Imposing the Minimum Overhang Angle in Topology Optimisation for Additive Manufacturing

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Introduction

3D printing, or additive manufacturing, has become increasingly popular in industry over the last decade. While it has been used as a prototyping tool, it is currently used more and more as a production technique as well. Additive manufacturing enables the production of complex parts which cannot be manufactured by conventional production methods such as casting or milling. In order to fully utilize the design freedom offered by additive manufacturing, topology optimization can be used to create designs that outperform any human design.

Topology optimization is a design tool that generates the optimal layout for a certain task. For example, it can minimize the weight of a structure while maintaining a specified stiffness, or maximize the heat dissipation of a structure towards its surroundings. The resulting designs tend to be 3D, complex and organically shaped, which are usually not manufacturable with conventional production techniques. Combining topology optimization and additive manufacturing therefore seems natural. Unfortunately, additive manufacturing also has some limitations, with one of the most prominent being the overhang constraint: down facing surfaces should have a minimum $45°$ angle with the base plate. If this minimum is exceeded, support structures need to be added, which have to be removed after the process.

In order to prevent the need for supports, the overhang limitation can be added as a constraint in the topology optimization scheme. However, current overhang constraints for topology optimization are fixed to structured mesh types, or lack convergence. Therefore, a new overhang constraint formulation is presented which utilizes front propagation methods to detect the overhang. The front propagation resembles the printing process in a simplified manner, and is used to indicate overhanging areas. This information is then passed to the topology optimization to suppress these overhanging areas. The resulting designs are free of overhang and can be printed without the need for supports. This can save material and labor cost involved with support removal. By using front propagation, the constraint can be applied on unstructured mesh types, in 2D as well as in 3D, and is computationally efficient. In this presentation, this new overhang constraint formulation will be presented, and its properties will be illustrated using several numerical examples.