Topology Optimization of Coupled Thermo-Mechanical Problems with Contact

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ABSTRACT

Thermo-mechanical coupling phenomena need to be accounted for in the design of a broad class of engineering problems, ranging between micro-electro-mechanical systems, high precision optical devices, and components in combustion systems. In most cases, only thermally induced deformations and stresses need to be considered and the influence of the structural deformation on the energy transport and temperature distribution is insignificant, allowing the simplification of the interaction to a one-sided coupling mechanism. However, if the structural deformations alter, for example, the external heat flux, as it is the case in aero-thermo-elasticity, or the conductive heat flux within the structure, this simplification is not applicable and a two-way coupling mechanism needs to be modeled.

In this paper, we focus on the structures undergoing bi-lateral contact. As two bodies touch, due to external mechanical forces and/or due to applied heat loads and thermal expansion, the diffusive heat conduction path may change significantly. This interaction can be utilized to tailor the structural response, including deformation and stress states, as well as the temperature field and energy flux. We propose to solve the associated design problem by a level set topology optimization approach. Restricting ourselves to two-phase problems, the geometry of the material interface is described by an explicit level set method and the structural response is predicted by the eXtended Finite Element Method (XFEM). Our mechanical model assumes a linear elastic isotropic material, infinitesimal strain theory, and a quasi-static response. The traction-separation relation at the interface is described by a bilinear cohesive zone model. Similarly, a bilinear model is adopted to approximate the dependency of the heat flux on the separation in the direction of the surface normal. The non-penetration condition is enforced by a stabilized Lagrange multiplier method. The resulting optimization problem is solved by a nonlinear programming method and the design sensitivities are computed by the adjoint method. The characteristics of the proposed method is evaluated by numerical examples in two dimensions. The optimization results demonstrate that both the structural and thermal response can be tuned well toward a target performance by topology optimization considering thermo-mechanical coupling phenomena.