

EXTERNAL COMPRESSIBLE FLOW DESIGNS OPTIMISED BY TOPOLOGY OPTIMISATION

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Abstract

Immersed bodies are generally modelled as though they were placed within an infinite medium. For this reason, these flows are commonly denoted external flows. Such are the cases of submerged bodies in the ocean and aerodynamics structures. In the latter case, as well as in many others, the external flow reaches compressible conditions, resulting in significant changes in density and Mach number. Despite the relevance of these practical applications, in terms of external flows, so far, topology optimisation has been concerned strictly with creeping and incompressible flows, as well as inviscid fluid. None of these conditions meet the challenges stemming from compressibility, involving both complex physical considerations and a more involved numerical setup. This work aims to fulfil that gap. Topology optimisation is employed with a density-based formulation. A gradient-based optimisation is conducted, algorithmically solved through IPOPT, with sensitivities computed by automatic differentiation in FEniCS/dolfin-adjoint. Finite volume simulations are carried out in OpenFOAM in two instances. In one, a flexible material distribution (fluid and solid) over the design domain is allowed, by introducing a porous medium model term in the momentum equation, so that over the optimisation iterations a single grid can be used. In post-processing, however, body-fitted grids of the optimised bodies are developed and the flow fields are evaluated, now free from porous effects. Overall, these capacities are joined in the FEniCS TopOpt Foam framework. Four functionals are considered and combined in our investigation, spanning energy dissipation, vorticity, drag and lift as objective and multiobjective functions, constrained by fluid volume fraction and an upper drag. The resulting topologies exhibit improved behaviour in all circumstances, supported by convergence curves; and satisfy constraints. Relative to a benchmark of a NACA 0012 aerofoil, superior performance is noted, with the exception of a single functional. Physical insights are discussed to draw insights relative to the phenomenon itself and to remedy optimisation issues. Moreover, a Gurney flap is systematically generated through our methodology --- in contrast with previous trial-and-error, intuition-based and parametric approaches.