# Heat exchanger design for distributed electric propulsion

## Electric Propulsors for Regional Aircraft (EPROREF)

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### In Short

- Heat exchanger design optimization
- Propeller - heat exchanger interaction

Distributed Electric Propulsion (DEP) approach is the use of multiple propulsion units placed at different positions over an aircraft in order to achieve a beneficial aircraft-propulsor coupling. Propellers can be distributed over the span of the wing and also placed on the wing tips. In this configuration the propellers along the wing span, generate a higher dynamic pressure over the wing surface giving rise to the possibility to reduce the wing span required during take-off, which will reduce the wing drag. The propellers placed at the wing tips can be used to decrease the drag induced by the wing tip vortices which would further reduce the overall drag. Studies have shown that using DEP it is possible to achieve an efficiency multiplier of 4.8 at selected cruise conditions.

The objective of EPROREF ("Electric Propulsors for Regional Aircraft-) is the investigation and preliminary design of electric propulsion system for a regional aircraft for 20 to 50 passengers and a range of up to 1000 km. The concept is part of the technology focus "Hybrid-Electric Propulsion Systems in Aeronautics.

IFAS focuses its research on the potentials and synergies of distributed electric propulsion systems and the design of the necessary propellers adapted to electric motors. In aviation, electric propulsion systems in higher power classes for regional aircraft (approx. 1 MW) and above are largely unexplored. In order to achieve the necessary high efficiency in electric motors, it is currently assumed that the use of superconductors may already be necessary from around 1 MW size. However, their use leads to considerable technical and weight costs for the cryogenic system. Furthermore, a compact design of the cryogenic systems including power electronics and motor is problematic for typical aerospace propulsion architectures (distribution on fuselage and nacelle). Using the distributed electric propulsion (DEP) approach compared to conventional, 2-motor regional aircraft, there is an opportunity to keep the individual motors small enough and thus eliminate the need for superconducting materials in the powertrain, while maintaining high overall efficiencies through the synergies of distributed propulsion.

The most important advantages of an electric drive are the extension of the usable speed range, higher efficiencies and better scalability with less dependence on the machine size [5]. The feasibility of electric powertrains has already been demonstrated for very small aircraft such as the eFan. Some of the concepts are based on conversions of conventionally powered aircraft, which means that in most cases series components are used that have not been optimized in any way with regard to the interaction of electric motor and propeller. Current new developments are mainly in the field of VTOL aircraft and PAVs, where both multicopter and tilted-wing configurations are being pursued. In addition, due to improved scalability, there are new opportunities for integrating distributed propulsion with a variety of small electric motors on aircraft that were not possible with internal combustion engines. These new approaches allow much greater emphasis to be placed on functional integration of the propulsor and wing. The greatest advantage here is the significant increase in lift due to the additional velocity induced by the propellers over the entire wing span, which already occurs during takeoff[3]. By Deere et al [4] a doubling of the Lift coefficient demonstrated by this approach. This results in a wing in which optimization can give a much greater weighting to the cruise condition, thereby minimizing drag. Another approach to minimize the drag of the wingtip vortex due to the resulting wings of large aspect ratio and high wing loading is to position additional propulsor units at the wingtips that rotate in the opposite direction to the outgoing vortex.

One of the challenges for DEP systems is the heat generated by the electric motors. If the waste heat generated from the losses in the motor are not ejected out of the system, it can lead to significant degradation of the motor performance. Studies have also shown that the rate of climb of an electric aircraft had to be limited due to the heat generated. The electric motor used in EPROREF generates a maximum power of 200kW and at this power rating it produces 14kW of waste heat. One of the objectives of EPROREF is to cool the motor heat exchangers using the propeller slipstream, see Figure 1. This is done so that an additional cooling unit is not required. In order to increase the heat flux from the heat exchangers, the slipstream velocity in the vicinity of the heat exchangers is increased by modifying the propeller geometry. The propeller geometry is modified using Patterson approach outlined in [7], and the algorithm developed at IFAS which implements the BEMT and the Patterson approach described in [6]. The heat removed from the heat exchanger plates can also be increased by modifying the geometry of the plates. For example, the inclination angle of the plate can be modified to match the propeller flow exit angle, the gap between the plates

can be modified to reduce blockage and the height of the of the plate in the streamwise direction can be varied as well. The objectives of the study to be performed using the HLRN resources are:

- Study the geometrical parameters of the heat exchanger plate that has the most impact on the heat transfer.
- Perform design of experiment (DOE) studies on the heat exchanger plate geometry and propose the optimal design for the configuration
- Compare the results
- Perform URANS simulation and study the affect the heat exchanger has on the blade performance.

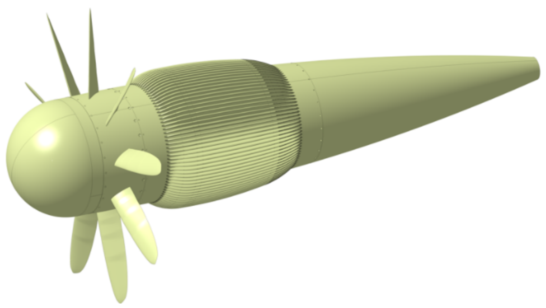

***Figure 1:*** *Propeller with heat exchangers placed downstream.*

## WWW

https://www.tu-braunschweig.de/index.php?eID=dumpFile&t=f&f=136270&token=7f964d51204182706c8015507eb88fcc69929c7b

## More Information

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## Project Partners

Oswald, IMAB TU Braunschweig

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