Surface Finishing of Additively Manufactured Components by Magnetic Abrasive Finishing

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Abstract

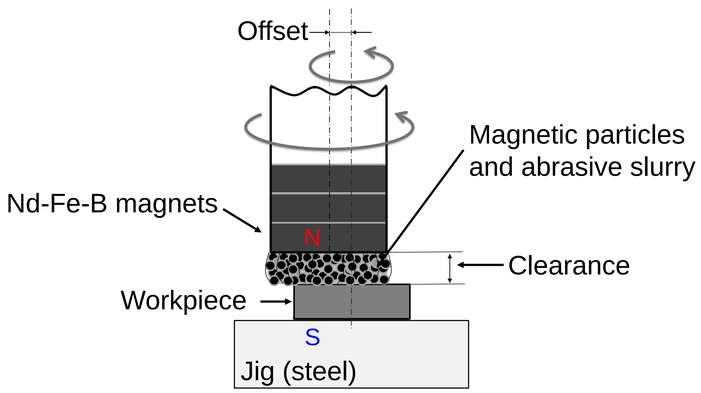
Additively manufactured components facilitate the manufacturing of complicated metal parts. However, these components require post-processing to meet the rigorous surface quality requirements. The focus of this project is using Magnetic Abrasive Finishing (MAF) to modify the surfaces of 316L stainless steel components made by selective laser melting (SLM). MAF can be used for altering the surface geometry, eliminating surface defects, and achieving different levels of surface roughness.

Magnetic Abrasive Finishing

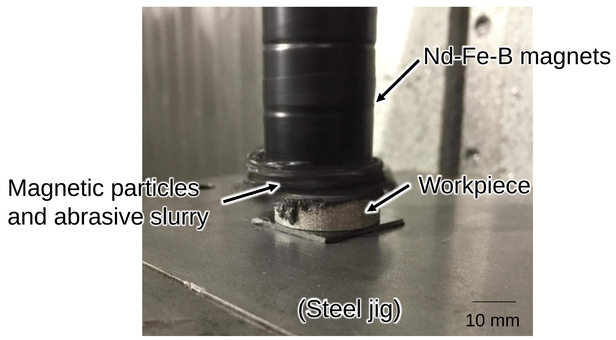
By controlling the magnetic field, a brush composed of magnetic and abrasive particles with lubricant can move against and apply force on the workpiece. The finishing force can be described by the following equation:

$$F = V\chi H \cdot \nabla H$$

where V is the volume of the magnetic particle, χ is the magnetic susceptibility of the material, and H and ∇H are the intensity and gradient of the magnetic field, respectively.

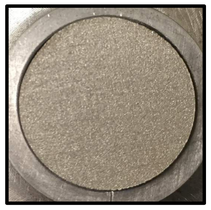


Schematic of Processing Principle

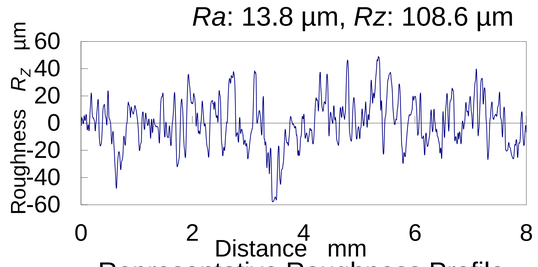


Photograph of MAF Processing

As-received SLM-processed Workpiece



316L stainless steel disk (∅25 × 6.7 mm)

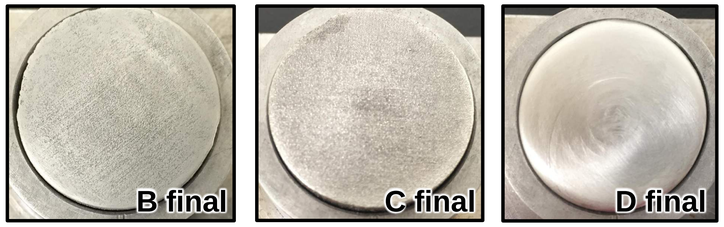


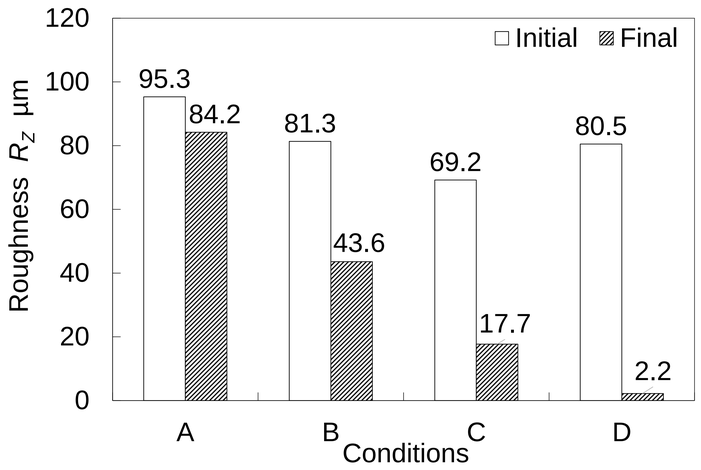
Representative Roughness Profile

Experimental Conditions

Conditions	A	B	C	D	
Processing time	1 hr	0.5 hr	1 hr	2 hr	2 hr
Magnetic particle	-50/+100 mesh iron particles	G14 steel grit			G25 steel grit
Diamond abrasive	N/A	120 µm			
Magnetic abrasive	80 µm mean dia. (Alumina abrasive: <10 µm dia.)				
Magnet motion	Revolution: 600 min^{-1}, Feed: 1 mm/s				

Experimental Results

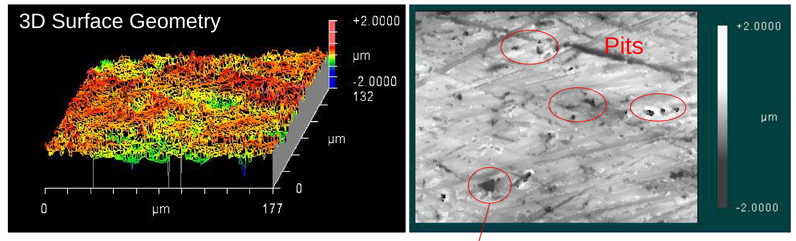


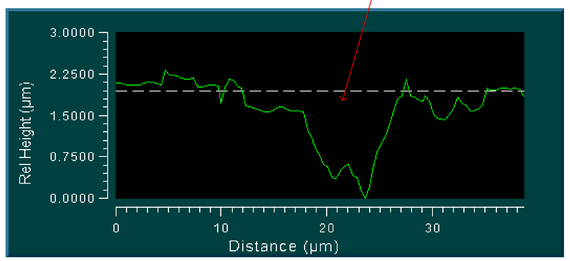


Surface Roughness *Rz* Before and After Processing

Conclusions

Magnetic Abrasive Finishing enables the surface smoothing of additively-manufactured 316L stainless steel components. The roughness levels can be decreased from around 100 µm R_Z to about 2 µm R_Z. Due to the nature of additive manufacturing, the creation of pits on the component's surface is unavoidable. MAF revealed these defects and emphasizes the pits during processing (see below).





Profile Curves of Surface after Polishing

Future Work

Future research will include clarification of the process mechanism and the removal of the pits that currently remain on the surface. In addition, the residual stress imparted to the surface by the SLM and MAF processes will be evaluated so that component functionality can be better controlled. It has been demonstrated that MAF can impart compressive residual stress; however, the effect on additively manufactured parts is still unknown. The ability of MAF to impart compressive residual stress to AM parts will be another focus of future work.

References

[1] Yamaguchi H., et. al., Magnetic abrasive finishing of cutting tools for machining of titanium alloys. *CIRP Annals – Manufacturing Technology*, 61(1), 311 – 314, 2012.
[2] Yamaguchi H., et. al., Surface finishing of cobalt chromium alloy femoral knee components. *CIRP Annals – Manufacturing Technology*, 63(1), 309 – 312, 2014.

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