CLASSIFICATION

OF

FOUNDRIES

TYPE OF

MOULDING

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CONTENT

1. INTRODUCTION

Casting is a process by which a fluid melt is introduced into a mould, allowed to cool in the shape of the form, and then ejected to make a fabricated part or casing.

Four main elements are required in the process of casting:

1. pattern,
2. mould,
3. cores, and
4. the part.

The pattern, the original template from which the mould is prepared, creates a corresponding cavity in the casting material. Cores are used to produce tunnels or holes in the finished mould, and the part is the final output of the process.

Substitution is always a factor in deciding whether other techniques should be used instead of casting.

Alternatives include parts that can be stamped out on a punch press or deep-drawn, items that can be manufactured by extrusion or by cold-bending, forgings and parts that can be made from highly active metals.

2. TYPES

The casting process is subdivided into two distinct subgroups: expendable or “lost” mould and nonexpendable or “permanent” mould casting.

Expendable mould or “one use mould” casting is a generic classification that includes sand, plastic, shell, and investment (lost-wax technique) mouldings. All of these involve the use of temporary and nonreusable moulds, and need gravity to help force molten fluid into casting cavities.In this process the mould is used only once.

Nonexpendable mould or “permanent mould” casting differs from expendable processes in that the mould need not be reformed after each production cycle. This technique includes at least four different methods: permanent, die, centrifugal, and continuous casting.

2.1 ONE USE MOULD PROCESS – EXPANDABLE MOULD

CLASSIFICATION

1.1 PERMANENT PATTERNS

- 1.1.1 Green sand (clay – water bound)
  Silica sand, Olivine sand, Chromite sand, Zircon sand
- 1.1.2 Heat cured resin binder process
  - 1.1.2.1 Shell process (Croning process)
  - 1.1.2.2 Furan hot box
  - 1.1.2.3 Phenolic hot box
  - 1.1.2.4 Warm box (furfuryl – catalyst)
  - 1.1.2.5 Oven bake system (oil sand)
- 1.1.3 Cold box resin binder process
  - 1.1.3.1 Phenolic urethane
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  - 1.1.3.3 Free radical cure (acrylic – epoxy)
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- 1.1.4 No-bake resin binder process
  - 1.1.4.1 Furan (acid catalysed)
  - 1.1.4.2 Phenolic (acid catalysed)
  - 1.1.4.3 Oil urethane
  - 1.1.4.4 Phenolic urethane
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- 1.1.5 Silicate and phosphate bonds
  - 1.1.5.1 Sodium silicate – CO_2
  - 1.1.5.2 Shaw process (ceramic moulding)
  - 1.1.5.3 Unicast process (ceramic moulding)
  - 1.1.5.4 Alumina phosphate
- 1.1.6 Plaster bonds
  - 1.1.6.1 Gypsum bond
- 1.1.7 No bond
  - 1.1.7.1 Magnetic moulding
  - 1.1.7.2 Vacuum moulding

1.2 ONE USE PATTERNS

- 1.2.1 Foamed patterns
  - 1.2.1.1 Evaporative foam
  - 1.2.1.2 Replicast process
- 1.2.2 Wax patterns (investment casting)
  - 1.2.2.1 Ethyl silicate bonded bloc mould
  - 1.2.2.2 Ethyl silicate bonded ceramic shell moulds
  - 1.2.2.3 Colloid silica bond
  - 1.2.2.4 Plaster bond
  - 1.2.2.5 Counter-gravity low-pressure process

DETAILED INFO

Sand Casting

Sand casting requires a lead time of days for production at high output rates (1 - 20 pieces / hr - mould), and is unsurpassed for large-part production.

Dry (mostly chemical bounded sand) sand has almost no part weight limit, whereas green (wet) sand has a practical part mass limit of 2.300 – 2.700 kg. Minimum part weight ranges from 0,075 – 0,1 kg. Sand in most operations can be recycled many times and requires little additional input.

Preparation of the sand mould is fast and requires a pattern which can "stamp" out the casting template.

Typically, sand casting is used for processing low - temperature steel and aluminium, magnesium, and nickel alloys.

It is by far the oldest and best understood of all techniques.
Consequently, automation may easily be adapted to the production process, somewhat less easily to the design and preparation of forms. These forms must satisfy exacting standards as they are the heart of the sand casting process - creating the most obvious necessity for human control.

Plaster mould casting for metals

Plaster casting is similar to sand moulding except that plaster is substituted for sand. Plaster compound is actually composed of 70 – 80 % gypsum and 20 – 30 % strengthener and water.

Generally, the form takes less than a week to prepare, after which a production rate of 1 - 10 units / hr - mould is achieved with a capability to pour items as massive as 45 kg and as small as 30 g with very high surface resolution and fine tolerances.

Once used and cracked away, normal plaster cannot easily be recast.

Plaster casting is normally used for nonferrous metals such as aluminium-, zinc-, or copper-based alloys. It cannot be used to cast ferrous material because sulfur in gypsum slowly reacts with iron.

Prior to mould preparation the pattern is sprayed with a thin film of parting compound to prevent the mould from sticking to the pattern. The unit is shaken so plaster fills the small cavities around the pattern. The form is removed after the plaster sets.

Plaster casting represents a step up in sophistication and required skill. The automatic functions easily are handed over to robots, yet the higher-precision pattern designs required demand even higher levels of direct human assistance.

Plaster mould for casting plaster or concrete pattern

Plaster itself may be cast - either using single use waste moulds, multiple use piece moulds, or moulds made of flexible material such as latex rubber (which is in turn supported by an exterior mould).

The finished product is, unlike marble, relatively unattractive, lacking in transparency, and so is usually painted, often in ways that give the appearance of metal.

Alternatively, the first layers cast may contain colored sand so as to give an appearance of stone. By casting concrete, rather than plaster, it is possible to create sculptures, fountains, or seating for outdoor use.

Shell moulding

Shell moulding is also similar to sand moulding except that a mixture of sand and 3 – 6 % resin holds the grains together.

Set-up and production of shell mould patterns takes weeks, after which an output of 5 - 50 pieces / hr - mould is attainable.

Aluminium 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.

Shell mould walling varies from 3 - 10 mm thick, depending on the forming time of the resin.

There are a dozen different stages in shell mould processing that include:

1. initially preparing a metal-matched plate
2. mixing resin and sand
3. heating pattern, usually to between 505 - 550 °K
4. inverting the pattern (the sand is at one end of a box and the pattern at the other, and the box is inverted for a time determined by the desired thickness of the mill)
5. curing shell and baking it
6. removing investment
7. inserting cores
8. repeating for other half
9. assembling mould
10. pouring mould
11. removing casting
12. cleaning and trimming.

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

Investment Casting

Investment casting (lost-wax process) yields a finely detailed and accurate product, with excellent metallurgical properties.
Polystrene foam is also used in investment casting - see Lost-foam casting.

After a variable lead time, usually weeks, 1 - 1000 pieces / hr - mould can be produced in the mass range 2,3 – 2,7 kg. Items up to 45 kg and as light as 30 g are possible for unit production.

The process starts by creating an injection die to the desired specifications. This die will be used to inject wax to create the patterns needed for investment casting. The patterns are attached to a central wax sprue, creating an assembly, or mould. The sprue contains the fill cup where the molten metal will be poured into the assembly.

The wax assembly is now dipped multiple times in a ceramic slurry, depending on the shell thickness desired. A layer of fine sand (usually Zircon) is added on top of each ceramic layer. This process will be repeated until the desired shell is created.

After the shell is created to the specifications desired, the wax must be removed,this is normally achieved using an autoclave. This is where the name "lost-wax process" comes from. This leaves an impression of the desired castings, which will be filled with metal. Before being cast, however, the shells must be heated up in a furnace so they don't break during the casting process.

Next, the desired metal is poured into the hot ceramic shell. The metal fills each part on the assembly, and the central sprue cavity and fill cup. The individual parts will be removed after the mould cools and the shell is removed. The shell is generally removed with water-blasting, although alternate methods can be used. What remains is the casted metal parts, but they are still attached to the sprue assembly. The individual parts are removed by cold-break (dipping in liquid nitrogen and breaking the parts off with hammer and chisel) or with large cutoff saws. Now all that remains is finishing.

First the gate, or the place where the part was connected to the sprue, must be removed. The gate is ground off to part specifications. Parts are also inspected to make sure they were cast properly, and if not are either fixed or scrapped. Depending on the investment casting facility and specifications, more finishing work can be done on-site, sub-contracted, or not done at all. Investment casting yields exceedingly fine quality products made of all types of metals. It has special applications in fabricating very high-temperature metals, especially those which cannot be cast in metal or plaster moulds and those which are difficult to machine or work.

2. 2 PERMANENT MOULD PROCESS – NON EXPANDABLE

CLASSIFICATION

2.2.1 DIE CASTING
- 2.2.1.1 High-pressure die casting
- 2.2.1.2 Low-pressure die casting
- 2.2.1.3 Gravity die casting (metal cores)
- 2.2.1.4 Semi-permanent gravity die casting (sand or plaster cores)

2.2. CENTRIFUGAL CASTING
- 2.2.1 Vertical centrifugal casting
- 2.2.2 Horizontal centrifugal casting

2.3 HYBRID PROCESSES
- 2.3.1 Squeeze casting
- 2.3.2 Semisolid metal casting (rheocasting)

DETAILED INFO

Permanent Mould Casting

Permanent mould casting (typically for non-ferrous metals) requires a set-up time on the order of weeks to prepare a steel tool, after which production rates of 5 - 50 pieces / hr - mould are achieved with an upper mass limit of 9 kg per iron alloy item (cf., up to 135 kg for many nonferrous metal parts) and a lower limit of about 0,1 kg.

Steel cavities are coated with refractory wash of acetylene soot before processing to allow easy removal of the workpiece and promote longer tool life.

Permanent moulds have a life which varies depending on maintenance of after which they require refinishing or replacement. Casted parts from a permanent mould generally show 20 % increase in tensile strength and 30 % increase in elongation as compared to the products of sand casting.

The only necessary input is the coating applied regularly.

Typically, permanent mould casting is used in forming iron-, aluminium-, magnesium-, and copper-based alloys. The process is highly automated. Even castings up to 10.000 kg in ductile iron (hydraulic cylinders) are poured in permanent moulds.

Die-Casting

In die-casting molten metal is injected into a mould at high pressures.

Set-up time for dies is 1 - 2 hours, after which production rates of 20 – 200 pieces per hour-mould are normally obtained.

Maximum mass limits for magnesium, zinc, and aluminium parts are roughly 4,5 kg, 18 kg and 45 kg, respectively (though larger machines do exist); the lower limit in all cases is about 30 g.

Die injection machines are generally large (up to 3 × 8 m) and operate at high pressures — 100 megapascals (1000 kgf / cm^2) and higher, although aluminium usually is processed at lower pressure.

A well-designed unit produces over 500.000 castings during the production lifetime of a single mould. While the dies used in the process are quite expensive, if a very large number of castings can be produced, significant cost savings can be achieved when a component is manufactured by die casting.

The major production step is die construction, usually a steel alloy requiring a great deal of skill and fine tooling to prepare. Mostly non-ferrous materials are die-cast, such as aluminium, zinc, magnesium, and copper-based alloys.

This is the process used in the production of certain toys, notably that of model automobiles, see: die-cast toy, Matchbox

Centrifugal casting

Centrifugal casting is both gravity- and pressure-independent since it creates its own force feed using a temporary sand mould held in a spinning chamber at up to 90 g (900 m/s^2).

Lead time varies with the application. Semi- and true-centrifugal processing permit 30 - 50 pieces / hr - mould to be produced, with a practical limit for batch processing of approximately 9000 kg total mass with a typical per-item limit of 2,3 – 4,5 kg.

Industrially, the centrifugal casting of railway wheels was an early application of the method developed by German industrial company Krupp and this capability enabled the rapid growth of the enterprise.

Small art pieces such as jewelry are often cast by this method using the lost wax process, as the forces enable the rather viscous liquid metals to flow through very small passages and into fine details such as leaves and petals. This effect is similar to the benefits from vacuum casting, also applied to jewelry casting.

Continuous Casting

Continuous casting is a refinement of the casting process for the continuous, high-volume production of metal sections with a constant cross-section.

Molten metal is poured into an open-ended, water-cooled copper mould, which allows a 'skin' of solid metal to form over the still-liquid centre. The strand, as it is now called, is withdrawn from the mould and passed into a chamber of rollers and water sprays; the rollers support the thin skin of the strand while the sprays remove heat from the strand, gradually solidifying the strand from the outside in.

After solidification, predetermined lengths of the strand are cut off by either mechanical shears or travelling oxyacetylene torches and transferred to further forming processes, or to a stockpile.

Cast sizes can range from strip (a few millimetres thick by about five metres wide) to billets (90 to 160 mm square) to slabs (1,25 m wide by 230 mm thick). Sometimes, the strand may undergo an initial hot rolling process before being cut.

Continuous casting provides better quality product as it allows finer control over the casting process, along with the obvious advantages inherent in a continuous forming process. Metals such as steel, copper and aluminium are continuously cast, with the largest tonnage poured being steel.

3. DETAILED DESCRIPTION

3.1 GREEN SAND MOULDING

The green sand process utilizes a mould made of compressed or compacted moisturised sand, packed around a wood or metal pattern. A metal frame or flask is placed over the pattern to produce a cavity representing one half of the casting. The sand is compacted by either jolting or squeezing the mould.
The other half of the mould is produced in like manner and the two flasks are positioned together to form the complete mould. If the casting has hollow sections, cores consisting of hardened sand (baked or chemically hardened) are used.

High-Density Moulding (High Squeeze Pressure / Impact)
Large air cylinders, hydraulics, and innovative explosive methods have improved the sand compaction around the pattern, improving the standards of accuracy and finish which can be achieved with certain types of castings.

Advantages
- Most ferrous / non-ferrous metals can be used.
- Low Pattern & Material costs.
- Almost no limit on size, shape or weight of part.
- Adaptable to large or small quantities
- Used best for light, bench moulding for medium-sized castings or for use with production moulding machines.

Disadvantages
- Low design complexity.

* Lower dimensional accuracy.

3.2 NO-BAKE MOULDING

Chemical binders (furan or urethane) are mixed with sand and placed in mould boxes surrounding the pattern halves. At room temperature, the moulds become rigid with the help of catalysts. The pattern halves are removed and the mould is assembled with or without cores.

Advantages

- Most ferrous / non-ferrous metals can be used.
- Adaptable to large or small quantities
- High strength mould
- Better as-cast surfaces.
- Improved dimensional repeatability
- Less skill and labour required then in conventional sand moulding.
- Better dimensional control.

Disadvantages

- Sand temperatures critical.

* Patterns require additional maintenance.

3.3 RESIN SHELL MOULDING

Resin-bonded silica sand is placed onto a heated pattern, forming shell-like mould halves. Pattern halves are bonded together with or without cores.

Probably the earliest, most automated and most rapid of mould (and core making) processes was the heat-curing technique known as the shell process.

Ejector pins enable the mould to be released from the pattern and the entire cycle is completed in seconds depending upon the shell thickness desired. The two halves of the mould, suitably cored, are glued and clamped together prior to the pouring of the metal. Shell moulds may be stored for long periods if desired. Because of pattern costs, this method is best suited to higher volume production.

Advantages

- Adaptable to large or medium quantities
- Most ferrous / non-ferrous metals can be used.
- Rapid production rate.
- * Good dimensional casting detail and accuracy.
- Shell moulds are lightweight and may be stored almost indefinitely.

Disadvantages

- Since the tooling requires heat to cure the mould, pattern costs and pattern wear can be higher.
- Energy costs are higher.

* Material costs are higher than those for green sand moulding.

3.4 PERMANENT MOULD

Permanent moulds consist of mould cavities machined into metal die blocks and designed for repetitive use. Currently, moulds are usually made of cast iron or steel, although graphite, copper and aluminium have been used.
Permanent mould castings can be produced from all of the metals including iron and copper alloys, but are usually light metals such as zinc-base, magnesium and aluminium.

Gravity Permanent Mould
The flow of metal into a permanent mould using gravity only is referred to as a gravity permanent mould. There are two techniques in use: static pouring, where metal is introduced into the top of the mould through sprues similar to sand casting; and tilt pouring, where metal is poured into a basin while the mould is in a horizontal position and flows into the cavity as the mould is gradually tilted to a vertical position.
Normally, gravity moulding is used because it is more accurate than shell moulding. It is preferred almost exclusively to shell moulding for light alloy components.

Low-Pressure Permanent Mould
Low-pressure permanent mould is a method of producing a casting by using a minimal amount of pressure (usually 5-15 lb/sq in.) to fill the die. It is a casting process that helps to further bridge the gap between sand and pressure die casting.

Advantages

- Superior mechanical properties.
- Produces dense, uniform castings with high dimensional accuracy.
- Excellent surface finish and grain structure.
- The process lends itself very well to the use of expendable cores and makes possible the production of parts that are not suitable for the pressure die casting process.
- Repeated use of moulds.
- Rapid production rate with low scrap loss.

Disadvantages

- Higher cost of tooling requires a higher volume of castings.
* The process is generally limited to the production of somewhat small castings of simple exterior design, although complex castings such as alumini um engine blocks and heads are now commonplace.

3.5 DIE CASTING

This process is used for producing large volumes of zinc, aluminium and magnesium castings of intricate shapes. The essential feature of die casting is the use of permanent metal dies into which the molten metal is injected under high pressure (normally 5000 psi or more).

The rate of production of die casting depends largely on the complexity of design, the section thickness of the casting, and the properties of the cast metal. Great care must be taken with the design and gating of the mould to avoid high-pressure porosity to which this process is prone.

Advantages

- Cost of castings is relatively low with high volumes.
- High degree of design complexity and accuracy.
- Excellent smooth surface finish.
- * Suitable for relatively low melting point metals (1600F/871C) like lead, zinc, aluminium, magnesium and some copper alloys.
- High production rates.

Disadvantages

- Limits on the size of castings - most suitable for small castings up to about 75 lb.

* Equipment and die costs are high.

3.6 INVESTMENT CASTING – LOST WAX CASTING

Investment Casting is the process of completely investing a three-dimensional pattern in all of its dimensions to produce a one-piece destructible mould into which molten metal will be poured. A refractory slurry flows around the wax pattern, providing excellent detail.

The wax patterns are assembled on a "tree" and invested with a ceramic slurry. The tree is then immersed into a fluidized bed of refractory particles to form the first layer of the ceramic shell. The mould is allowed to dry and the process repeated with coarser material until sufficient thickness has been built up to withstand the impact of hot metal.

When the slurry hardens, the wax pattern is melted out and recovered and the mould or ceramic shell is oven cured prior to casting.

Most materials can be cast by this process but the economics indicate that fairly high volume is necessary and the shape and complexity of the castings should be such that savings are made by eliminating machining.

Advantages

- Excellent accuracy and flexibility of design.
- Useful for casting alloys that are difficult to machine.
- Exceptionally fine finish.
- Suitable for large or small quantities of parts.
- Almost unlimited intricacy.
- Suitable for most ferrous / non-ferrous metals.
- No flash to be removed or parting line tolerances.

Disadvantages

- Limitations on size of casting.
- Higher casting costs make it important to take full advantage of the process to eliminate all machining operations.

3.7 EXPENDABLE PATTERN – LOST FOAM CASTING

Also known as Expanded Polystyrene Moulding or Full Mould Process, the EPC or Lost Foam process is an economical method for producing complex, close-tolerance castings using an expandable polystyrene pattern and non-bounded sand.

The EPC process involves attaching expandable polystyrene patterns to an expandable polystyrene gating system and applying a refractory coating to the entire assembly. After the coating has dried, the foam pattern assembly is positioned on several inches of loose dry sand in a vented flask. Additional sand is then added while the flask is vibrated until the pattern assembly is completely embedded in sand.

A suitable sprue is located above the gating system and sand is again added until it is level to the top of the sprue. Molten metal is poured into the sprue, vaporizing the foam polystyrene, perfectly reproducing the pattern. Gases formed from the vaporized pattern permeate through the coating on the pattern, the sand and finally through the flask vents.

In this process, a pattern refers to the expandable polystyrene or foamed polystyrene part that is vaporized by the molten metal. A pattern is required for each casting.

Advantages

- No cores are required.
- Reduction in capital investment and operating costs.
- Closer tolerances and walls as thin as 0.120 in.
- No binders or other additives are required for the sand, which is reusable.
- Flasks for containing the mould assembly are inexpensive, and shakeout of the castings in non-bounded sand is simplified and do not require the heavy shakeout machinery required for other sand casting methods.
- Need for skilled labour is greatly reduced.
- Casting cleaning is minimized since there are no parting lines or core fins.

Disadvantages

- The pattern coating process is time-consuming, and pattern handling requires great care.
* Good process control is required as a scrapped casting means replacement not only of the mould but the pattern as well.

3.8 VACUUM PROCESS MOULDING V-PROCESS

This adaptation of vacuum forming permits moulds to be made out of free-flowing, dry, non-bounded sand without using high-pressure squeezing, jolting, slinging or blowing as a means of compaction. The V-process is dimensionally consistent, economical, environmentally and ecologically acceptable, energy thrifty, versatile and clean.

The moulding medium is clean, dry, non-bounded silica sand, which is consolidated through application of a vacuum or negative pressure to the body of the sand. The patterns must be mounted on plates or boards and each board is perforated with vent holes connected to a vacuum chamber behind the board. A preheated sheet of highly flexible plastic material is draped over the pattern and board. When the vacuum is applied, the sheet clings closely to the pattern contours. Each part of the moulding box is furnished with its own vacuum chamber connected to a series of hollow perforated flask bars. The pattern is stripped from the mould and the two halves assembled and cast with the vacuum on.

Advantages

- Superb finishes.
- Good dimensional accuracy.
- No defects from gas holes unless from cores.
- All sizes and shapes (complex shapes are solved with cores)of castings are possible
- Most ferrous / non-ferrous metals can be used.

Disadvantages

- The V-process requires plated pattern equipment
- Difficult to make automatic
- Film applying must be trained
- Complex shapes needs extra cores
- No blind risers possible.

3.9 CENTRIFUGAL PROCESS MOULDING

The Centrifugal Casting process consists of a metal or graphite mould that is rotated in the horizontal or vertical plane during solidification of the casting.

Centrifugal force shapes and feeds the molten metal into the designed crevices and details of the mould. The centrifugal force improves both homogeneity and accuracy of the casting.

This method is ideally suited to the casting of cylindrical shapes, but the outer shape may be modified with the use of special techniques. The Centrifugal Casting process consists of a metal or graphite mould that is rotated in the horizontal or vertical plane during solidification of the casting. Centrifugal force shapes and feeds the molten metal into the designed crevices and details of the mould. The centrifugal force improves both homogeneity and accuracy of the casting.

This method is ideally suited to the casting of cylindrical shapes, but the outer shape may be modified with the use of special techniques.

Advantages

- Rapid production rate.
- Suitable for Ferrous / Non-ferrous parts.
- Good soundness and cleanliness of castings.
- Ability to produce extremely large cylindrical parts.

Disadvantages

* Limitations on shape of castings. Normally restricted to the production of cylindrical geometric shapes.