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Topology optimisation of passive coolers for light-emitting diode lamps

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Abstract

This work applies topology optimisation to the design of passive coolers for light-emitting diode (LED) lamps. The heat sinks are cooled by the natural convection currents arising from the temperature difference between the LED lamp and the surrounding air. A large scale parallel computational framework [1] is used to perform topology optimisation for minimising the temperature of the LED package subjected to highly convection-dominated heat transfer.

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 discretised using stabilised trilinear equal-order finite elements and solved using Newtons method and a multigrid-preconditioned iterative method.

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, consisting of F-GMRES in combination with a Galerkin-projection geometric multigrid (GMG) preconditioner. Although this is known not to be an optimal solver for non-elliptic systems of equations, the observed performance is very good and allows for the optimisation of large scale problems, for small to medium Grashof number flows, in a reasonable amount of time.

The optimisation results show interesting features that are currently being incorporated into industrial designs for enhanced passive cooling abilities.

References

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