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Topology Optimization of Heat and Mass Transfer Systems using Level-Sets and Anisotropic Mesh Adaptation

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Extended Abstract

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This study is devoted to the topology optimization of conjugate heat transfer systems governed by the coupled Navier-Stokes and heat equations. It is motivated by the need for performance improvement of the industrial heat exchangers used to regulate process temperatures, but thermal conditioning is of tremendous importance for a variety of applications ranging, for instance aircraft cabin climatization where the focus is on regulating in-cabin thermal conditions (temperature, humidity) under substantial variations of the ambient conditions to provide high-quality comfort for passengers.

Numerical experiments are performed using an in-house implementation of the variational multiscale stabilized finite element method [1]. The solid and fluid phases are represented on a single computational mesh with variable density, viscosity, conductivity, and specific heat. This removes the need for a heat transfer coefficient, as the amount of heat exchanged at the interface proceeds solely from the individual material properties on either side of it. The interface itself is described by level-set functions and is accurately discretized using anisotropic mesh adaptation to highly stretch the nearest cells [2]. Continuous adjoint problems are derived for cost functions typical of ducted flows [3]. Efficient enforcement of geometrical constraints (fixed/lower-bounded surface or volume) is achieved using not classical Lagrange multipliers, but a smooth Heaviside function that allows transporting the level-set (which in turn enlarges/shrinks the shape) when the current value strays too far away from the target.

For several cases involving competition between heat transfer enhancement and pressure drop reduction [4], this numerical framework has been found to yield accurate results while maintaining the CPU cost affordable. We will discuss the main results obtained in 2-D and 3-D, and will present novel optimal designs never documented in the literature, computed for extreme weights of the thermal objective.

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