Scaling Up Metals Additive Manufacturing

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Introduction

Much of the recent work in metals additive manufacturing (AM) has taken place using the laser powder bed fusion (L-PBF) process. This bottom-up, layer-by-layer build method has allowed for greatly increased design freedom and the production of parts which are not possible using conventional subtractive manufacturing methods. The addition of structural meshes and internal cavities is straightforward and can drastically reduce part weight. As industry leaders and early adopters have begun to employ L-PBF, the need for larger build envelopes has become apparent. OEMs have started to address this issue by increasing powder bed size and adding secondary lasers to decrease exposure time. While the latter effectively decreases the time required for laser manipulation of each layer, the larger bed size requires additional time for recoating, laser scanning, part removal, and cleaning. Laser directed energy deposition (L-DED) provides an alternative solution which can offer greater overall time savings for large parts.

Laser Directed Energy Deposition

L-DED is an additive manufacturing process that combines a laser and a material feed system to build freeform parts. As the laser is manipulated along a programmed tool path, metal powder or wire is fed into the melt pool to create a deposit. As with L-PBF, the process continues layer by layer until the part is completed. A demonstration part being built using this process is shown in Figure 1. Unlike L-PBF, the full build volume does not need to be filled with powder. The deposition head is typically manipulated using a gantry system or robot arm which allows for build volumes on the scale of feet rather than inches.

Figure 1: Demonstration part being built using the RPMI 557 L-DED system

EWI's RPMI 557 L-DED System

EWI recognized the need for large-scale metal AM and worked with RPM Innovations to purchase the RPMI 557: a L-DED system with a total build volume of 175 ft^3 (5 × 5 × 7 ft), or 4.95 m^3 (~1.52 × 1.52 × 2.13 m) (Figure 2). The system employs a dual-hopper metal powder feed system and a 3 kW IPG fiber laser to build components within the chamber. The dual-hopper system allows multiple materials to be functionally graded within a build without the need for interruptions. Argon is pumped into the chamber before the build begins and the oxygen level can be reduced to less than 5 ppm. Laser spot size and power are varied to produce deposits with widths

Figure 2: RPMI 557 installed at EWI's Buffalo facility

ranging from 1.5 mm to 4.3 mm and thicknesses of 0.25 mm to 0.75 mm. Parameter sets have been developed to deposit multiple steels alloys, titanium alloys, cobalt alloys, and nickel alloys. Generally speaking, if an alloy can be welded autogenously and can be purchased as a powder with a size range of 45 to 150 µm, it has a high chance of compatibility with the L-DED process. With most materials, build designs are limited to a 30-degree overhang to prevent melt pool degradation.

The surface roughness of the demo part shown in Figure 3 is typical for the mid-range deposition rate and is comparable to a cast surface. A computed tomography (CT) scan generated at EWI's Buffalo facility shows internal features which are difficult to produce using subtractive manufacturing methods (Figure 4). Volumetric flaw inspection and CAD to CT geometric comparisons can also be completed using the CT scan data. Having the CT technology under the same roof as the RPMI 557 and multiple other AM systems greatly increases EWI's capability to inspect complex AM components.

Figure 3: Small "jet engine" demonstration part

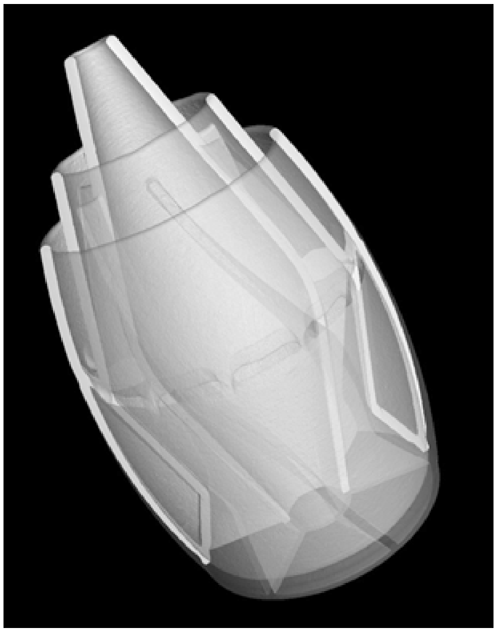

Figure 4: CT scan of the "jet engine" demonstration part

Current and Future Work

As of the beginning of 2017, EWI has the only RPMI 557 system available for commercial project work outside of the RPM Innovations company itself. EWI has aligned with RPM Innovations as a development partner to continue to advance the technology and open the system up to new materials. Work has already begun on several alloy development projects and innovative build designs which take advantage of the unique capabilities of the system. In addition to these efforts, EWI has plans to leverage its multidisciplinary expert resources to improve the surface finish of as-built parts, reduce build times through parameter and code modifications, and increase the multi-material functionality of the system.

***Bryant Foster** is an Applications Engineer in EWI's AM group. He is the primary investigator on laser powder bed fusion (L-PBF) AM projects, and recent laser directed energy deposition (L-DED) projects, predominantly working on the EOS M280, Standard Test Bed (STB), and RPMI 557 AM machines. Project work spans from the development of process parameters for new materials to the production of full-scale engineered parts and their respective heat treatments.*