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Eliminating Support Material in Additive Manufacturing: A Projection-Based Approach for Maximum Overhang Constraints

Andrew T. Gaynor[1] and James K. Guest[1]

[1]Johns Hopkins University, Baltimore, MD, USA

Abstract

Additive manufacturing (AM) drastically expands the design freedoms over traditional manufacturing methods. These freedoms are not limitless, however, and must be considered when designing a part to be additively manufactured. One such limitation is the need for sacrificial support material during the build process to achieve certain topological features. After printing, the support material must be removed by dissolving in a liquid bath for such technologies as polymer-based Fused Deposition Modeling (FDM), or through manual removal in the case of Selective Laser Melting (SLM) and Stereolithography (SLA) type methods. Interestingly, every AM technology possesses a maximum overhang angle at which it may print without requiring support material.

In this work we propose a new topology optimization algorithm to eliminate the need for sacrificial support material through design, exploiting the maximum achievable overhang for each AM technology of concern. This algorithm is formulated through a modification to the typical topology optimization formulation to include an additional projection scheme in which the overhang constraint is imposed. In this way, the overhang constraint is naturally achieved in a similar fashion to the Heaviside Projection Method (HPM) for minimum length scale control, without explicit constraints. The key changes are that the physical meaning of the independent design variables and the mapping of these variables onto finite element space is modified to capture the existence of underlying material. The proposed algorithm is tested on standard design problems – including the MBB beam and cantilever problems – with designs built from various directions (bottom-up, top-down, etc.). Preliminary results show excellent agreement with the imposed constraint, exhibiting the ability to adhere to various magnitudes of the overhang angle constraint in combination with different build directions. As one might expect, the optimized designs clearly depends on the specified build direction.