Design of Thermal Systems Using Topology Optimization - DTU Orbit (23/05/2019)

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The goal of this thesis is to apply topology optimization to the design of different thermal systems such as heat sinks and heat exchangers in order to improve the thermal performance of these systems compared to conventional designs. The design of thermal systems is a complex task that has traditionally relied on experience, intuition, and trial and error approaches. Topology optimization, in contrast, allows for a systematic optimization of such systems and the identification of unintuitive and unexpected geometries. Both numerical optimizations and, to a lesser extent, experimental validations of optimized designs are presented within this thesis. The main contribution of the thesis is the development of several numerical optimization models that are applied to different design challenges within thermal engineering.

Topology optimization is applied in an industrial project to design the heat rejection system of a robotic downhole oil well intervention tool and an optimized prototype is built that can operate in environments of 200°C instead of 175°C, opening a new market for the company. A similar model is used in a different project to optimize the heat sink of a commercial tablet. The design of 3D printed dry-cooled power plant condensers using a simplified thermouid topology optimization model is presented in another study. A benchmarking of the optimized geometries against a conventional heat exchanger design is conducted and the topology-optimized designs show a superior performance. A thermouid topology optimization heat sink model is applied to the design of forced convection air-cooled heat sinks. Two topology optimized designs are exemplarily benchmarked against a size-optimized parallel fin heat sink and an up to 13% lower thermal resistance is found to be realized by the topology optimization. The design of cross ow heat exchangers using thermouid topology optimization is presented in another work. This novel approach can explicitly solve the Navier-Stokes equations and capture the heat transfer in both fluids at a low computational cost. Lastly, the fabrication and experimental validation of different topology optimized heat transfer devices is summarized. The developed robotic downhole tool prototypes are successfully tested in the laboratory under conditions similar to those in boreholes. Two optimized commercial tablet heat sinks are manufactured, mounted in the device, and experimentally compared to an unoptimized heat sink. Moreover, the fabrication and experimental benchmarking of 3D optimized natural convection heat sinks against conventional heat sink designs is presented. Investment casting using 3D stereolithography printed patterns is used to fabricate different heat sink designs and this technology is demonstrated to be promising for the fabrication of topology-optimized metal parts.

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