Modeling of Cold Plates for Power Electronic Cooling

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Abstract

This paper deals with the cooling of high power electronic devices. Usually those devices dissipate 5 - 10% of their electrical power, therefore (convective) cooling is needed. Power electronics can be cooled directly by air or a non-conductive fluid via (forced) convection. However discharging the heat of the power electronics via convective heat transfer with air leads often to a large cooling elements due to the poor heat transfer coefficient of air. Also in most applications the direct contact between the electronic and the cooling fluid is undesirable.
For these applications the use of cold plates can be an option. The fluid flows through a plate (see. fig.1) which is directly connected to the electronic. This type of cooling is far more effective than air cooling, since the cold plate can be designed in order to cool also high power density electronics without resulting in a disproportional increase of the space envelope. The fluid temperature can be increased with respect to the air temperature, without decreasing reliability and durability of the power electronics components.
Using cold plates open up possibilities of decentralised cooling which can improve the efficiency of the cooling system.

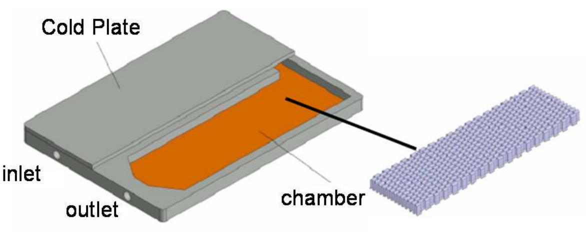

Figure 1: Cold plate

This paper presents a model library developed in order to model power electronics cooling. The library provides on the one hand heat loss models for basic power electronics equipment itself, like IGBTs, and on the other hand thermodynamic models for different cold plates. Lumped models of the cold plates can be used in large system simulations whereas cold plate models using a distributed approach are foreseen for more detailed analysis.
To be able to calculate the temperature distribution in the cold plate, the solid and fluid parts of the cold plate have to be discretised in all directions (see fig.2).

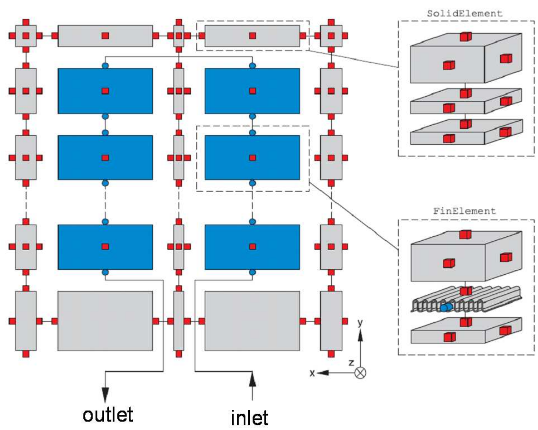

Figure 2: Cold plate model

The library is based on Modelica.Fluid, however for the modeling of the single phase cooling medium, the compressibility of the liquid is considered in order to avoid large non-linear system of equations.
An important aspect of the library is the coupling of the power electronic models to the cold plate model. Hereby an efficient algorithm is needed which enables the user to connect an unlimited number of power electronic components of any size to arbitrary places on the cold plate.

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Additional to the simulations a test rig is built, where the cold plates are tested. Whereas the models can be used for both, single phase and two phase cooling, on the test rig only single phase cooling is investigated. Since the fluid channels often have a complicated finned structure, where the geometric parameters are usually not accessible, the measurements are needed to validate the cold plate models. Hereby a large emphasis is placed on validating the pressure drop and heat transfer correlations, as well as the time constants.

Keywords: Modelica; Simulation; Cold plate; Cooling; Power Electronics