Structural Topology Optimization of Fluid-Structure Interaction Problems using the Levelset and Extended Finite Element Methods

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Topology optimization of coupled multi-physics systems is an appealing approach as intuitive solutions are often suboptimal due to strong nonlinearities dominating the system response. This paper focuses on topology optimization of fluid-structure interaction problems. Recently, density methods using a SIMP (Solid Isotropic Material Penalization) interpolation approach have been applied to find the optimal geometry of the internal structure for a given mold-line body design (Maute and Allen, 2004; Stanford and Ifju, 2009; James and Martins, 2008). To allow for changes of the overall topology, Kreissl and Maute (2010) and Yoon (2010) apply a density approach simultaneously to both the fluid and structure domain. All current methods suffer typically from the presence of large volumes of material with intermediate densities, and the lack of a clearly defined structural layout. In addition, the methods manipulating just the internal structure as well as the approach of Yoon are limited to rather small structural deformation due to mesh distortion issues.

In this paper we present an alternative approach combining a level-set method to describe the structural geometry and the extended (or general) finite element method (XFEM) to predict the coupled fluid-structure response. This approach leads inherently to a well described definition of the fluid-structure interfaces and the internal structural layout. The optimization problem is solved by the GCMMA algorithm operating directly on the parameters of the discretized level-set field.

We will compare this level-set/XFEM approach to SIMP approaches. Results will be presented for a flexible (hyperelastic) structure immersed in an incompressible flow. Our results will show that SIMP approaches require a highly refined mesh to mitigate the occurrence of large volumes of intermediate densities. Utilizing level-sets and XFEM allows a coarser resolution while retaining the ability to describe detailed geometric features.

References

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