Surface Finish Comparison between Metal Injection Molded (MIM) and 3D Printed (Printalloy®) 17-4PH components

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Advanced Powder Products, Inc (APP) produces metal components made by metal injection molding (MIM) and 3D printing of MIM powders (Printalloy®). In this whitepaper, APP has evaluated and compared surface finish and its impact on the mechanical properties of 17-4PHSS tensile bars made by both MIM and 3D printing of MIM powders (Printalloy®). MIM is a process that has been characterized extensively and the mechanical properties are documented in MPIF Standard 35.

Experimental procedure

MPIF Standard 50 tensile bars were fabricated using both MIM and 3D printed MIM 17-4PH SS powders (Fig 1). MPIF Standard 35 17-4PH SS properties are shown in Table 1. A total of six MIM tensile bars and nine 3D printing Printalloy® tensile bars were tested. All shaped bars were sintered, heat treated (H900) and sent for surface treatment. Four different chemically aided vibratory surface treatments (REM) were performed on the 3D samples and two different treatments were performed on the MIM tensile bars. The differences in each surface treatment were in vibratory time, media type and chemistry. For proprietary reasons, details of the surface treatment are not disclosed. Each group numbered 1-5 represents a different treatment, where Group 1 is referred to “as-is”. MIM bars were separated in 3 groups and 2 out of these 3 groups were surface treated. MIM products typically achieve smooth surface, thus the need for the more aggressive surface treatment was not performed. The Printalloy® bars were submitted to a total of 4 different surface treatments since they came out of the process with a rougher surface due to the stereolithography printed lines. After the bars were surface treated, surface roughness was measured using a profilometer and they were subsequently tensile tested. Surface roughness was measure 10 time per samples.

Table 1: MPIF Standard 35 typical values of mechanical properties of MIM 17-4PH

Alloy	Density (g/cc)	Hardness (HRC)	0.2% YS (ksi)	UTS (ksi)	Elongation (%)
MIM 17-4 PH (as sintered)	7.5	27	106	130	6
MIM 17-4 PH (H900)	7.5	33	158	172	6

Figure 1. 17-4PH Tensile bars made by MIM (left) and Printalloy® (right)

Results

Surface roughness

Table 2 reports the average and the range of the surface roughness measured on each sample. Group 1 "as-is" of the Printalloy® bars has the highest roughness due to the stereolithographic printing layers. Once the Printalloy® parts underwent surface treatment, their roughness were significantly decreased by a factor of 9. The roughness variability of the Printalloy® parts is also decreased from the "as-is" group to the group of treatments 4 and 5. The "as-is" MIM parts roughness are not as rough as the 3D components, but were also reduced by a factor of 3 after surface treatment. Variability of roughness is not high for the MIM parts. Figure 2 reports a boxplot of the roughness of the Printalloy® and MIM parts as function of the surface treatment groups.

During surface roughness measurement, it was observed that the Printalloy® parts have a rougher surface on one side compared to the other due to the nature of the printing process. Figure 3 shows the difference in roughness from the smoother side, side 1 to the rougher side 2. This graph shows that group 1 'as-is' has a significant difference in roughness from one side to the other. Treatments 2 and 3 did not equilibrate the roughness between the two sides. However treatments 4 and 5 did bring the surface roughness to the same range on each side. Figure 4 and 5 show pictures of Printalloy® and MIM after surface treatment.

Table 2: Surface roughness

Process	Group	Roughness range (µinches)	Average roughness (µinches)
3D Printed	1 “as-is”	70-207	127
	2	15-211	88
	3	17-91	45
	4	19-34	25
	5	9-23	14
MIM	1 “as-is”	38-51	41
	2	18-51	33
	3	6-26	13

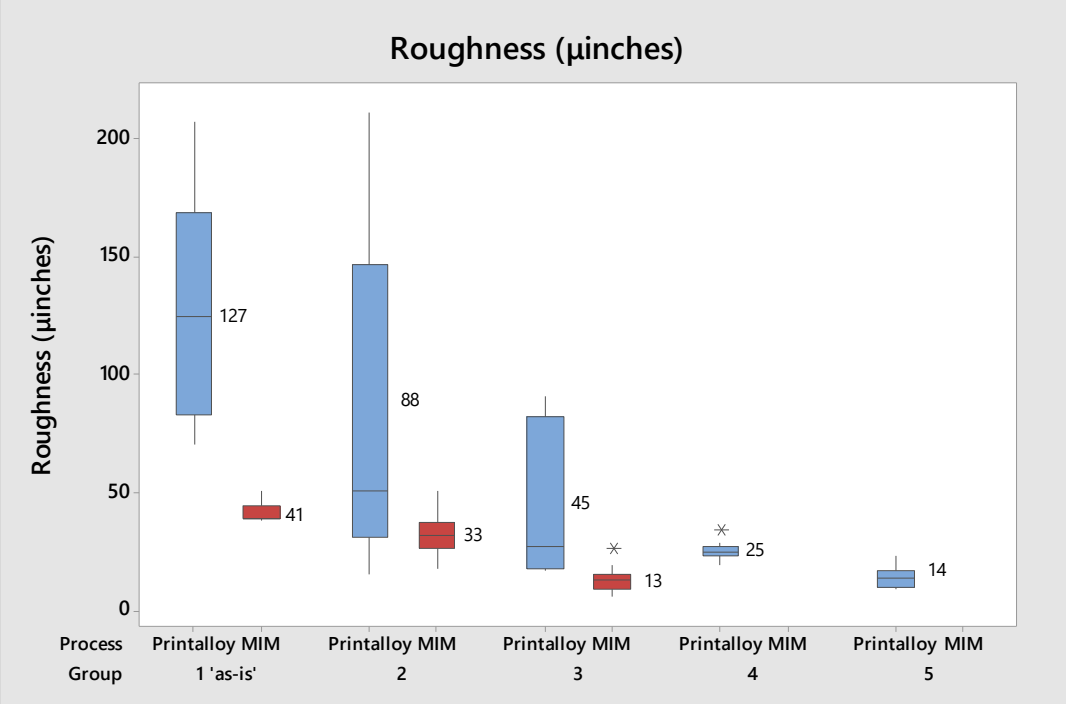

Figure 2. Roughness comparison between processes and surface treatments

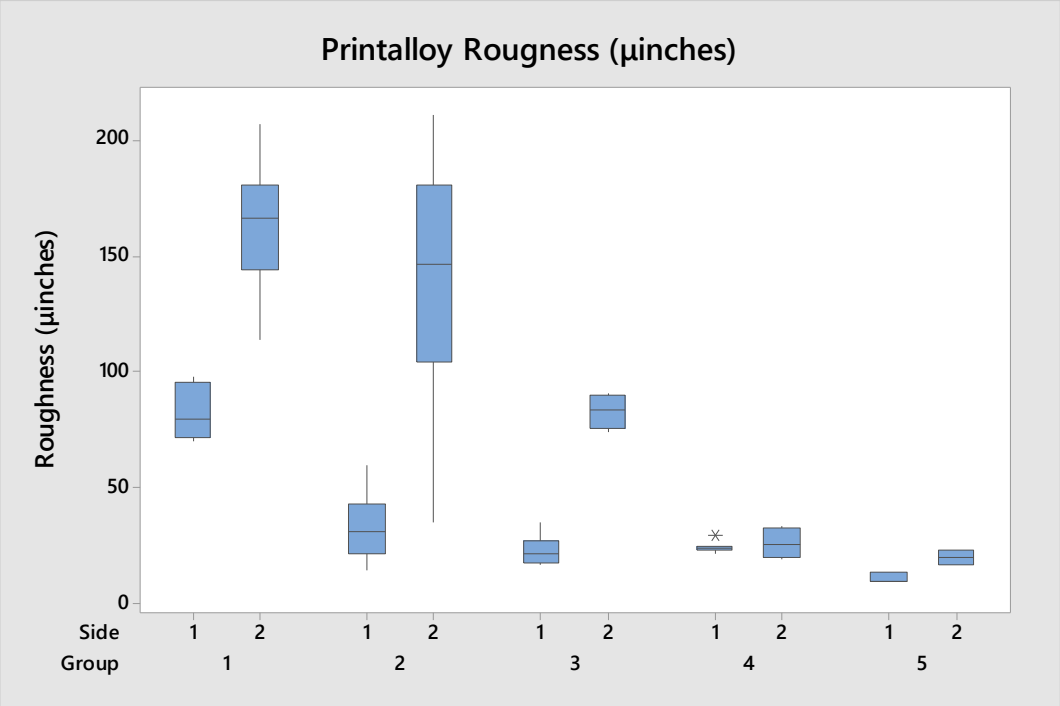

Figure 3. Comparison of the roughness on each side of the of Printalloy® parts for 5 surface treatments condition.

Figure 4. MIM tensile bars as a function of their surface treatment groups

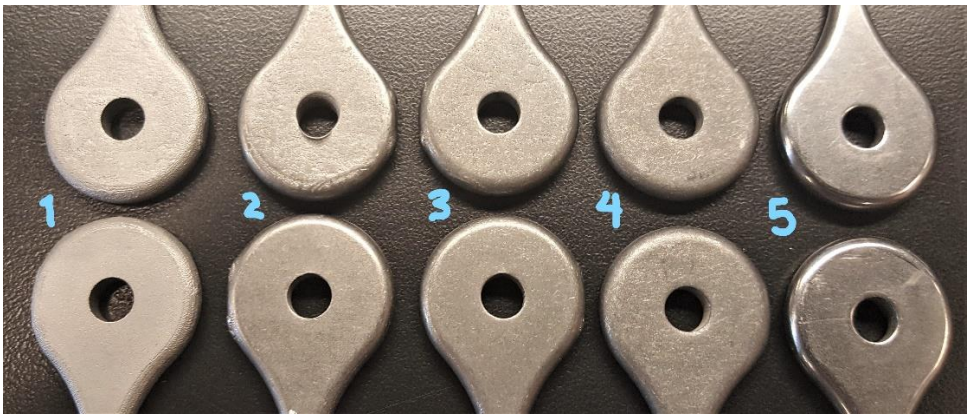

Figure 5. 3D tensile bars as a function of their surface treatment groups, bottom row: side 1, top row: side 2.

Tensile Properties

Figures 6 compares the tensile properties measured on the samples from different conditions. All of the material properties measured are in spec with MPIF Standard 35. Surface roughness is the highest for group 1 for both MIM and Printalloy® specimens. For the Printalloy® parts, it seems that each of the surface treatments increases slightly the UTS and the YS. This effect is not observed for the MIM parts. Group 5 is the smoothest of the Printalloy® bars and it also gives the highest Ultimate Tensile Strength (UTS) and 0.2% offset Yield Strength (YS). Magnification of the chart for UTS and YS is shown in Figure 7 and for Elongation in Figure 8. There was not enough samples tested to draw a scientific trend to the relation between surface roughness and mechanical properties, but results suggest that surface treatments increase the UTS and YS of Printalloy® parts.

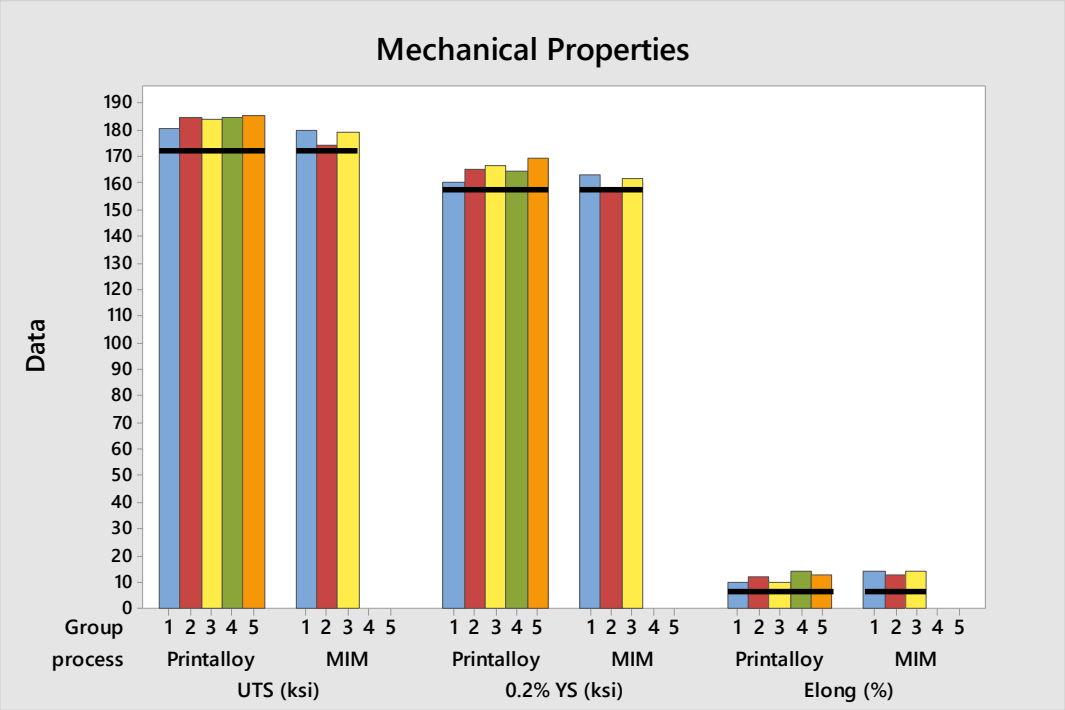

Figure 6. Comparison of mechanical properties of MIM and Printalloy® as a function of surface roughness (Group 1-5). Black line indicates MPIF Standard 35 typical values.

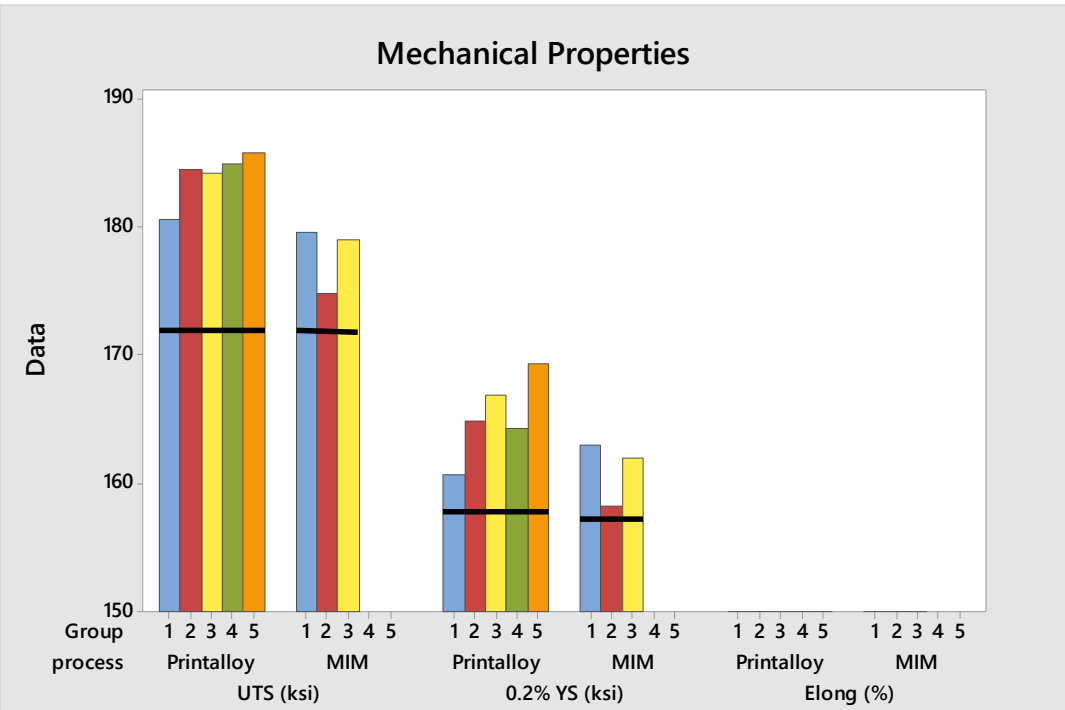

Figure 7. Comparison of UTS and YS properties of MIM and Printalloy® as a function of surface roughness (Group 1-5). Black line indicates MPIF Standard 35 typical values.

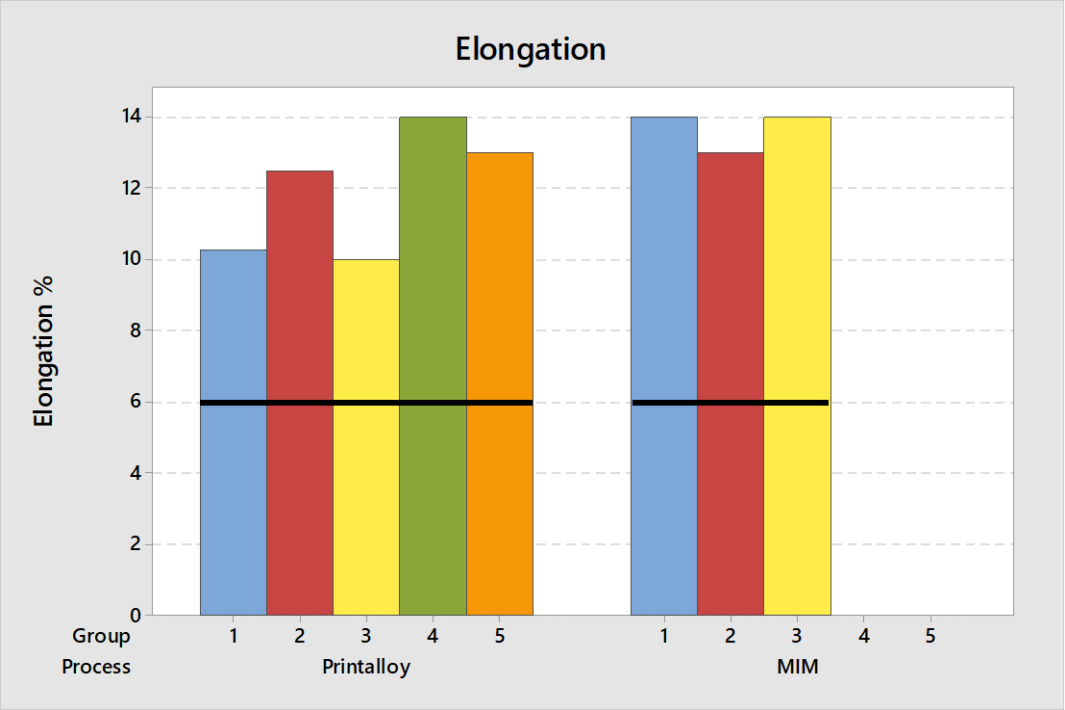

Figure 8. Comparison of elongation of MIM and Printalloy® as a function of surface roughness (Group 1-5). Black line indicates MPIF Standard 35 typical values.

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