Engineers' guide to metalcasting

bpi batesville products, inc.

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What you need to know to succeed

Metalcasting experts spend years perfecting their science and craft, but design engineers don’t have that kind of time on their hands.

This guide will help engineers understand the important aspects that go into a successful metalcasting project. We will describe the key factors for deciding which casting options are best for a particular project, and when other methods may be more advantageous.

Since we’re permanent mold casting experts, we’ll also offer additional insight on what makes permanent molding a standout casting method and what it’s like to work with a foundry engineer to set your operation on a path to success.

So let’s start from the beginning.

Do you actually need metalcasting?

Many engineers are guilty, at one point or another, of designing a component without stopping to ask themselves how they are going to make it. Fortunately, the first step in deciding the best production method for you is actually thinking about the last step, the finished product.

Start at the end and work your way backwards. Understand your end goals and think about the simplest way to meet them. Depending on the dimensions, tolerances and scheduling of a new product, permanent mold may be the best solution, then again, you may be better served by machining the parts or another molding method like sand or die casting.

The best method for your operation largely will be dictated by the size, geometry and quantity of your production goals. But factors like wall thickness, inserts and other surface finish requirements can play critical roles.

When designing your product, think about the qualities and tolerances that you absolutely need for the part to serve its purpose. Everything else is likely going to be a detriment to your operation.

Casting and machining

There are four main forms of casting, and each includes its own advantages and disadvantages, depending on the needs and abilities of an operation.

Some parts can also be produced by shaping metal through machining, which offers a wider array of alloy options but also produces much more waste.

Sand casting

Sand is the single-use version of metalcasting. Each mold is only used to cast a single part, like a coffee pod is used to brew one cup.

Sand casting molds and tooling can be relatively inexpensive, making it ideal for operations producing simply shaped, low-volume parts. Sand handles heavier metals than permanent mold or die casting, which use steel molds that can't stand up to the heat of molten metals like iron. But sand casting operations have to produce as many molds as they produce parts, so many times it isn't efficient for larger-scale productions unless the process is automated.

It's also difficult to create fine details or high surface finishes with sand casts, so they probably aren't the best option for highly visible products.

Die casting

If you're annually running tens or hundreds of thousands of parts, like an automotive company, you're going to want to go with die casting.

Where a sand mold can only be used to cast a single part, one steel die mold can cast thousands. But preparation is key because tooling is expensive and requires longer lead times.

The die casting process forces molten metal into the mold under pressure, filling the cavity. Die casted products can have thinner walls and less drafting than other casting methods. They also exhibit a decent as-cast surface and can hold tighter as-cast tolerances.

Permanent mold casting

Permanent mold casts are produced by pouring molten metal into steel molds, much like with die casting, but permanent mold casting is gravity induced, rather than pressure forced. The permanent mold casting process is slower than die casting, but it also causes less turbulence in the molten metal, resulting in denser casting.

The process is best for moderate- to high-volume operations producing parts with demanding tolerance requirements. Castings come out of permanent molds at near net shape with high-quality finishes, so minimal secondary machining and finishing is needed.

Investment casting

Investment casting is based on lost-wax casting. A shell made of ceramic, plaster or plastic is formed around a wax pattern. The wax is melted and removed in a furnace, then metal is poured into the shell to create the casting. A variety of metals can be cast into intricate shapes with this versatile process, but it's also the most expensive casting method when comparing apples to apples.

Machining

Machining parts involves taking a mass of metal and cutting it down to size, rather than shaping it to near net shape with a mold. Machining therefore requires much more time and waste to produce a final part.

This method is usually good for small batches with high part tolerances as machining is a slow process but can be performed with a high degree of accuracy. This is also a great way to prototype or prove out a design.

Machined parts can be made from a wider variety of metals than casting can offer. However, much more of that metal will be wasted on the cutting room floor. We've seen machining operations that lose 70% of their material to waste.

What makes permanent mold casting stand out?

Permanent mold castings are less prone to failure and defects than other casting options.

They can also include thicker cross sections because of the cavity fill and solidification process.

Sand and die casting have more porosity and shrink potential. Sand molds have low dimensional accuracy than steel molds and poor surface finish. Forcing molten metal into die molds causes more turbulence and air pockets in the molten metal, which can cause similar issues.

Density

Permanent mold casts really stand out due to their density and tight granular structure, so it's the way to go for pressure-tight and explosion-proof parts.

While most of the high-volume automotive parts are die casted, wheels, structural components and some transmission parts are created with permanent molds, because they need to be strong and pressure-tight.

Pouring

With permanent mold casting, molten metal is poured into the mold through a gating system. Gates control the feed and flow of molten metal into the mold cavity. The system also serves as a reservoir for the molten metal needed to supply the thick sections of the part as they shrink during solidification.

Tilt-pour

The tilt-pour method introduces metal by tilting the mold in a controlled fashion. This reduces turbulence, provides shorter cycle times and less metal for feeding the part, which helps reduce issues like gas porosity, pinholes and shrinking.

Inserts

Permanent mold casting is the best option for cast-in inserts where required.

Cast-in-place inserts allow for a wide range of securing methods. Steel tubing can be added inside the mold to provide a path for electrical wiring within the part.

Sand casts often aren't stable enough to add an insert into the molding process without an increased risk of sand particles breaking loose and contaminating the metal. Die cast operations are usually heavily automated and placing an insert into the die slows the process down dramatically.

Casting alloys

Aluminum alloys

Alloy A356 as our primary metal for its increased purity over other alloys.

This alloy offers great elongation, strength and ductility. It's corrosion resistant, easily weldable and can be mechanically finished to a shine.

A356 is best used in large, low-volume molds, such as structural and aerospace applications. It's also used as an alternative to 6061 aluminum alloy, one of the most common general use alloys.

Zinc alloys

Zinc is a heavier metal often used in household appliances, telecommunication devices and decorative finishes.

No. 5 is an ideal alloy for making small yet heavy parts. It's widely die cast in Europe and exhibits excellent characteristics, as well as improved is less likely to deform or creep compared other zinc alloys.

ZA12 is the most versatile zinc alloy, combining high-performance properties and ease of fabrication for gravity or pressure die casting. It offers a sound structure with high die cast elongation and impact properties.

It is important to remember that the casting qualities offered by a specific combination of casting alloy, foundry practices, gating designs and thermal treatments aren't always repeatable under different conditions. So creating a consistent process is paramount to produce high-quality parts.

Minimalistic designs, fast production

The more complex a design, the more time and expense to produce.

It's important to consult a foundry engineer while designing your part to avoid unnecessary features and tolerance requirements.

Think about the purpose of a part and decide what attributes are necessary and what can be done without. For example, if the part will not be highly visible to the end user, it probably doesn't need a high-quality surface finish and those tolerances can be relaxed.

Any production flexibilities will make things much easier on the foundry technicians and potentially increase speed to market.

In the past, we worked with a company to produce a product that didn't pass the first quality inspection. The failure was due to flexing on a hole with very tight tolerance requirements.

Our engineer went to the customer to better understand the purpose of the hole. We learned that it was only there to make way for a ground wire screw and did not need to be made with such tight tolerances. This realization allowed us to reject far fewer finished parts and greatly increase efficiencies without affecting the product's functionality ultimately resulted in a cheaper part on future orders.

Prototyping

Sometimes it's important to have a finished product before deciding if a design is ready for production. But that does not mean the prototype has to be created the same way you intend to create the final parts.

Prototypes can be created with 3D printers, one-off sand molds or machined so engineers can get a better sense of the form, fit and function of the product.

Foundry experts analyze the prototype and work with the customer to decide if it can be efficiently produced through permanent mold or another form of casting. They'll also consider if the production plan can be improved before a single mold is made.

Coatings, drafting and finishes

Appropriately implemented mold coatings play a critical role in proper solidification and casting removal.

Coatings are added to protect the molds and maintain the integrity of the surface. They can be used to insulate or cool a particular section of a mold for a variety of reasons. They also act as a lubricant to allow easy, consistent ejection of the part, like a nonstick baking pan spray. So it's very important to properly coat every crevice of the molding to ensure even ejection.

What else would you like to know?

We haven't even scratched the surface of metalcasting, so reach out to us for more information and/or to discuss your next project. If you're considering metalcasting, our experts can help save time, money and resources by getting involved during the planning stages.

You can email us at sales@batesvilleproducts.com or give us a call at 812-537-2275. You can also request a quote at batesvilleproducts.com/request-quote.