1P2-12

Detection of subsurface defects using laser ultrasonics for process monitoring of metal additive manufacturing

Atsushi Yamasaki[1†], Takahiro Hayashi[1*], and Naoki Mori[1]
([1] Grad. School Eng., Osaka Univ.)

1. Introduction

Additive manufacturing has emerged as an attractive technique for producing complex parts without molds. Thanks to the freedom of shape that can be produced by this technique, now it is becoming a more and more widely used technique in various fields such as aerospace and medical sector. Selective laser melting (SLM) is one of the most widely used techniques of metal additive manufacturing. In this technique, metal powder is spread over the building platform, and melted by laser. Metal layers are stacked, and desired form of the component is obtained by repeating the above processes.

One challenge of this technique is that various types of defects such as cracking, delamination and porosity sometimes occur, which decreases the strength of the parts[1)]. For this reason, defect evaluation of additively manufactured components is important to promote the use of this technique.

Many studies have been conducted to evaluate defects of completed parts using X-ray computed tomography or ultrasonic waves. However, effective methods for defect detection during the selective laser melting process have not been established. If defects can be found during manufacturing processes, closed-loop feedback is possible, which may lead to repairing the components that are being produced. Therefore, it is important to establish the way of in-process defect detection in order to produce non-defective components.

Laser ultrasonics has some advantages for the evaluation of components. For example, evaluation is totally non-contact, and defects inside the component can also be inspected. Moreover, a laser for generating ultrasonic waves can be the same as the one for melting metal powder, which can reduce the space of instrument. In this way, laser ultrasonics is regarded as a suitable way for in-process defect detection of additively manufactured components.

This study examines the effectiveness of in-process defect detection during additive manufacturing process using a scanning laser source technique, which is one of laser ultrasonic testing techniques.

2. Method

Scanning laser source technique (SLS) is a way of finding subsurface defects by generating ultrasonic waves (**Fig. 1**) [2)]. Ultrasonic waves are generated by a periodic fluctuation of thermal strain caused by the pulsed laser hitting on the surface of the material. When pulsed laser hits a defective area, the amplitude becomes larger compared to the case when the laser hits on the sound part of the material because of the resonance occurring at the thin part of the material. By using this principle, the location of defects can be detected. In a previous research, defect detection for a completed metal additive manufacturing component is proven to be feasible[2)]. **Fig. 2** shows an image of a circular flat-bottom hole inside an additively manufactured component after finishing producing it (depth: 0.125 mm, diameter: 2 mm). In the present research, this method is applied to in-process defect detection of additively manufactured component.

Fig. 3 shows an experiment system. Pulsed laser is used for both melting metal powder and generating ultrasonic waves. The diameter of the plate is 132 mm, and the thickness is 5 mm. Four transducers are attached at the back of the plate for receiving ultrasonic waves. The received signals are amplified and converted to digital ones. After that, they are sent to a computer and analyzed.

Firstly, a component is made by following SLM process. In this process, defects are intentionally introduced at the subsurface of the component. After that, defect inspection is conducted without separating the component from the plate. Scanning area, which means the area subject to inspection, is divided into small grids. Then, ultrasonic waves are generated at each grid. The waves propagate in the component and the plate, and transducers attached at the back of the plate receive the waves. Then, the signals are sent to the computer. By following this way, the signal from each grid is obtained. When defects are present, the amplitude of the signal is expected to become large. Therefore, the places where defects are present are located. The objective is to know the defective area as a form of an image.

E-mail: †a.yamasaki@nde.mech.eng.osaka-u.ac.jp,
*hayashi@mech.eng.osaka-u.ac.jp

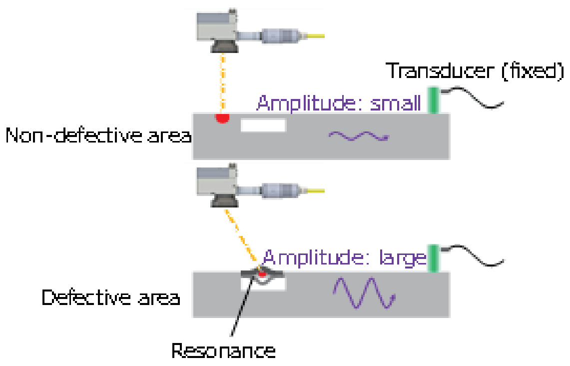

Fig. 1 Principle of scanning laser source technique (SLS)

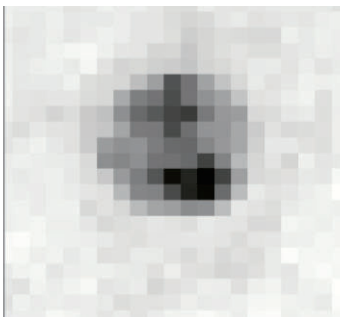

Fig. 2 An example of a defect image

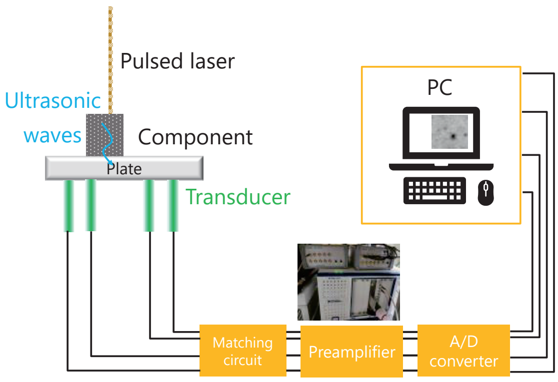

Fig. 3 Experimental system

3. Results

Fig. 4 shows a component made from stainless powder. (The conditions: power: 200 W, pulse frequency: 1000 kHz, scan speed: 0.35 m/s, hatch spacing: 0.05 mm, layer thickness: 0.1 mm) Inside the component, a cuboid defect was introduced. By using a scanning laser source technique, a defect image tried to be obtained. **Fig. 5** shows a defect image by using 50 kHz pulsed laser for generating ultrasonic waves. This result indicates that a defect image was not clearly obtained. By changing the condition, now clearer images try to be obtained.

4. Conclusions

Additive manufacturing is a promising technique, but various types of defects appear when metal components are made. Therefore, it is important to conduct defect detection. This study tries to get defect images of subsurface defects of additively manufactured component. The result indicates that now it is difficult to evaluate defects of stainless component.

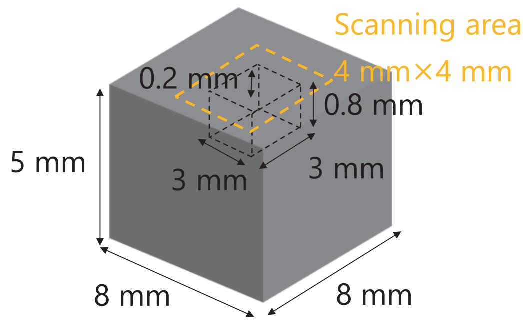

Fig. 4 A component made

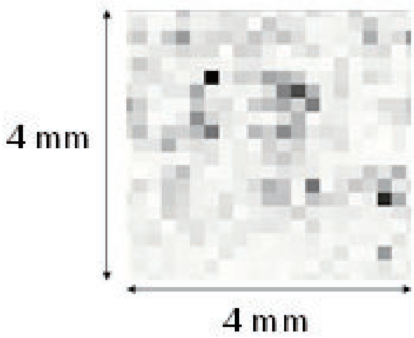

Fig. 5 A defect image

Acknowledgment
This publication was subsidized by JKA through its promotion funds from AUTORACE and by KAKENHI 21H01573.

References

1) M. Grasso, B.M. Colosimo, Meas. Sci. Technol. 28 (2017).
2) T. Hayashi, N. Mori, T. Ueno, Ultrasonics. 119 (2022) 106560.