

Microstructural Characterization of Additively Manufactured Inconel 625

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Additive Manufacturing (AM) is a method of fabricating parts by laying down successive layers of material using automated control. These layers range from several microns thick to a few thousandths, depending on the resolution on the printing process. AM was originally developed in commercial form by Kodama in 1981, by using a liquid photo-hardening polymer to create plastics. His method deposited layers of photopolymers, which were then quickly cured by ultraviolet lasers [1]. This method has also been applied to metals, where successive layers of material are sintered or melted into a desired shape, depending on the kind of process used.

Since that time AM has gotten significantly less expensive, more accurate, and more available allowing more complex parts to be manufactured with much more accurate geometries. AM produces little waste and allows for complex shapes to be formed that would not be possible with traditional machining in a single step; however, AM also has many current issues including inconsistent builds even when using the same process, inconsistent resolution, and significant anisotropy in material properties. Because of these reasons certification of AM parts is not a widely accepted occurrence and most AM parts serve in non-critical applications [2,3].

While AM is often associated with 3-D printers which use light sensitive plastics or extrude polymers in a wire fed process, a variety of high temperature sintering processes exist which are more appropriate for critical applications or applications involving metals. Examples of these processes include Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), and Selective Laser Melting (SLM). While different, all of these methods involve laser heating of a material (usually in powder form) to create net metallic shapes.

In this research AM Inconel 625 was analyzed by Energy Dispersive Spectroscopy (EDS) and Electron Backscatter Diffraction (EBSD), and results were compared to as received plate material. EDS results showed that distribution of elements were homogenous and the chemical composition of Inconel 625 was able to be replicated by AM. The AM component was able to be manufactured with no observable voids and a fully dense structure.

However, EBSD results showed that the AM Inconel 625 produced a highly anisotropic microstructure in particular in the build direction consisting of highly irregular and random grains compared to the nominally equiaxed and heavily twinned grain structure of the plate material. The irregular grain structure of the AM Inconel 625 is assessed to be highly undesirable due to the expected anisotropy of the resultant material properties. To compensate for this, attempts were made to recrystallize the AM Inconel 625 grain structure using typical annealing treatments of Inconel.

References:

- [1] H., Kidamo, Automatic method for fabricating a three-dimensional plastic model with photo-hardening polymer, *Review of Scientific Instruments* 52 (1981), p. 1770-1773.
- [2] S. Dadbakhsh, L. Hao, and N. Sewell, Effect of selective laser melting layout on the quality of stainless steel parts, , *Rapid Prototyping Journal* (2012), p. 241-249.
- [3] S. Ahn, M.Montero *et a.*, Anisotropic material properties of fused deposition modeling ABS, ,*Rapid Prototyping Journal* (2002), p. 248-257.

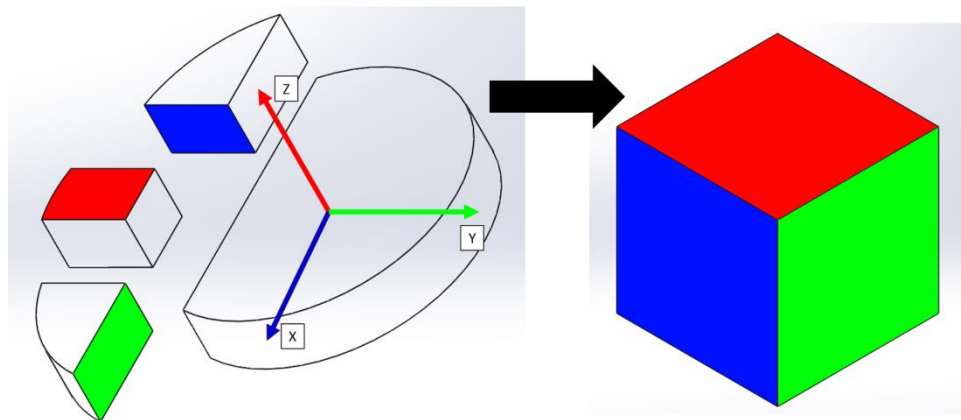


Figure 1. 3-D representation of additively manufactured Inconel 625 disk (actual size 1 ½” diameter and ¼” thick) and analysis planes. The z-direction corresponds to the build direction.

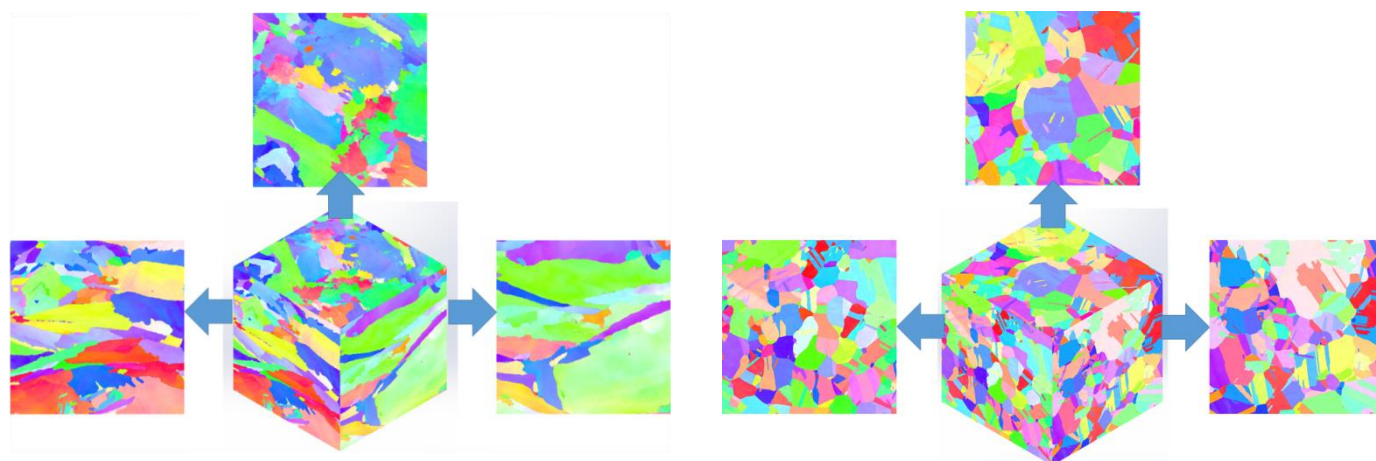


Figure 2. 200 micron square electron backscatter diffraction inverse pole figure maps of additively manufactured Inconel 625 (left) and as received Inconel 625 plate material. The additively manufactured specimen exhibits anisotropic and highly irregular grain microstructure compared to the highly organized equiaxed and heavily twinned microstructure of the as received plate material.