A Multi-Material Topology Optimization Method for the Resolution of Interfaces by means of the CISAMR-Algorithm

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Multi-material structures offer high potential in terms of lightweight design, but their development is often associated with a high level of complexity during product development. One way to support the product developer in the design of such structures is offered by multi-material topology optimization methods. The majority of these methods in the literature do not consider the response and the exact location of interfaces between different materials. However, these interfaces and their characteristics have substantial influence on the structural behavior of multi-material components and hence must be taken into account.

In recent years, several methods have been developed that take interface behavior into account during the optimization. However, the majority of these methods are 2D approaches and/ or based on extended FE methods. In the literature there are no contributions that describe a multi-material topology optimization considering interfacial behavior in 3D using non-iterative geometry-fitted meshes.

Therefore, a method for multi-material topology optimization using a geometry-fitted remeshing method is developed and an approach for its extension to take interface cohesion into account is outlined. The method couples the Conforming to Interface Structured Adaptive Mesh Refinement (CISAMR) algorithm and the Velocity Field Level Set method in the context of a compliance maximization problem.

The non-iterative CISAMR algorithm consists of four sequential phases. The Structured Adaptive Mesh Refinement phase refines the near-interface elements and the following r-adaptivity phase moves near-interface nodes on the interface. The last two phases Face-swap and Sub-tetrahedralization ensure a good tetrahedron quality and mesh conformity, respectively.

The advantage of the coupling of the two methods is that commercial and validated FE-solvers, such as e.g. Abaqus can be applied and that it handles a general number of materials as well as the resulting interfaces. Another advantage of the method is that the resolution of the mesh is higher in the interfacial region and thus stresses can be captured more accurately. This should lead to better convergence behavior of the optimization, especially when introducing nonlinear interfacial behavior later on. Since the response is also computed only in a limited domain instead of the entire design space, computational time advantages can be expected.

In addition, it is described how the coupled method can be extended to take interface cohesion during the multi-material topology optimization by means of cohesive elements or contacts into account. For this purpose, the vertices are doubled at the material interfaces and cohesive zone elements are generated. Moreover, the adaptation of the objective function and the sensitivities based on recent publications is discussed.