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Shape optimization for heat exchangers

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SUMMARY

A heat exchanger is a device that allows the heat exchange between two or more fluids without mixing of fluids. The aim of this work is to consider a multi-objective shape optimization in this context, namely to maximize the heat exchange and to minimize the pressure drop.

In [4] it was showed that the cylinder is not optimal for the energy dissipation of the fluid, using the eulerian derivative. In [3] a framework of two fluids separated by the solid distance was considered, imposing a minimum distance between the two fluids, using a lagrangian approach to get the shape derivative. Our work is a continuation of these previous works and a first step towards engineering/industrial applications. Particularly, we aim to take into account the thickness of the material that divides the fluids (that is the pipe). This would require a very fine mesh of this solid region, which is numerically too expensive. Hence, in order to avoid that difficulty, we use asymptotic analysis to obtain an effective transmission condition between the two fluids that takes into account the diffusion in the solid, without meshing it, thanks to the so-called Ventcell conditions.
Concerning the volume model, it is presented as a weak-coupled problem, between the steady-state Navier-Stokes equations for the two fluids dynamics and the convection-diffusion equation for the heat. We characterize the shape derivative for the objective functionals and perform numerical simulations in two and three dimensions to get an optimum heat exchanger, using FreeFem++ as in [2] to implement the numerical algorithm. In particular an objective is to improve the performance of an existing sine-helical heat exchanger presented in [1].

Keywords: Shape optimization, Navier-Stokes equations, heat exchanger.

AMS Classification: 74P10, 76B75, 74F05

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