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<th>Laser melting characterization for H13-steel 3D printing</th>
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ABSTRACT: Selective laser melting is one of the important 3d printing process for its capability of the complex shape production for metal part. H13 steel is one of the difficult metal material to fabricate due to its high hardness, thus selective laser melting process can be efficiently applied for its net-shape production. However, selective laser melting improper process condition results in pores inside printed part and it degrade the hardness of H13 steel component. We hereby studied the characteristic behavior of H13 steel laser melting with computational and experimental approach. Re-melting process of single, triple and quintuple was compared and triple times of laser scanning exposure showed the lowest amount of pores and highest hardness. Our characteristic study can be usefully employed for development of H13 component via selective laser melting process.

KEYWORDS: metal 3D printing, selective laser melting, powder bed fusion, H13 Steel, re-melting, pore percent amount, hardness

INTRODUCTION

H13 steel is widely used in tooling applications for its high hardness containing molybdenum and vanadium as strengthening agents. Due to its high hardness, it is difficult to obtain a desired complex shape with machining and metal 3D printing process can provide various application using newly designed H13 steel component. There are several metal 3d printing principle such as powder bed fusion, directed energy deposition and material extrusion. Selective laser melting (SLM), electron beam melting (EBM) and direct metal laser sintering (DMLS) processes are representative powder bed fusion process which exposes laser on spread powder on bed with desired pattern repeatedly. These processes require optimization of laser melting process to avoid incomplete densification and defects. In this study, we characterized the laser melting behavior of H13 steel powder for SLM process to obtain high hardness with minimized pores. Temperature distribution profile has been analyzed with finite element simulation and densification processes were compared with single, triple and quintuple laser scanning.

METHOD

For 3d printing of H13 steel, we used commercial H13 powder with spherical morphology as shown in figure 1 and mean size of 35 µm (D50 size). To spread powder evenly on fusion bed, this spherical shape with good flowability is very important. Concept laser M-lab equipment was used for SLM process. The beam size of laser is near to 40 µm and wavelength of 1064nm. The laser power and scanning speed was fixed at 100W and 10mm/min. The hardness of H13 specimen was measured by Rockwell Hardness with a load of 150kg.
RESULTS AND DISCUSSION

For temperature profile analysis, finite element simulation has been conducted with H13 material with thermal conductivity of 28.6W/mK and laser scanning of 100W. Figure 2 shows the simulated temperature profile and temperature iso-surface results at cut surface of H13 steel during laser scanning. As shown in Figure 2 a-d, the laser exposed H13 steel has the highest temperature of 1280K at the center of laser spot and temperature exponentially decrease as the distance with center increases. This exponential decaying of heat affected area temperature can cause imperfect densification of H13 steel across the direction of laser scanning direction, i.e.) orthogonal to laser forward direction. The iso-surface of temperature results shows forward biased shape in the direction of laser scanning proceeding which means the back tail area of laser spot has higher temperature than front area of laser spot. When we consider the scale of sintering temperature over 1000K, the simulation results can imply that a single laser scanning might not fully densify H13 steel.

Figure 2. 3D Simulation of H13 Steel Laser scanning. a-d. Cut surface temperature distribution during laser scanning. e-h. Iso-surface of temperature during laser scanning with 100W
For experimental characterization of densification, we have compared the laser melting of H13 steel powder with three different number of laser scanning times, i.e., 1 time, 3 times and 5 times. Figure 3 shows the optical microscopy of laser melted H13 cut surface for each cases and their melt pool morphology with etched surface. As shown in Figure 3 a, there exists many large and small pores for the single scanned H13 steel specimen. There also exist long cracks which connects pores. These type of defects are originated from the imperfect melting. Figure 3 b shows the cut surface of H13 steel specimen with 3 times laser scanning over same area. While there still exists very small pores, most of large pores were closed and better densification was obtained. Figure 3 c shows the case of 5 times laser scanning. There exists relatively large size of irregular shape pores. These defects can be due to the over melting during too much exposure to laser. Figure d-f shows the melt pool optical microscopy after etching the specimen. The case of three times laser scanning had most uniform melt pool shape over the surface.

![Figure 3. Optical microscopy of laser melted H13 cut surface a)-c). a) single laser scanning exposed, b) 3 times laser scanning exposed, c) 5 times laser scanning exposed and etched melt pool morphology d)-f). d) single laser scanning exposed, e) 3 times laser scanning exposed, f) 5 times laser scanning exposed](image)

The percent amount of pores based on the cut surface image was also calculated via image analysis as in Figure 4 a and it is clearly shown that the triple laser scanning case have lowest amount of pores (0.55%). The measured hardness of 3D printed H13 steel specimen was summarized in Figure 4 b. The hardness of 3 times laser scanned H13 specimen had the highest hardness (291 Hv) over 1 time (283Hv) and 5 times (280Hv) cases.
CONCLUSION

The selective laser melting (SLM) of H13 steel was characterized via computational and experimental analysis. The laser scanning simulation revealed that the highest temperature on the surface of H13 steel can approximately 1280K and there exists exponential temperature decaying near laser affected area. To obtain full density via SLM process, the re-melting of triple laser scanning exposure allowed minimized amount pores without extra defect from over-melting. This study is expected to provide the fundamental understanding of SLM process with H13 steel and further study with various printing parameter such as laser power, scan speed and spot size can be useful to develop H13 steel 3d printed component.

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REFERENCES