University of Salford

BEng(Hons) Mechanical Engineering

Manufacturing

Metal Casting Processes

With Emphasis On Die Casting

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Summary

This report was written to outline the solidification processes used in modern industrial manufacturing, with an appreciation of the methods needed to produce a finished product that meets a specification, with that in mind the selection of solidification process is a topic which all engineers should be informed of in order to best meet the specification with the equipment and resources available.

1 Introduction

A solidification process is any process that relies on making use of material in liquid form in order to produce a product, the basic method of any solidification process is to heat the material until it has become a liquid (read molten) and then pour the liquid into a mold such that it takes the shape of the mold and is allowed to cool to become a solid again.

Solidification processes see use in a number of applications with varying levels of precision, from producing huge ingots of steel to high precision molding of gears with tolerances lower than the thickness of a human hair.

Typically the costs of this method of manufacturing are found in purchasing the material, heating it, and the cost of fabricating the mold. solidification processes are suitable for all levels of production volume, as cheap parts can be produced quickly and in large quantities using an investment cast, or high precision products can be produced using a high quality one-off mold.

2 Overview of solidification processes

There are a number of casting methods and all require the use of mold to pour the liquid metal into, some methods involve a permanent mold that use a reusable mold for castings, while other methods make use a temporary mold that is destroyed or discarded after use.

2.1 Sand casting

Sand casting is the most common form of solidification process Over 70% of all metal castings are produced via a sand casting process. This method allows for small batches to be cheaply made, the medium for sand casts (sand) is cheap, and reusable.

The mold consists of two halves known as the Cope and the Drag (upper and lower half respectively.) and the cavity in between them is known as the pattern, this cavity is the space the molten metal is poured into.
For parts that require internal variations a core is added, this can be used to create a hollow section in the cast. In terms of suitability for alloys, nearly all metals and alloys can be cast using sand casting.

Sand casting allows for smaller batches to be made compared to permanent mold casting and at a very reasonable cost.

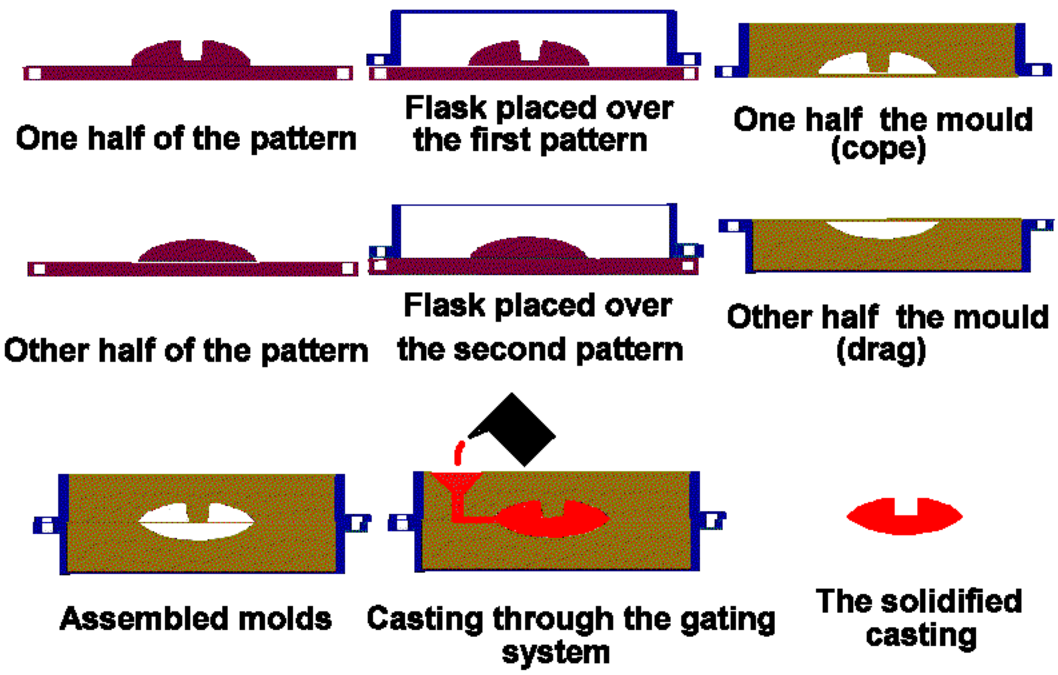
Not only does this method allow manufacturers to create products at a low cost, but there are other benefits to sand casting, such as very small size operations. From castings that fit in the palm of your hand to train beds (one casting can create the entire bed for one rail car), it can all be done with sand casting.

Sand casting also allows most metals to be cast depending on the type of sand used for the molds. Sand casting requires a lead time of days for production at high output rates (1–20 pieces/hr-mold) and is unsurpassed for large-part production. Green (moist) sand has almost no part weight limit, whereas dry sand has a practical part mass limit of 2,300–2,700 kg . Minimum part weight ranges from 0.075–0.1 kg .[2]

The common composition for the sand used is standard Silicone Dioxide, however for specialized conditions such as a high temperature melting alloy, other sand compositions may be used. The sand is bonded together using clays, chemical binders, or polymerized oils (such as motor oil). Sand can be recycled many times in most operations and requires little maintenance.

The advantages of sand casting as a solidification process include the cost, typically sand casting is a cheap operation, is well suited to automation and can be carried out at large production volumes. Some disadvantages are that the casting is not particularly accurate, and the sand cast mold does not lend itself well to producing a good finish or dimensional accuracy.

Sand casting sees use in myriad of industrial applications and as the most widely used solidification process sand casting can be used to produce almost all products.



2.2 Shell molding

Shell molding is a casting process in which the mold is a thin shell made of sand held together by a thermosetting resin binder, the mold is created by applying a sand-resin mix to a heated pattern, then removing the pattern and using it to cast the metal, generally this is done to produce a more intricate, more accurate mold.
Compared to sand casting, shell casting has many advantages, shell molding produces a better surface finish due to the difference in mold composition, the sand-resin mixture is typically smoother than the sand-water mixture used in sand casting, typically finishes of 2.5 μm can be achieved.
Good dimensional accuracy is also possible with tolerances in measurement as low as $\pm$ 0.25mm possible on small-medium sized parts.[1]
This accuracy is cost effective because less post-casting operations such as machining need to be carried out.

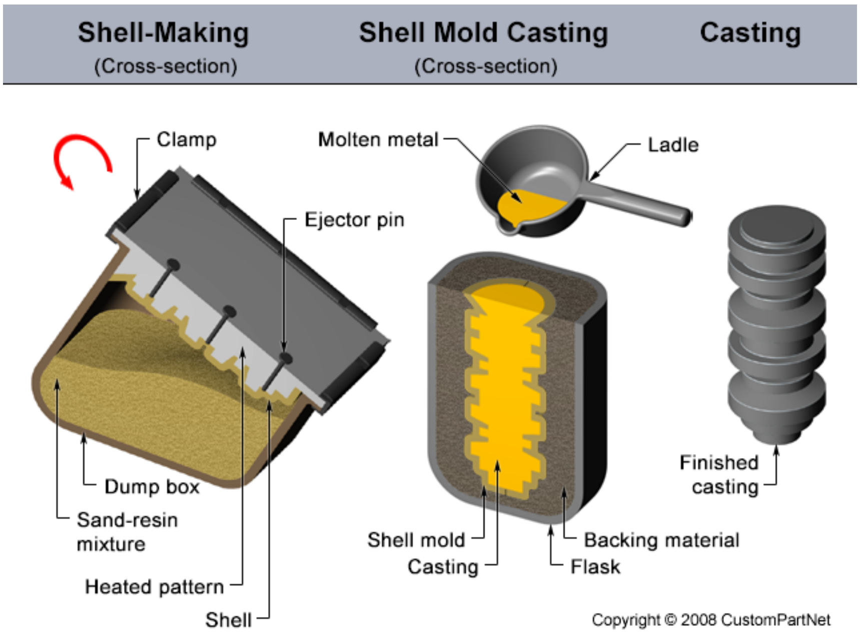
Setup and production of shell mold patterns takes weeks, after which an output of 5–50 pieces/hr-mold is attainable. Common materials include cast iron, aluminum and copper alloys.[3]
Aluminum and magnesium products average about 13.5 kg as a normal limit, but it is possible to cast items in the 45–90 kg range.[3] The small end of the limit is 30 g . Depending on the material, the thinnest cross-section castable is 1.5 to 6 mm. The minimum draft is 0.25 to 0.5 degrees.[3]

Typical tolerances are 0.005mm because the sand compound is designed to barely shrink and a metal pattern is used. The cast surface finish is 0.3–4.0 micrometers because a finer sand is used. The resin also assists in forming a very smooth surface. The process, in general, produces very consistent castings from one casting to the next.[3]

The sand-resin mix can be recycled by burning off the resin at high temperatures.[4]

Some disadvantages include the cost to produce the metal pattern, which would be cheaper if the same part were to be produced for a sand casting, this initial cost makes sand casting expensive for a small production volume.

Shell molding is widely used to produce steel castings of less than 9kg, for example Gears and Camshafts.[1]

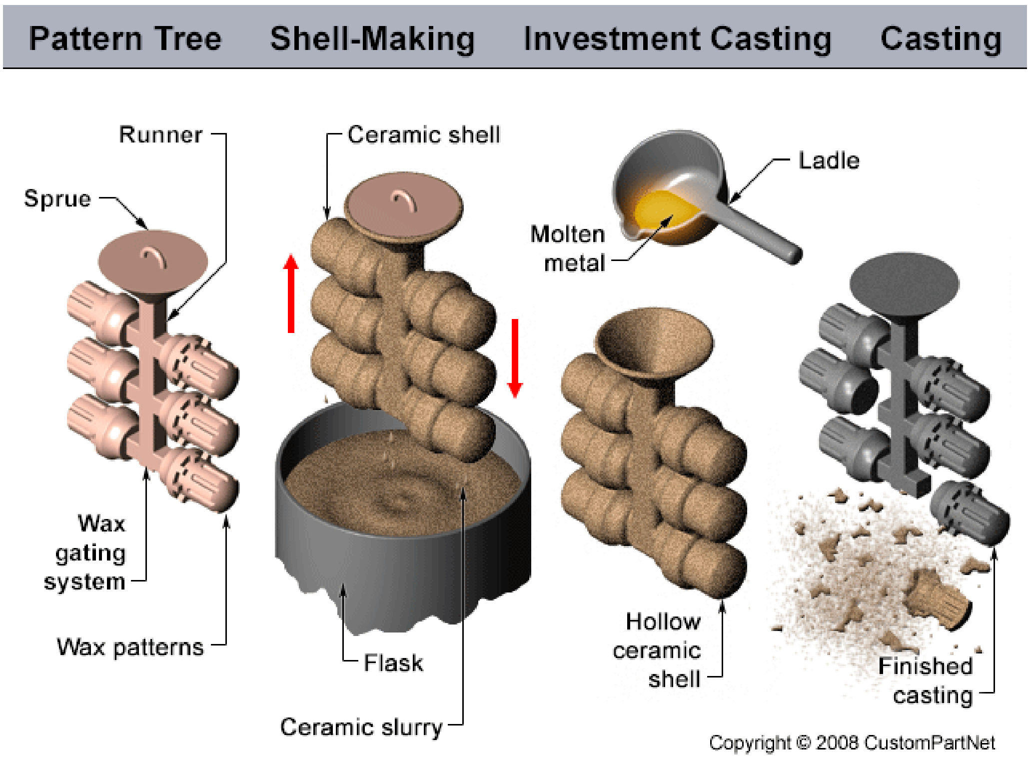


2.3 Investment casting

Investment casting involves the use of a wax mold used to produce multiple parts, the mold is made up of multiple patterns connected by a central runner, having them all connected allows a large amount of material to be poured into the mold, and multiple parts can be cast, at the same time which increases production rates.

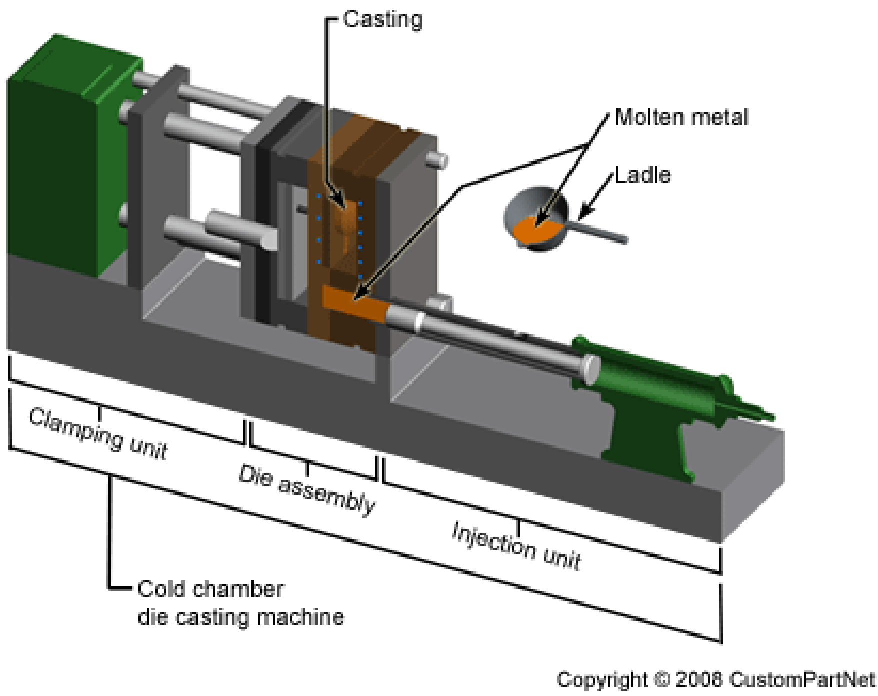
Investment casting is one of the oldest manufacturing processes, dating back thousands of years, in which molten metal is poured into an expendable ceramic mold. The mold is formed by using a wax pattern - a disposable piece in the shape of the desired part. The pattern is surrounded, or "invested", into ceramic slurry that hardens into the mold. Investment casting is often referred to as "lost-wax casting" because the wax pattern is melted out of the mold after it has been formed. Lox-wax processes are one-to-one (one pattern creates one part), which increases production time and costs relative to other casting processes. However, since the mold is destroyed during the process, parts with complex geometries and intricate details can be created.[6]

Investment casting can make use of most metals, most commonly using aluminum alloys, bronze alloys, magnesium alloys, cast iron, stainless steel, and tool steel. This process is beneficial for casting metals with high melting temperatures that can not be molded in plaster or metal. Parts that are typically made by investment casting include those with complex geometry such as turbine blades or firearm components. High temperature applications are also common, which includes parts for the automotive, aircraft, and military industries.[6]



2.4 Die casting

Die casting is a manufacturing process that can produce geometrically complex metal parts through the use of reusable molds, called dies. Each die is made to the pattern of the desired part, as such this is typically a high volume process because making a die is expensive and not feasible if only a small number of parts are to be made. The dies are commonly made from hardened tool steel. The die casting process involves pouring molten metal into a reusable mold, the mold is split into two patterns in order to remove the finished part after it has set, during pouring the mold is clamped together and a piston forces the liquid into the cavity in order fill the mold. Typical pressures are between 7 to 350 MPa.[1]



3 An in-depth review of Die Casting

In the last section die casting was discussed breifly and the chief operating processes were outlined, in this section the aim is to discuss the advantages, disadvantages, limitations, and appropriate components that are commonly produced using the die casting method.

Depending on the temperature of the cavity two processes exist: Cold-chamber die casting, and Hot-chamber die casting. Hot chamber casting can have production rates of 500 parts per hour, however the material is limited in that the injection system is subject to the same temperatures and this results in a short tool life, therefore typically low melting point metals are used such as zinc,tin,lead and sometimes magnesium.[1]

In cold chamber casting molten metal is poured into an unheated chamber and then forced into the mold cavity by a piston and ram, production rates are slower compared to hot chambered casting. if there is excess metal this is known as *flash*. Lubricant must be applied to the mold cavity to prevent the part from bonding to the pattern surface.

3.1 Advantages:

As the Die is reusable it is often economical to produce a very large or very accurate die, because the high volume covers the initial cost therefore very large parts can be produced, and also very good tolerances and surface finishes can be achieved with a good die.
Due to the injection system of forcing the molten metal into the mold very complex parts can be produced because the injected metal is forced into every available space of the cavity. Cast parts are also commonly very hard and of high strength. Due to a high level of automation, high production rates are achievable. The main cost is the machinery required, and skilled workers are not needed for many situations therefore die casting involves low labor costs. Scrap and flash can be recycled which is an advantage, in other techniques the flash may become contaminated such as with sand in the case of sand casting.

3.2 Disadvantages:

Some disadvantages include the need to trim the flash which adds to production times, and the high tooling and equipment cost, along with the limited die life due to wear and heat exposure. Also in order to begin producing a new part an entire new mold has to be made which leads to a long lead time.

3.3 Applications:

some applications, due to their high strength and accuracy include: Engine components, pump components, appliance housings, and machine components.

3.4 Possible defects in the casting process:

3.4.1 Flash

Flash is a left over section of metal that has to be cut from the part when it is removed, some causes of this are the injection pressure being too high and causing the molten metal to blow back or be forced through the sides of the die parting and also if the clamp force is too low molten metal can seep out from the cavity causing a flash between the patterns.

3.4.2 Unfilled Sections

An unfilled section is a void area of the cavity where molten metal has not reached and solidified, this can cause weaknesses in the metal and if the void isn't near the surface then it may be hard to detect. Possible reasons for an unfilled section to occur are insufficient shot volume, which means there is simply not enough material to fill the cavity volume, another cause could be slow injection, if the molten metal is poured too slowly it has time to cool and set prematurely, which prevents the rest of the shot from filling the cavity. Similarly a low temperature yields the same effect even if the pour rate is adequate.

3.4.3 Hot Tearing

Hot tearing is a process that occurs when the molten metal cools at a non-uniform rate, the thermal contraction as the metal cools warps and distorts the metal, and can cause cracks and tears to propagate.

3.4.4 Bubbles

Bubbling in the molten metal can cause weaknesses in the material, this defect occurs due to the injection temperature being too high or the material undergoing a non unform cooling rate, this causes areas of the molten metal to contract faster than others, causing a gap between them.

3.4.5 Ejector Marks

Ejector marks are a part defect in the form of small indentations that are made where the ejection system pushed the part out of the mold, this is due to the material not being given adequate cooling time or using an ejection force that is too high.

4 References

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