6th German-Japanese Workshop on Computational Mechanics,
RWTH Aachen University, December 04-05, 2023

Structural and laser path optimizations to reduce residual deformation in metal additive manufacturing

Akihiro Takezawa*

Department of Applied Mechanics and Aerospace Engineering,
School of Fundamental Science and Engineering,
Waseda University, Tokyo, Japan
* E-mail: atakezawa@waseda.jp

Extended Abstract

Reducing the residual warpage caused by metal additive manufacturing's fabrication is an important issue. The source of the warpage is the layer-wise stacking of the residual stress during layer-by-layer fabrication. There are two different scale approaches to reducing stress stacking in design optimization. The first one is the macro-scale approach controlling the stiffness of the fabricated part through structural design optimization. The second one is the micro-scale approach controlling the anisotropy of the local residual stress caused by the elliptic shape of the molten pool through the laser path direction optimization. In the authors' previous research, single optimizations of each aspect are performed through the lattice infill density distribution and the laser hatching orientation optimization based on an inherent strain method considering the stress stacking of metal AM [1-3]. In this research, the simultaneous optimization of the laser hatching orientation and lattice density distribution was conducted to minimize the residual warpage in lattice infill structures and confirm their synergetic effect [4]. The mutual effect of each layer was highlighted when considering the mechanical background of the optimal results because an imbalance in the residual stress caused the warpage of the AM parts between the layers. Assuming a cube with a sphere void as the base lattice shape, the optimization problem is constructed based on the recurrent formula inherent method, the sensitivity analysis, and the method of moving asymptotes (MMA). The design variables are the representative size of the lattice geometry and the laser hatching orientation. The lattice's effective stiffness tensor is derived using the homogenization method, and the approximation function between the design variable and the effective properties is derived. The inherent strain value is calibrated using some test pieces with uniform lattice densities and hatching orientations. The proposed methodology was validated via experimental verification using a quasi-2D plate, 3D bracket, and 3D connecting-rod design problems.

References

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