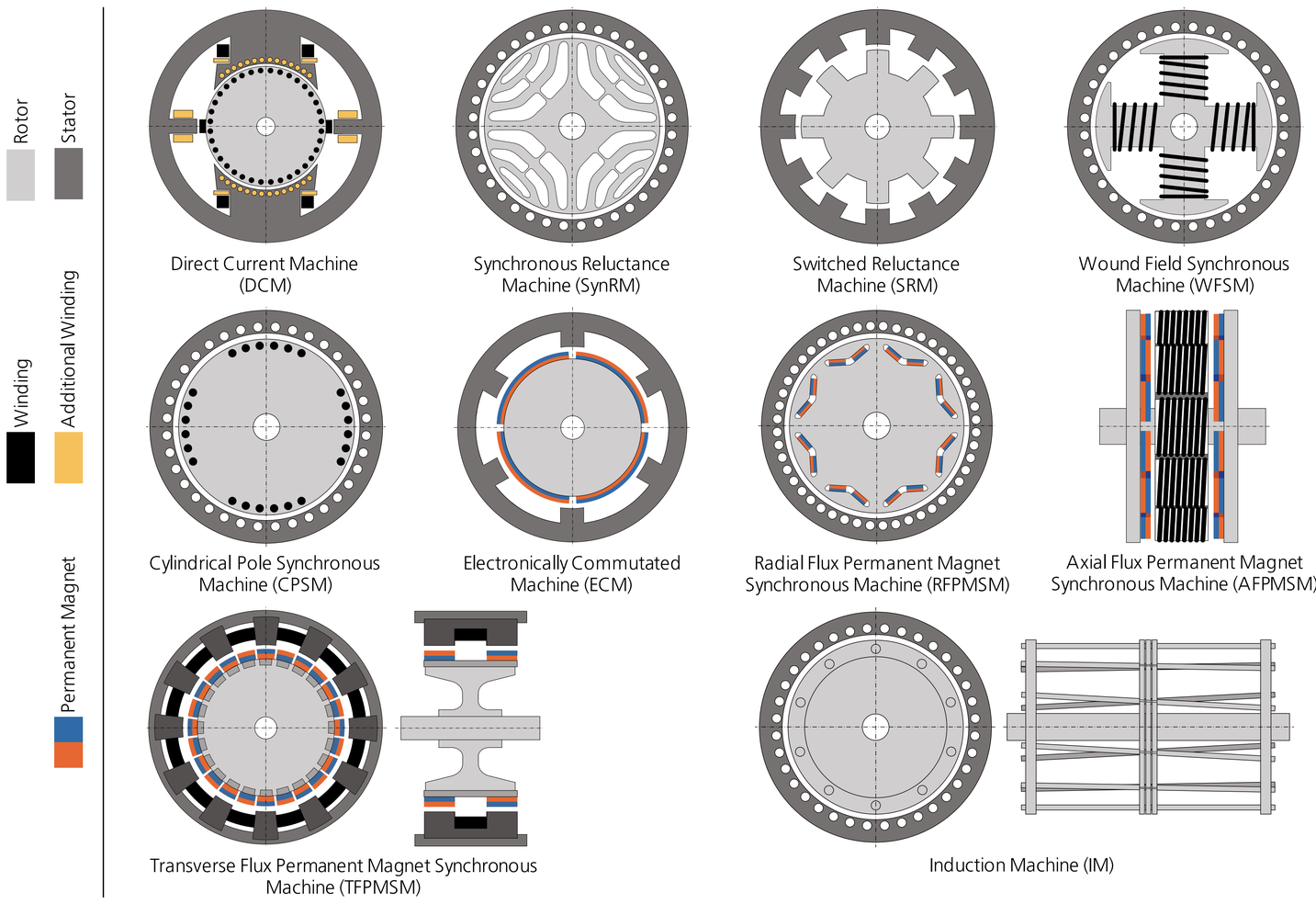
ELECTRIC MACHINES

High Specific Power MW-Class Electric Machines for Electrified Aircraft Propulsion

F. Heise, E. Teichert, S. Kazula – Institute of Electrified Aero Engines – German Aerospace Center (DLR)



Overview and principle structure of common electric machines

Electric Machines

Electric machines are used in a wide range of applications. In future electrified aviation, high power classes and power densities will be essential to meet the strict requirements in terms of safety, reliability, and durability under varying conditions of altitude, temperature, and air pressure. This opens up numerous research questions and investigations.

In view of the diversity of machine topologies, the evaluation of their suitability is essential as an initial investigation for further analyses and can be carried out with the aid of evaluation criteria derived from aviation-specific requirements:

- Performance and Mass (P)
- Ease of Integration (I)
- Safety (S)
- Reliability and Life Cycle Costs (R)
- Technology Readiness (T)

Using the weighting from a pairwise comparison, the most promising topologies can be evaluated after pre-selection by exclusion criteria.

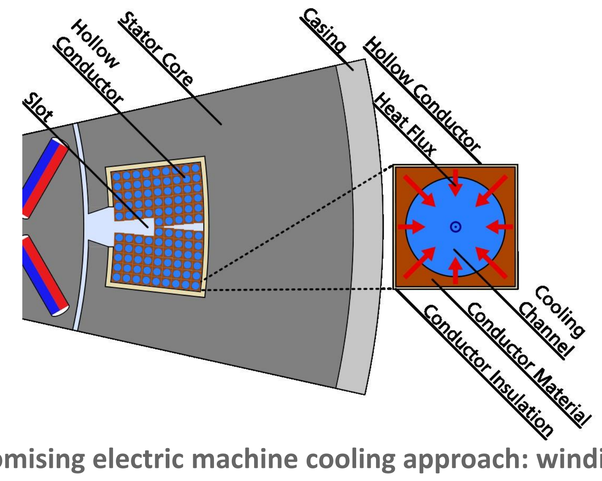
The RF- and AFPMSM show great potential due to their high power density and ease of integration as well as the SRM due to its high reliability. The WFSM and IM are rated with less potential in the highly application-specific evaluation, but are the preferred choice in certain applications.

Overall, it is clear that the analyses need to be extended to system level in order to take into account dependencies between components. With regard to future electric machines, materials, cooling systems and power electronics will be key technologies for high performance motors.

Results and evaluation factors of the criteria-weighted evaluation of relevant electric machine topologies

	P	I	S	R	T	r_j
RFPMSM	+	+	+	o	+	**0.71**
AFPMSM	++	++	+	-	o	**0.78**
WFSM	o	+	+	-	+	**0.59**
SRM	-	+	++	+	o	**0.65**
IM	-	+	+	o	+	**0.54**

r_j – Normalized and weighted evaluation factor



Promising electric machine cooling approach: winding cooling through coolant-perfused hollow conductors

Cooling of Electric Machines

Electrified aviation requires high power electric motors with low weight and low volume. Highly capable cooling systems allow to increase current densities and/or rotational speeds to obtain more power output while maintaining geometrical extents and mass of the electric machine – thus, to increase power density. Such cooling technology requires to be highly suitable for aviation applications, leading to the following assessment criteria:

- Cooling Effectivity
- Energy Efficiency
- Additional Mass
- Safety & Reliability
- Costs & Durability

To enable a quantitative comparison and well-founded selection of preferable cooling concepts, these criteria were subjected to aviation-adjusted weighting through pairwise comparison. This facilitates the expedient evaluation of established cooling technology. The assessment results indicate outstanding technical characteristics of three approaches: channel cooling (CC), hollow conductor cooling (HCC) and heat pipe cooling (HPC).

Results of the criteria-weighted evaluation of electric machine cooling concepts

As their strengths and weaknesses are concept-specific, the advantageousness of a combination of those promising cooling methods seems obvious. Such cooling system could potentially increase the electric machine's power density, enabling electric aircraft propulsion and hence mitigating aviation-related climate impact.

Contact
Enrico Teichert
German Aerospace Center (DLR)
Institute of Electrified Aero Engines
Component Technologies
enrico.teichert@dlr.de

Publication
Teichert, E.; Kazula, S. (2024): Overview and Evaluation of Electric Machines for Electric Regional Aircraft Propulsion Systems. Deutsche Gesellschaft für Luft- und Raumfahrt - Lilienthal-Oberth e.V.. https://doi.org/10.25967/630118

Contact
Frederik Heise
German Aerospace Center (DLR)
Institute of Electrified Aero Engines
Component Technologies
frederik.heise@dlr.de

Publication
Heise, F.; Kazula, S. (2024): Overview and Weighted Evaluation of Cooling Concepts for High-Power Electric Machines in Electrified Aircraft Propulsion Systems. Deutsche Gesellschaft für Luft- und Raumfahrt - Lilienthal-Oberth e.V.. https://doi.org/10.25967/630180