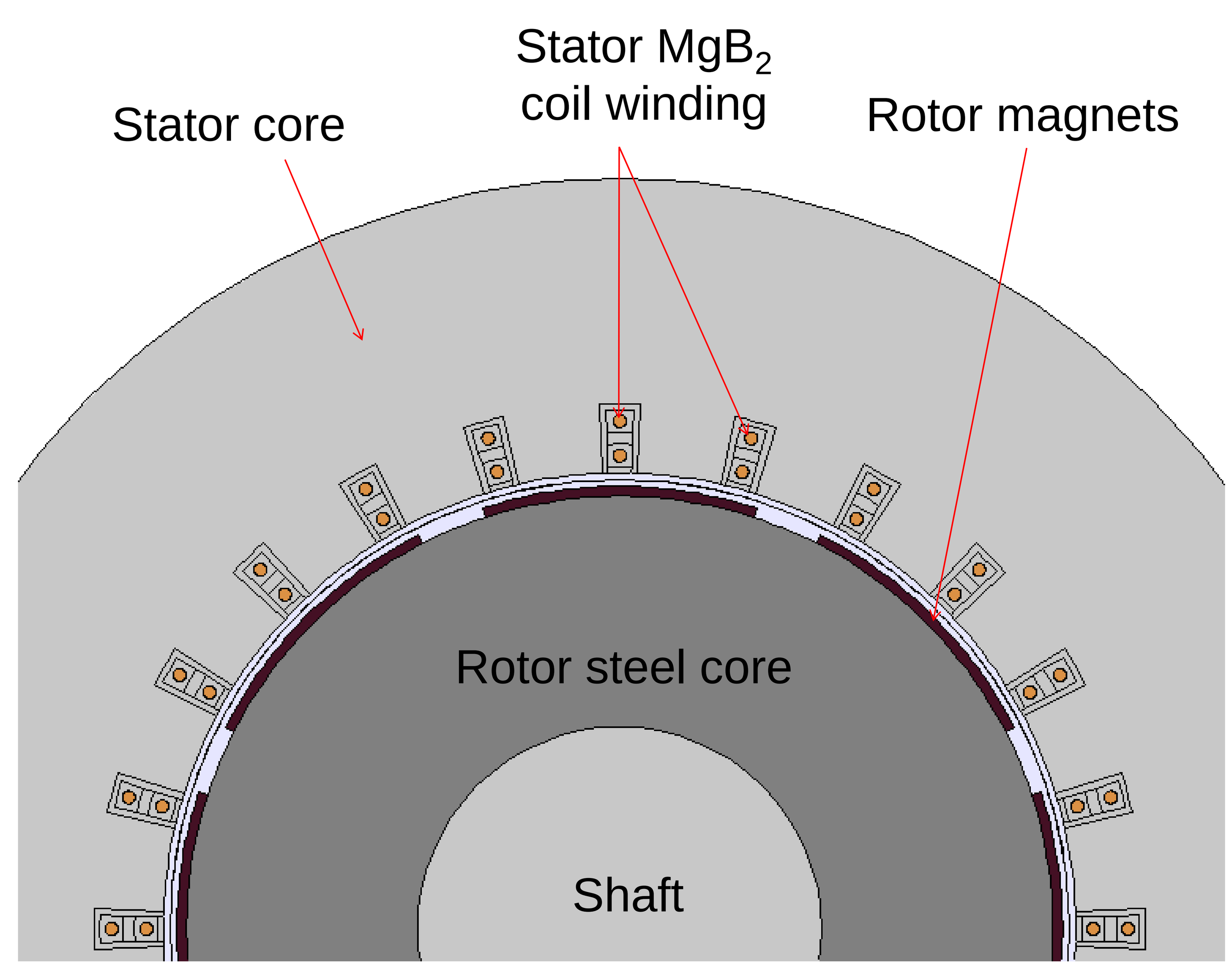

Fig 1: 1MW Superconducting AC machine concept model

Project Objectives-Specifications

This project is focussed mainly on the AC superconducting stator winding. A benchmark 1MW, 12000rpm motor specification is used: Figure 1 illustrates the 1MW AC fully superconducting machine model. The work looks at the impact of removing the magnetic stator core to reduce weight and the effect of the rotor field on the conductor losses with and without flux diverters around the coils. The machine performance is evaluated in terms of weight and efficiency.

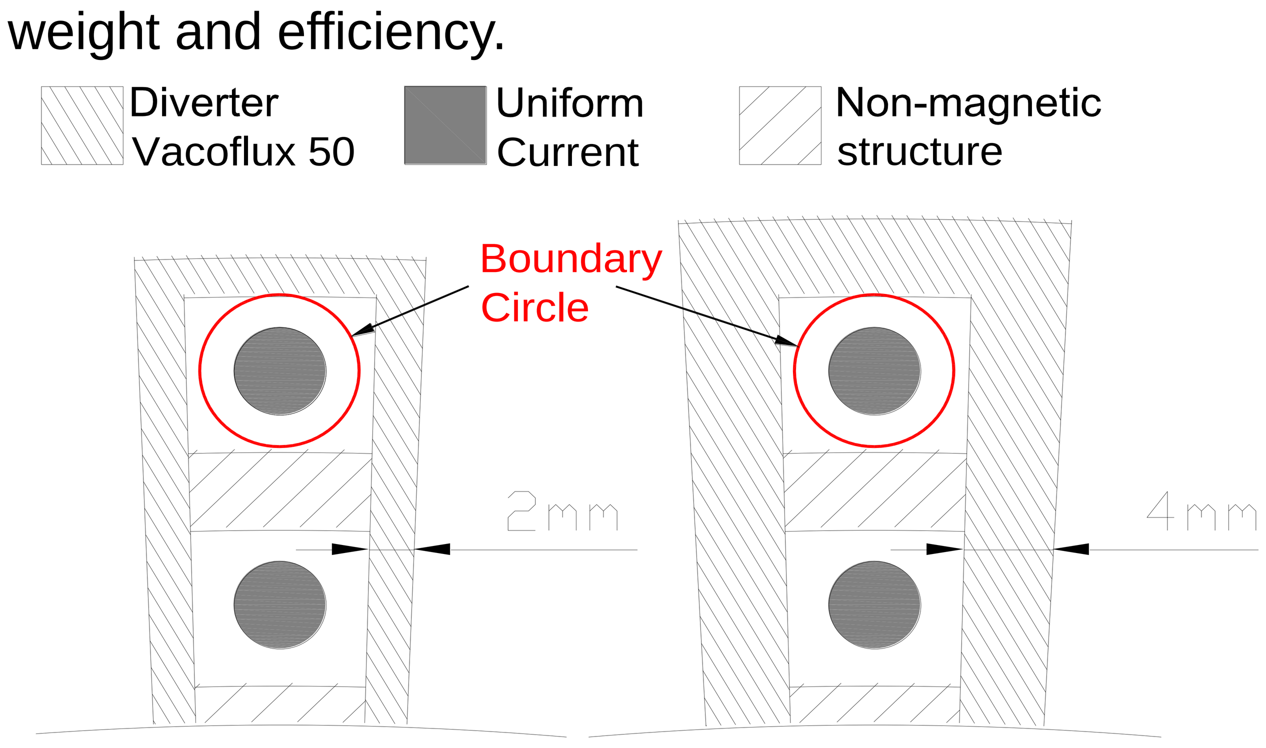

Fig 2: Schematic diagram of thin (left) and thick (right) flux diverter position around the superconducting coils. The boundary circle is used to couple the machine model with the superconducting wire model.

Superconducting machine modelling & armature loss estimation

The machine model uses uniform current density to calculate the field distribution, neglecting the superconducting properties. The rotor was assumed to have superconducting bulks or stacks of superconducting tapes acting as equivalent PM blocks. The tangential magnetic field at the boundary circle is then applied to the superconducting wire model to obtain the current distribution and finally the superconducting losses. The flux diverter design and the boundary circle used to couple the two models are shown in figure 2. Figure 3 illustrates the real arrangement of the MgB_2 superconducting strands inside the boundary circle and the current distribution for the air-cored design.

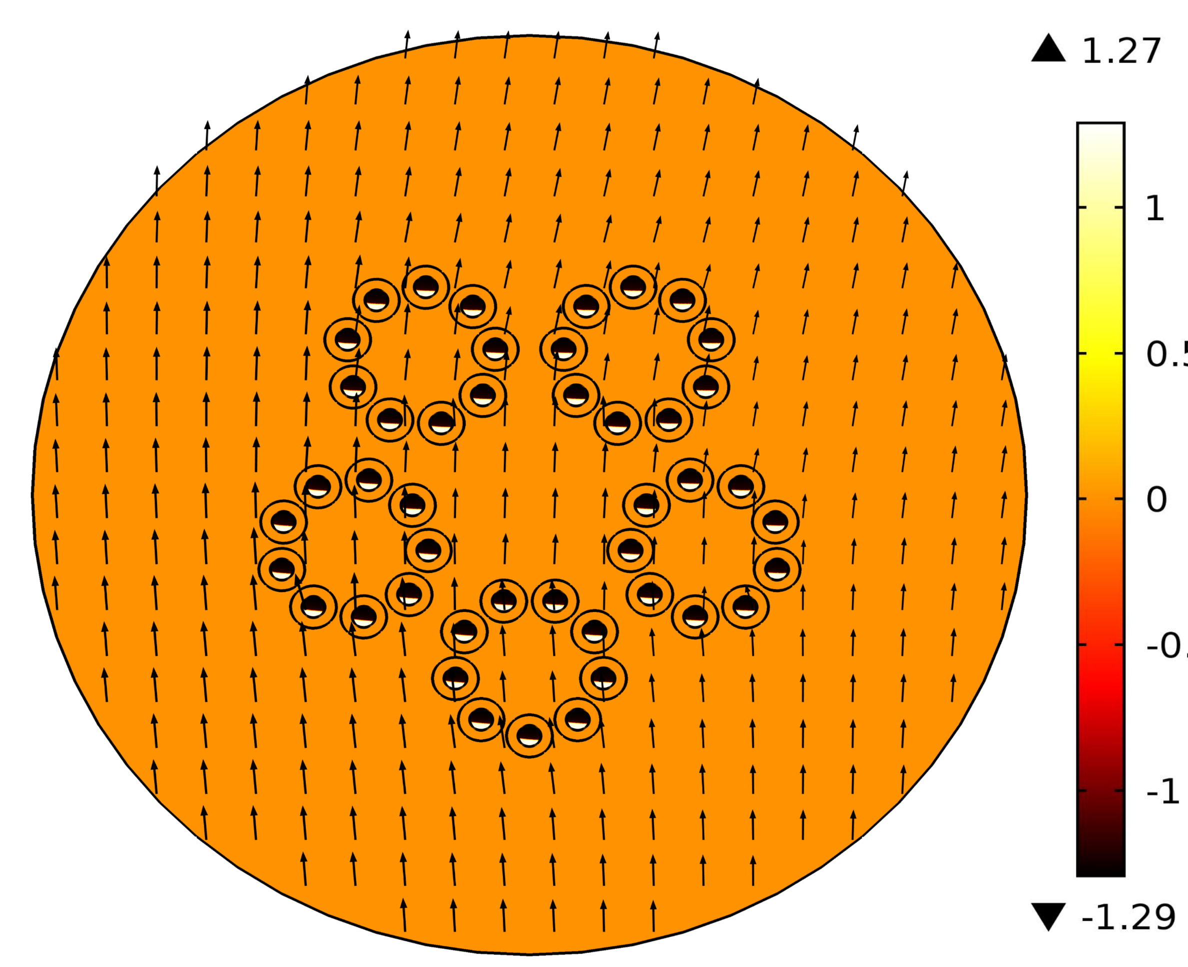

Fig 3: Normalized current density distribution J/Jc in an outer-layer coil of the air-core stator. The coil has 5 turns composed of 9 mono-core strands. Each strand carries the same current as transposition is assumed.

Results

Figure 4 shows that, as the volume of the iron is increased in the machine, the more effective the screening becomes and the lower the superconducting losses are. However, the added iron reduces the power density significantly. Direct comparison is possible because the magnetic and electric loadings are the same for all the designs. The 4-pole designs have half frequency; however they produce higher superconducting losses because of the stronger field seen by the superconducting armature coils. The magnetic stator design has the lowest armature losses but it has high iron losses and weight. The flux diverters do not add significant weight but the superconducting loss reduction is not sufficient compared to air-core design.

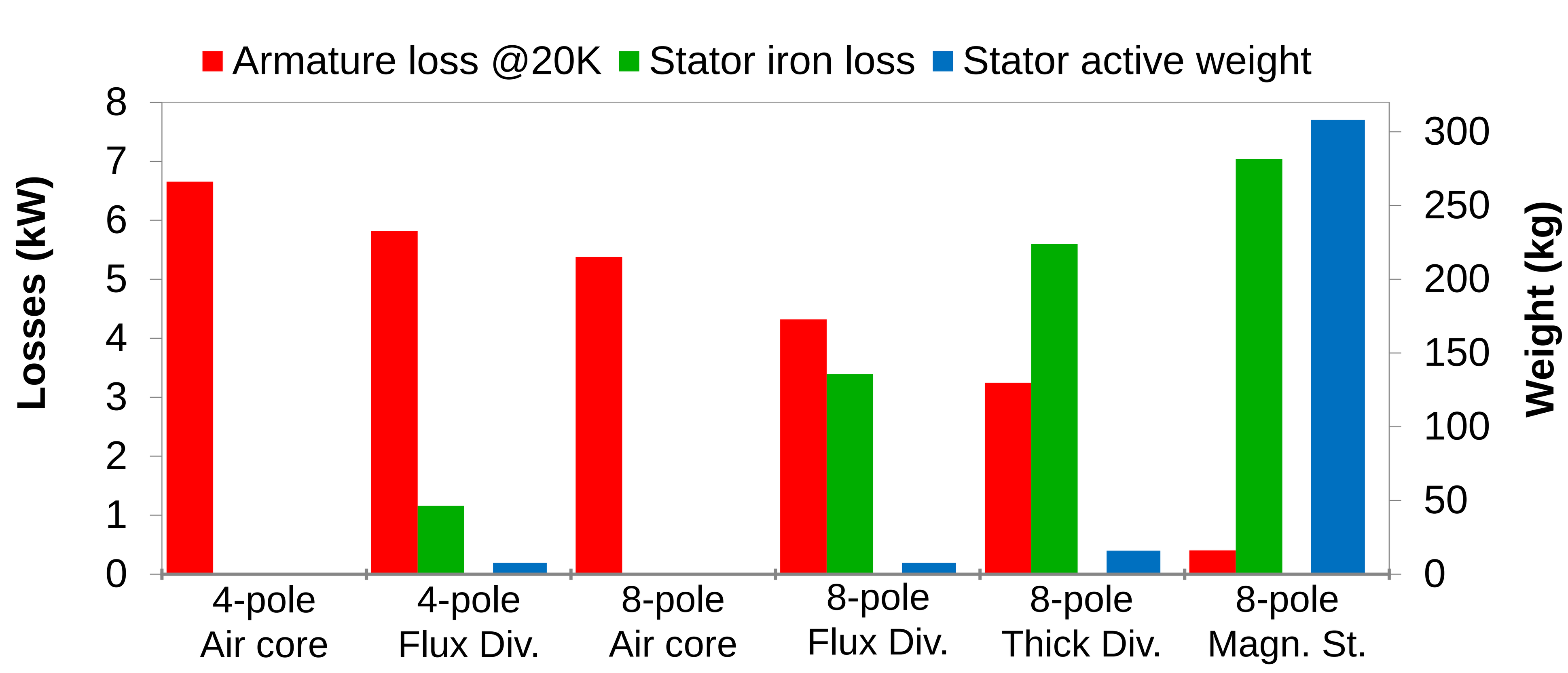

Fig 4: Stator losses and weight for different designs.

Conclusions

The results showed that there is a trade-off between added iron losses and the superconducting losses. Further research on superconducting materials and/or winding techniques that reduce the sensitivity of the AC losses to external fields is required to enable a fully superconducting machine concept for hybrid-electric aero-propulsion.

Power & Energy Division
School of Electrical and Electronic Engineering
The University of Manchester

For details contact: ***Charalampos Manolopoulos***; Tel.: ***+44(0)7451409507***;
E-Mail: ***charalampos.manolopoulos@postgrad.manchester.ac.uk***
Supervisors: ***Prof. Sandy Smith & Dr. Matteo Iacchetti***
E-Mail: ***sandy.smith@manchester.ac.uk***; ***matteo.iacchetti@manchester.ac.uk***

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