SAND CASTING

DESIGN GUIDEBOOK

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Sand casting is one of the oldest methods for making metal objects. However, obtaining consistently high-quality results requires a detailed understanding of the process and that parts be designed with its strengths and limitations in mind. This guide offers advice on when sand casting is appropriate and how to design parts that will cast well. Sections address:

- Process overview
- Strengths and limitations
- Suitable metals
- Dimensional control
- Casting sand and surface finish
- Casting defects
- Design considerations

Process Overview

Sand casting entails pouring molten metal into a cavity made in sand. That cavity is created by a pattern, which is a facsimile of the part to be made.

The pattern is placed into an open-topped box called the flask. Flasks usually comprise two halves, the upper being the cope and the lower the drag. The pattern goes into the drag, and sand is packed around it until the drag is full. Now the drag is flipped over, exposing the pattern. The pattern is carefully removed, leaving a void or cavity in the shape of the part to be cast.

The cope is then prepared with sand and placed on top. Depending on how the part is designed, some of the features may be formed in the cope and positioned to line up with the cavity in the lower flask. The cope will also incorporate channels for metal to be poured in, and other channels where it can rise up once the part cavity has filled.

This latter channel is the riser. It serves three main functions:

- Provides a visual indication that the cavity is full
- Carries impurities that float on top of the metal out of the cavity
- Forms a reservoir of molten metal that is drawn back into the cavity as the metal there solidifies and contracts

Once the metal has solidified, the flask is opened up and sand shaken out to release the cast part. This sand can be reused, although some treatment may be needed. The metal feeding channels are then cut off, and the casting can move into machining.

STRENGTHS AND LIMITATIONS

Sand casting is both inexpensive and versatile. It's economical for small quantities and even one-offs as well as for medium and even high volumes (providing appropriate automation is employed). Sand cast parts can range in size from the very small – weighing just a few ounces – to many tons.

Most metals are suitable for sand casting although cast iron flows and casts particularly well. By incorporating cores in the drag, (separate loose pieces,) it's possible to cast undercuts, (re-entrant features,) and create hollow regions. Thin walls are possible, provided attention is paid to how metal will flow and solidify.

The biggest limitation of sand casting is the need to pull the pattern out of the sand. First, this prohibits features that create re-entrants, unless special cores are added, which increases the cost of the process. Second, there is a risk of dragging sand out with the pattern. To address this, vertical surfaces must have a draft angle added to enable easy release.

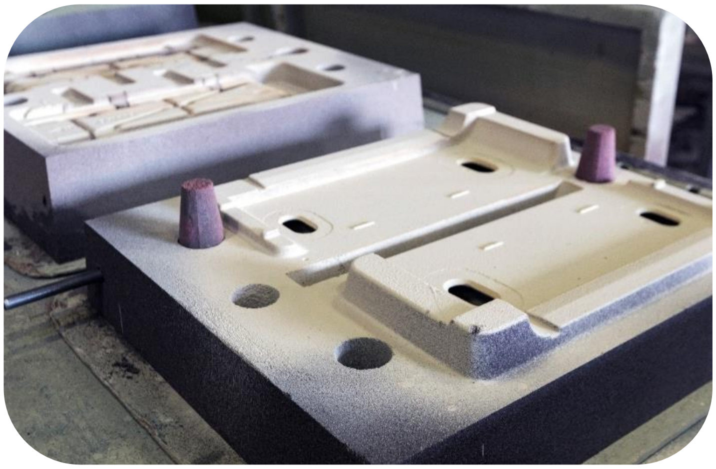
Unless the casting cavity is located entirely in the drag the cast part will have a parting line at the boundary with the cope. Inevitably, some metal will flow out here to form a thin line of flash. In addition, a small amount of misalignment between cavities in cope and drag is to be expected and must be accommodated in the part design.

When designing the pattern for the cope, it's best to avoid areas that will fill with air as metal flows in. If necessary, incorporate galleries to let this air escape. However, an advantage of sand casting over permanent die casting is that the sand provides a small degree of gas permeability. Thus small areas of air entrapment are permissible because the air can get out slowly through the sand.

The relatively coarse nature of sand limits the amount of fine detail that may be cast and the surface finish attainable. In addition, it's important to add machining allowances to the pattern that accommodate parting line misalignment and are big enough to ensure surfaces will clean up adequately in milling or turning.

SUITABLE METALS

Any metal with good flow characteristics is suitable for sand casting. This includes aluminum, brass, and most types of steel as well as cast iron.



Impro specializes in sand casting of:

- Ductile iron
- High SiMo ductile iron
- Austempered ductile iron
- High nickel ductile iron
- Compacted graphite iron
- Gray iron

For guidance on casting other metals, directly.

DIMENSIONAL CONTROL

The pattern must incorporate allowances for machining, shrinkage and misalignment between cope and drag. For this reason sand casting is not a high precision or near net-shape process.

A good machining allowance is 1% of each dimension. Thus on a feature 6" long (152mm) add 0.060" (1.52mm). (On shorter dimensions it's advisable not to go below this allowance.) Collaboration between mold tool designer and CNC machining specialist will help ensure allowances are sufficient but not excessive.

Shrinkage is material dependent. Consult with a foundry specialist to determine how much allowance to include.

Misalignment at the parting line results from tolerances in cope and drag and how they fit together. With well-maintained equipment, misalignment should be under 0.020" (0.51mm).

CASTING SAND AND SURFACE FINISH

Surface finish is related to the type of sand used. The primary choices are green sand and resin sand. These require equipment adapted to the particular type of sand. Thus sand casting lines are set up to run either green or resin sand and switching between the two is infeasible.

Resin sand produces a denser, stronger, but less permeable mold. It is also a more expensive process than green sand casting.

Green sand leaves a somewhat rough surface on the casting. This will typically be in the region of 200-500μinch Ra (5.0-12.5μmRa).

CASTING DEFECTS

The most common defects in sand casting are:

- Porosity
- Nonfills
- Cold shuts
- Inclusions
- Shrinkage defects

Porosity is actually air bubbles trapped in the molten metal as it solidifies. Porosity is reduced by minimizing turbulence during filling, which means filling more slowly. However, filling speed is a compromise between avoiding porosity and avoiding nonfills.

Nonfills result when metal fails to flow into the more extreme regions of the casting cavity. This may be due to the metal solidifying before the cavity is full, (filling too slowly,) or air entrapment.

Cold shuts occur when metal flowing in opposing directions, (around a core, for example) meets. In this case, a skin on each advancing metal front stops the metal from joining completely.

Inclusions are foreign bodies trapped within the metal. In sand casting it’s not uncommon for grains of sand to break away from the mold and become inclusions. Inclusions can be particularly harmful if exposed during machining.

Shrinkage defects look like cracks or nonfills. They result when the metal contracts as it solidifies and are particularly likely around corners.

DESIGN CONSIDERATIONS

The most important points to address are parting line position (and by extension, part orientation) and metal solidification.

Parting line position determines which features are formed in the drag and which in the cope. Remembering that misalignment and some flash are both likely at the parting line, most designers try to hide this by placing it at an edge. The parting line should also be placed so as to minimize re-entrant features and the need for cores.

Metal solidifies first where it contacts cold surfaces. Regions further from the sides of the mold take longer to cool and "freeze." Cooling rate determines the size of crystals formed in the metal. Faster cooling leads to smaller crystals and a harder "skin" on the casting. It also determines shrinkage direction, with metal pulling in towards the regions that cool slowest.

When necessary, cooling can be accelerated with the addition of "chills." These are metal inserts that conduct heat away quickly, promoting faster solidification and a finer crystalline structure.

Other points to consider when designing a part to be sand cast are:

- Include draft angles on all vertical surfaces – typically 1.5°-2° but may be smaller in select areas if necessary
- Avoid abrupt changes in the section – use wedged forms where transitions are essential
- Maximize radii on all internal corners to reduce the risk of shrinkage tearing/cracking
- Maximize radii on external corners for optimal flow and filling
- Incorporate datum pads which will be used to position the casting for the first machining operations
- Locate risers where they will help metal impurities float out, and preferably on surfaces that will subsequently be machined

APPLICATIONS FOR SAND CASTING

Church bells and machine tool bases are just two examples, drawn from the larger end of the size. spectrum, of objects that are sand cast. (Bells are usually bronze, a copper-tin alloy, and machine tool bases are usually cast iron.) Other examples include:

- Engine blocks
- Cylinder heads
- Manifolds
- Impellers
- Housings
- Pump and valve bodies
- Brackets
- Piston rings

As mentioned previously, sand casting is used from very low to very high volume manufacturing. High volume casting operations normally incorporate extensive automation in order to minimize piece part costs. Low volume operations are more manual.

CHOOSING TO SAND CAST THE PARTS YOU NEED

Sand casting is an economical method of producing metal parts in quantities from one-offs to high volume. It's the nature of the process that sand cast parts will require machining. This should be taken into consideration when costing parts made this way.

Impro is a leading producer of sand cast parts for customers in industries from automotive and power generation to hydraulic and agricultural equipment. Capabilities include both resin and green sand casting plus core-making and molding. Heat treatment and part inspection are also available. Contact us to learn how Impro could meet your needs for quality sand cast parts.