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3D-FEM ANALYSIS FOR COMPRESSIVE PROPERTIES IN SELECTIVE LASER MELTED POROUS ALUMINUM ALLOYS

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ABSTRACT

Porous aluminum produced by 3D selective laser melting can change the properties of the porous energy absorbed by changing the cell shape from the viewpoint of the large degree of shape selectivity. Therefore, compressive properties (plateau stress and energy absorption) are predicted for porous aluminum having various unit cell geometries by using finite element method (FEM) analysis. For the cell configurations, we used truncated octahedron and rhombic dodecahedrons as unit cell, which are the space filling polyhedrons. Also, in order to investigate anisotropy in each cell geometry, compressive characteristics were investigated for the rotated cell shape. We estimated compressive properties in terms of strength and energy absorption property by comparing each unit cell geometry.

INTRODUCTION

Porous metal having numerous pores in themselves are widely used as bumper of vehicles and energy absorbed material on the landing spaceship. In particular, it is known that the mechanical properties of the porous metal produced by additive manufacturing are largely dependent on its own unit cell geometry. The unit cells are used by space-filling polyhedron having a periodic structure (Yue, 2017). Space filling polyhedron are various forms, but, in this study, We focused on truncated octahedrons and rhombic dodecahedrons formed when Voronoi division was made using cubic body centered cubic lattice placement and face centered cubic lattice placement as point arrangement. Although porous metal which they are formed in a periodic cell as is well known that the anisotropy of varying mechanical properties by compression axis are different are present, research elucidated the deformation behavior in aluminum alloys has not been done sufficiently. We aimed at clarifying the anisotropy and mechanical properties of porous aluminum having these unit cells by finite element analysis.

NUMERICAL ANALYSIS

Unit cells are obtained by applying Voronoi division to the point arrangement of bcc arrangement and fcc arrangement. These cells are generally space-filled polyhedrons called truncated octahedrons and rhombic dodecahedrons. A porous model of an open cell type can be created by giving a thickness to the line elements of the cell obtained here. The porosity is determined by the length of a side of the lattice and the diameter of the cell edge. Different compression directions are defined for the bcc cell and fcc cell produced by Voronoi division as analysis model. Two types of [001] and [111] are used in the bcc cell, and one type of [001] is used in the fcc cell (Figure 1). These models are hereafter referred to as bcc_Voronoi_ [001], bcc_Voronoi_ [111], fcc_Voronoi_ [001]. The compression axis is parallel to *z* axis in Figure 1.

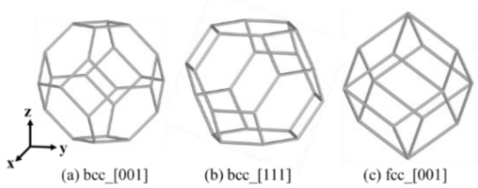

Figure 1. Images of unit cells of bcc_Voronoi_(a),(b) and fcc_Voronoi_(c)

ANSYS LS-DYNA was used as analysis software. For the material properties, the elastic-plasticity model of two linear hardening law was applied. The yield strength, Young's modulus and tangent line coefficient of Al-10Si-0.3Mg alloy obtained from the literature were entered. We installed a rigid plate to top and bottom of the model, gave a strain rate of 10^3 s^{-1} to the top plate, fix the bottom plate and simulated compression. Contact conditions were defined as frictionless contact for the top plate and model, bond contact for the bottom plate and model, single surface contact for the entire model.

RESULTS AND DISCUSSION

Elastic, plateau and densified areas could be reproduced in all models (Figure 2). From the viewpoint of impact absorption, the plateau stress was compared in each model (Ashby, 1983). Compared to bcc_Voronoi and fcc_Voronoi with compression axis of [001] on same porosity, bcc_Voronoi has higher plateau stress. This is due to the number, length of the cell edges constituting the unit cell and the angle with respect to the compression axis. In the bcc_Voronoi model where the cell edge length is short and the number is large, the deformation mode of the material is predominant in the bending mode. Symmetrically, in the fcc_Voronoi model where the cell edge length is longer than the bcc_Voronoi model, the deformation mode not only the bending mode but also the buckling mode is added. Compared to [001] and [111] of bcc_Voronoi, plateau stress of bcc_Voronoi_[001] was higher than of the other bcc_Voronoi_[111]. This is because the number of cell edges perpendicular to the compression axis is large.

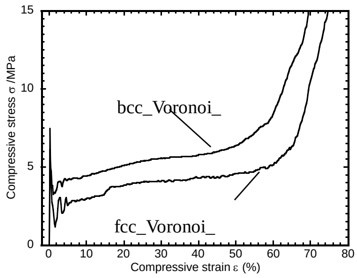

Figure 2. Compressive stress-strain curves of bcc_Voronoi_[001] and fcc_Voronoi_[001]

CONCLUSIONS

We investigated compressive properties of porous aluminum having unit cells formed by truncated octahedron and rhombic dodecahedron. Plateau stress of bcc_Voronoi_[001] is the highest of three models. Since bcc_Voronoi_[001] exhibits better compressive properties, it is most suitable as an energy absorbed material.

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KEYWORDS

Finite element method, Porous aluminum, Space-filling polyhedron, Voronoi division