



Material Matters

Choosing Alloys for Complex Sand Castings

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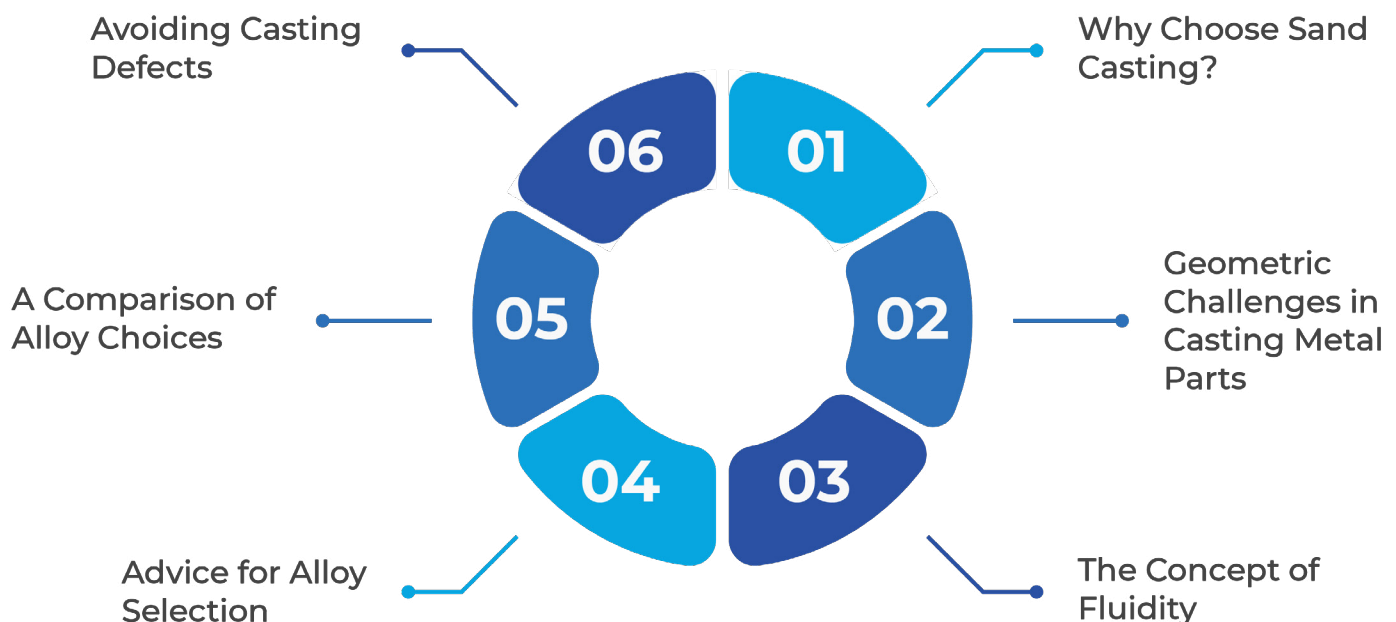
One of the biggest challenges in sand casting is to completely fill the mold cavity before the metal starts to freeze. It's a problem that grows harder as the shape being cast gets more complex. Narrow galleries are a particular issue, with metal tending to solidify before the space is full.

Experienced foundries have many tools at their disposal to tackle this problem, but a big factor is the type of alloy used. Some alloys flow and fill better than others, and understanding these

characteristics is key to selecting an alloy that meets economic as well as mechanical goals.

This eBook reviews what to consider when choosing an alloy for complex sand castings. After exploring the nature of the problem, which may help engineers optimize part designs, it moves on to desirable alloy characteristics. On completion, the reader will have the information they need to choose an alloy that will produce high quality parts.

Individual headings address:



Why Choose Sand Casting?

In sand casting, sand is placed in a box and packed around a pattern that reproduces the shape to be made. The pattern is lifted out to leave a cavity that will be filled with metal. A second box, also filled with packed sand, is placed on top to enclose the cavity. Channels are created in the sand to pour metal in through. If necessary, a portion of the part being cast may also be formed in the upper box, using a second pattern.



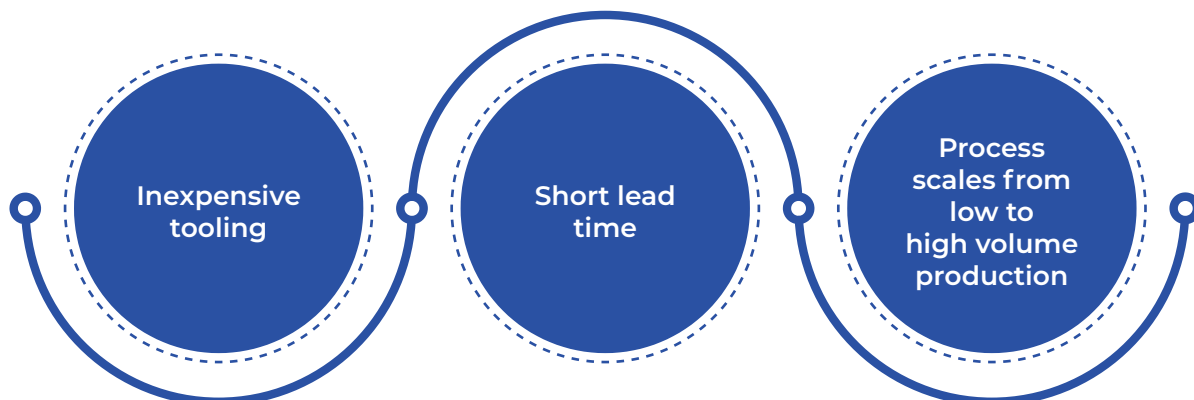
Hollow regions in the metal part are formed by placing cores in the sand cavity. Complex parts like engine blocks and cylinder heads need large numbers of cores, all of which must be precisely positioned.

Two types of sand are used in sand casting: green sand and resin sand. Green sand is so-called because it has some moisture from the clay binder used to hold it together. Resin sand is bound together with an adhesive coating.

Resin sand can maintain tighter tolerances than green sand. It's often preferred for cores and more complex castings.



The main reasons for choosing to sand cast a part are:



Geometric Challenges in Casting Metal Parts

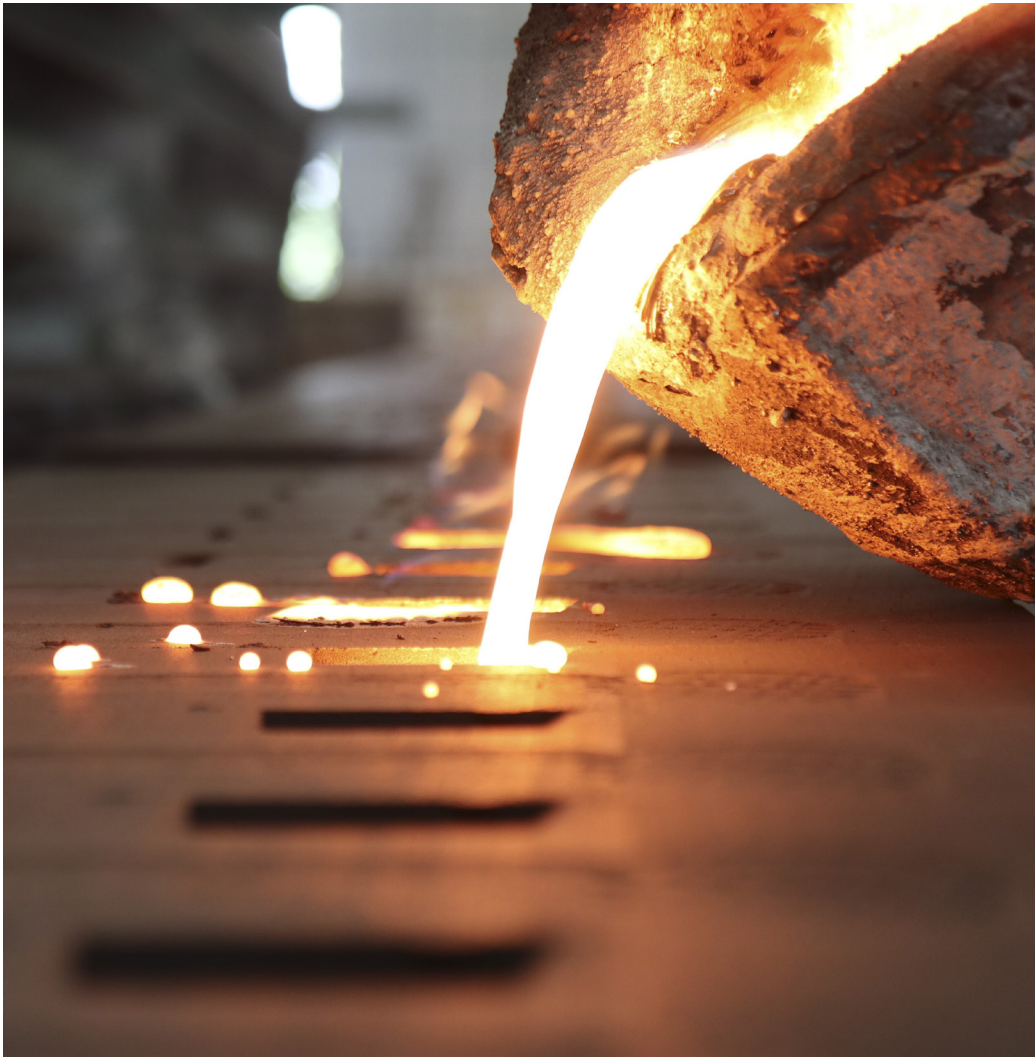
An assembled and closed mold resembles a three-dimensional negative of the part being cast with voids where there will eventually be solid metal. Usually, the metal feeding system is arranged to fill the cavity from the bottom as this minimizes turbulence in the metal.

The challenge for the design team and the foundry is that the metal is cooling as it fills the cavity. Metals have different solidification characteristics, with some making a rapid transition, (like water turning to ice), and others going through a pasty or slushy transformation which increases their viscosity. In both cases, as the surface begins to freeze it stops rising up in the cavity.



Heat is lost faster in regions where there's a lot of surface area in proportion to the volume of space, so the metal tends to freeze earlier there than in areas with a large mass of metal that stays hot longer. For designers and the foundry team, this means small areas, thin walls, and similar sections are challenging to cast successfully.

The Concept of Fluidity



Experienced foundry engineers know that some metals are easier to cast than others. This relates particularly to the ease with which they will fill small areas, which is described in terms of fluidity. Metals with good fluidity will flow easily into small areas whereas those with poor fluidity flow less readily.

Fluidity is similar to, but not the same as, viscosity. Fluidity is a qualitative measure of how well a metal flows. Viscosity is part of this, but other factors are at work too. Surface tension, solidification behavior, (where viscosity may increase before the metal crystalizes), and thermal conductivity are also significant.

Pouring temperature is another factor affecting fluidity. Generally, viscosity is lower at higher temperatures. Foundries however prefer to pour at the lowest temperature possible as this lessens thermal gradients in the mold and reduces the occurrence of defects.

Foundries assess the fluidity of a metal with a “spiral test”. This entails pouring metal into the mouth of a spiral tube approximately ½” diameter. The metal cools as it flows down the tube, eventually solidifying. The distance the metal flows from the mouth provides an indication of its fluidity.

With multiple variables at work, this is not a very scientific test. At the same time, it has been used in foundries for many years and is trusted as a reliable indicator of fluidity.

Avoiding Casting Defects

Given that fluidity is better at higher temperatures, it’s reasonable to ask why a foundry doesn’t just raise the pour temperature. This is an option, but there are adverse consequences:

***Steeper thermal gradient in the mold:** This affects the speed with which the metal solidifies and determines crystal size and orientation, in turn influencing hardness and tensile strength.*

***Longer cooling period:** More time is needed for solidification, which increases the time between pouring and breaking apart the sand mold, with implications for foundry space and productivity.*

***Increased defect rates:** Shrinkage can result in defects, especially hot tears. Higher pouring temperatures and steeper thermal gradients tend to exacerbate this problem.*

A Comparison of Alloy Choices

Alloys with good fluidity tend to be those with lower melting points and higher thermal conductivity, which are mostly non-ferrous. Alloy composition affects fluidity, which is one reason for performing a spiral test when evaluating the feasibility of casting a particular form in a specific alloy. However, the following list gives an indication of relative fluidity, from highest to lowest.

Highest: Aluminum alloys, especially those with high levels of silicon.

Copper alloys: Bronze, brass, not those with high proportions of tin or zinc.

Gray iron

Ductile iron

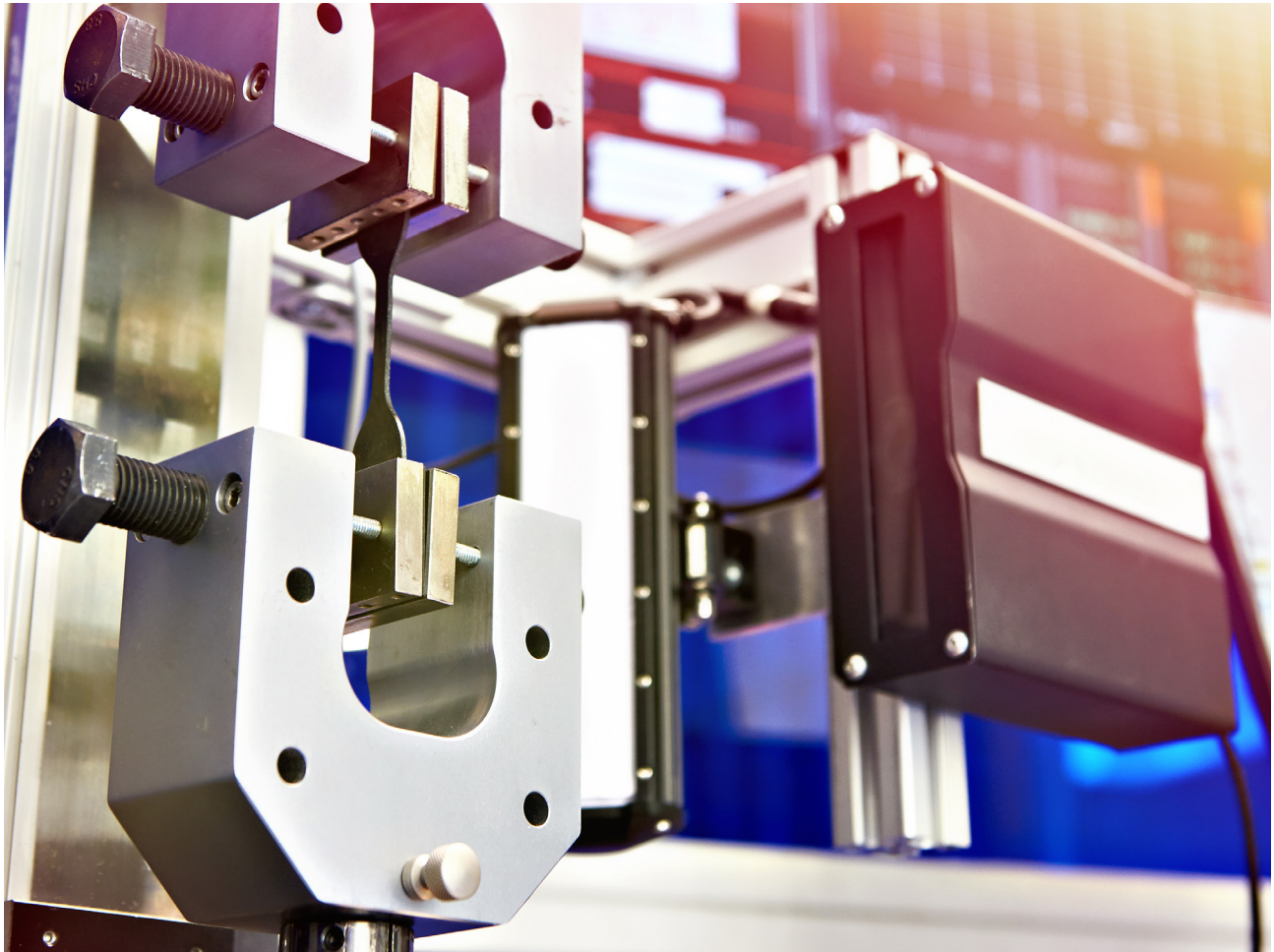
Lowest: Superalloys like Inconel

Importantly, low fluidity does not mean an alloy cannot be used in the sand casting process. It means only that small features like webs and thin sections will be difficult to fill.

Advice for Alloy Selection

Selecting an alloy involves considering the application requirements, the manufacturing processes, and the economics (volume, tooling costs, processing costs, finishing costs).

The application should always come first, as this establishes the mechanical (tensile strength, hardness), corrosion-resistance, and appearance requirements. However, there are tradeoffs to be made between mass, strength, corrosion-resistance and cost.



To give an example, it might be possible to substitute aluminum for steel by increasing the size of the part being cast to hit the strength goal. Material costs would probably be higher, but savings might be possible on corrosion protection and machining. Furthermore, the superior fluidity of aluminum would enable casting of smaller and more complex features and yields may be higher too. Depending on the application, this could allow some component consolidation while reducing machining requirements.

The casting process itself adds more complexity to the decision-making process. Tooling for sand casting is inexpensive and manufacturing lead times are often short. Taking this route rather than a process like investment casting gets the part into production faster and at less cost, but perhaps at the expense of additional machining operations.

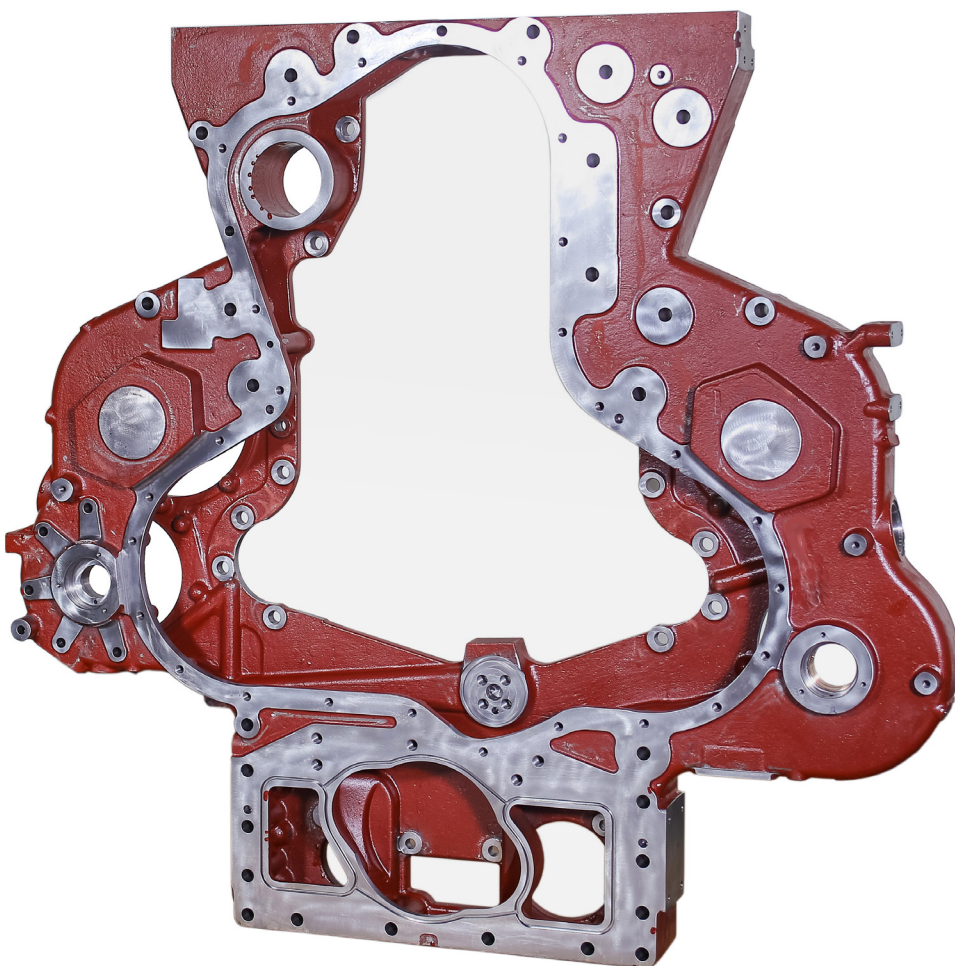
Overall, given the complexity of these tradeoffs, a prudent approach is to consult the foundry about alloy choices for the part design and production quantities.

Partner With Foundry Experts

Metals have different flow characteristics in their molten state, and this affects the ease with which they fill the mold. Sand casting, especially when using resin sand, can reproduce thin walls, as needed for ribs, webs and similar part features. However, not all alloys will flow readily into such spaces.

An experienced foundry can adjust casting conditions to improve fill and yield, but whenever possible, a better approach is to select an alloy with good fluidity.

This eBook has provided an explanation of fluidity in casting and addressed the main considerations in alloy selection. Before committing to a metal, a design and a process, a detailed discussion with a foundry partner is strongly recommended.





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