Combining Lattice Optimization and AM Overhang Constraint for Self-supporting Structures Based on Topology Optimization

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It is widely known that topology optimization offers a significant benefit in designing parts for additive manufacturing (AM) due to the full usage of the design possibilities presented by the process. However, manufacturing limitations entail the need to avoid critical overhanging sections in the finished part. Most overhanging areas lead to lowered material properties and may thereby reduce the structural performance of the part. However, completely eliminating overhanging regions by applying an overhang constraint during the topology optimization process significantly reduces the design freedom and thus eliminates a lot of the advantages that come with the combination of topology optimization and AM. AM also presents the possibility of producing lattice structures which are usually used to substitute solid areas in a structure in order to generate more lightweight parts. Due to a number of problems encountered by the usage of lattice structures in performance relevant regions, they are often not suitable in these scenarios.

In this work we combine the advantages of the two methods, i.e. support-free structures and lattice structures in order to eliminate most of their individual drawbacks. This is achieved by constraining overhanging regions during topology optimization while allowing elements of lower density to satisfy this constraint. The resulting lower density elements represent lattice regions which the optimizer typically places in areas where material is mainly needed to support more structurally important material above or where a material of lower stiffness is sufficient to fulfill the structural requirement for the overall structure to perform optimally. The lattice regions will contribute to the overall performance and will not be removed after manufacturing but remain a part of it. There are three major benefits from this approach. It is seen that heat conduction is highly increased which leads to less manufacturing problems and better part quality, especially where members would become larger due to the added material needed to avoid the violation of the overhang constraint. The transition from fully dense to more semi dense supporting elements leads to more lightweight designs and the structural durability is unaffected by the introduction of lattice support in mechanically irrelevant or less relevant parts of the structure. Integrated lattice structures acting as support are particularly relevant in undercut zones with restricted access for support removal.

The above method is implemented in Altair OptiStruct and realized by combining a usual stiffness penalty with a specific support penalty that leads to semi dense elements in regions that act more as support and have less structural importance. These elements enable new design freedom for the optimization process and thus result in more suitable geometries. This work also covers the application of above method to a real-world structural part and highlights the advantages and challenges this approach faces especially in the context of manufacturing as well as potential use.