Topology optimisation for coupled multi-physics flow problems involving Conjugate Heat Transfer

Enrico Savona*, Matteo Giacomini and Antonio Huerta

Laboratori de Càlcul Numèric (LaCàN), E.T.S. de Ingeniería de Caminos, Canales y Puertos, Universitat Politècnica de Catalunya, Barcelona, Spain
Centre Internacional de Mètodes Numèrics en Enginyeria (CIMNE), Barcelona, Spain

ABSTRACT

Electromobility plays a crucial role in the reduction of greenhouse gas emissions. The suitability of electric vehicles to respond to the challenge of novel passenger and freight transportation significantly depends on the efficiency of battery technology. To maximise their performance and lifespan, design and optimisation of battery thermal management systems (BTMS) are of outmost importance. [1]

Topology optimisation allows to mathematically formulate these problems as the minimisation of an objective functional (e.g., the average temperature in the BTMS) to determine the *optimal* layout and shape of the domain, under physical and geometric constraints. The former include the underlying governing equations for viscous incompressible flows (i.e., Navier-Stokes equations), Fourier's law for conjugate heat transfer, and restrictions over the admissible pressure drops. The latter accounts for constraints over the maximum volume fractions of fluid and solid domain. [2]

In this work a topology optimisation algorithm for Conjugate Heat Transfer problems is developed coupling the continuous adjoint method with a phase field formulation. An optimise-then-discretise approach is employed to compute the sensitivity of the objective functional with respect to the design variable, that is, the phase field description of the interface between solid and fluid. Contrary to traditional strategies based on level set, the phase field variable provides a smoother, regularised representation of the interface, significantly simplifying its tracking and evolution by means of a reaction-diffusion equation, coupled with a double well potential to penalise inadmissible, intermediate design solutions. Numerical tests benchmarking comprehensive Navier-Stokes-Fourier and simplified Darcy-Fourier models will be presented to optimise the topology of thermal management systems.

[1] J. Kim, J. Oh, H. Lee, "Review on battery thermal management system for electric vehicles", Applied Thermal Engineering, 149, 192-212 (2019)

[2] K. Yaji, T. Yamada, S. Kubo, K. Izui, S. Nishiwaki, "A topology optimization method for a coupled thermal–fluid problem using level set boundary expressions", International Journal of Heat and Mass Transfer, 81, 878-888 (2015)

* Presenting author