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Abstracts

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Topology optimization is universally recognized as the key design method to fully exploit the tremendous design freedom offered by additive manufacturing (AM) techniques. However, classical topology optimization approaches do not consider specific restrictions of typical AM processes. From a design-for-manufacturing viewpoint, ideally all restrictions of the manufacturing process are already included at the design stage [1]. One such restriction present in many AM processes is the maximum overhang angle of downward-facing surfaces of a part. Surfaces that violate this restriction need to be supported by sacrificial support material. This adds costs in terms of material consumption, extra build time, and labor costs for the support removal process. Taking these extra process-related costs into consideration in the part design phase is therefore desired.

In past research, we have proposed a topology optimization formulation including an AM filter, emulating a simplified layer-by-layer manufacturing process [2]. This formulation generates fully self-supporting parts for a given build orientation, i.e. parts free from surfaces violating the critical angle. As a result, the optimized part can be produced without adding support material to meet the overhang criterion. Focusing exclusively on fully self-supporting designs however restricts the design space, and this can result in decreased performance. To allow for trade-off solutions that balance performance and costs, an extended formulation was proposed where the optimization process could still introduce a suitable amount of supports [3].

In this contribution, we extend our design-for-AM topology optimization procedure with the consideration of machining forces. This particularly targets powderbed-based metal AM (e.g. SLM, SLS), which are presently used for most printed metal end-use parts. Subtractive machining (e.g. milling, drilling, tapping) after the build process is commonly necessary, to e.g. reach the specified surface roughness and tolerances on contact surfaces, as present metal AM technology lacks the required resolution. A typical practice is to machine the part while it is still connected to the base plate. The stiffness of the part in this configuration should be sufficient to suitably limit the deformations due to machining loads, in order to reach specified tolerances.

Hence, when post-build machining is considered as part of the fabrication process, support material has a double function. It may be needed to support overhanging regions, but it also serves to firmly connect the part to the base plate, to ensure sufficient stiffness during the machining operations. This can lead to different trade-off solutions compared to design approaches only focusing on the overhang aspect. Based on the AM filter, we computationally form the as-built structure consisting of part and supports during the optimization process, and evaluate its stiffness in the defined machining load cases. By adding this as compliance constraints to the topology optimization problem, both part and support layout can be optimized simultaneously while meeting the demands of critical overhang angles as well as machining-related criteria. The objective of the optimization process is a combination of part performance in a defined service load case, and a cost term related to the amount of support material. The approach is demonstrated on 3D numerical examples, with a preliminary result depicted in Figure 1.

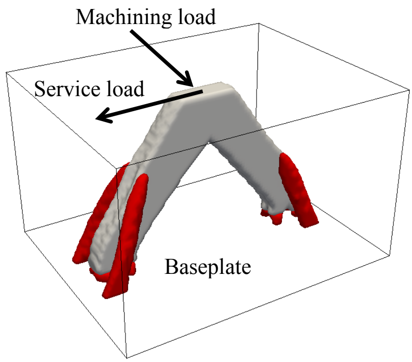

Figure 1: Preliminary example of a design obtained by combined topology optimization for AM overhang restrictions and machining load requirements. The part geometry optimized for minimum in-service compliance is shown in gray, and the sacrificial support material is shown in red. A 45° critical overhang angle was assumed.

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