Designing the Future of Castings

Authors:
Brandon Lamoncha - Humtown
Kirk Rogers – The Barnes Global Advisors

Metalcasting is one of the oldest manufacturing methods in existence, dating back over 5,000 years to 4th century BC. The process of pouring molten metal into molds to create metal parts and machinery is relatively unchanged, and with it, the creativity in design has pretty much remained the same as well. That was until additive manufacturing came along.

At The Barnes Global Advisors (TBGA) we have spent a great deal of time analyzing Design for Additive Manufacturing (DfAM) and Modifying for Additive Manufacturing (MfAM), as applied to directly printed parts. In looking at castings and other more traditional forms of production, do these concepts also apply when Additive Manufacturing (AM) is utilized? The answer is a resounding yes! Casting using additively manufactured tools enables more flexibility in design and rapid supply chain response like direct AM, and has the additional advantage in that the metal part can still produced by a traditional method, eliminating the qualification of a new manufacturing methodology.

What is additive-enabled casting?

Additive-enabled casting uses the best features of Additive Manufacturing and traditional casting to manufacture complex metal parts cost effectively. Essentially, you can use industrial 3d printing to produce molds, cores and patterns when casting metal parts, using nearly any castable metal. This approach eliminates the need for permanent tooling and allows for complex parts to be manufactured immediately.

The advantage of this method is that it's viable for first prototypes right through to large annual production volumes. For example, with additive manufacturing, there is no need for prototype tooling in the early stages of a new product design as the designer can prototype several variations on a design rapidly and with no additional cost.

Not only that, but additive enabled casting is suitable for many casting processes, from small investment castings such as jewelry to mid-sized V-process parts, to large sand castings (Fig 1.).

Fig 1. Example of a 2500 kg (5500 lb.) Pelton injector being poured in a multi-part 3D sand printed mold Credit: Kirk Rogers.

Let’s explore a little further how the elimination of tooling can speed up the response of the foundry. By eliminating the need for tooling in the sand casting process, the tool doesn’t need to be removed from the molded sand, eliminating the need for draft in the as-cast design. This results in a casting closer to the net shape of the final part. Since these kinds of molds are typically produced by the Binder Jetting Process (BJP; often called Sand Binder Jetting in this context) the biggest design limitation is ensuring there is a way to remove sand out of a mold cavity. Also by eliminating tooling, undercut and overhanging features are possible. One of the other big restrictions of traditional sand cast tooling is limiting the placement of the parting line between the Cope (upper tool) and Drag (lower tool), because tooling has to be removable from the cavity. This allows the designer using AM-produced casting molds to move the parting line to a less important area of the part or make it easier to remove any flash.

For even more complex or more difficult castings, BJP casting molds make it easy to incorporate cheek or side molds to the cavity design, add alignment and assembly features, add gas vents at precise locations to reduce porosity or add gating or runner features to better control metal flow into the mold. All of which can improve casting quality and reduce cost.

The table below highlights how DfAM and MfAM enables the designer to increase complexity of the design while reducing cost and improving quality of the resultant casting (Table 1).

Table 1: Cope and Drag DfAM and MfAM considerations

Consideration	Draft	Section thickness	Parting line	Assembly & alignment features	Gas vents
Impact	Lighter weight casting	Lighter weight, more complex castings	Better quality casting	Improved alignment between mold parts = Better quality casting	Lower gas porosity = Better quality casting
DfAM or MfAM	DfAM	DfAM	MfAM	MfAM	MfAM

Taking a look at cores and the casting design, there are additional MfAM and DfAM considerations (Table 2). Traditionally produced cores have similar tooling requirements to the cavity, so complex cores need to be molded as several pieces that are later assembled by hand and glued together. By additively manufacturing this core, the assembly steps and variation in that assembly are reduced. This enables better control of the cavity during the casting process, and potentially a reduction in metal section thickness due to reduced tolerance stack up. Again, the designer also has the freedom to incorporate more complexity into the design, without sacrificing cost or speed to market. For fragile, large or complex cores, 3D sand printing also enables the addition of features to the core that can simplify assembly (such as a handle that is removed before casting) or add shipping features (such as mounting point or shipping box) to improve reliability from the point of printing at a foundry service provider, to the foundry, which may be separated by hundreds or thousands of miles. One additional bonus, with printed sand tools are that they can be recycled in the foundry sand reclamation system, instead of generating trash in the form of dunnage for shipping.

Table 2: Core DfAM and MfAM considerations

Consideration	Tolerance stack up (multiple cores)	Parting line	Gas vents	assembly, shipping features
Impact	Lighter weight casting	Better quality casting	Lower gas porosity = Better quality casting	Improved core quality
DfAM or MfAM	DfAM	MfAM	MfAM	MfAM

The following US patent application US20180339334, helps to illustrate the previous considerations. This design shows a highly engineered, lightweight engine casting that would not be producible by casting tool methods. The design integrates what would traditionally be separate cores for exhaust ports, intake ports, water jacket, and cylinders combined into one 3D printed piece. In addition, the design incorporates features to aid assembly in the foundry, as well as gas vents to improve casting quality.

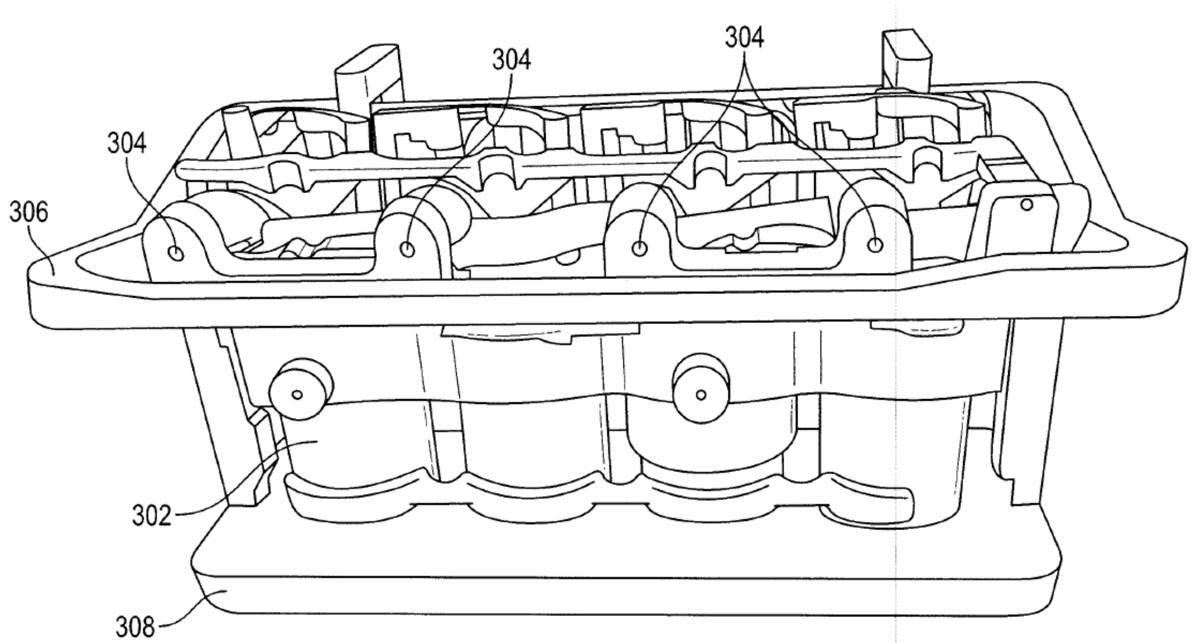

FIG. 3

Figure 2. Figure from patent application US20180339334 showing complex core assembly united into a single piece.

Even with all the above considerations, why is there not wide-spread adoption of additive manufacturing into the casting process? It comes down to the fundamentals. Finding these AM-enabled casting sweet spots requires awareness by engineering and sourcing teams to know how to best apply these techniques. Robust DfAM and MfAM training can help your team identify opportunities to apply additive manufacturing to cores and molds, and it can also help determine when AM is not the right method to use. Ultimately, investing in AM can save substantial time and money. In an interview with Bob Braun from Wisconsin Aluminum Foundry, he showcased how their team was able to significantly reduce lead time by using additive manufacturing, producing a casting for a customer in less than two weeks. These results simply come down to the ability of a team to apply the right design principles to the process.

"Additive tools are half the cost and done in half the time of conventional foundry solutions."

- *Marshall Miller, Foundry Innovator*

What was good in 14 BC can be great in 2021. Additive manufacturing enables design freedoms never thought possible in metal casting. It is time to design the future of the industry!

[Ask your foundry and foundry service provider what they are doing and how they can help – many are actively working on AM-projects to improve their operations. Or Join the American Foundry Society where the Additive Manufacturing Division members would be happy to help you along in your AM journey.]