INFULENCE OF THE GEOMETRIC FACTOR FOR THE WIDTH OF THE CONTOUR SCAN IN SELECTIVE LASER MELTING

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ABSTRACT: Selective laser melting (SLM) is one of additive manufacturing technologies and based on the metallic powders. SLM process can fabricate a part with high geometric complexity with layer-by-layer fashion. During the process, there are two types of laser scans as their rules. Among them, contour scan makes the contour of a part and is mainly responsible for the surface quality like a surface roughness, and geometric/dimensional accuracy of a part. In viewpoint of the dimensional accuracy, the accurate estimation of the width in the contour scan is important. It has been known that the width is affected by process parameters related to the energy density such as laser power and scan speed. However, it should be noted that the width can be changed with the shape of a path for the contour scan due to the change of the exposure time as change of the scan direction. In this study, to estimate the influence of the exposure time for the width, specimens with thin wall and circular shape are fabricated on the different scan speed. The width of fabricated parts is measured. The measured results shows that the width decreases with the diameter of the circle. It proves that the geometric factor affects the dimensional accuracy as the change of the width.

Keywords: Additive Manufacturing, Selective Laser Melting, Geometric Factor

1. Introduction

Selective laser melting (SLM) is one of additive manufacturing technologies and can fabricate a part with the complex structure that cannot be achieved by the conventional process due to the layer-by-layer fashion. In SLM process, there are two types of the scans which are classified by their roles. Among them, contour scan makes the contour of a part and is responsible for the surface quality like surface roughness, and the geometric/dimensional accuracies of a designed part (Mumtaz and Hipkinson, 2009; Arrieta *et al.*, 2012; Ko *et al.*, 2015). Thus, the understanding of the change of the contour scan with process parameters is very important to make an accurate part.

In viewpoint of the geometric accuracy, the main issues is to generate an accurate path. In the path generation of SLM process, STL format transformed from a 3D model is widely used (Choi and Kwok, 2002). In the transformation, there is an approximation error between the curved surface in a 3D model and the tessellated surface in a STL format, known as chordal error (Fedel and Kirschman, 1996). The chordal error can be controlled by the chord height tolerance. The small tolerance reduces the chordal error but increases the file size that results in the more computational load and pre-processing time. Zha and Anand (2015), Navangul *et al.* (2013) have developed the modification algorithms of STL model to minimize the chord error with unnecessary increase of the file size. The algorithm has been still on laboratory and the uniform

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chord tolerance algorithm is used in the commercialized package. The chordal error distorts the shape of the contour and leads the geometric error. To improve the geometric accuracy, the relationship between the geometric error and the chordal tolerance should be investigated.

In the dimensional accuracy, the width of the contour scan is important. The width can be varied with process parameters related the energy density such as laser power and scan speed (Di et al., 2012,Yao *et al.*, 2016). The variation of the width comes from the variation of the amount of the heat transferred from the laser beam. The variation can be changed by the shape of a path due to the change of the exposure time as the change of the scan direction (Li *et al.*, 2009). There is few research to show the change of the width in the contour scan due to the change of the exposure time.

In this study, to estimate the influence of the exposure time for the width, specimens with thin wall and circular shape are fabricated on the different scan speed. The width of fabricated parts is measured. The measured results shows that the width decreases with the diameter of the circle. It proves that the geometric factor affects the dimensional accuracy as the change of the width.

2. Experiments

For the fabrication of specimens, we used SLM250 HL (SLM solutions, Germany) machine with the process as shown in Figure 1. Table 1 shows process parameter to use the fabrication of specimens. Argon gas is used to maintain the content of oxygen below 0.2%. AlSi10Mg powders were used for this study, which are also widely used for aluminum castings (Vojtech *et al.*, 2004). The particle size of powders is the range of 26 μm ~ 62 μm. The layer thickness for fabrication is 50 μm. The design thickness of the specimens is set as the same of the laser spot size to sure the single track and multi-layer conditions. The shape, manufacturing direction of specimens are shown in Figure 2. The fabricated specimen and the measurement of the width of the contour scan are shown in Figure 3. The width of the contour scan is measured by using the low magnification optical scope. The representative value is obtained by averaging 10 measurements.

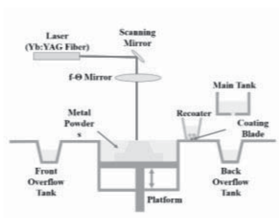

Figure 1. Schematic diagram of SLM process

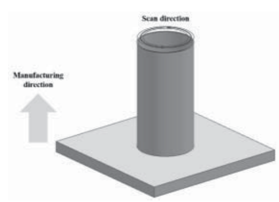

Figure 2. Shape and manufacturing direction of specimens

Table 1.Process parameters for specimens

Parameters	Unit	Values
Layer thickness	μm	50
Laser power	W	350
Scan speed	mm/s	500, 1000, 1500
Diameter	mm	5, 10, 15, 20

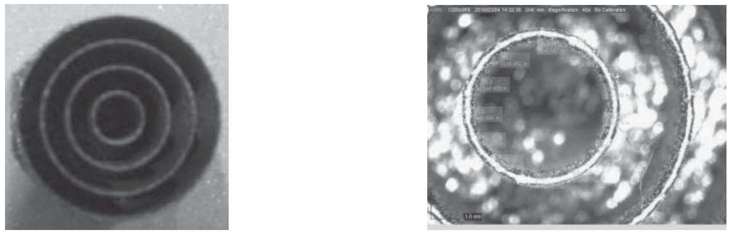

Figure 3. Fabricated specimen and the width of the solidified contour in 500 mm/s and 350W

3. Results and discussions

3.1 Results of the measurements for the width of the solidified contour scan

As shown in Figure 3, measurements of the width of the contour scan were conducted along the path of the contour scan. The representative width is determined by averaging 10 measurements. The measured results are shown in Figure 4. In Figure 4, the width decreases with the diameter of the circle. In the case of the same diameter, the width decreases with the scan speed. To clear the influence of the geometric factor for the width, t-test was conducted for two cases. First case is to investigate the significance between two scan speeds (500 mm/s and 1500 mm/s). Results tell that the width on 5 mm diameter is not different ($p=0.053$) but the width on more than 5 mm diameter is significantly different ($p < 0.05$). Second case is to investigate the significance between 5 mm and 20 mm diameters at 500 mm/s scan speed. p-value from t-test is 0.00035. From results of t-test on two cases, we can conclude that the width is affected from the geometric factor.

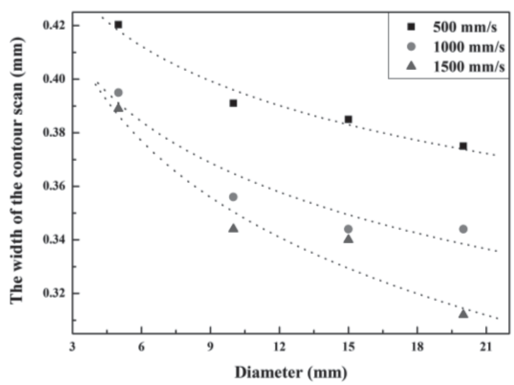

Figure 4. The width of the solidified contour scan with the diameter of circle

The width of the scan is mainly affected by laser power and scan speed. The two parameters determine the theoretical amount of the input energy to melt powders but actual input energy determined by considering two factors. They are the net input energy and the exposure time (Glardona *et al.*, 2001). The net input energy is obtained from subtracting the energy transferred to surrounding from the theoretical input energy. The exposure time can be calculated from dividing the spot diameter by the scan speed and is important to judge the minimum energy to guarantee bonding between the current and previous depositions. The calculation of the exposure time is valid for the straight scan path. If the scan path is curved or bent, the exposure time could be changed. The change of the exposure time might change the amount of the real input energy. The results in Figure 4 can be understood as the change of the amount of the real input energy due to the continuous change of the scan direction.

4. Conclusions

In this paper, we investigate the influence of the geometric factor for the width of the contour scan. The measured width of the contour scan with the diameter of a part shows the significant difference, which means that the width of the scan can be affected by the geometric factor. We finally conclude that the change of the width is due to change the exposure time from the continuous change of the path, and the relationship among physical outcomes, process parameters and the geometry of a part should be deeply studied to fabricate an accurate part. Thus, we will investigate the influence of process parameters for the change of the width and conduct the numerical analysis to verify the influence of the geometric factor.

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