



*Tackling Complexity:
Overcoming
Challenges*
in Complex Sand
Casting Projects

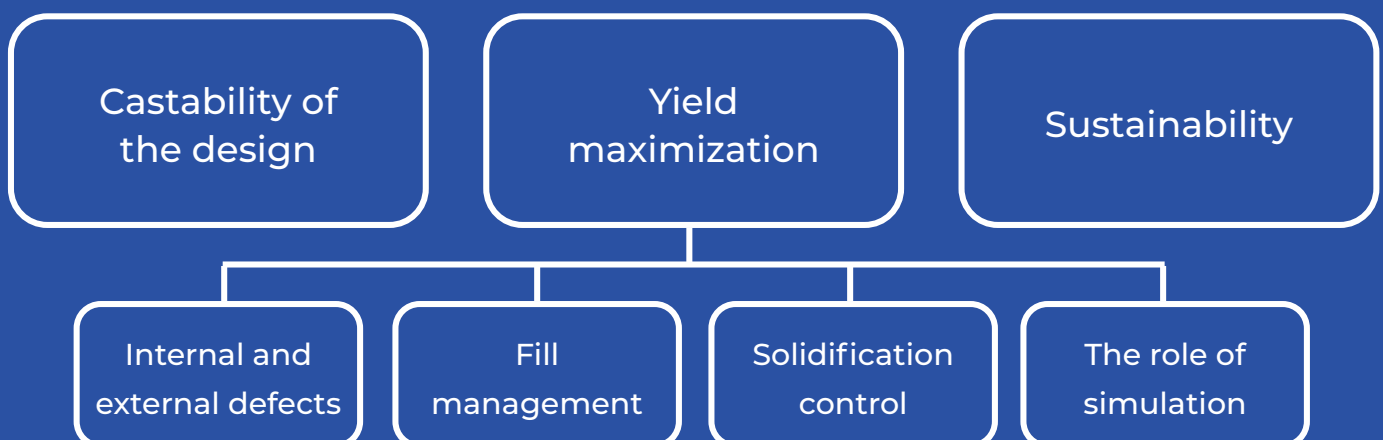
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Housings, manifolds, valve bodies, brackets. Just a few of the many parts, simple and complex, that can be produced economically by sand casting. Most metals can be sand cast, and with the right tooling and materials it's possible to produce fine detail and intricate features. Galleries for water cooling, to give one example. However, the more complicated the part being cast, the bigger the challenges for the foundry and the part designer to address.



This eBook was written as a guide for anyone considering sand casting parts with complex geometries. While it's not practical to cover every scenario in this book, it addresses the main challenges, and provides guidance on addressing them. Sections address:



Castability of the design

Sand casting involves creating a cavity in sand that becomes the mold. The cavity is produced by packing sand around a pattern, which is then lifted out. It's this requirement to remove the pattern that creates most of the constraints on part design. To be castable, the following points must be addressed:

- ✓ **Draft angles on vertical walls:** A slope of 1° to 2° away from the pattern allows the pattern to come free without dislodging sand.
- ✓ **No re-entrant features:** These would prevent removal of the pattern.
- ✓ **Location of the parting line:** The cavity is made in two halves, which are subsequently joined together. This will leave a small line – the parting line – around the part.
- ✓ **No sections thinner than $\frac{1}{4}"$:** Alloys have differing fluidity but most will not readily fill a region with a cross-sectional dimension smaller than this.



Note that for small quantity production it is possible to produce sand molds by 3D printing, (specifically, a binder-jetting process). This removes the draft angle and re-entrant constraints, but becomes less economic as quantities rise.

A further consideration is the need to form hollow regions within the casting. A valve body, for example, needs a large empty internal volume.

These spaces are created by placing cores in the sand cavity. Cores are made from sand and broken up after the part has been cast. Core placement must be considered during tooling design to ensure they will remain in place as flowing metal pushes up against them.

Alloy selection also has an influence on the castability of a design. This relates to the fluidity (similar to viscosity) of the metal in its liquid state.



Yield Maximization

Sand casting is a complex process with many variables. These can result in defects in the parts being cast. If discovered at the foundry, while still wasteful, there is an opportunity to cast more parts to make up the shortage. However, if defects are found during machining it may be impractical to cast more. (Tooling may have been placed into storage). In the worst case scenario, defects aren't discovered until the part is placed into service, at which point it fails prematurely.

This section explores the main factors and considerations in maximizing the production of "good" parts.

Internal and external defects

Defects visible on the outer surface of the cast part are primarily nonfills and blow holes or open porosity. These are detectable through visual inspection and so almost always found at the foundry. Internal, or sub-surface, defects may be discovered during machining. Porosity is a prime example, and hot tears and other shrinkage defects are others.

Internal defects may be detectable with x-ray inspection, and this is sometimes used for safety-critical and high-value parts. More generally though, a better approach is to prevent defects by addressing the root causes.

Fill management

How a mold cavity fills has a large influence on the potential for defects to arise. The metal feeding system should be designed so metal enters at the bottom and rises steadily, like water filling a bathtub. The goal is to avoid turbulence which can leave air bubbles (porosity) in the metal.

Filling should also be configured to avoid metal meeting from different directions, as this causes cold shuts. This is where oxide skins on the approaching fronts prevent fusion. It's a particular problem with aluminum due to its strong affinity for oxygen.



Filling is governed by the placement and cross-section of the gates, risers and sprue used in the metal feeding system. The volume and shape of the pouring cup, (the volume at the top of the sprue where metal is poured in), plays a significant role by providing pressure behind the flow.

Solidification control

The rate at which the alloy solidifies in the mold affects both yield and the mechanical properties of the part. Important factors in this are:

- **The liquid-to-solid transition:** Most alloys don't go through an immediate phase change but instead have a slurry or paste-like phase which greatly reduces how they flow.
- **Shrinkage resulting from contraction of the metal:** This is addressed by designing the mold with a reservoir of metal – a riser – that can replenish the biggest volume within the mold cavity.
- **Grain structure:** This establishes properties like strength and machinability, and is determined by the speed and direction of solidification.
- **Pouring temperature:** This influences both viscosity and solidification rate, but also has implications for energy consumption.



For most parts being cast the goal is to have rapid solidification, after the cavity is full. Solidification can be accelerated locally by placing chills in the mold. These are metal inserts that act as heat sinks, drawing thermal energy away from the molten alloy.

The Role of Simulation

Today's foundry engineers have sophisticated simulation programs to help optimize mold filling and metal solidification. Applying computational fluid dynamics (CFD) and computational heat transfer (CHT) to the CAD models of the mold and feeder system, this lets the engineers visualize the casting process before tooling is manufactured and even before the part design is frozen.

Simulating the sand casting process in this way reveals where problems are likely. Engineers can then experiment with changes to the many variables, minimizing defects while maximizing production rates and yields. Additional benefits are the potential for reducing the amount of inspection needed, and the possibility of compressing development lead times by avoiding changes to physical tooling.

Sustainability

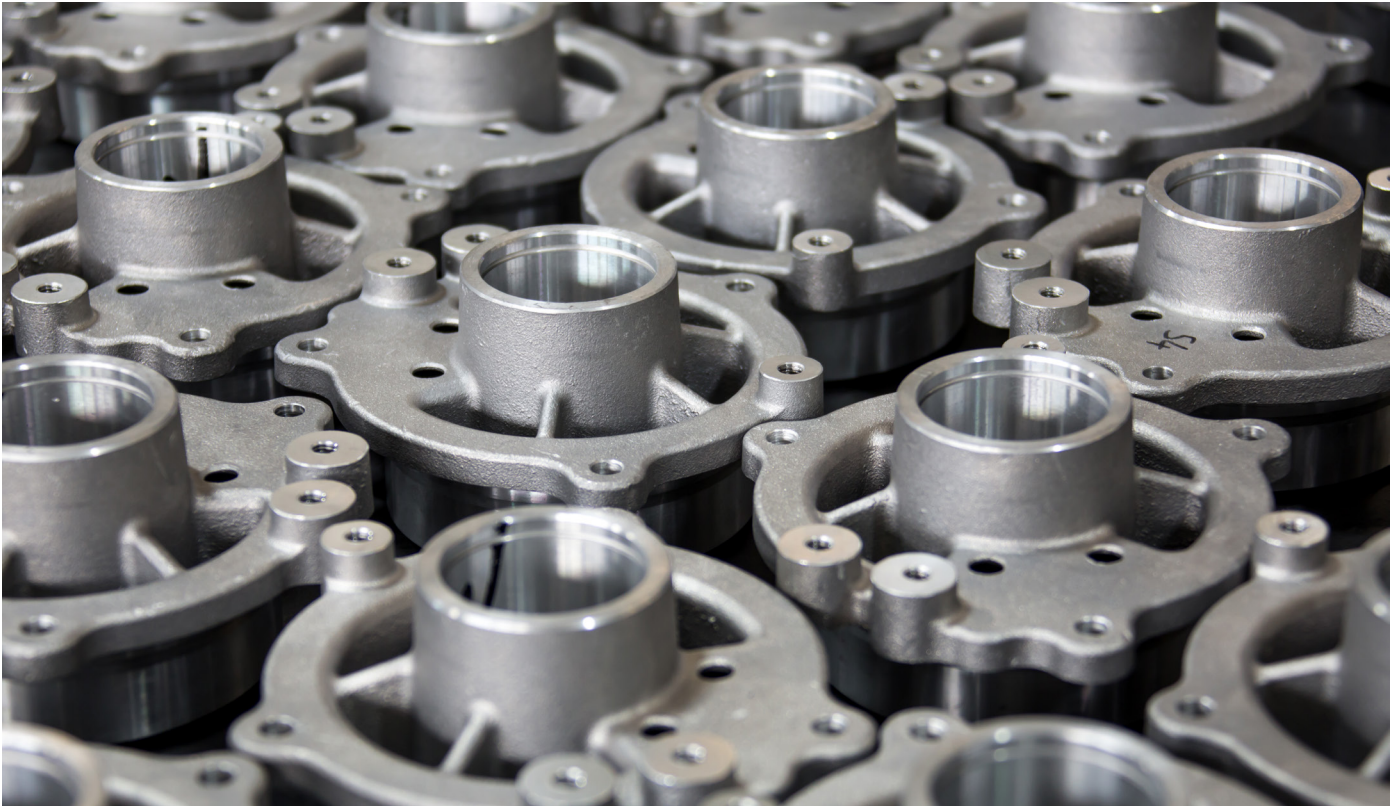
This is a topic of growing importance for buyers of sand castings and the foundries themselves. Melting metal is clearly energy-intensive, but other aspects of the sand casting process are more sustainable. In particular, in addition to metal, which is readily recycled, sand is the only other major resource consumed. Many foundries are addressing this through sand reclamation systems.

Whether working with green or resin sand, reclamation is not straightforward. Particle size is a major consideration as this affects both surface finish of the part being cast, and gas permeability of the mold. Sand tends to break down when it is reused, so a proportion becomes unusable and is discarded. Furthermore, resin sand needs recoating with resin while green sand needs appropriate levels of bentonite clay binder incorporating.

Other aspects of sustainability many foundries are addressing are waste reduction (of which yield maximization plays a large part), heat recovery, recycling of cooling water, and improved insulation.

Partner With Experts for Best Results

Sand casting is a cost-effective production method for metal parts weighing from ounces to hundreds of pounds. (Small valve bodies and engine blocks for large diesels illustrate the range of possibilities.) Most metals can be sand cast, and with sufficient attention to part design and operational parameters, the process produces high-quality parts with good levels of detail and acceptable surface finish.



As the parts being cast become larger and more complex, it becomes harder to fully optimize the process. Important points to address are: part design, methods of maximizing yields, and for many buyers, sustainability of the process.

This eBook has given some general guidelines to help in achieving satisfactory results from sand casting. To delve deeper into solutions and explore ways of handling design-specific issues, readers are advised to arrange a discussion with the foundry experts at Impro.



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