PROPERTIES OF STRUCTURE WITH NEGATIVE POISSON'S RATIO BUILT BY METAL POWDER BED FUSION ADDITIVE MANUFACTURING

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ABSTRACT
In this study, the two-dimensional structure with negative Poisson's ratio was built using the powder bed fusion (PBF) process which was one of the additive manufacturing method, and its mechanical characteristics were investigated. The unit cell was designed based on the topology optimization and the homogenization method. The bead model including the unit cell size of 20 × 20 mm was built, and the tensile test was performed by a universal tensing equipment. The bead model during the tensile test was captured by the digital camera, and the Poisson's ratio was evaluated by the digital image correlation method. The metal powder used was a mixture of chromium molybdenum steel, copper alloy and nickel. As results, the width of the bead model was increased as the bead model was extended by the tensile test. The Poisson's ratio calculated was -0.55. The difference of the Poisson's ratio between the target value and the calculated value was due to the limitation of the PBF processes. The micro structure in the designed model was filled by the partially melted powder which was formed around the built structure, and resulted in the decrease of the Poisson's ratio.

INTRODUCTION
In powder bed fusion (PBF) processes, a three-dimensional CAD data is sliced into a thin layer and built on the substrate as an original data. Recently, the dimensional accuracy and the material properties of the built structure by PBF processes with metals are improved, so that the small and the complicated structure is applied to the practical products [1].

This study focuses on the building of complicated structure with a negative Poisson’s ratio by the metal-based PBF processes. The unit model with a negative Poisson’s ratio was designed based on the topology optimization and the homogenization method. The bead model including the unit cell size of 20 × 20 mm was built by the PBF processes, and the tensile test was performed by a universal tensioning equipment. The bead model during the tensile test was captured by the digital camera, and the Poisson's ratio was evaluated by the digital image correlation method.

EXPERIMENTAL METHOD
Figure 1 shows the unit cell with a negative Poisson's ratio, and Fig. 2 shows the bead model for the tensile test. The unit cell was designed based on the topology optimization and the homogenization method [2]. The unit cell was 1 × 1 and the target value of the Poisson's ratio was -0.7, respectively. The bead model including the unit cell size of 20 × 20 mm was designed and built by the PBF equipment (Matsuura Machinery Corp.: LUMEX25C). The laser beam used was a Yb-fiber laser with a wavelength of 1070 nm, and the beam diameter at the powdered surface was 0.1 mm. The metal powder used was a mixture of 70% alloy steel, 20% copper phosphorous alloy and 10% nickel powders by weight. The average particle size was 25
μm. The PBF processes were performed in a nitrogen atmosphere to prevent the oxidization of metal powder during laser irradiation.

Table 1 shows the experimental conditions for the tensile test. The tensile test was performed by a universal tensing equipment (SHIMADZU Corp.: AG-100kND) with a feed rate of 1 mm/min at the room temperature. The stress-strain curve was measured from the displacement and the stress values, and the elastic region was determined based on it. The bead model during the testing was captured by the digital camera with a resolution of 3456 × 5184 and a frame rate of 1/5 fps, respectively. The Poisson's ratio of bead model was evaluated by the digital image correlation method. The deformation of bead model was measured by comparing the captured images at the time interval of 5 s. The edges of built structure were classified into eight types, and the deformation of each structure was evaluated.

RESULT AND DISCUSSION

Figure 3 shows the typical stress-strain curve obtained from the tensile test. The nominal stress was increased linearly until the nominal strain was 0.01, so that the deformation of the bead model was evaluated when the nominal strain was 0.01.

Figure 4 shows the variation of the displacement in X and Y direction at the center of unit cell. The width of the bead model was increased linearly as the bead model was extended by the tensile test. The Poisson's ratio calculated was -0.55. When the unit cell size was 20 × 20 mm, the small hall inside the unit cell was not formed as shown in Fig. 5. The difference of the Poisson's ratio between the target value and the calculated value was due to the limitation of the PBF processes. The microstructure in the designed model was filled by the partially melted powder which was formed around the built structure, and resulted in the decrease of the Poisson's ratio. This result suggested that the unit model with the negative Poisson's ratio has to be designed by considering the limitation of PBF processes, such as the minimum shape decided by the diameter of laser beam and the following physical phenomena.

CONCLUSION

The bead model including the unit cell with the negative Poisson's ratio was built by the metal-based PBF processes, and the Poisson's ratio in the bead model was evaluated by the digital image correlation method. The following results were obtained.

[1] The width of the bead model was increased as the bead model was extended, and the Poisson's ratio calculated was -0.55.
[2] The unit cell with the negative Poisson's ratio has to be designed by considering the limitation of metal-based PBF processes.

REFERENCES