Development of Algorithm-Based and Transitional Lattice Structures in Additive Manufacturing

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Abstract

Additive Manufacturing (AM) technologies are composed of a set of modern production techniques based on layer-upon-layer material addition. One important characteristic of AM technologies is their geometrically-unbounded feature, which qualifies them to be used for the fabrication of complex parts. This acts as a motivation to scientists and engineers to think of redesigning an existing part produced by conventional manufacturing methods by means of AM technologies in a lightweight manner. One way to lighten a part is to use lattice structures. The simplest scenario is to utilize a lattice pattern all across or in some sections of the part. A better approach is to foster intelligent algorithms contemplating loads applied on the part in the respective application. One way to realize the latter is to use different lattice structures in the part. Another way is to have the same lattice type with different scales in the geometrical space of the part. Having diverse lattice structures in the part, either due to different lattice types or scales, requires a special treatment when they should merge with each other within the part geometry. It would be good if a smart algorithm were available to create a transitional geometry between adjacent lattice structures.

The current work focuses on the lattice generation algorithms in the Laser-Powder Bed Fusion (L-PBF) process, which is the widely used AM technology for metallic materials. This production technology is used for different metals such as stainless steel-, titanium- or aluminum-based alloys, and carries some constraints, such as overhang angles, tolerances and minimum achievable lattice diameter and resolution, dependent on the utilized material, part application and type of the L-PBF machine. These constraints are desired to be regarded when generating a part geometry or some sectional geometries such as lattice structures. This can be difficult when a geometrical orientation is also preferred to be included in the lattice generation algorithm. A geometrical orientation is a local or global path defined based on the geometrical shape in a section or the whole part geometry. Furthermore, this is sensible to use the loads and boundary conditions of the part to decide about the lattice type and the lattice element size in different sections of the part. Using different types of lattice structures within the part geometry necessitates the development of a transitional geometry more likely similar to both of the neighboring structures. Therefore, a design rule is developed to help engineers and scientists with choosing different types of lattice structures within the part geometry. Then, an algorithm-based lattice structure generation tool is created which considers a local geometrical orientation, loads and boundary conditions and the manufacturing constraints of the part. A finite element analysis package is made and embedded into the tool to provide the size information for the struts, a strut is a basic element of a lattice structure. Additionally, an algorithm is developed for the transitional areas between different lattice structure types. All the considerations for the generation of a lattice structure, as described in the previous development part, will be considered in this step as well. The transitional algorithm is used to connect different lattices in a so-called smooth manner. Smoothness will be determined based on the results of finite element analysis of the transitional-equipped structure compared to the one without transitional lattice structure. It is also crucial to optimize the all developments such that they can provide an acceptable solution real time or at least within a reasonable time. The results can serve as a CAD tool for lattice-based lightweight structures produced by AM technologies. The tool is not only limited to mechanical problems, and it can be used for thermal or thermomechanical problems in which different heat transfer or cooling rates are desired in distinct sections of a part.