Influence of SLM Processing Parameters on Mechanical Properties of Tungsten-Heavy Alloys

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Introduction

3D-printing parameters were investigated to improve part quality for a tungsten-heavy alloy (93W-5.6Ni-1.4Fe). Tungsten is a **refractory material**, with a high melting point of 3,422°C. Its high hardness also contributes to difficulties in manufacturing through traditional processes, such as press and sinter. However, additive manufacturing (AM) techniques like **selective laser melting (SLM)** may serve as a solution.

Selective Laser Melting (SLM) Technique

SLM is a powder-based process. A layer of powder is spread on a platform, and the powder is melted together with a high power-density laser. Each layer is rolled onto the previous, and melted in place. A schematic of the process is shown in *Fig. 1*.

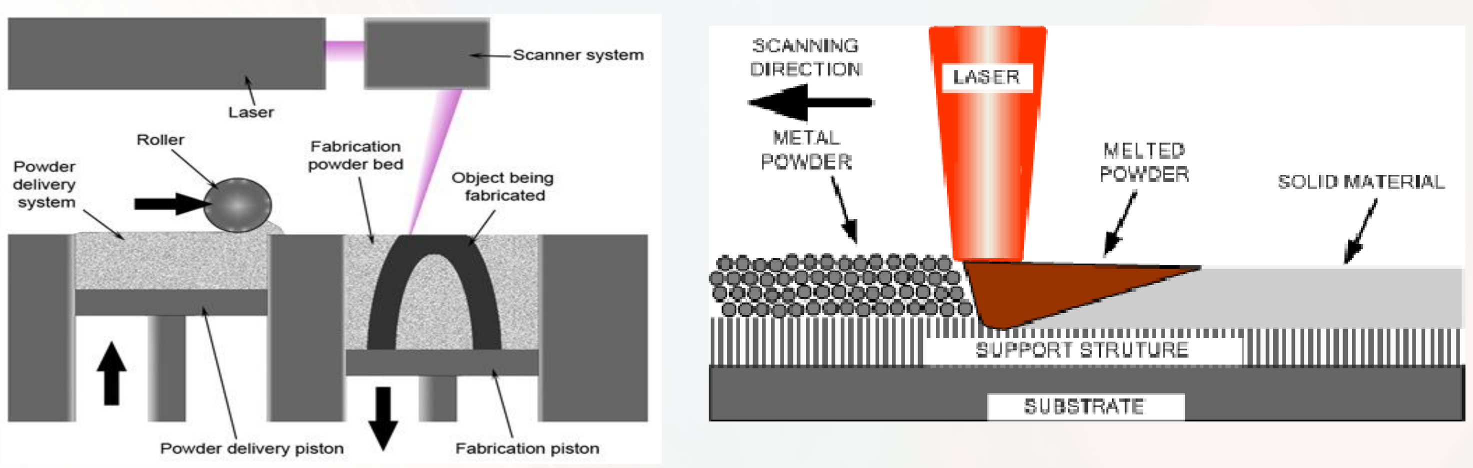

Figure 1. *(left)* Powder delivered with piston and flattened with roller *(right)* Laser scan passes through the powder layer, melting it in place to form solid material

Lehigh performs SLM with a Renishaw AM 400 printer. It is possible to vary over 130 processing parameters to influence part quality [1]. This research focused on the following:

- Powder morphology (**mixed** and **pre-alloyed**)
- Layer thickness (**20 μm** and **30 μm**)
- Exposure time (**400**, **500**, **600**, **700**, **800 μs**)
- Point distance (**130**, **110**, **90**, **70 μm**)

Powder Morphology

Mixed Powder (**Powder 1**)
- Easily Compressed
- Alloyed after processing
- Rough surfaces worsen flowability
- Low cost

Pre-Alloyed Powder (**Powder 2**)
- Less compressible
- Homogeneous composition
- Smooth surfaces improve powder flow
- Greater cost for higher strength

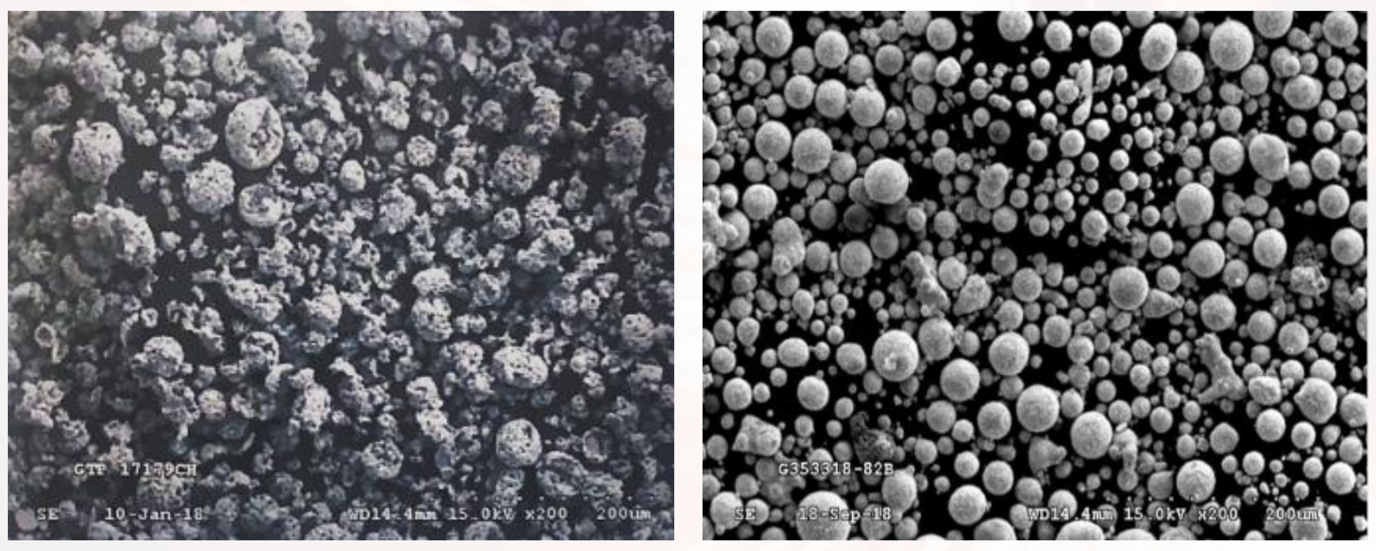

Figure 2. SEM images provided by Global Tungsten & Powders Corp. *(left)* mixed powder distribution *(right)* pre-alloyed powder distribution [2]

Tungsten-Heavy Alloy (WHA) Investigation

80 WHA samples were printed in an array as 5x5x5 mm^3 cubes, on four separate steel build-trays, as shown in *Fig. 3*.

Figure 3. WHA Powder 2 cubes, printed on steel build tray with 30 μm layer thickness.

Exposure time varied horizontally
- increase left to right

Point distance varied vertically
- decrease top to bottom

References

1. C. Kamath, B. El-dasher, G. F. Gallegos, W. E., King, A. Sisto, Density of Additively-Manufactured, 316L SS Parts Using Laser Powder-Bed Fusion at Powers Up to 400W, December 23, 2013
2. Global Tungsten & Powders Corp. 2018.

SLM Parameter Impact on WHA Density

Optical density measurements were collected through ImageJ software. *Fig 4* shows average densities of Powder 1 and 2, with 20 and 30 μm layers. *Fig. 5* shows four images, representative of each print condition.

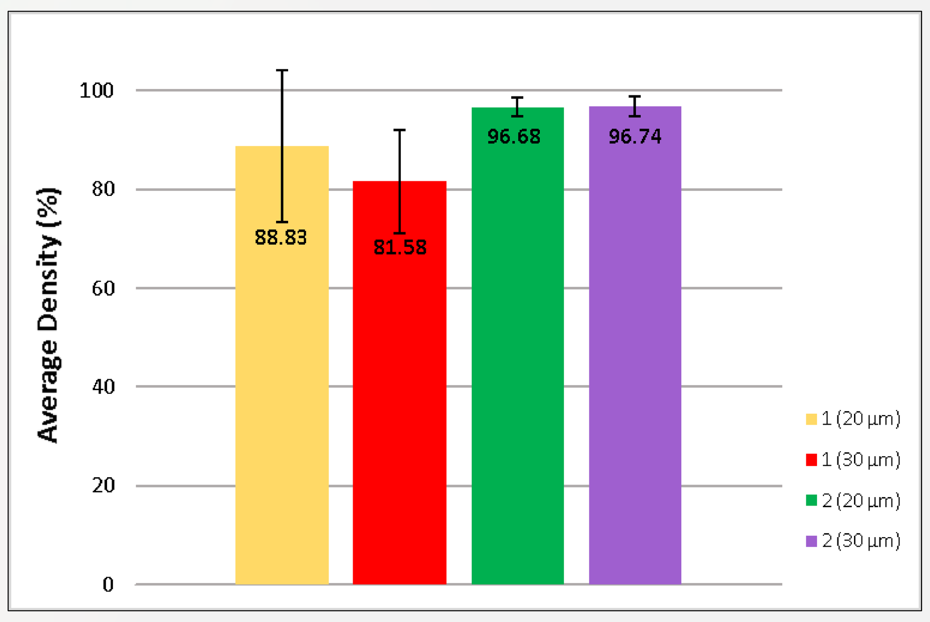

Figure 4. Average densities of mixed and pre-alloyed powders, printed at 20 and 30 μm layer thickness.

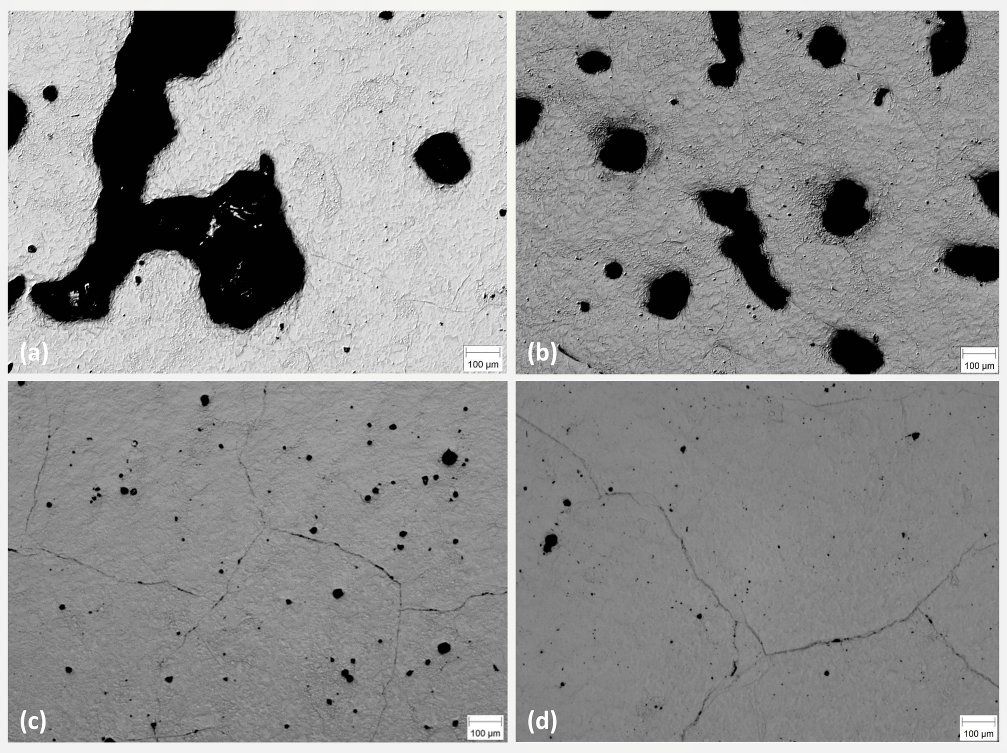

Figure 5. LOM images of (a) Powder 1, 20 μm (b) Powder 1, 30 μm (c) Powder 2, 20 μm (d) Powder 2, 30 μm

Due to **rough surfaces** of mixed powders, which contribute to **poor flow rates**, it was expected that Powder 1 would melt unevenly. This contributed to high density variance in Powder 1, as compared to Powder 2, which is pre-alloyed powder with **smooth surfaces**. **Better flow** contributed to higher densities for Powder 2.

Powder 1 with 20 μm layers printed average density of 88.83%, much higher than the 81.58% observed in 30 μm. Since 20 μm layers have less powder for the laser to melt, they are expected to achieve higher density.

Longer exposure time allotted time for powders to melt and fuse before the laser passed, leading to higher density. Similarly, shorter point distance focused the laser closer to the powder for improved melt fusion and sample density.

SEM Investigation

The purpose of scanning electron microscopy (SEM) was to investigate dispersion of composition in the WHA microstructure. One concern was the loss of Ni and Fe during the melt process. A mixed powder sample is shown in *Fig. 6*, along with trace peaks that verified presence of Ni and Fe.

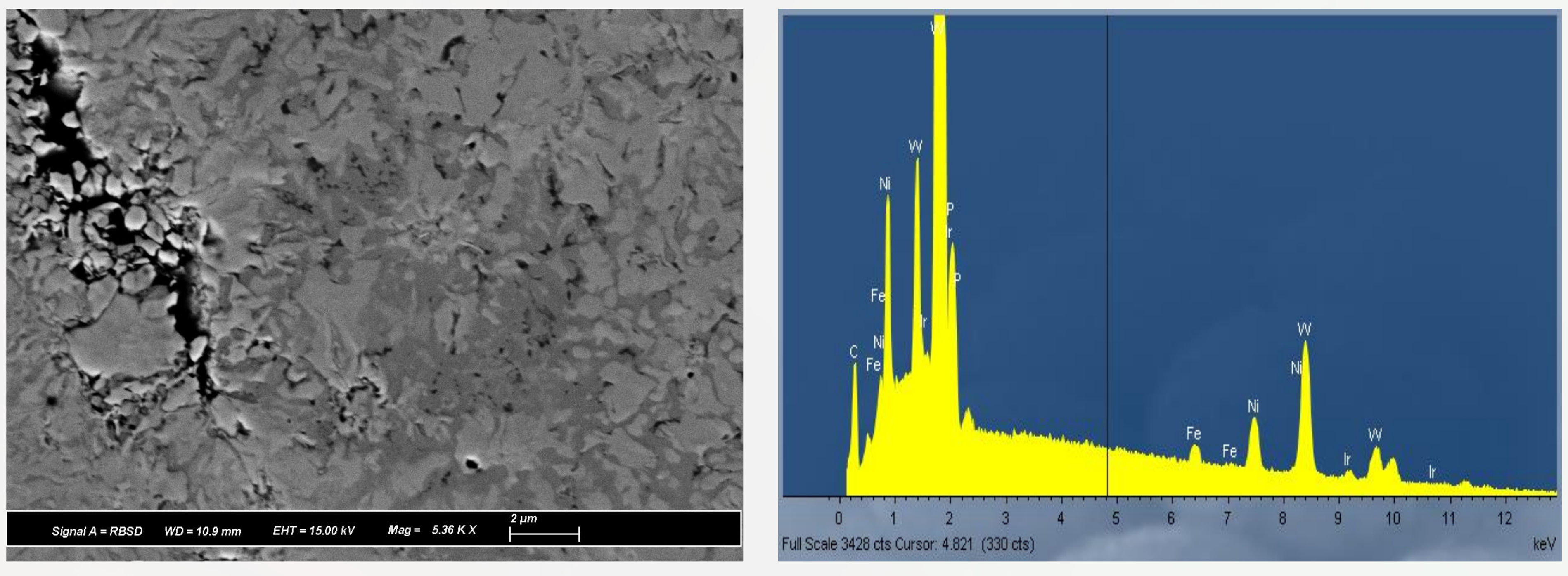

Figure 6. *(left)* Image of mixed powder printed with 600 μs exposure time and 130 μm point distance *(right)* Trace peaks

Conclusions

- Best print quality was achieved through pre-alloyed powder, 20 μm layer, long exposure times, and short point distances
- Peak traces verified Ni and Fe are not lost during the melt process

AM Industry Impact

Additive Manufacturing technologies present new opportunities for application of heavy alloys and refractory materials.

Future Considerations

- EDS mapping and Back Scatter imaging for phase identification
- Mechanical testing through microhardness along surface to confirm distribution of W, Ni, and Fe in the microstructure

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