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Topology Optimization of Conjugate heat transfer in microchannel heatsinks

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The increase in power density for microelectronics requires a leap in the cooling capacity of standard heat sinks in order to maintain the electronic components under their maximum tolerated temperatures. The adoption of liquid cooling combined with high surface-to-volume ratio's heat sinks allows increasing the heat transfer coefficient, with the penalty of increasing the pumping power. The size, shape and number of microchannels or pins, are usually optimized for given flow conditions, which restricts the design space of optimized designs.

In this work, topology optimization is used to generate the design of a heat sink using a one-way coupled steady-state Navier-Stokes-Brinkman formulation and a single Convection-Diffusion equation [1]. The liquid and solid phases are modelled using Brinkman penalization and proper interpolations functions for the physical properties of the fluid and solid. However, the compactness of microchannel heat sinks generates large pressure drops, which challenges the numerical stability and the interpolation schemes used during optimization. Several solutions are proposed and discussed in this work, such as local flow control regularization and the use of crosswind diffusion typically used where large gradients in the state fields are present [2]. The influence of the penalty parameters are also discussed in term of solution accuracy and simulation time.

Finally, the optimized designs are compared with state-of-the-art microchannels heat sinks found in the industry, using commercial CFD software. The results show that the optimized heat sinks can acheive a lower temperature for the microelectronic component, as well as a lower pressure drop, when compared with the standard geometry. Moreover, the use of 2.5D designs where material is able to grow exclusively normal to the heated surface [3], higlights that the pressure drop can be drastically reduced if higher temperatures are allowed for the microelectronic components.

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