Large scale three-dimensional topology optimisation of heat sinks cooled by natural convection

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ABSTRACT

This work applies topology optimisation to the design heat sinks cooled by natural convection in three dimensions. Numerous applications in several branches of engineering can benefit from such a design methodology, e.g. CPU coolers and passive cooling of LEDs.

The governing equations are the steady-state incompressible Navier-Stokes equations coupled to the thermal convection-diffusion equation through the Bousinessq approximation. The fully coupled non-linear multiphysics system is solved using stabilised trilinear equal-order finite elements in a parallel framework [1].

Topology optimisation is carried out using the density-based approach as detailed in [2] for two-dimensional natural convection problems. Despite the methodology being the same, the extension to three-dimensions has been far from trivial in the sense of the vast growth in computational workload.

The fully coupled non-linear system of equations at each design iteration is solved using a fully parallelised damped Newton-Krylov method. The linear solver used is F-GMRES [3] in combination with a Galerkin-projection geometric multigrid (GMG) preconditioner. We use GMRES with Jacobi preconditioners for both the GMG smoother and coarse grid solver, which in turn renders the GMG preconditioner as variable and therefore dictates the choice of the F-GMRES. Although this is known not to be an optimal solver for non-elliptic systems of equations, the performance is very good and allows for the optimisation of large scale problems, with order of 10 million degrees of freedom for small to medium Grashof number flows, in a reasonable amount of time.

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