Metal Powder Recycling and Reconditioning in Additive Manufacturing

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With the advent of metal powder-based additive manufacturing (AM) and its acceptance for critical applications, it has become important to understand the behavior of raw materials used in different AM techniques. Powder-based AM comprises processes such as powder bed fusion (laser and electron beam), direct energy deposition, and binder jetting. Each of these have their own requirements for material properties in terms of chemistry, size distribution, porosity, flow-ability, morphology, and apparent density which will affect the properties of the final part. Specialty powders designed for applications in the aerospace, defense, and biomedical sectors are highly expensive. It is possible to recycle AM powders, which can make the process more affordable. However, the limits of reusing powders must be understood so that quality specifications can be maintained.

Powder Degradation

Different degradation issues are observed with different types of powders. It has been found that high-temperature powder alloys such as Inconel 718 and others are chemically stable over many powder recycles, but their reusability is limited by their physical characteristics such as morphology and flow-ability. As these materials are melted at higher temperatures, the material surrounding the melt becomes distorted and sintered together which can make powder particles larger and unusable. On the other hand, titanium powders are more susceptible to oxygen pick-up, and therefore can only be used a couple of times before the powder falls out of specification due to the high oxygen content. Currently, there are no standards to determine the factors that could guide powder recyclability practices.

In a study performed with Inconel 718, the same lot of powder was used and analyzed through multiple laser powder bed fusion builds (Figure 1) to understand the effects on powder and part properties. Through the course of these builds, the powder particles started to fuse together and form conglomerates, the flow and packing density was affected (Figure 2), the size distribution widened, and the oxygen content of the powder increased (Figure 3).

Powder Reconditioning

To increase reusability of metal powders, it is important to identify qualified techniques to recondition out-of-spec powders to bring them back into the AM eco-system. One popular method is to blend virgin powder with the used powder before each build. This reduces oxygen content of powders (such as titanium) that are more susceptible to oxygen pickup.

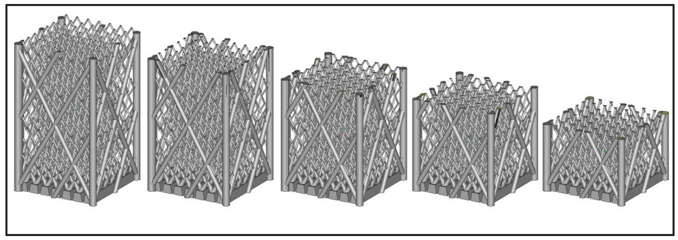

Figure 1: Recyclability builds

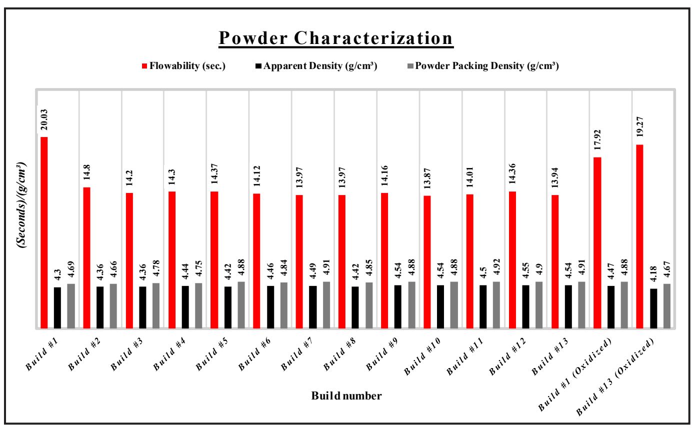

Figure 2: Flow and packing density of powder

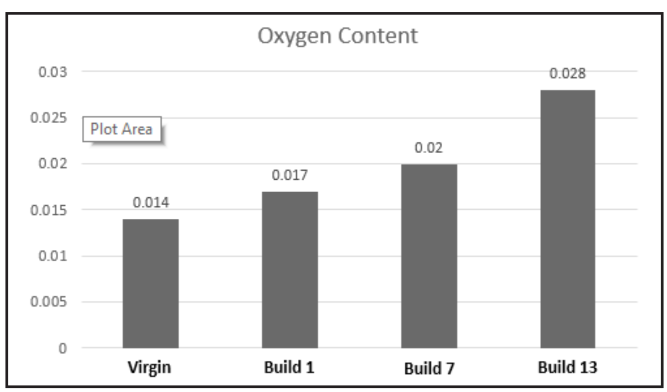

Figure 3:Oxygen pick-up throughout the builds

Another plausible technique is the induction plasma process. This process consists of in-flight heating and melting of feedstock by induction plasma, followed by solidification under controlled conditions. This method can improve powder characteristics such as flow by making spherical particles (Figure 4), decreasing porosity by re-melting and re-solidifying the powder particles, increasing powder density, and improving powder purity through the selective/reactive vaporization of impurities by increasing the plasma melting temperature and modifying the shielded gas.

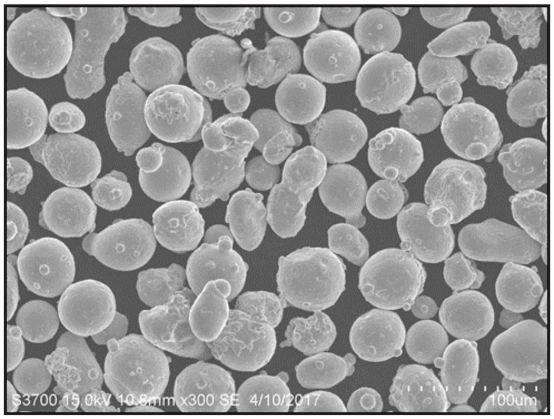

Figure 4(a): Used powder

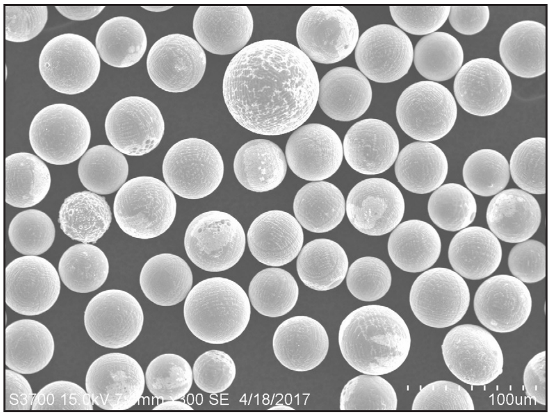

Figure 4(b): Powder after induction plasma process

Conclusion

Though a few powder reconditioning techniques are in practice today, they are not completely qualified yet. For example, while powder blending reduces the overall oxygen content, the powder batch can still contain particles with high oxygen content. These final particles have the potential to cause catastrophic failure in components, as observed in Ti-6Al-4V powders in which higher oxygen content leads to lower ultimate tensile strength.

Currently, companies tend to use virgin powders for AM builds to maintain consistency in manufactured part properties and minimize risk. This practice has produced thousands of pounds of "out-of-spec" powder, either stored or wasted. As AM production increases, more powder will be used and keeping track of it is going to become a growing concern. All of these factors contribute to higher costs and a larger energy footprint of AM processes. To keep AM materials affordable as the technology expands, there is a need to develop qualified methods to not only recondition the powders but also re-qualify and bring them back into production.

To learn more about EWI's ongoing work in powder recycling and reconditioning for additive manufacturing, contact Frank Medina at fmedina@ewi.org.

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