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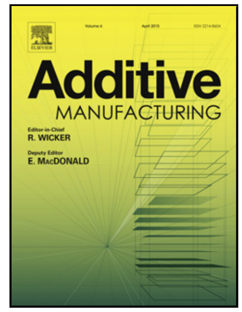

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Topology optimization of self-supporting support structures for additive manufacturing

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Abstract

In this paper, we formulate the generation of support structures for additive manufacturing as a topology optimization problem. Compared with usual geometric considerations based support structure design, this formulation affords mechanistic meaning to the computed support structures. Moreover, our study reveals that the topology optimization formulation generally leads to self-supporting designs without extraneous self-supporting constraints. We show the generality of the procedure by computing supports for a variety of parts in both two and three dimensions, including a complex model of the mascot of the University of Wisconsin-Madison. The resulting support structures have been 3D printed, demonstrating that the computed designs can successfully be used as supports.

1 Introduction

In recent years, additive manufacturing has become increasingly important in several fields. A distinctive feature that made additive manufacturing popular is its ability to produce complex parts easily and with no part-specific fixturing or tooling. For this reason, additive manufacturing is attractive, for instance, for producing parts obtained from topology optimization, which are frequently of complex shape and with internal voids.

On the other hand, some drawbacks of additive manufacturing exist as well. Indeed, the very idea at the basis of additive manufacturing consists in building a part layer by layer. This makes so that long downward-facing surfaces need to be supported by some other structure which will then have to be removed after the printing. These "support structures" are thus made of sacrificial material which is basically wasted (recycling is limited to a few times before needing re-polymerization) and their removal adds a post-processing step.

This problem can be handled in different ways, depending on whether we can modify the part to print or not. In the first case, we can try to modify parts by removing all overhangs which are not self-supporting. This is, for instance, the trend that has been recently followed by the topology optimization community. Thus, several manufacturability constraints and filters have been introduced in topology optimization frameworks to compute optimal designs which are free of non self-supporting surfaces. Since the first work in this direction [1], strategies to achieve manufacturability in a topology optimization context have greatly evolved, allowing, for instance, to compute the optimal design for arbitrary choices of the critical overhang angle. For instance, [2] introduced an overhang constraint acting on the directional gradient of density along the build direction, allowing an arbitrary choice of both build direction and critical overhang angle. In [3], instead, the constraint is based on the volume of the support structures, while other approaches rely on filter-based overhang restrictions [4, 5]. Overhang control has then also been analyzed in the framework of shape optimization by

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