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Title
Two-phase pumped cooling system for power electronics; analyses and experimental results

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Abstract
With the introduction of hybrid-electric propulsion, the amount of electrical power in the next generation of aircraft dramatically increases compared to current day architectures. Therefore, the total power dissipation from electrical components will be up to orders of magnitudes higher than for conventional aircraft, even if high levels of efficiency are achieved within the electrical components. For this reason, novel mechanically pumped fluid cooling systems have gained attention as a means to cool power electronics on these aircraft, with a reduced effect on system performance compared to currently applied cooling technologies.
In the EU-funded H2020 EASIER project, both liquid and two-phase Mechanically Pumped Loops (MPL) are analysed. A two-phase MPL is similar to a liquid MPL, with the exception that in a two-phase MPL the working fluid (partly) evaporates, at the interface with the heat source. A two-phase MPL shows several advantages compared to a liquid (i.e. water-eglycol) MPL: (1) the fluid temperature is independent of the heat load due to the isothermal evaporation process, resulting in a uniform temperature distribution over the interface with the power electronics; (2) the required massflow is much smaller, hence the electrical power consumption of the pump is low and smaller piping diameters can be used; (3) the two-phase heat transfer coefficient is higher than liquid heat transfer coefficient, which lets the cooling system operate at a higher fluid temperature, meaning that a smaller air heat exchanger is needed as heat sink; and (4) the freezing point of fluids that are used for two-phase cooling is much lower than the freezing point of water-eglycol that is used for liquid cooling. This is opposed by only minor disadvantages, e.g. a liquid MPL has a smaller expansion vessel that is needed for a two-phase MPL; leak tightness is a more significant point of attention in a two-phase MPL; and a relatively more complex design is needed for the two-phase MPL.
In this paper we present the results of a detailed trade-off between the two types of cooling systems. The use case for this analysis is the development of a cooling system for of the power electronics to drive a motor in an electric aircraft: here, one boost converter and three ANPC inverters. Particular attention is given to the interface between the power electronics and cooling system working fluid. Resulting from analysis, the coldplate used for this interface can be significantly smaller for a two-phase MPL than for a liquid MPL. A volume and mass saving of 68% was achieved for 4000

W of cooling performance, with a heat flux at the power electronics footprint of 19.3 W/cm^2. Successful experimental validation of this design was done by testing an $AlSi_{10}Mg$ 3d-printed design of this coldplate, integrated in the two-phase MPL demonstrator at NLR's premises. The volume and mass saving achieved mark a significant leap forward in decreasing cooling system size. Additionally, the working of the two-phase MPL will positively impact the overall drag on the aircraft, as the air heat exchanger sizing can be reduced.

References

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