ADENEAS Newsletter #3

High power electronics cooling system developments

Hello! I am Johannes van Es, and I am a principal R&D Manager within the "Energy Management" group at the Royal Netherlands Aerospace Centre (NLR). Within the ADENEAS consortium I am the Work Package (WP5) Lead on "Cooling Solutions". In this newsletter, I will discuss the Architectural Design of the novel developed cooling systems including the major trade-offs.

ADENEAS develops technology enablers to pave the way for a safe, light, self-configuring, autonomous and modular power and data distribution network that is scalable to all aircraft sizes. The required new power electronics and electrical engines have higher power densities and therefore require improved cooling technologies. The current state-of-the art aircraft electronics cooling is either by air or by liquid cooling. For large heat fluxes (> 20 W/cm^2) air cooling is insufficient and liquid cooling becomes an engineering challenge. In ADENEAS WP5 a team existing of thermal specialists from NLR, Synano, ECMS, EVEKTOR and ADSE, join forces to develop advanced cooling systems. The focus in the architectural design phase was on Mechanically Pumped Cooling Systems and includes the development of a modular and scalable two-phase cooling system that makes use of latent heat to transport the heat from electronics to the RAM air heat exchangers (HX). In a later phase heat transfer improvements with nanofluids will be investigated.

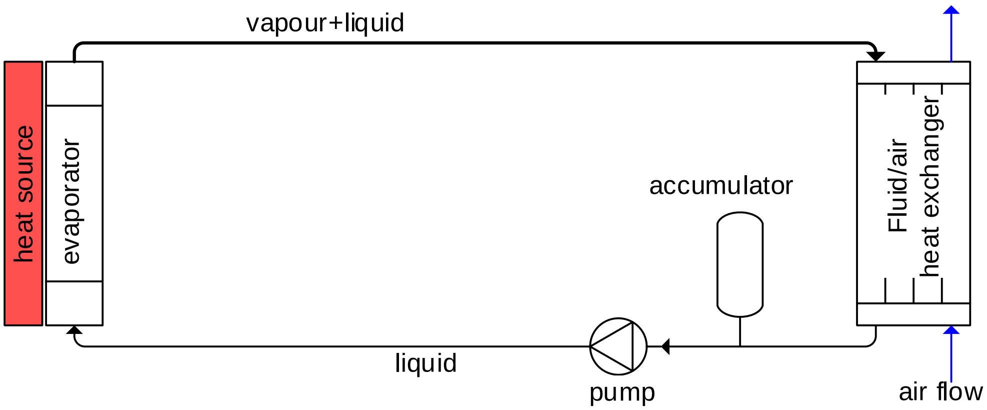

Figure 1: Schematic drawing of a two-phase mechanically pumped loop (MPL).

A schematic drawing of the two-phase mechanically pumped loop (MPL) system is given Figure 1. In the 2-phase MPL the flow is generated by the pump in the liquid part of the loop. Downstream the pump fluid enters the evaporator, where it is heated up to the coolant's saturation temperature, at which point the fluid starts to boil. The evaporator is connected to the power electronics and absorbs the excess heat. The partly evaporated mixture (vapour+liquid) travels along a pipe towards the RAM air condenser. In the condenser, the heat from the coolant is transferred to the air by vapour condensation, and once fully condensed the liquid is slightly sub-cooled to avoid cavitation in the pump.

The two-phase MPL has the following advantages:

- Higher heat transfer coefficients and higher heat flux capabilities
- More uniform temperatures over the evaporator
- Smaller pump as the required mass flow is lower when the heat is absorbed by vaporization than by sensible heat
- Smaller RAM air HX due to a negligible temperature drop between heat source and heat sink

These advantages come at the expense of additional complexity in the cooling system. In the architectural design phase first the optimal working fluid for airborne two-phase MPL, seven cooling fluids were considered and the following two are selected. Ammonia is selected for further study for its superior thermal performance. R1233zd(E) is also selected as the best option in case ammonia will not be allowed to be used on-board future aircraft for safety reasons. A detailed steady-state simulation has been performed to analyse the various systems. Figure 2 illustrates two-phase MPL operation with unbalanced heat loads over 3 evaporator branches. By adding passive restrictions in each branch, the single (2kW) operating branch is still supplied with enough mass flow to avoid dry-out. This demonstrates that the parallel evaporator instability issue, as frequently mentioned in literature, can be addressed by passive means. The concept will be tested in the ADENEAS two-phase MPL demonstrator.

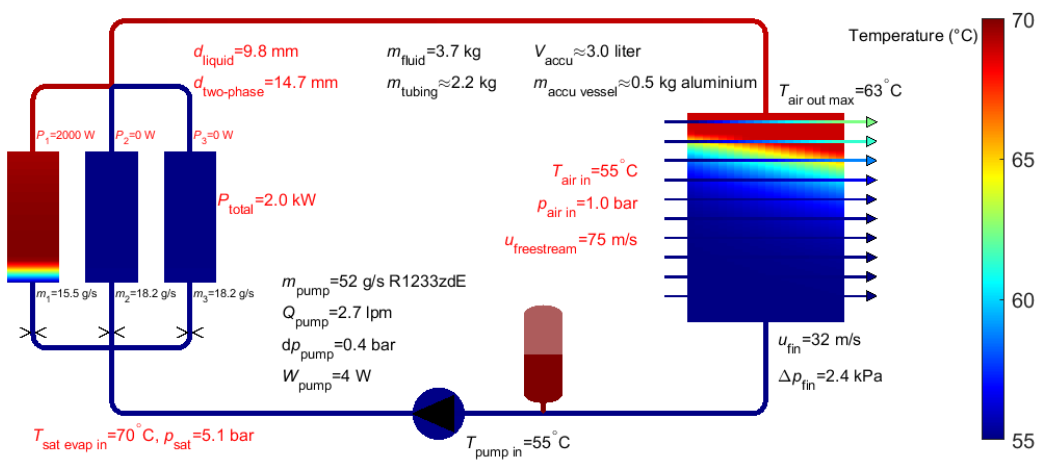

Figure 2: Stable Two-phase MPL operation with unbalanced heat loads on parallel evaporator branches

To verify the two-phase MPL development is better than the current state-of-the-art liquid cooled systems, a mass comparison has been made with a Propylene Water-Glycol cooling system. The results in Figure 3 show an overall mass benefit for powers > 1kW and increasing mass benefit >6kW where the PGW system requires increasing mass flows to cope with the high heat fluxes.

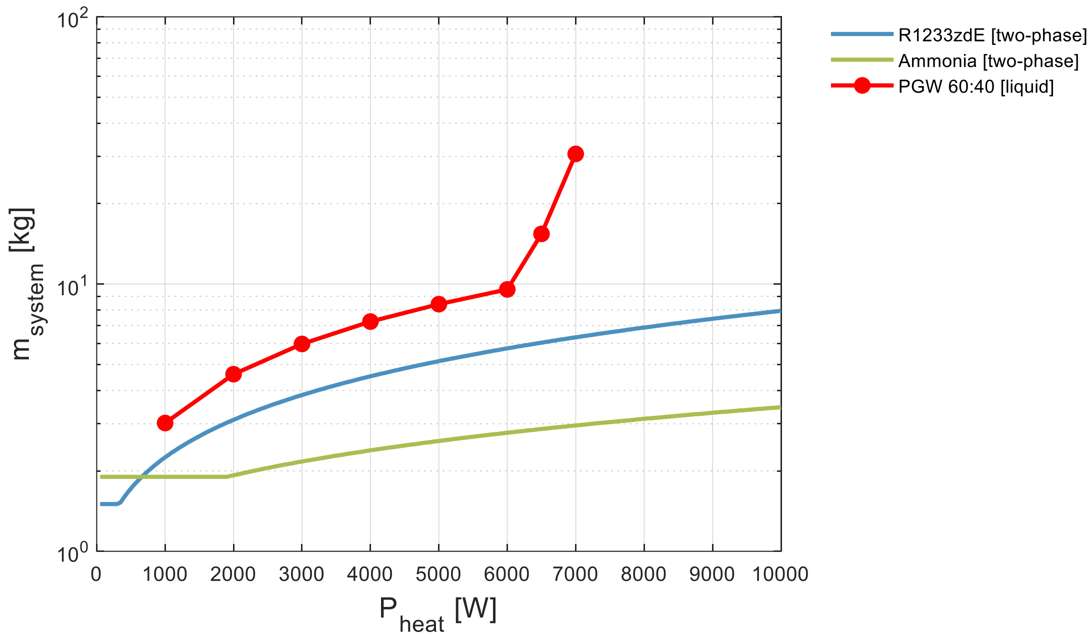

Figure 3: System mass as function of dissipated heat load, shown for a two-phase cooling system with R1233zd(E) and Ammonia, and for a liquid cooling system with PGW 60:40 as a working fluid. Note that the y-axis is logarithmic

The trade-offs convincingly showed the two-phase MPL has a substantial better weight performance compared to conventional liquid systems. The design will now be further detailed and implemented in a demonstrator.