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Design optimization with anisotropic materials in the context of additive manufacturing

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Abstract

In powder-bed based additive manufacturing the layer-wise build-up process commonly results in anisotropic material properties. Moreover, for some materials the material's microstructure can be locally varied by using different process parameters, which in turn can be used for a local control of the resulting effective material properties. These characteristics are considered in the definition of the optimization problem and a general setting for simultaneous material and topology optimization in linear elasticity is proposed. In this setting, the admissible material tensors are represented using a parametrized tensor formulation and the topology optimization is achieved by multiplying the material tensor with a penalized SIMP-type topological design variable. The well-posedness of the given setting is achieved by a combination of different regularization techniques (density filters, slope constraints), which, at the same time, serve to limit the local grading of material properties.

The concepts are demonstrated for the simultaneous optimization of build orientation and topology as well as for the simultaneous optimization of build orientation, topology and material grading in additive manufacturing. The resulting design optimization problems are solved via a two-stage optimization process, in which a simplified separable approximation of the optimization problem is used to generate a starting value.

Numerical results are presented in studies for plastics (PA12) and a parametrization based on material properties of the metallic alloy IN718 for different microstructures. Furthermore, the relevance of an accurate material description is shown by a comparison to results obtained with standard optimization methods neglecting the anisotropic material behavior.