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ABSTRACT

Topology optimization has been used to design two-dimensional material structures with specific elastic properties, but optimized designs of three-dimensional material structures are more scarsely seen. Partly because it requires more computational power, and partly because it is a major challenge to include manufacturing constraints in the optimization.

This work focuses on incorporating the manufacturability into the optimization procedure, allowing the resulting material structure to be manufactured directly using rapid manufacturing techniques, such as selective laser melting/sintering (SLM/S). The available manufacturing methods are best suited for porous materials (one constituent and void), but the optimization procedure can easily include more constituents.

The elasticity tensor is found from one unit cell using the homogenization method together with a standard finite element (FE) discretization. The distribution of the material in the unit cell is optimized according to a given objective (e.g. maximum bulk modulus or minimum Poisson's ratio) and some given constraints (e.g. isotropy) using topology optimization. The manufacturability is achieved using various filtering techniques together with a stochastic approach, where the mean performance of several slightly different designs is optimized. In most cases this assures a minimum length scale for the intermediate design, and thereby manufacturability is achieved.

Furthermore, the study will look at how "negative" aspects of the manufacturing method can be exploited to achieve exotic material properties. An example of this is how the SLM/S causes softer regions in the structure due to insufficient heating of the metal powder. If the goal is to design a material, which to some degree is compliant, such as negative Poisson's ratio material, softer regions are desirable. Another example is closed-cell materials, e.g. maximum bulk modulus material, where the cells will be filled by metal powder if manufactured using SLM/S. This is considered as a drawback, because it makes the structure heavier. However, it also drastically increases the damping ratio of the structure, which is beneficial in many applications.