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Topology Enhancement of a Straight Fin Using a Porous Media Computational Fluid Dynamics Simulation Approach

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Abstract : Designing the optimal heat exchanger is still an essential objective to be achieved. Parametrical optimization involves the evaluation of the heat exchanger dimensions to find those that best satisfy certain objectives. This method contributes to an enhanced design rather than an optimized one. On the contrary, topology optimization finds the optimal structure that satisfies the design objectives. The huge development in metal additive manufacturing allowed topology optimization to find its way into engineering applications especially in the aerospace field to optimize metal structures. Using topology optimization in 3d heat and mass transfer problems requires huge computational time, therefore coupling it with CFD simulations can reduce this it. However, existed CFD models cannot be coupled with topology optimization. The CFD model must allow creating a uniform mesh despite the initial geometry complexity and also to swap the cells from fluid to solid and vice versa. In this paper, a porous media approach compatible with topology optimization criteria is developed. It consists of modeling the fluid region of the heat exchanger as porous media having high porosity and similarly the solid region is modeled as porous media having low porosity. The switching from fluid to solid cells required by topology optimization is simply done by changing each cell porosity using a user defined function. This model is tested on a plate and fin heat exchanger and validated by comparing its results to experimental data and simulations results. Furthermore, this model is used to perform a material reallocation based on local criteria to optimize a plate and fin heat exchanger under a constant heat duty constraint. The optimized fin uses 20% fewer materials than the first while the pressure drop is reduced by about 13%.

Keywords : computational methods, finite element method, heat exchanger, porous media, topology optimization
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