

Surface quality improvement of a laser-polished Co-free high entropy alloy prepared by selective laser melting

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Abstract. In order to improve the quality of the Co-free high entropy alloy surface, a Co-free high entropy alloy specimen prepared by selective laser melting was polished by laser in this work. Optimal laser polishing process parameters were explored, and the best surface roughness Sa value reached 0.4626μm, which is much lower than the original surface roughness. Through microscope, SEM, EDS and other tests, the surface quality after polishing is obviously improved. The big improvement in high entropy alloy specimen's surface quality has potential significance in promoting the application of this material in high precision situations.

Keywords: High entropy alloy, laser polish, selective laser melting, surface roughness.

1. Introduction

High entropy alloy is a new type of material with excellent properties, and it has been widely concerned by the scientific community for its excellent mechanical properties, corrosion resistance and excellent thermal stability [1,2]. Selective laser melting is a very promising additive manufacturing method for complex shape parts, especially for metals [3]. Selective laser melting of Co-free high entropy alloy attracted a lot of research [4, 5]. But the poor surface quality limited the SLMed parts' direct applications in many occasions which have strict requirements on surface performance. Therefore, post-processing for Co-free high entropy alloy surface is always needed [6].

Conventional post-processing means of metallic additive-manufactured components include manual polishing, chemical polishing, electrolytic polishing, mechanical milling, ultrasonic polishing, and so on. These means are always difficult to machine materials, low geometrical flexibility, low processing efficiency, inconvenient for automation [7]. Xiao et al. [8, 9] studied influence of laser additive manufacturing and laser polishing on microstructures and mechanical properties of high-strength maraging steel metal materials. Hofele M et al. [10] has developed a process parameter dependency of continuous and pulsed laser modes on surface polishing of additive manufactured aluminium AlSi10Mg parts. Recent researches have reported laser polish's applications in many different materials fabricated by laser additive manufacturing [11,12], it can be seen from these literatures that there are few researches on polishing high entropy alloy. In this work, a new process of surface quality improvement of a laser-polished Co-free high entropy alloy will be studied prepared by selective laser melting.

2. Materials and Methods

The SLM-ed Fe₃₂Cr₃₃Ni₂₉Al₃Ti₈ high entropy alloy specimen was first cleaned by ultrasonic in alcohol and then dried in the vacuum environment. Polishing equipment with 1000W is composed of fiber laser using a wavelength of 1070nm continuous fiber laser, optical transmission system, laser vibrator lens, numerical control system, computer, water cooling radiator, control of laser head movement, air compressor, gas protection covers and other parts. The composition of laser polishing

system is shown in Figure 1. After that, the specimen was placed in a transparent plastic box under the scanning system of the laser polish equipment is shown in Figure 1.



Figure 1. Laser polish equipment system

Optimal laser polishing process parameters were explored, is shown in Table 1. The specimens were numbered as shown in the first column of Table 1.

Table 1. Laser polishing parameters of different samples

Parameters	Numerical value	Parameters	Numerical value
Laser power(W)	200 W,300 W	Spot diameter	0.3mm
Scanning Velocity(mm/s)	50,60,80,100,120mm/s	Wavelength	1064nm
Scanning Times	Once, twice	Scanning route	Zigag
Scanning spacing(mm)	0.0375	Beam quality	1.3

3. Results and disscussion

The surface profile was measured by a Mahr MarSurf CM mobile series laser confocal microscope. Fig.2 shows the results of as-received and laser polishing SLM-ed Co-free high entropy alloy specimen' topography. Fig.1a shows that the original SLM-ed surface and surface roughness values Sa and Sz were 4.159 μ m and 250.2 μ m, respectively, which were attributed to the large number of partially melted powders that accumulated at the surface during the SLM process [8]. Fig.2b shows the ronghness results of samples listed in the Table 1 and the best laser polishing quality is obtained when the scanning velocity is 60mm/s with a laser power of 200W and scanning for twice. Significant improvement of surface finishing is observed, as shown is Fig.2. After laser polishing, surface roughness Sa and Sz values were reduced to 0.4626 μ m and 9.319 μ m respectively. The measurement results of surface topography indicate that the partially melted powders were further melted at the laser polished surface and hence the surface appeared smooth.

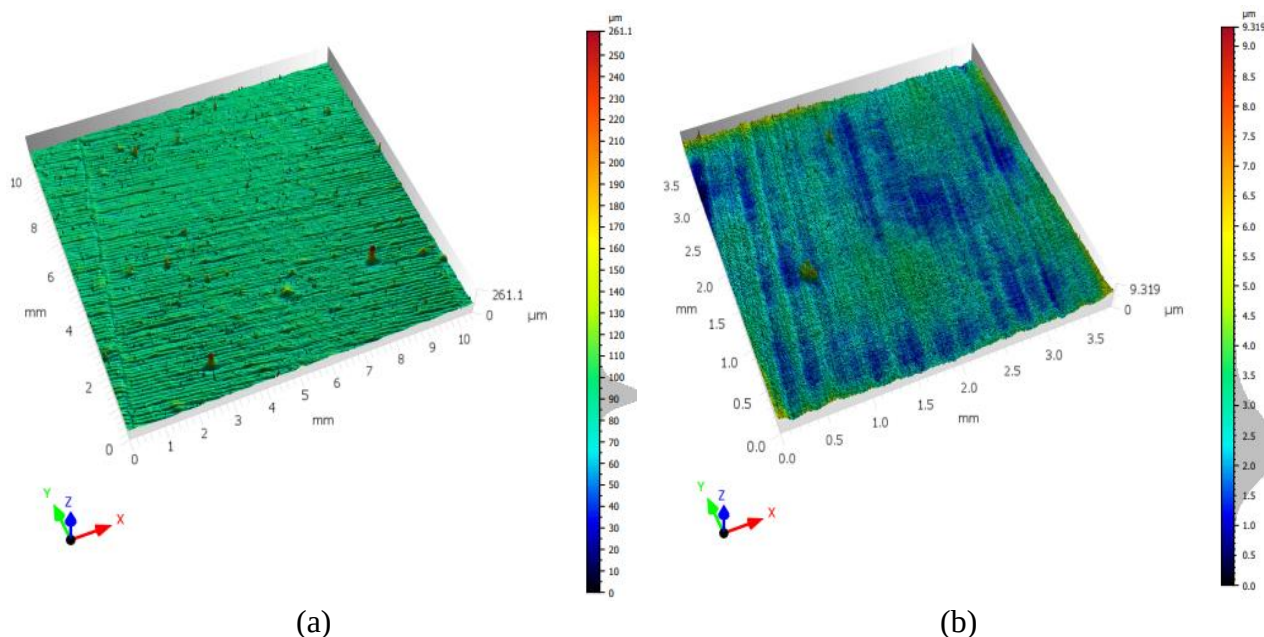


Figure 2. Effect of laser polish on SLM-ed Co-free high entropy alloy specimen: a) the original SLM-ed surface and surface roughness; b) the best surface and surface roughness after laser polish.

According to the previous researches, the Marangoni flow was the main factor driving the liquid flow and it was produced by non-uniform temperature or concentration distribution on the interface of two fluids. Accordingly, Marangoni flow that is radially outward results in a depression of the liquid surface under the laser beam and ridging of the liquid surface elsewhere. When the laser beam moves to the next area of the irradiated surface, deformation of the liquid surface caused by thermally-driven flow and the molten material were redistributed by surface tension and gravity. Finally, a smoothened surface was realized through laser polishing. Polished sample and SEM before and after polishing is shown in Fig. 3.

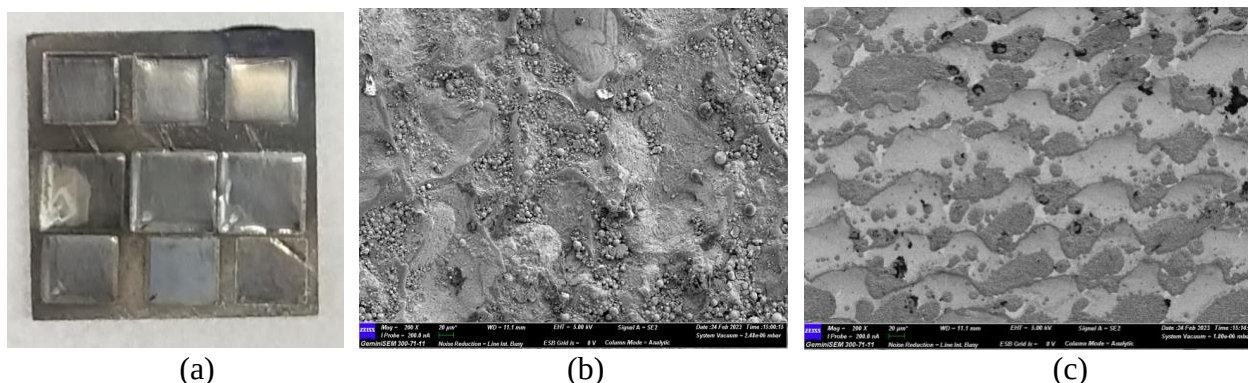


Figure 3. Polished sample and SEM before and after polishing (a) Polished sample, (b) SEM before polishing, (c) SEM after polishing

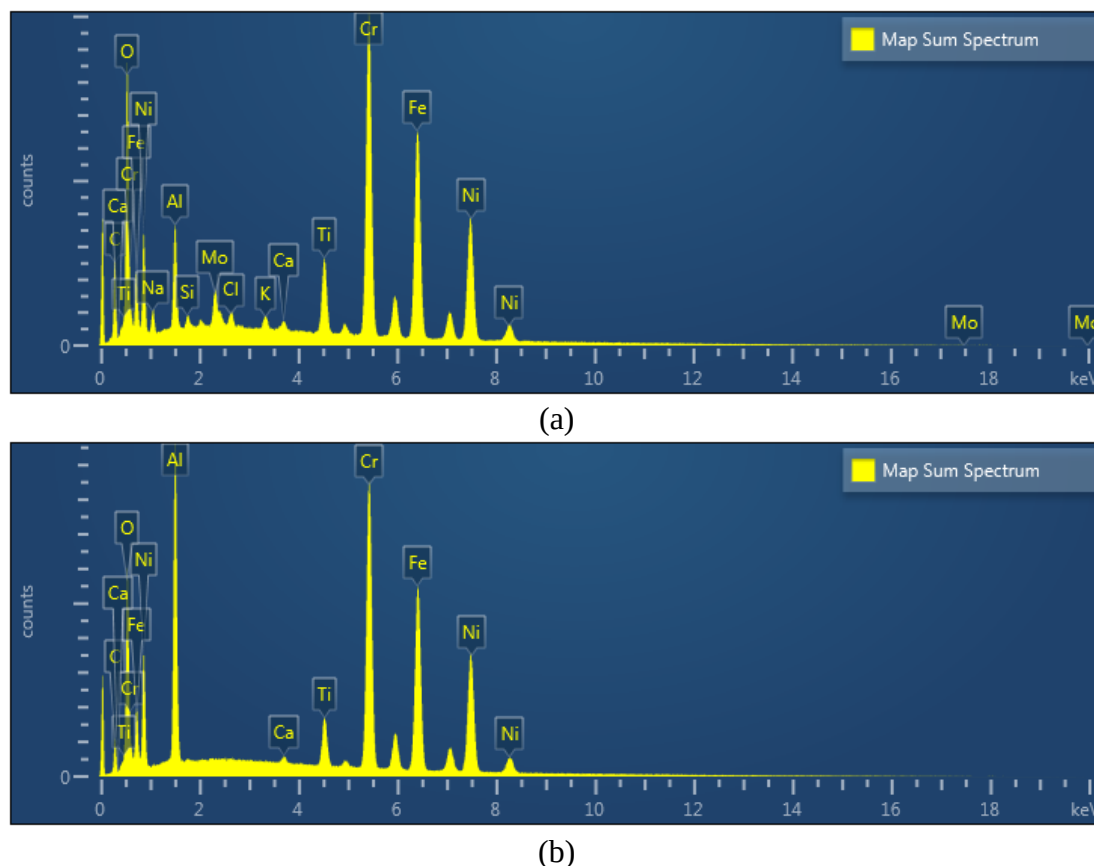


Figure 4. EDS surface before and after laser polishing, (a) EDS surface before polishing, (b) EDS surface after polishing

EDS surface before and after laser polishing are shown in Fig.4. It can be seen in Fig.4 (a), the main elements on the surface of the high entropy alloy are C, O, Na, Al, Si, Cl, K, Ca, Cr, Fe, Ni and so on. The content of some elements in Fig.4 (b) after polishing has been changed, with the content of C dropping from 34.63% to 21.15% and Al rising from 3.28% to 14.66%, comparing with Fig.4(a).

4. Conclusion

Optimal laser polishing process parameters were explored on a Co-free high entropy alloy specimen prepared by selective laser melting, and the best surface roughness S_a and S_z values were reduced to $0.4626\mu\text{m}$ and $9.319\mu\text{m}$ respectively, which is a great improvement compared to the original surface roughness. This research has potential significance in promoting high entropy alloy's application in high precision situations.

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