Three-dimensional high resolution topology optimization considering additive manufacturing constraints

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Abstract

This paper studied a three-dimensional structure topology optimization for minimum structural compliance with consideration of the overhang constraint, minimum length constraint and high resolution demand together in additive manufacturing (AM). These are regarded as challenging issues in additive manufacturing (AM) oriented topology optimization. By fitting the 18 neighboring element densities with local linear hypersurfaces in $\mathbb{R}^4$ for each element and making use of these hypersurfaces' gradients, we develop an effective method to handle the acknowledged problem in SIMP, that how to estimate the overhang angles of the optimum and intermediate designs of three-dimensional structures with zigzag and blurry boundaries. Based on this estimation, we construct the element-wise overhang angle constraint. To control the horizontal minimum length of three-dimensional structural component, we further formulate a constraint on the average density of horizontal adjacent elements for each element. To reduce the computational effort, these element-wise constraints are surrogated into two constraints by penalizing the material volume for the elements which violate the overhang angle or minimum length constraints. But, different from the 2D case, the traditional surrogated constraints cannot make every point satisfy the AM constraints accurately. To handle this, an improvement of numerical implement scheme is introduced. The numerical experiment shows that these constraints work well for the case even when the printing direction is not in alignment with the vertical direction. Suppressing

the hanging feature is an additional tough problem because it lacks an accurate mathematic description. In this paper an effective way to suppress hanging feature is proposed by combining the overhang angle and minimum length constraints together. To get a more authentic description of the structure geometry cheaply, which is also needed in AM, the multi-resolution topology optimization (MTOP) is applied to get a high resolution result. The minimum compliance topology optimization subject to the material volume constraint and the two surrogated constraints is solved by MMA. Several three dimensional structure examples are optimized and their optimum designs are AM-manufactured to demonstrate the effectiveness of the proposed algorithm.

Keywords Additive manufacturing; Structural topology optimization; Overhang constraint; High resolution; Three-dimension; Minimum length control.