Microstructure and Mechanical Properties of Selective Laser Melting 0Cr18Ni9 Stainless Steel

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Abstract. The 0Cr18Ni9 samples were prepared by laser selective melting technique, and the effects of different power and scanning speed on the microstructure evolution were observed. Through the observation of the microstructure and the analysis of the densification test results, the optimum process parameter was 280W, 960mm/s. The tensile strength (678MPa) and yield strength (554MPa) of the transverse tensile specimens formed under this condition are higher than that of the longitudinal specimens. However, the longitudinal specimen is more plastic than the transverse specimen.

1. Introduction
The design, materials and manufacturing techniques of advanced aircraft play a key role in the development of the defense industry. In order to improve the reliability of the aircraft, advanced aircraft and the engine is increasingly increasing the amount of high-strength alloys such as titanium alloys, high-temperature alloys, high-strength aluminum alloys and high-strength steels, and the structure is more and more complex, the processing precision is higher and higher, higher requirements are placed on the manufacturing process [1]. Selective laser melting (SLM) technology is an additive manufacturing technology that utilizes metal powder to be completely melted under the action of the heat of the laser beam and solidified by cooling [2, 3].

0Cr18Ni9 stainless steel is widely used in the nuclear industry, building materials, chemical and food processing industries due to its good corrosion resistance, heat resistance, low temperature strength and mechanical properties [4]. The formation of 0Cr18Ni9 stainless steel by different additive manufacturing processes has been studied [5-8]. However, the study on the influence of different laser selective melting process parameters on the microstructure and mechanical properties of 0Cr18Ni9 forming specimens has not been reported.

In this paper, the microstructure evolution of 0Cr18Ni9 stainless steel with different laser power and scanning speed was studied. Besides, the tensile properties of the specimens in different directions were also tested.

2. Experimental setup
The chemical composition of 0Cr18Ni9 powder used in this experiment is shown in Table 1, and the morphology is shown in Figure 1.
|     | C     | Cr       | Ni       | Si | Mn | P   | S     | Ti   | Mo |
|-----|-------|----------|----------|----|----|-----|-------|------|----|
|     | 0.07  | 17.00–19.00 | 8.00–11.00 | 0.80 | 2.00 | 0.035 | 0.020 | ≤0.50% | ≤0.30% |

Table 1 Chemical composition of 0Cr18Ni9 powder (mass fraction, %)

Fig.1 Powder morphology of 0Cr18Ni9

Laser selective melt forming tests were performed on EOS-290 equipment. Arrays with different laser powers \( P \) (225W, 255W, 285W, 315W, 345W) and scanning speeds \( \nu \) (860 mm/s, 960 mm/s, 1060 mm/s, 1160 mm/s, 1260 mm/s). The test piece size was 15 mm × 15 mm × 5 mm, and the microstructure of the formed test piece was observed with an optical microscope and the density of the test piece was measured.

3. Results and discussion

It can be seen from Fig. 2 that when the laser power is 285W, the density of the sample is the largest. At different laser powers, when the scanning speed is 860mm/s and 960mm/s, the density of the formed samples is not much different. Compared with other scanning parameters, it is relatively good (except for two samples formed at 255W and 285W with a scanning speed of 1160 mm/s). Therefore, under the laser power of 285W, the effects of different scanning speeds on the microstructure were studied, and the influence of different laser power on the microstructure was studied under the scanning speed of 960 mm/s.

Fig.2 Density of 0Cr18Ni9 sample at different laser powers and scanning speeds
It can be seen from Fig. 3 that under the laser power of 285W, the number of pores increases with the increase of the scanning speed. This is because the speed of the SLM forming process is too fast, the heat input is small, the penetration depth is not enough, and the scanning line is Poor fusion occurs between the scan lines and between the layers, resulting in voids [9, 10].

Further research is made on the case where the scanning speed is constant and the power is changed. The scanning speed of 960 mm/s was selected and the laser power was studied. The results are shown in Fig. 4. As the power is increased, the number of pores is gradually reduced. When the laser power is 285 W, the number of pores is small and the shape is good. However, as the power continues to increase, the number of pores gradually increases. This is because when the laser power is large, the heat input is large, and the gas metal is too late to escape when the molten pool moves. The results of the microstructure are consistent with the results of the densification test.

Fig. 4 shows the microstructure of the shaped test piece with a laser power of 285 W and a scanning speed of 960 mm/s. The entire microstructure is dense, free of pores and cracks, and has typical rapid solidification structure characteristics.

In summary, the laser melting process parameters selected for 0Cr18Ni9 are 285W and 960mm/s. This parameter was used to print the subsequent 0Cr18Ni9 mechanical properties.
The optimized process parameters of 285W and 960mm/s were used to carry out the additive manufacturing of the room temperature tensile test specimens, and the tensile properties at room temperature were tested, as shown in Table 2.

The transverse sample is labeled T and the longitudinal sample is labeled L, respectively. The room temperature tensile properties of the two orientations were tested. The results are shown in Table 2. It can be seen from Table 2 that the strength of the transverse specimen is higher than that of the longitudinal specimen, but the plasticity of the transverse specimen is lower than that of the longitudinal specimen, and anisotropy exists. This result is similar to the result in [11], the high strength and low plasticity of the transverse specimen.

Table 2. Tensile mechanical properties of 0Cr18Ni9 at room temperature

|     | Tensile Strengt (MPa) | Yield Strength (MPa) | Elongation(%) | rate of reduction in area(%) |
|-----|-----------------------|----------------------|---------------|-----------------------------|
| T1  | 679                   | 552                  | 46.5          | 72                          |
| T2  | 678                   | 556                  | 45.5          | 68                          |
| T3  | 679                   | 555                  | 46.5          | 72                          |
| T4  | 675                   | 552                  | 46.0          | 71                          |
| L1  | 600                   | 491                  | 71.0          | 77                          |
| L2  | 600                   | 491                  | 66.0          | 76                          |
| L3  | 601                   | 490                  | 67.0          | 75                          |
| L4  | 599                   | 486                  | 66.5          | 76                          |

4. Conclusion
(1) Observing the density and microstructure of selective laser melted 0Cr18Ni9 samples by different power and scanning speed, it was found that the optimum process parameters were 280W, 960mm/s.
(2) The tensile strength and yield strength of the transverse specimen were larger than those of the longitudinal specimen, the average tensile strength was 678 MPa, and the average value of the yield strength was 554 MPa. However, the plasticity of the longitudinal specimen was larger than that of the transverse specimen.

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