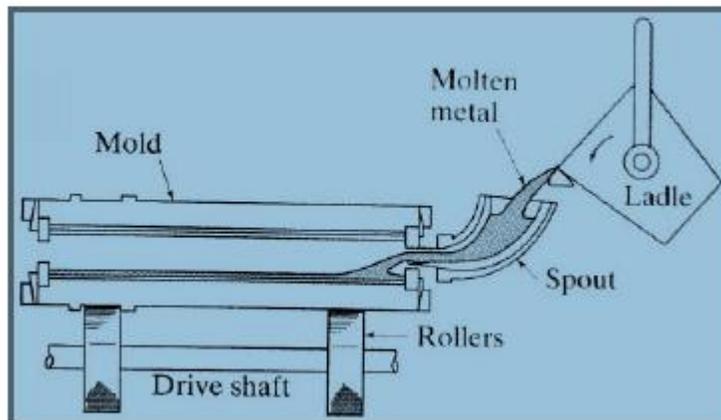


### Permanent mould casting:

The two halves of the mould are made of metal, usually cast iron, steel, or refractory alloys. The cavity, including the runners and gating system are machined into the mould halves. For hollow parts, either permanent cores (made of metal) or sand-bonded ones may be used, depending on whether the core can be extracted from the part without damage after casting. The surface of the mould is coated with clay or other hard refractory material – this improves the life of the mold. Before molding, the surface is covered with a spray of graphite or silica, which acts as a lubricant. This has two purposes – it improves the flow of the liquid metal, and it allows the cast part to be withdrawn from the mould more easily. The process can be automated, and therefore yields high throughput rates. Also, it produces very good tolerance and surface finish. It is commonly used for producing pistons used in car engines, gear blanks, cylinder heads, and other parts made of low melting point metals, e.g. copper, bronze, aluminum, magnesium, etc.

### Centrifugal casting:

Centrifugal casting uses a permanent mould that is rotated about its axis at a speed between 300 to 3000 rpm as the molten metal is poured. Centrifugal forces cause the metal to be pushed out towards the mold walls, where it solidifies after cooling. Parts cast in this method have a fine grain microstructure, which is resistant to atmospheric corrosion; hence this method has been used to manufacture pipes. Since metal is heavier than impurities, most of the impurities and inclusions are closer to the inner diameter and can be machined away. Surface finish along the inner diameter is also much worse than along the outer surface.



Centrifugal casting schematic

Mold for centrifugal casting can be divided to three types:

**1-The Permanent Mold:** Made of steel, iron or graphite. Inside surface is coated with a thin refractory wash to increase mold life. The mold is preheated before coating, so as to dry the coating and improve the adherence to the mold surface.

**2-Rammed Mold:** It consists of a steel metal flask, lined with a layer of refractory molding mix. The inside lining is coated with a refractory wash which is baked until dry and hard.

**3-Spun or Centrifugally Cast Mold:** In the metal flask a predetermined mass of refractory material in slurry form is poured.

The flask on rotation makes the refractory materials centrifuged onto the wall of the flask. The rotation is stopped and the liquid portion of the slurry drained off. It leaves the mold with a refractory coating, to be baked until dry before use.

### Features of Centrifugal Casting

- Castings can be made in almost any length, thickness and diameter.
- Different wall thicknesses can be produced from the same size mold.
- Eliminates the need for cores.
- Resistant to atmospheric corrosion, a typical situation with pipes.
- Mechanical properties of centrifugal castings are (50 feet) length.
- Wall thickness range from 2.5 mm to 125 mm.
- Tolerance limit: on the OD can be 2.5 mm on the ID can be 3.8 mm.
- Surface finish ranges from 2.5 mm to 12.5 mm rms.
- Only cylindrical shapes can be produced with this process.

**Application of centrifugal casting:** Typical materials that can be cast with this process are iron, steel, stainless steels and alloys of excellent. Size limits are up to 3 m diameter and 15 m (aluminum, copper and nickel. Two materials can be cast by introducing a second material during the process. Typical parts made by this process are pipes, boilers, pressure vessels, flywheels, cylinder liners and other parts that are axi-symmetric.

Centrifugal force acting on a rotating body is:  $C.F = mv^2 r$   
(where, m – mass (kg), V – peripheral speed (m/s), r – radius (m)).

### Defects in Centrifugal Casting:

-Conventional static casting defects like internal shrinkage, gas porosity and nonmetallic inclusions are less likely to occur in centrifugal casting.

-Hot Tears – Hot tears are developed in centrifugal castings for which the highest rotation speeds are used. Longitudinal tears occur when contraction of casting combined with the expansion of the mould, generates hoop stresses exceeding the cohesive strength of the metal at temperatures in the solidus region.

The casting process is usually performed on a horizontal centrifugal casting machine (vertical machines are also available) and includes the following steps:

1. *Mold preparation* - The walls of a cylindrical mold are first coated with a refractory ceramic coating, which involves a few steps (application, rotation, drying,

and baking). Once prepared and secured, the mold is rotated about its axis at high speeds (300-3000 RPM), typically around 1000 RPM.

2. *Pouring* - Molten metal is poured directly into the rotating mold, without the use of runners or a gating system. The centrifugal force drives the material towards the mold walls as the mold fills.

3. *Cooling* - With all of the molten metal in the mold, the mold remains spinning as the metal cools. Cooling begins quickly at the mold walls and proceeds inwards.

4. *Casting removal* - After the casting has cooled and solidified the rotation is stopped and the casting can be removed.

5. *Finishing* - While the centrifugal force drives the dense metal to the mold walls, any less dense impurities or bubbles flow to the inner surface of the casting. As a result, secondary processes such as machining, grinding, or sand-blasting, are required to clean and smooth the inner diameter of the part.

## **Wax mould casting**

Investment casting is also known as the lost wax process. This process is one of the oldest manufacturing processes. Intricate shapes can be made with high accuracy. In addition, metals that are hard to machine or fabricate are good candidates for this process. It can be used to make parts that cannot be produced by normal manufacturing techniques, such as turbine blades that have complex shapes.

### **Features of Lost Wax Precision Casting**

- \* Precise dimension, excellent surface and luminosity.
- \* It is suitable for parts with complex shapes, dedicate design and complex operation sequence.
- \* For saving material cost and reducing weight of all parts.
- \* For reducing cost of processing and cutting.
- \* It is Resuitable for all king of metal material. Available for mass production.

### **Lost wax casting process:**

#### **PATTERN PRODUCTION-**

The process begins with production of a one-piece heat-disposable pattern. This pattern is made by injecting wax into a metal die. A pattern is required for each casting. These disposable patterns have the exact geometry of the required finished part, but they are made slightly larger, to compensate for volumetric shrinkage in the pattern production state and during solidification of metal in the ceramic mold.

#### **PATTERN ASSEMBLY –**

Patterns are fastened on to one or more runners and the runners are attached to the pouring cup. Patterns, runners and pouring cups comprise the cluster or tree, which is needed to produce the ceramic mold. The number of runners per section and their arrangement on the pouring cup can vary considerably, depending on alloy type, size, and configuration of the casting.

**CERAMIC SHELL MOLD PROCESS –**

The ceramic shell mold technique involves dipping the entire cluster into a ceramic slurry, draining it, then coating it with fine ceramic sand. After drying, this process is repeated again and again, using progressively coarser grades of ceramic material, until a self-supporting shell has been formed

**REMOVING THE WAX –**

The coated cluster is placed in a high temperature furnace where the pattern melts and runs out through the gates, runners and pouring cup. This leaves a ceramic shell containing cavities of the casting shape desired with passages leading to them.

**CASTING –**

The ceramic shell molds must be fired to burn out the last traces of pattern material and to preheat the mold in preparation for casting usually in the range of 1600 to 2000 degrees Fahrenheit. The hot molds may be poured with the assistance of vacuum, pressure and/or centrifugal force. This enables reproduction of the most intricate details and extremely thin walls of an original wax pattern.

**CLEANING –**

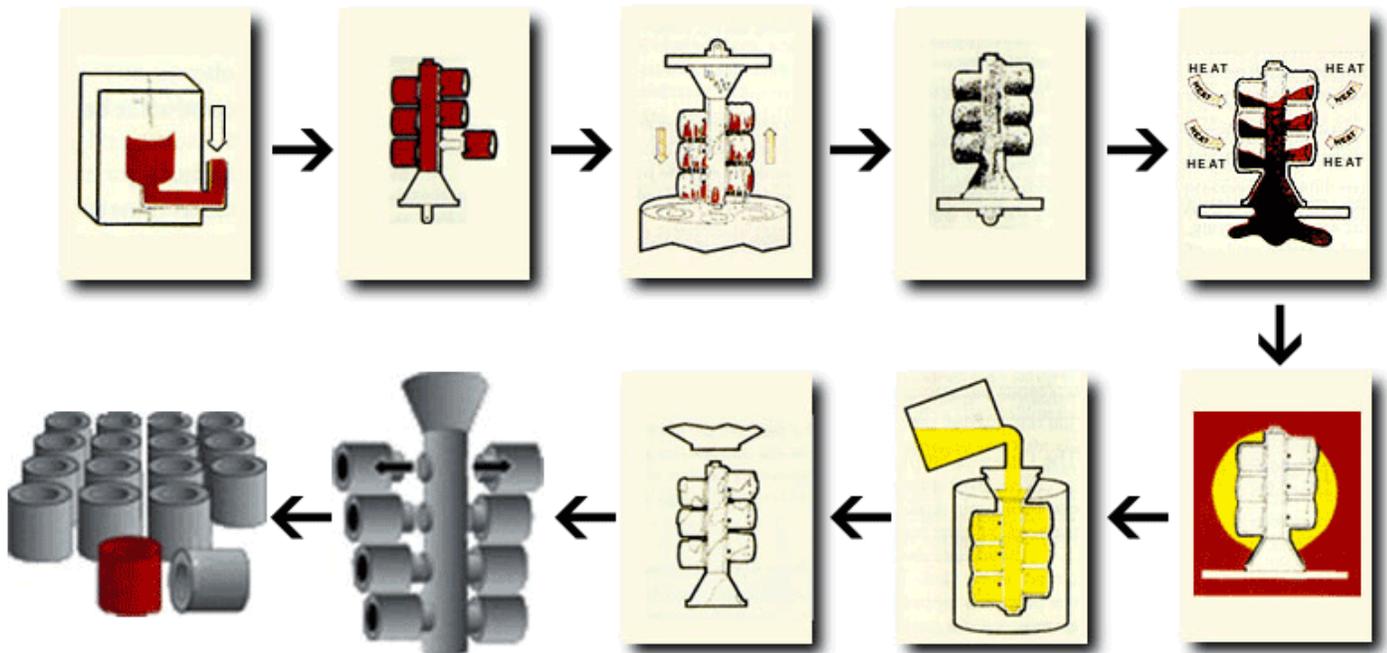
After the poured molds have cooled, the mold material is removed from the casting cluster. This is done by mechanical vibration, abrasive blasting, and chemical cleaning.

**CASTING REMOVAL –**

Individual castings are then removed from the cluster by means of cut-off wheels and any remaining protrusions left by gates or runners are removed by belt-grinding.

**FINISH PROCESS –**

The castings are then ready for secondary operations such as: heat-treating, straightening, machining, finishing, inspection, non-destructive testing, and then shipment to the customer.



## **SHELL MOLD CASTING**

The shell moulding process is a precision sand casting process capable of producing castings with a superior surface finish and better dimensional accuracy than conventional sand castings. These qualities of precision can be obtained in a wider range of alloys and with greater flexibility in design than die-casting and at a lower cost than investment casting.

The fundamental feature of the process is the use of fine-grained, high purity sand that contributes the attributes of a smooth surface and dimensional accuracy to moulds cores and castings alike. In conventional sand moulding the use of such fine sand is precluded because it would dramatically reduce mould permeability. This has the effect of retarding the escape of air and mould gases, causing short-run castings or castings containing gas defects. However, the distinguishing feature of the shell moulding process is that the mould is literally a shell, being in the region of only 10mm (0.4in) thick. It was the ability to produce such a thin shell mould, which made the process a revolutionary development in metal founding. The coincident development of plastics, like Bakelite, which were based on thermosetting resins such as phenol formaldehyde, provided the basis for shell moulding. In shell moulding the fine sand is coated with a thermosetting resin which provides the relatively high strength required enabling a thin section, or shell, mould to be produced.

The requirement that the mould should accurately replicate the pattern detail and dimensions if a precision casting is to be produced is also met by the shell moulding process. This is achieved because the resin bond is developed whilst the mould is in contact with a heated pattern plate. Furthermore, the mould is separated from the pattern without the need to enlarge the cavity, as is the case in green sand moulding. These features apply equally to the production of cores by the process. A further improvement in casting accuracy can be obtained if zircon sand is used instead of silica sand. That arises because the expansion of zircon sand, caused by the heat of the cast metal, is both lower and more predictable than that of silica sand. Foundry production of castings by the process is comparatively straightforward and the process lends itself readily to close control, with the advantage of consistency in the castings produced.

The advantages and disadvantages of the process are summarized below :

### **Advantages**

- lower capital plant costs, when compared with mechanized green sand moulding
- capital outlay on sand preparation plant is not essential
- good utilization of space
- low sand to metal ratio
- mould coatings are unnecessary
- lightweight moulds are produced which are readily handled and have good storage characteristics

- skilled labour is not required
- shells have excellent breakdown at the knockout stage
- lower cleaning and fettling costs
- castings have a superior surface finish and dimensional accuracy, when compared with green sand moulded castings

#### Disadvantages

- the raw materials are relatively expensive
- the size and weight range of castings is limited
- the process generates noxious fumes which must be effectively extracted

A metal pattern is produced first, and the metal used must have good heat capacity and thermal conductivity, as well as a good surface finish and the ability to withstand the abrasion of sand mixes. A shell mold is formed by heating the metal pattern and then bringing a sand and resin mixture into contact with the pattern. The heat from the pattern cures the resin in the mixture for a predetermined time, and any further curing needed is carried out in an oven. When fully cured, the rigid shell is ejected from the pattern plate. Cope and drag shell sections are made for each mold, and they are joined together with bonding resin or clamps to form the complete mold. Any cores required are placed inside the cope and drag before they are joined. When heavy castings are being produced, the thin shell mold is usually supported with metal shot or other back-up material. Shells for light castings do not require support.

The process is good for producing parts requiring:

- Thin Sections
- Intricate Details
- Close Dimensional Tolerances
- Excellent Surface Finish
- High Volumes

Typical alloys cast in this process are:

- Cast Iron
- Carbon Steel
- Alloy Steel
- Stainless Steel
- Aluminum Alloys
- Copper Alloys

#### **Process:**

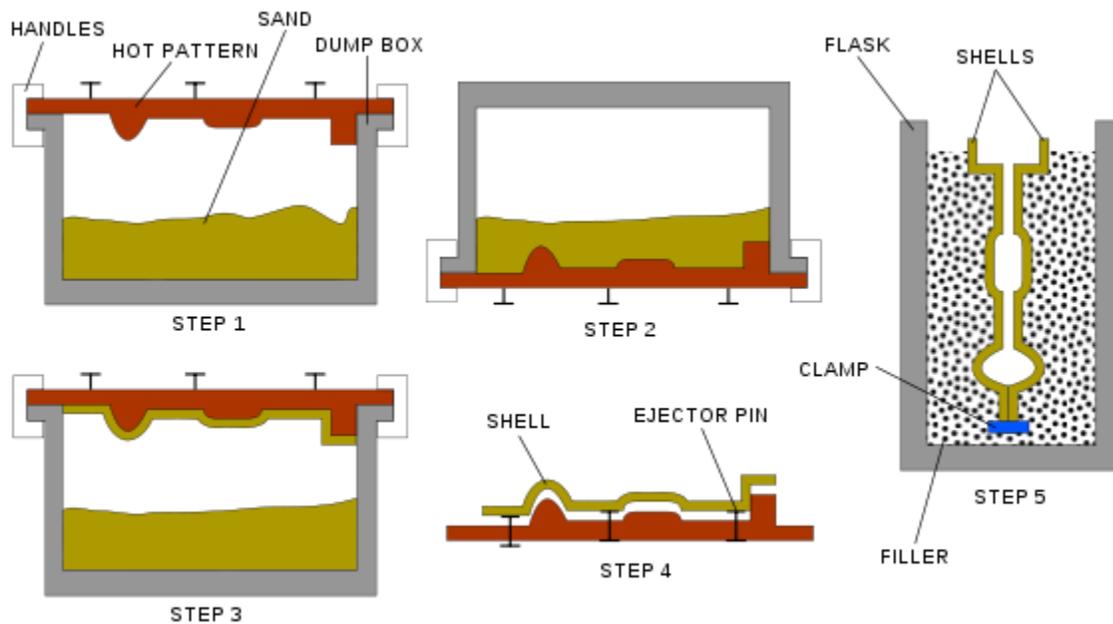
The process of creating a shell mold consists of six steps:

1. Fine silica sand that is covered in a thin (3–6%) thermosetting phenolic resin and liquid catalyst is dumped, blown, or shot onto a hot pattern. The pattern is usually made from cast iron and is

heated to 230 to 315 C°. The sand is allowed to sit on the pattern for a few minutes to allow the sand to partially cure.

2. The pattern and sand are then inverted so the excess sand drops free of the pattern, leaving just the "shell". Depending on the time and temperature of the pattern the thickness of the shell is 10 to 20 mm.
3. The pattern and shell together are placed in an oven to finish curing the sand. The shell now has a tensile strength of (2.4 to 3.1 MPa).
4. The hardened shell is then stripped from the pattern.
5. Two or more shells are then combined, via clamping or gluing using a thermoset adhesive, to form a mold. This finished mold can then be used immediately or stored almost indefinitely.
6. For casting the shell mold is placed inside a flask and surrounded with shot, sand, or gravel to reinforce the shell.

The machine that is used for this process is called a *shell molding machine*. It heats the pattern, applies the sand mixture, and bakes the shell.



Setup and production of shell mold patterns takes weeks, after which an output of 5–50 pieces/hr-mold is attainable.<sup>1</sup> Common materials include cast iron, aluminum and copper alloys. 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. The small end of the limit is 30 g. Depending on the material, the thinnest cross-section castable is 1.5 mm to 6 mm. The minimum draft is 0.25 to 0.5 degrees.

Typical tolerances are 0.005 mm/mm or 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. The sand-resin mix can be recycled by burning off the resin at high temperatures.