How will 3D Metal Printing Impact Investment Casting?

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Background

Metal Additive Manufacturing, or 3D metal printing, has received a lot of attention in the last couple years. GE spent more than a billion dollars to purchase Arcam and Concept Laser and formed a new division called GE Additive. They predict they will have manufactured more than 100,000 metal components for their own use by 2020 and will be generating more than a billion dollars in AM revenues by that same year. Furthermore, they predict they will sell 10,000 metal printers in the next decade.

Desktop Metal, a startup formed by MIT professors, has received $115 million in funding from such corporations as Caterpillar, BMW and Lowes.

IDTechEx, a marketing research firm has predicted that the metal AM market will reach $6.6 billion by 2026, about the same size as the US investment casting market. 3Diligent, a metal printing service provider, claims that metal 3D printing will shape the Aerospace industry.

With press like this, it is no wonder that investment foundries are concerned about the potential loss of business to metal printing. Is metal printing likely to make investment casting obsolete?

This study was undertaken to examine that question.

Methodology

There are a number of reasons that one manufacturing method is chosen over another to create a metal component. Manufacturers may choose the method that provides the components in the shortest period of time, the method that provides the best metallurgical properties, or the method that provides the best surface finish. Most often, however, manufacturers will choose the least expensive method that provides acceptable quality. The objective of the study was to find those situations where metal printing might be less expensive than investment casting.

Of course the least expensive method in one situation may not be the least expensive in another. The potential scenarios in investment casting are many. Scenarios vary with part size, part complexity and production volumes. To cover the majority of the investment casting landscape, 75 different scenarios were defined consisting of 3 different part sizes, 5 different part complexities and 5 production volumes.

Part sizes chosen were 4 inches, 8 inches and 16 inches. Clearly investment casting is used to manufacture components both larger and smaller than this range, but this will cover the majority of the market.

Geometric complexities ranged from very simple to so complex they cannot likely be cast. Geometry 1 is a simple dome illustrated in Figure 1. The pattern could be created in a simple two part mold with no side actions or inserts.

Figure 1. Geometry 1, a domed cap

Geometry 2, an open impeller, is a little more complex. It still can be created in a two part mold but the vanes create a more complex casting situation. Geometry 2 is shown in Figure 2.

Geometry 3, a closed impeller, is a step up in complexity and cannot be molded in a two part mold. Creating wax patterns will require either soluble or ceramic cores, resulting in multiple tools and increased cost. Geometry 3 is shown in Figure 3.

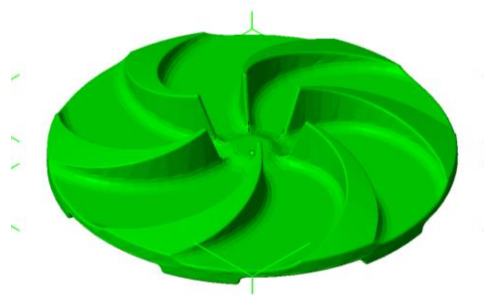

Figure 2. Geometry 2, an open impeller

Geometry 4, a drone frame, is another step up in complexity and is a geometry that cannot be molded. Investment casting would require printed patterns.

Geometry 5, another drone frame, is a lattice structure designed to minimize the weight of the casting. The tight spacing of the lattice makes it unlikely that the pattern could be shelled without bridging. Even if it could be shelled, the thin web of the lattice would be difficult to fill. This geometry probably could only be created with metal printing.

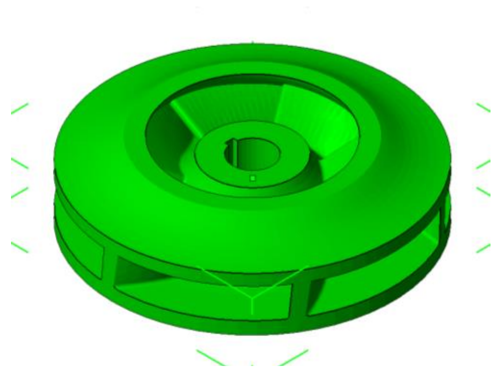

Figure 3 Geometry 3, a closed impeller

All five geometry files were sized so that the major dimension was four inches. To create the eight and sixteen inch sizes, the files were scaled by a factor of 2 and 4 respectively.

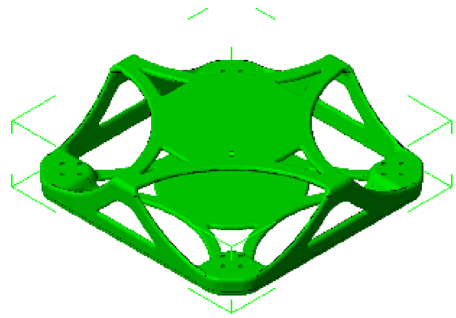

Figure 4- Geometry 4, a drone frame

Five levels of production volume were used; 1, 10, 100, 1000 and 10,000 copies.

These values of three major variables define a manufacturing space that includes the majority of the investment casting industry.

Figure 5 - Geometry 5, a lattice structure drone frame.

Several investment foundries were asked to quote each of the combinations of part complexity, part size and production volumes. They were asked to quote both conventional investment casting and hybrid investment casting using printed patterns.

For the conventional investment casting quotes, they were asked to estimate the cost of tooling rather than actually seek bids from tooling suppliers.

Printed pattern suppliers were asked to quote the same scenarios. The quoted prices were averaged for each pattern printing method and those averages were supplied to foundries for use in quoting hybrid investment casting prices. The foundries were asked to use the prices for whichever printing technology they were most comfortable with.

Several companies who provide metal printing services were also asked to quote printed metal components for the same scenarios.

For each scenario, all prices for conventional investment casting were averaged, as were the hybrid investment casting and metal printing prices. In each scenario, the lowest price was identified.

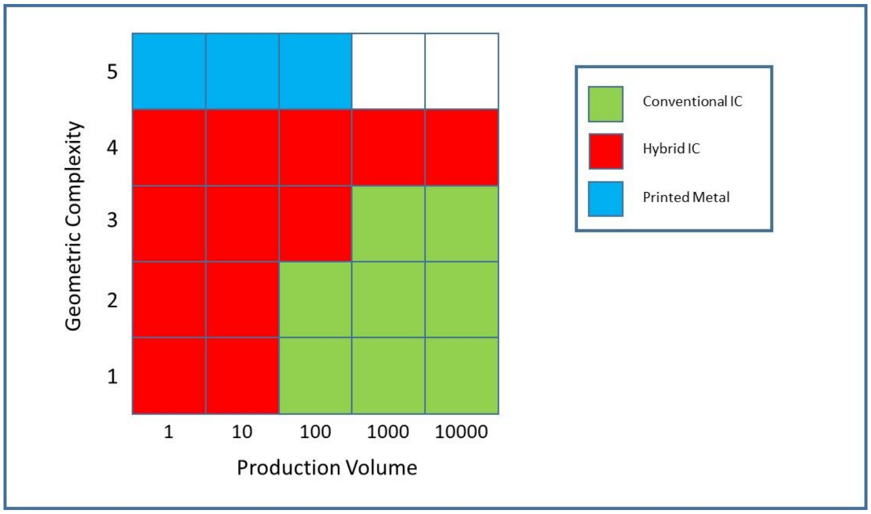

Figure 6 - Lowest methods of manufacture for 4 inch parts

Figure 6 illustrates the lowest prices for the 25 scenarios for 4 inch components. In those scenarios colored green, conventional investment casting with molded wax patterns was the least expensive method of manufacture. As expected, it is the least expensive method for all higher production volumes that can be done with conventional investment casting.

In those scenarios colored red, hybrid investment casting with printed patterns was the least expensive method of manufacture. For geometries 1 and 2, the simpler geometries, hybrid investment casting was least expensive for only very low quantities of 10 or less. Hybrid investment casting is least expensive up to 100 copies for geometry 3, which has a significantly higher tooling cost. For geometry 4, which can only be done with printed patterns or printed metal, hybrid investment casting is always the least expensive.

Metal printing is the least expensiv eoption only for geometry 5, which can only be done with printed metal. The suppliers did not quote the higher quantities of 1000 or 10,000. Those quantities would tie up their production for months.

Figure 7 illustrates the lowest prices for the 25 scenarios for the 8 inch components. Very little has changed from the pricing for 4 inch components. The only scenario that changed was the 100 copies of geometry three in which conventional investment casting is now least expensive.

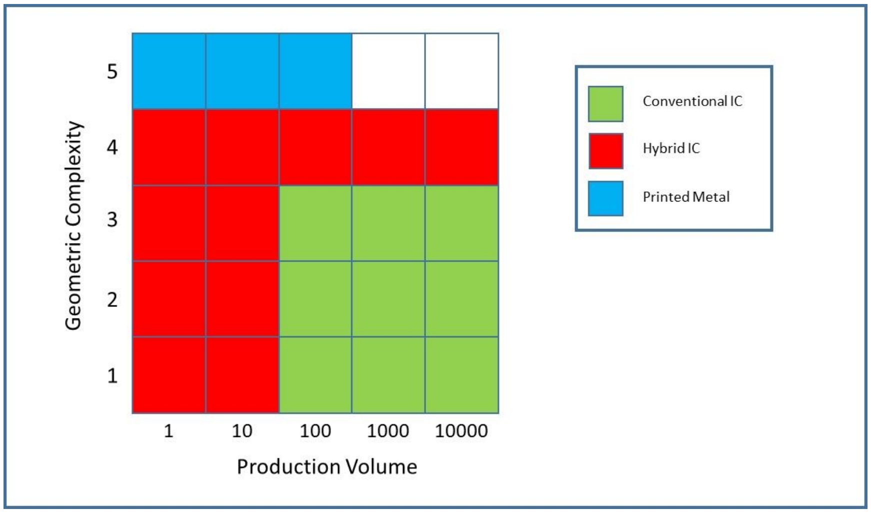

Figure 7. Least expensive method of manufacture for 8 inch parts

Figure 8 illustrates the lowest prices for the 25 scenarios for the 16 inch parts. There are a number of changes here. First, hybrid investment casting is less competitive on the larger parts. It is the least expensive method for only the first part on geometries 1 and 2. Printed metal does not show up at all. Current metal printers cannot handle parts this large.

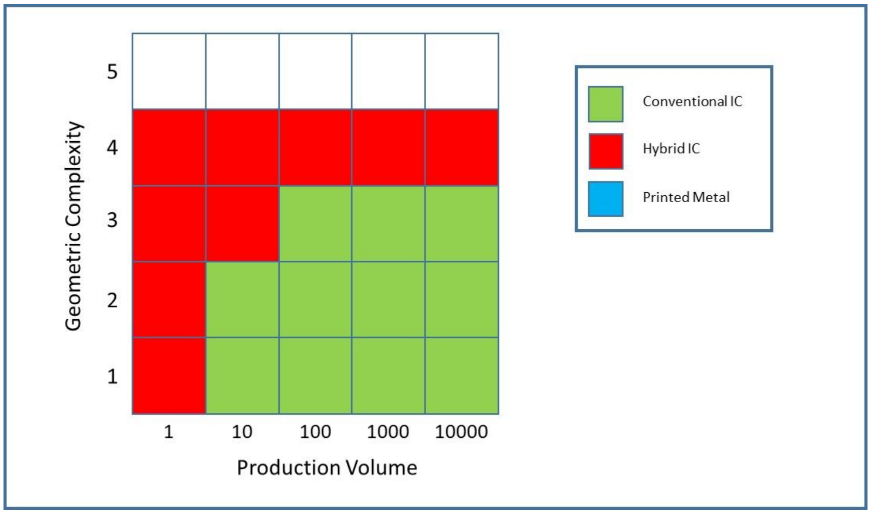

Figure 8 Least expensive method of manufacture for 16 inch parts

Observations

From these results, several observations can be made:

1. Printed metal does not provide a lower cost method of manufacture for components larger than 4 inches which can be created with either conventional or hybrid investment casting.
2. Hybrid investment casting is most competitive for smaller part sizes. As the part size increases, the break-even quantity decreases.
3. Hybrid investment casting appears to be less expensive than metal printing for complex geometries that cannot be molded conventionally.

Effect of Reduced Prices for Metal Printing

There is no doubt that over time, the cost of metal printing will come down. The number of manufacturers of metal printers is increasing rapidly, increasing competition and putting pressure on prices. In addition, as the number of printers sold increases, economies of scale will reduce manufacturing costs. Also, we may well see new printing technologies introduced that will lower costs. If metal printing costs come down, will it become a lower cost alternative for part of the investment casting landscape?

To answer that question, all metal printing prices were reduced by 50%. All 75 scenarios were then re-examined to determine the lowest cost method for each.

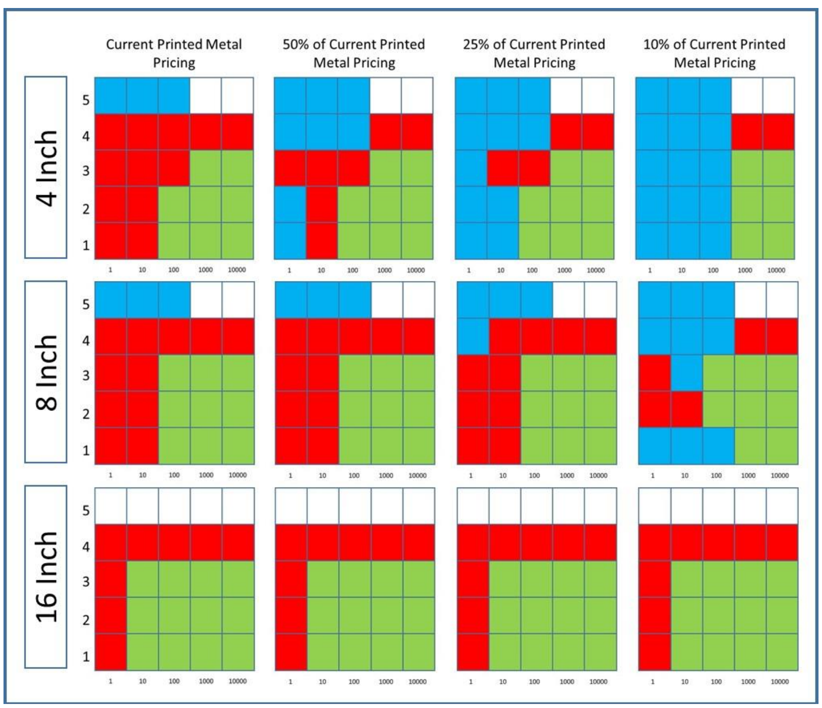

Figure 9. Affext of Reduced Pricing of Printed Metal Components

That analysis was repeated for price reductions of 75% and 90%. The results are shown in Figure 9.

Several observations can be made from these results:

1. A 50% reduction in metal printing prices has only a minor effect on the investment casting landscape.
    a. There are no changes in the low cost method for 8 inch and 16 inch parts.
    b. Metal printing becomes the lowest cost method for single copies of 4 inch parts with the lowest complexity.
    c. Metal printing is lower cost than hybrid investment casting for low quantities of castable but un-moldable 4 inch parts (Geometry 4).
2. A 75% reduction in metal printing prices has a relatively minor effect on the investment casting landscape
    a. Metal printing becomes the lowest cost method to create a single copy of the 8 inch version of Geometry 4.
    b. Metal printing is the low cost method of manufacture for most of the low volume production of the 4 inch part, regardless of complexity.
    c. There is no effect shown for 16 inch parts, but current machines cannot print parts that large. Once larger print capacity is available, there may be some impact on larger parts.
3. A 90% reduction in metal printing prices results in a much larger impact on the investment casting landscape.
    a. On the 4 inch parts, metal printing is the lowest cost method of manufacture for quantities of 100 or less regardless of complexity.
    b. On 8 inch parts, metal printing is the lowest cost method of manufacture or close to the lowest cost for quantities of 10 or less.

How much will metal printing prices come down? It is tempting to assume the same kind of price reductions seen in consumer electronics. Consider the drop in prices of video cassette recorders or personal computers over the first 10 or 15 years of life. Based on that, a price reduction of 90% might be possible.

However, there are significant differences between metal printers and consumer electronics. First, the majority of the printer is mechanical and there have not been similar reductions in the cost of mechanical components. Even with production scaling from tens of units per year to thousands, it is doubtful that there would be reductions of more than 50%. Secondly, a major portion of the cost of printed metal parts is the cost of raw materials. The majority of metal printers use powdered metal to create the parts. The powdered metal starts with the same material that foundries use for castings, but it is then further processed to create the fine powders needed for the printing process. As a result, powdered metal for printing sells at a significant premium to alloys for casting. For example, powdered titanium sells for about $150 per pound compared to $5 a pound for titanium for casting. Economies of scale may reduce that, but it will never be as inexpensive as the ingots foundries purchase. It is unlikely that prices will ever decline more than 50%.

Conclusions

1. Metal printing will not be competitive with conventional investment casting for components larger than 4 inches, quantities above prototype quantities, and moldable geometries. Normal production quantities will be least expensive to produce with investment casting.

Recommendations

1. The push toward light-weighting and the development of topology optimization tools will significantly increase the demand for castings which cannot be molded using conventional wax pattern tooling (example Geometry 4) and can only be cast using hybrid investment casting. This increase in demand will be at the cost of demand for conventional investment castings. It will be in the best interest of foundries to develop the capability to handle hybrid investment casting in production quantities, not just prototype.