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Master's thesis: Optimization of the cooling system for a fuel cell powered regional aircraft

Background:

Fuel cell powered electric aircraft are being investigated as a possible future solution for decreasing emissions from commercial aviation. Low temperature polymer electrolyte membrane (LT-PEM) fuel cells are being considered a promising candidate, as they feature the highest power density among the existing fuel cell technologies. Their low operating temperature (typically below 95 °C) has several benefits, because it allows for using cell components with superior electrochemical performance and lifetime compared to those suited for high temperature operation. However, the low operating temperature results in challenges for the fuel cell's waste heat removal.

While in conventional aircraft engines the waste heat is removed with the exhaust air, LT-PEM fuel cells require an additional cooling system as only part of the waste heat can be removed via the cathode outlet air flow. State of the art LT-PEM stacks use a recirculated liquid coolant to remove waste heat. The additional mass and aerodynamic drag of the heat exchangers required for the heat transfer from coolant to ambient air can be a major challenge for the integration of fuel cells into larger aircraft. This effect is especially pronounced for LT-PEM stacks due to the small temperature difference between coolant and ambient air. Possible solutions include improvements of the cooling system, improvements of the LT-PEM stack and auxiliary components.

Objectives:

The research will be carried out with the example of a hypothetical fuel cell powered ATR 72 size aircraft. Building on an overall aircraft design carried out in a previous study, this work focusses on improvements on the cooling system for that design. The following aspects will be investigated:

1) Literature study on conventional and innovative cooling system components (heat exchanger, air intakes, etc.). Identification of applicable aircraft certification requirements.
2) Preliminary system-level design of promising cooling system concept(s) for which the integration (structurally and thermodynamically) into the aircraft seems feasible.
3) Development of a system-level simulation model for promising cooling system concept(s) that allows for investigating the most relevant aspects regarding thermodynamic effects and operating strategies
4) Estimation of the component size dependent system mass, volume and aerodynamic drag based on the developed model and empirical data (as found in public literature and/or provided by DLR)
5) Optimization of the cooling system's component sizes with the objective of reducing the overall system mass, volume and aerodynamic drag

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