

LEVEL-SET TOPOLOGY OPTIMIZATION FOR HEAT EXCHANGERS OPERATING IN THE TURBULENT REGIME

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Abstract

Topology optimization is extremely powerful in obtaining innovative designs for several applications. The use of topology optimization in the Computational Fluid Dynamics (CFD) community is growing, with for example in Ref. [1] the topology optimization of a two-fluid heat exchanger and in Ref. [2] the optimization of a heat sink for the cooling of microelectronics. Whereas topology optimization has been frequently applied to laminar flows, its use for turbulent flows is still in its infancy.

The difficulty of density-based topology optimization with a Reynolds-Averaged Navier-Stokes (RANS) model is that the unknown location of fluid-solid interfaces hampers the required grid refinement near the walls for a wall-resolved RANS approach or hinders the application of wall functions. The solution here is the use of body-fitted level-set topology optimization algorithms that facilitate a grid refinement near the solid-fluid interfaces or the application of appropriate wall functions.

Ref. [3] demonstrated the power of level-set topology optimization for 2D and 3D heat exchangers operating in the laminar regime. We have successfully transferred the methods from the Finite-Element framework in Ref. [3] to the Finite-Volume CFD code SU2 [4]. In contrast to the continuous adjoint approach of Ref. [3], a discrete adjoint approach by means of Algorithmic Differentiation (AD) now allows the calculation of the gradients with respect to the mesh nodes, which is translated in an advection of the level set function. AD makes the framework flexible for future model adaptations.

The main challenge is maintaining a high-quality mesh during the optimization iterations. Therefore, we have implemented the option to introduce inflation layers with quadrilateral cells near the boundaries with the Gmsh tool [5]. Although these inflation layers generally improve the quality of the simulation results, issues can still occur when individual solid structures tend to merge.

We treat two heat exchanger configurations. The first case considers the cross-flow of air over tubes containing oil. The oil tubes are considered isothermal and their shape and the number of tubes is optimized to maximize the heat transfer for a certain pressure drop, with a minimum thickness constraint for the tubes to ensure

manufacturability. This case – based on Ref. [3] – is initially optimized for laminar flow conditions, for which we are able to double the transferred heat compared to an initial design with five circular tubes. Subsequently, we repeat the optimizations for turbulent flow conditions using the wall-resolved k- ω SST model and discuss the impact of flow conditions on the obtained shapes with a scan of the Reynolds number. The second case deals with the optimization of the channel geometries for a counterflow heat exchanger, based on Ref. [1].

References

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