Can Metal Additive Manufacturing Compete with Casting?

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There is no question that additive manufacturing (AM) or 3D printing is in the process of disrupting the manufacturing world. This is in part due to how easy it is to manufacturing complex geometries, the relatively short production times, the relatively limited process planning required, and the ability to make a few parts economically. Everything—from tooling and fixtures to full size automobiles—is being considered for production via AM today.

Although relatively young, metal additive manufacturing has been advancing quickly, moving from research labs to production facilities (some already making critical aerospace components) in about a decade. With mechanical properties approaching those of forged materials and complexities limited only by imagination, the trajectory of metal of AM adoption is likely to continue.

In contrast, casting is one of the oldest and most common manufacturing processes for metals. By some estimations, cast components can be found in up to 90% of all manufacturing goods [1]. There are obvious benefits to castings including the relatively low price, the number of available materials, the physical size capability, and the maturity of the process. So, is it conceivable that castings could be replaced by metal AM in the future?

Costs

The first question often raised when considering metal AM is cost. Because the raw materials for AM are often up to an order of magnitude more expensive than casting materials it seems obvious that AM will lose this battle. However, when considering the value of reduced lead times, AM can shine in comparison. The cost and tie-up of capital for long lead-time castings can impact the final cost of parts beyond the monetary expense. In addition to capital outlay, the cost of fixing final designs nearly a year in advance of receiving a part adds risks from competition and market forces. Shrinking these lead times can have a dramatic effect on 'actual' costs for additive manufacturing parts.

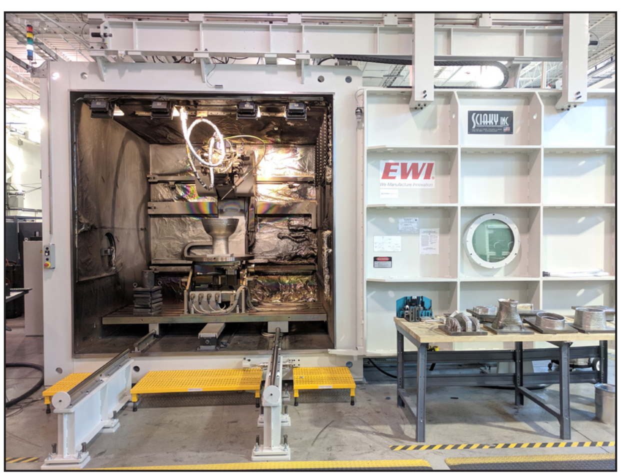
Size

The common laser and electron beam powder bed processes compare favorably to part sizes of small castings, with linear dimensions on the order of 250 mm (10 in) per side (Figure 1). Feature sizes available on some of these systems can be as fine as 100 μm (0.004 in) or better.

Figure 1: Small sample part built using the electron beam additive manufacturing process.

Larger parts, up to 1.5 to 2.1 m (5 to 7 ft) on a side or larger can be produced using directed energy deposition (DED) processes (Figure 2). Wire-fed processes can achieve deposition speeds of 4000 CC/hr (245 $in.^3$/hr) with minimum feature resolutions of approximately 3–6 mm (0.125–0.25 in.). This corresponds to roughly 18Kg/hr (40 lb/hr) in titanium. Blown powder DED processes commonly reach 165 CC/hr (10 in.3/hr) which corresponds to approximately 0.75 Kg/hr (1.6 lb/hr) with minimum feature sizes on the order of 1.0–1.25 mm (0.04–0.05 in).

Figure 2: Large sample part built using the electron beam additive manufacturing process.



The Sciaky EBAM 110, in place at EWI's Buffalo Manufacturing Works, produces AM parts through electron-beam directed energy deposition.

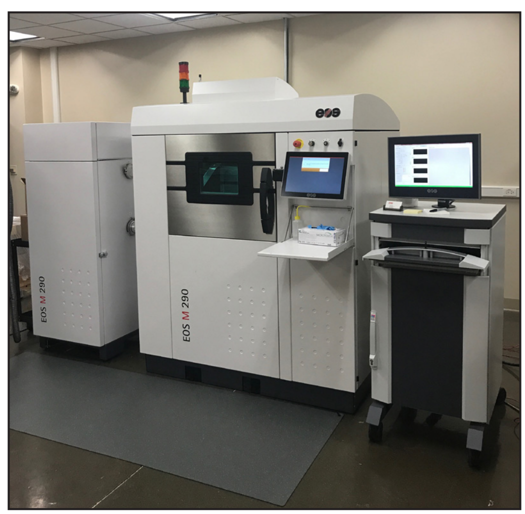
Materials

Metal AM has matured quickly around materials for the aerospace industry. Titanium and nickel super alloys are becoming common for nearly all metal AM service bureaus. But, other more common materials such as aluminums, steels (stainless and alloy), copper alloys and precious metals are gaining popularity in the metal AM field as well.

Mechanical Properties

Mechanical properties of castings have been the tradeoff to the reduced cost and relative design freedoms. With internal defects and solidification microstructure, material strength (yield and ultimate) is typically well below that of wrought properties. In metal AM, material properties often exceed the standards for wrought materials and in some cases approach or meet the standards for forgings [2].

Given the current state, a competitive assessment comparing a particular part design across casting and metal AM is likely to conclude casting is the lower-cost manufacturing process. However, with the improved mechanical properties and design freedoms afforded by AM, optimizing the part design for AM processes could result in near parity in costs. Taking the time value of money and competitive risks into account, the AM processes could end up being the preferred alternative.



The EOS M290 at EWI Ohio creates builds using the laser powder bed fusion process.

Somewhat counterintuitively, higher design complexity actually reduces costs in AM. This stems from the idea that as a part's complexity increases the mass or volume of material needed to achieve the part function actually decreases. Since a majority of a part's cost in AM comes from material usage and deposition time, reducing mass will lower the final part cost.

With reduced lead times, comparable size capability, better material properties and an ever-increasing number of materials available in metal AM, the time to evaluate porting castings to metal AM processes could be today.

At EWI we are constantly pushing the boundaries of metal AM. As an EOS material development partner and on our other six metal AM process platforms (Fabrisonic , RPMI 557, Sciaky EBAM 110, Arcam A2X, ExOne Innovent, and our open architecture DED wire and blown powder system) we've developed process parameters for nearly 40 different materials.

References

[1] http://www.afsinc.org accessed 8/29/17 http://www.afsinc.org/files/engineered_%20solutions%20_through_%20metalcasting.pdf

[2] RPM TIMET study on Ti64 properties

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