CARPENTER ADDITIVE®

CASE STUDY

Testing Powder for Optimal Processing Window

Why is the Metal Powder Processing Window Important?

The Additive Manufacturing (AM) process relies on key parameters to be developed for the laser interaction with the powder bed. How sensitive a material is to process conditions is defined by how broad or narrow its processing window is.

The flexibility of the powder processing window for AM is of interest as this can make the build less sensitive to process variables including:

- Laser characteristics changing between service interval
- Optical degradation and the impact on beam focus
- Operational variation- process control

The above characteristics can all influence the energy density of all laser beam at the powder bed as it is governed by: laser power, spot size and scan rate.

Effect of Build Parameters on Material and Part Performance

Different powders have different properties, and even those designated 'the same' in terms of size and chemistry can behave very differently under subtly varying process parameters. This study demonstrates that processing conditions, including laser hatch spacing, power, scan speed and spot size, and even the cleanliness of the AM machine's mirror and lens, will all affect the response of the powder and therefore the quality of the end product. Using metal powder optimized for the specific AM machine and application will deliver optimal results. By using a well characterized powder with a wide processing window, the material is able to tolerate a range of build variables, resulting in increased success in AM builds.

The Study

To investigate the response of similar stainless-steel powders, four batches of stainless steel 316L were tested. SS 316L is an austenitic stainless steel, which is not age or precipitation hardenable. It possesses high corrosion resistance and toughness as well as good all-round mechanical properties to 300°C. It is also noted as being highly machinable.

The materials were produced using different atomization processes (melting conditions and atomization gases) and with variation of particle size distribution within a range of D10=15 µm to D90=45 µm. Using a Design of Experiment (DoE) process a series of builds was completed with each powder, systematically varying the energy density delivered by the laser and measuring the resulting microstructural density of the part. A range of laser parameters – laser power, spot size, scan speed, and hatch distance – was set for a defined cross-sectional area to be melted. All the combinations of the minimum and maximum of these parameters were processed in a randomized order through Laser Powder Bed Fusion.

Once processed the density of each sample was measured after sectioning and polishing samples, using an optical microscope with image analysis software to measure any porosity as a percentage of cross-sectional area. A target density greater than 99.5% is desirable as this represents the point at which good properties can be predicted. Figures 1 to 5 show the variation of optical density vs energy density for the 316L powders analyzed.

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FIGURE 1 - BATCH A

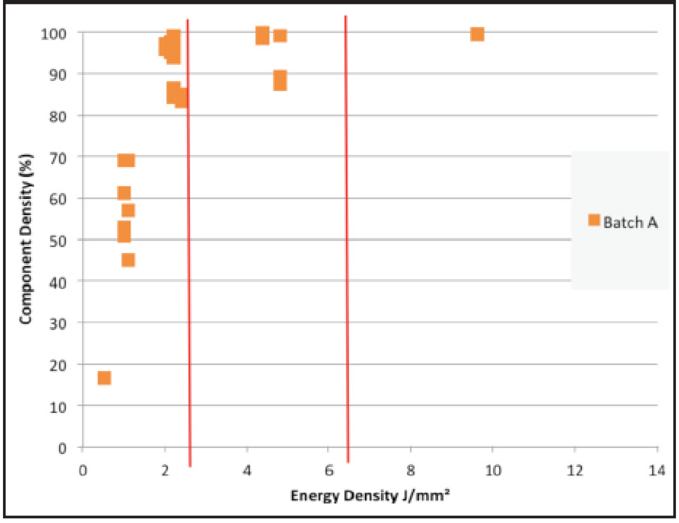

Figure 1. Batch A demonstrates that, as expected, as energy density increases so too does component density. However, it can also be seen that at 2.5 – 6.5 J/mm2 (indicated by the red lines) both acceptable and unacceptable parts are produced as parameters vary.

FIGURE 2 - BATCH B

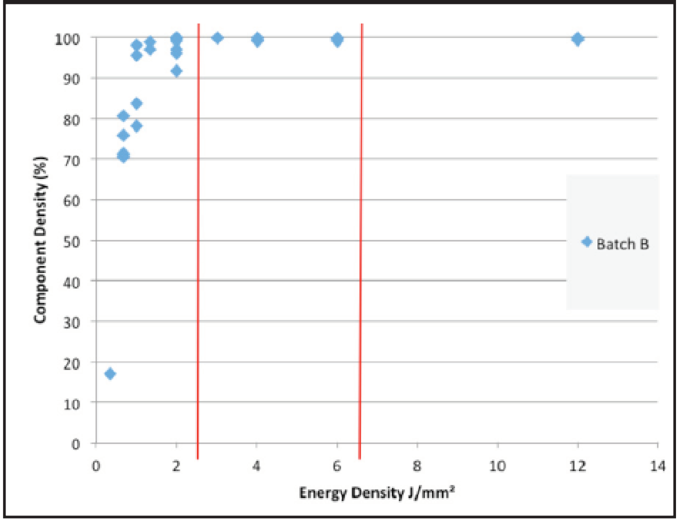

Figure 2. Batch B displays good component density achieved at a wider range of process parameters. This demonstrates that even with some changes to process variables acceptable component density can still be achieved.

FIGURE 3 - BATCH C

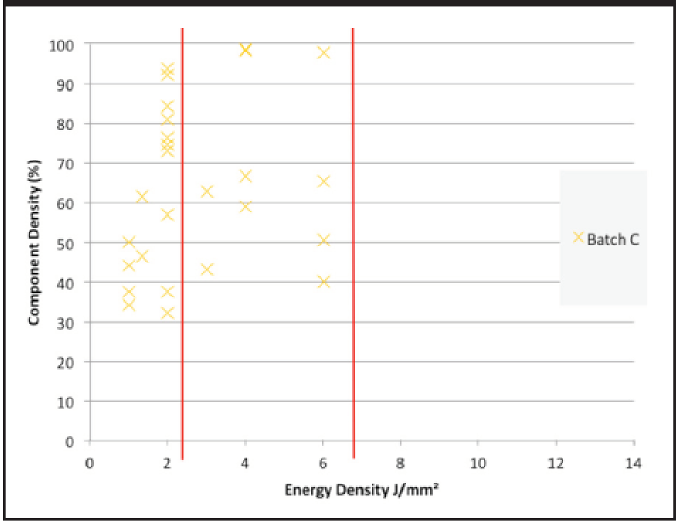

Figure 3. Batch C displays significant component density variation. In some circumstances good densities have been achieved, however, it demonstrates clear sensitivity to changes in process parameters, producing unreliable results.

FIGURE 4 - BATCH D

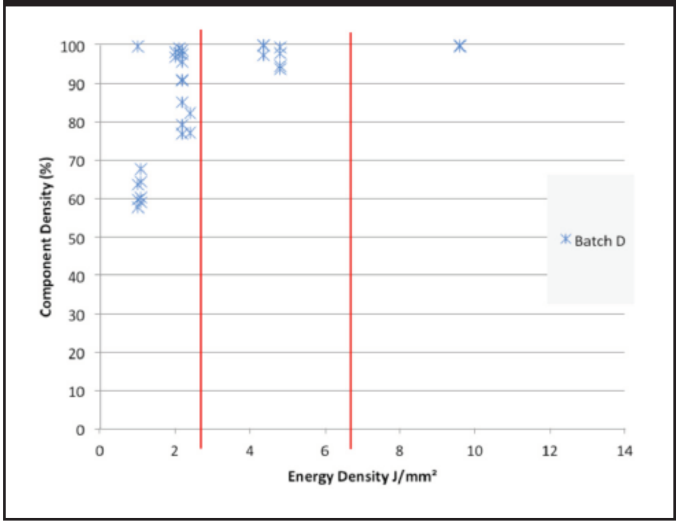

Figure 4. Batch D displays similar results to Batch A- some acceptable densities, but slight changes in process parameters result in poor component density.

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Results

Figure 5 combines all results and demonstrates that Batch C did not deliver the required density of >99.5% across the energy range measured.

While Batches A, B and D reached the optical density of >99.5% for certain parameter sets, Batches A and D displayed variable results for the same lower energy densities. Batch B performed significantly better under these conditions and delivered the widest process parameter window, showing a density >99.5% with minimal variation at a wider range of energy densities.

Conclusions

The parameters varied in the study represent the key process variables and can also correspond to the degradation of laser diodes and optical components. Using metal powder optimized for the specific AM machine and application will deliver optimal results. By using a well characterized powder with a wide processing window, the material is able to tolerate a range of build variables, resulting in increased success in AM builds.

The variation in response to build parameters of the starting material indicates the importance of selecting a metal powder which has been carefully characterized for additive manufacturing.

Carpenter Additive undertakes a program of continuous research and development to identify and characterize the optimal metal powder compositions for different Additive Manufacturing processes.

FIGURE 5 - ALL RESULTS