IC LEARNING SERIES

Foundry Practice

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Foundry Practice

Objectives:

✔ To understand the fundamental principles and basic operations of industrial used casting processes.
✔ To be conversant with the commonly used terminology in casting industry.
✔ To recognize the importance of safety in a foundry and execute proper safety measures in carrying out casting processes.

1. Introduction

This foundry workshop training aims to provide students good appreciation of commonly used industrial casting technologies. The applications, limitations, advantages and the common industrial practices in obtaining integrity metal castings will be addressed throughout this training.

In the training students will acquire both theoretical and limited empirical casting knowledge by short lectures, group discussions and individual hand-on practices. Students can benefit the most by active interactions with our staff members and self-exploration while doing the casting exercises.

1.1 Foundry Industry

Foundry is a manufacturing factory where ferrous or non-ferrous metals are melted and poured into moulds to form metal castings. Usually, a foundry consists of design, patternshop, moulding, furnaces, heat treatment, machining, inspection and testing facilities customized for production run of one piece to a million metal parts.

Casting is the process of producing near net-shape metal components, steps involve melting of metal alloy, pour or force the molten metal into a cavity; normally call mould or die, left it cool and finally casting is taken out from mould. Although there are only a few steps involved, casting is a sophisticated manufacturing process and required detail planning, execution and inspection to ensure not only the physical features but also the metallurgical integrity of the castings that are typically used in engineering structures demanding high static or cyclic load bearing of temperature, pressure or mechanical forces. All those steps needed to be planned and controlled correctly and simultaneously. Incorrectness of any one step will probably cause failure of the castings.
1.2 Foundry Safety

Safety is a critical concern in a foundry. Since one minor mistake can make serious consequence which is deathful and irrevocable. Foundry accident normally influences not only the operator, but also the surroundings and the family members of the injurers. One of the most important safety rules in a foundry is never put water-containing object into melting furnace, explosive power of one pound of aluminium melt is equivalent with 3 pounds of TNT / 7.5 pounds of normal bomb, if water is contacted with the melts accidentally.

Therefore, preventive safety measures are essential and more valuable than post-actions to save the human life. Therefore, wear proper Personal Protective Equipment (PPE), pre-heat ingots and casting ladle, check machinery and tools regularly, are all important preventive safety measures in a foundry. In addition, never touch any castings if you are not sure whether they are cool.

![Fig. 1.1 PPE commonly used in foundry; from left to right: heat resistant glove, safety shoe, leather apron, face shield.](image)

1.3 Types of Casting

Casting processes can be simply divided into 3 categories; continuous casting/ingots casting, expendable mould and permanent mould casting. Expendable Mould processes are further categorized as permanent pattern and expendable pattern processes. Figure 1.2 shows the classification of typical industrial used casting processes.

![Fig. 1.2 Classification of typical casting processes](image)
1.4 Types of metal

<table>
<thead>
<tr>
<th>Metal</th>
<th>Density (g/cm³)</th>
<th>Melting Temperature (°C)</th>
<th>Typical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg</td>
<td>1.74</td>
<td>650</td>
<td>Light weight, good high temperature mechanical strength</td>
</tr>
<tr>
<td>Al</td>
<td>2.70</td>
<td>660</td>
<td>High strength-to weight ratio, chemical resistance</td>
</tr>
<tr>
<td>Ti</td>
<td>4.50</td>
<td>1800</td>
<td>Excellent strength-to weight ratio, fatigue strength and corrosion resistance</td>
</tr>
<tr>
<td>Zn</td>
<td>7.1</td>
<td>419</td>
<td>Good stiffness and mechanical strength, low corrosion resistance</td>
</tr>
<tr>
<td>Sn</td>
<td>7.29</td>
<td>232</td>
<td>Soft, easy to alloy with other metal, high boiling temperature</td>
</tr>
<tr>
<td>Fe</td>
<td>7.86</td>
<td>1530</td>
<td>Usually alloying with carbon to form steel, cast iron. High tensile strength.</td>
</tr>
<tr>
<td>Cu</td>
<td>8.94</td>
<td>1083</td>
<td>Good thermal and electrical conductivity, excellent wear and corrosion resistance</td>
</tr>
<tr>
<td>Ag</td>
<td>10.50</td>
<td>961</td>
<td>Excellent electrical conductivity</td>
</tr>
<tr>
<td>Pb</td>
<td>11.37</td>
<td>327</td>
<td>Soft, easy to alloy with other metal, toxic</td>
</tr>
<tr>
<td>Au</td>
<td>19.32</td>
<td>1063</td>
<td>Excellent ductility</td>
</tr>
</tbody>
</table>

1.4.1 Metal Alloy

Almost all metal components exists in our daily life are in alloy state as the physical properties of pure metal is usually insufficient to withstand most engineering applications. Alloy can be simply described as a mixture of two or more metal elements to form a metallic matrix. Proper alloying, mechanical strength of a metal can be enhanced significantly. In additions of physical properties improvement, the fluidity of molten metal can also be improved by adding proper elements. The following will describe some fundamental concepts of alloying.

**Solid Solution** can be simply described as the minor element which is added to the major element but unchanged its crystal structure. Minor element is solute (i.e. Silicon) and major element is solvent (i.e. Aluminum). If the size of the solute atom is similar to that of the solvent atom, the solute atoms can replace solvent atom...
and form a substitutional solid solution. Interstitial solid solution is formed if the size of the solute atom is much smaller than that of solvent atom.

**Phase Diagram**, also called equilibrium diagram, is a graphical presentation to show the relationship among temperature, composition, and the phase present in a particular alloy system. A typical iron-carbon phase diagram is shown in figure 1.3

![Typical iron-carbon phase diagram](Source: calphad.com)

**Impurities**, also refers to slag and inclusions, is those unwanted element existed in solid solution which affect significantly engineering properties of an alloy after solidification. Impurities are normally generated by oxidation of melts and reaction among melts and crucible, ladle, etc.. For steel casting, some elements are harmful to the melts and should not introduce to iron, i.e. lead, chromium, aluminum. Basicity of the slag may be controlled by adding CaO in the form of lime.

**1.4.2 Ferrous metal: Steel, Cast Iron, Stainless Steel**

**Steel** is the alloy of iron and carbon, or other element such as manganese, chromium, vanadium and tungsten, etc. But carbon is the major element to improve hardness of iron. Low carbon steel, (medium carbon) mild steel and high carbon steel represents different amount of carbon content inside the alloy in the range of 0.2-1.7%. The strength and hardness of steel can be enhanced by increasing of carbon content but it will become more brittle also.

**Cast Iron** usually refer to gray iron, is actually high carbon content (2.1-4%) iron alloy with additional 1-3% of silicon ingredient. Cast iron has relatively lower melting temperature comparing with pure iron, excellent machinability and wear resistance, it is therefore extensively be used in high-load application such as machinery basement, manhole cover, etc.

**Stainless steel** possesses superior ant-rusting ability / corrosion resistance which differs from common carbon steel, is because of the existence of chromium. This
protection is actually caused by a passive film of chromium oxide generated and which prevents further surface corrosion and blocks corrosion from spreading into the metal’s internal structure.

1.4.3 Non-ferrous metal: Copper based, Zinc, Pewter, light metals: magnesium, aluminum, titanium

Brass is an alloy of copper and zinc, a typical composition being 60% copper and 40% of zinc. Most brasses have good corrosion resistance. The addition of a small amount of tin produces excellent resistance to sea-water corrosion. A small amount of lead can be added to improve machinability of the alloy.

Bronze is an alloy of copper and tin, which are normally more expensive than brass because of the high price of tin. Bronze usually contains less than 12% of tin. Apart from tin; aluminum, zinc, lead, phosphorous etc. are also present in many types of bronze. They are characterized by good strength, toughness, and wear and corrosion resistance. Typical applications include bearings, gears, and fittings which are subjected to heavy compressive loads.

Zinc is a low melting point metal that has good mechanical strength and is relatively inexpensive. It is considerable importance because of its extensive use in die casting. Typical examples include door handles, radiator grills, motor mounts, etc.

Pewter is a Tin-based alloy, copper, antimony are the basic elements combined with tin to form the pewter. It is worth to be pointed out that, because of the RoHs regulation, the existing used pewter composition has been changed to Tin-cupper-antimony based instead of the original tin-lead based.

Aluminum alloy is light weight, high thermal and electrical conductivities, and corrosion resistance. There are many types of aluminum alloy used for casting. Silicon, copper and magnesium are the main element added to enhance strength and hardness. Aluminum-based cast alloys have many application, including automotive engine blocks, architectural, decorative, aerospace and electrical.

Magnesium is lighter than aluminum; density is only 2/3 of aluminum, it has very good mechanical properties even in high temperature application environment. Therefore it has widely been used in automotive, aerospace, and 3C product applications.

Remark: 3C stand for consumable, computers and communications

Titanium alloy has excellent strength-to-weight ratio, corrosion resistance at room and elevated temperature, it is most suitable for high loading applications such as aircraft components, jet-engine, racing car, etc. Since titanium does not react within the human body, it is usually used to create artificial hips, pins for setting bones and for other biological implants. While nickel is alloyed with titanium, it can possess the shape memory effect.
2. Sand Casting

2.1 Process Description

Sand casting is one of the traditional casting methods fabricating metal parts. The sand cast part is produced by forming a mould from a sand mixture and pouring molten liquid metal into the cavity in the mould. A pattern, with a shape very similar to the desired casting, is first placed in sand to make an imprint. A gating system is incorporated and the resultant cavity is filled with molten metal. After the melts cool and solidify, casting can then be obtained by broken the sand mould. Since the moulding material of sand casting is sand, rough surface and lack of dimensional accuracy are the intended results and therefore post machining and surface fishing is usually needed. Typical applications of sand casting are machine tool bases, engine blocks and cylinder heads.

2.2 Casting Mould

A sand casting mould usually consists of two mould pieces, the upper section is named Cope and the lower section is named Drag. Sand core is a preformed sand aggregate inserted in a mould to shape the interior or that part of a casting that cannot be shaped by the pattern. It may have to be broken in order to remove it afterwards. Flask is a frame, normally made by metal or wood, as the main structure to carry the sand and avoid looseness of sand while assembling of the mould halves. Figure 2.1 shows a typical sand casting mould.

![Fig. 2.1 Cross section view of a sand mould assembly](Source: American Foundrymen’s Society)
2.3 Filling and Feeding System

Molten metal is filled into the moulding cavity from pouring cup through a series of filling channels which is called filling/runner system. Feeding is the process after filling up of liquid metal till to freezing of melts. Both of them are curtail for getting good quality of castings. A proper designed runner system can eliminate generation of casting defects such as porosity, inclusion, etc. and feeding mechanism is mainly to deal with shrinkage problems.

Sprue, runner and gate are the basic components of a runner system. Riser is a typical feeding mechanism. Figure 2.2 shows a typical example of riser-gated casting and the functions of the filling and feeding components are further explained as below;

**Sprue** is a vertical channel though which the molten metal flows downward in the mould.

**Runners** channels that carry the molten metal from the sprue to the mould cavity.

**Gate** is the portion of the runner though which the molten metal enters the mould cavity.

**Risers** serve as reservoirs, supplying molten metal to the casting as it shrinks during solidification. Top riser is attached directly at top position of casting and side riser normally attached near the gates.

![Schematic illustration of a typical riser-gated casting](Source: American Foundrymen's Society)
2.4 The Moulder’s Tools

In spite of automation has widely been utilized in modern foundry to improve the productivity as well as better control the casting quality, manual fabrication of sand mould is still the most suitable and flexible approach if small quantity of casting is needed. The following introduce the most commonly used hand tools for making sand mould manually; figure 2.3 shows the corresponding pictures of them.

**Round Nose Trowel** - It is used for general trowel of the moulding sand to sleek down a surface, to repair a surface, or cut away the sand around the cope of a snap flask.

**Rammer** - A ramming tool used to compress sand around the pattern, and around the inside of the flask. Peen rammer is utilized to compress the sand inside the flask whereas flat rammer is used at the end to flat the top surface of mould.

**Slicker Spoon** - A small spoon shaped tool used for contouring of the mold such as cutting the pouring basin or shaping the gates.

**Lifter/Cleaner** - The lifter is a simple steel tool with a right angled square foot on one end of a flat bent blade. It is used to repair sand moulds and lift out any tramp or loose sand that might have fallen into a pocket.

**Spatula** - The spatula is a general use moulding tool used for slicker flat surfaces.

![Fig. 2.3 Common tools for sand casting – (a) round nose trowel, (b) peen rammer, (c) flat rammer, (d) slicker spoon, (e) lifer/cleaner, (f) spatula](image)

2.5 Master Pattern

In casting, a pattern is an exact representation of the item you wish to cast. It is typically made out of wood, plastic, or metal. And it is the tool which the sand is compressed around, to form the cavity of the mold.
If the object is hollow or has parts with holes or other empty spaces, a core is needed to be made. The core is inserted into the mould so that the casting can take appropriate shape and that metal does not fill in area that should be left empty. The core is collapsible so it can be removed after the casting process without any damage to the finished product.

Pattern design can be treated as a series of transformations starting from the product shape to finally obtain the shape corresponding to the mould cavity. Below are some important factors on the pattern design that must be considered:

2.5.1 Shrinkage Factor

Shrinkage factor is an allowance intended to compensate for the shrinkage of metal when cooled from its molten state to solid state. Their exact values depend on the alloy being cast and exact casting method being used. The following are the linear shrinkage allowances of commonly used metal alloy:

- Cast Iron   0.8-1%
- Steel       1.5-2%
- Aluminum Alloy  1.2-1.4%
- Bronze      1.2-1.4%
- Brass       1.5%

2.5.2 Draft

Draft is one of the most important features of a pattern. It is what allows the pattern to be removed from the mould without damaging the delicate cavity formed by the pattern. The amount of draft is determined by the size and shape of the pattern. It is also known as taper and draft angle is between 1 and 3 degrees typically.

![Fig. 2.4 Taper on patterns for ease of removal from the sand mould](Source: Manufacturing Engineering and Technology, Serope Kalpakjian, Steven R. Schmid, Upper Saddle River, NJ : Prentice Hall, 2001)

2.5.3 Fillet

All sharp corners and edges of the pattern must be rounded so that it can be take out of the sand without dislodging any sand grains. Indeed, it is not only ease for the mould making process but also benefit to the casting that no stress concentration will be left after solidification of workpiece.
2.5.4 Machining Allowance

Machining allowance is a small amount of material which is added to the pattern in areas where it will be machined in order to meet exacting standards. The amount of allowance depends on the dimensional tolerance achieved by the process, sub-surface quality, part size and the type of machining.

2.6 Casting Sand

Obviously, sand is the major raw material for sand mould making, but different ingredients are required to add such that the sand particles can be adhered together to form a rigid mould. The following section introduces three type of sand; include green sand, resin-sand and CO₂-sand that are commonly used in casting industry.

2.6.1 Green Sand

The most common method used to make metal casing is green sand moulding. “Green sand” is a mixture of silica sand / zircon sands, bentonite clay, moisture and other additives. The additives help to harden and hold the mould shape to withstand the pressures of the molten metal. The moisture contents have to control in around 7%, too dry or too wet of sand mixture are also not suitable. The “Green sand” mixture can be compacted by hand or through mechanical force around a pattern to create a mould. It is the least expensive method of making moulds.

2.6.2 Resin-Sand

Resin-sand is a mixture of sand and 2.5%-4% of thermoset resin binder. The binder coats the sand particles altogether and it become hard and bond the sand particles together once head applied. Resin-sand mould has better dimensional accuracy than green sand mould but is more expensive. Therefore, it is usually utilized for producing sand core instead of cope and drag.

2.6.3 CO₂-Sand

CO₂-Sand is a mixture of sand and 3-4% sodium silicate (waterglass). Moulding procedures are similar to that of the green sand process. However, after removal of the pattern, the mould is hardened by blowing of carbon dioxide gas via a tube. Since no heat is involved it is called a cold-setting process.
2.7 Mass Production Machinery

2.7.1 Sand Muller

As explained, to bond the sand particles together additives, such as water, fire clay, are needed to be added. All of the ingredients are required to be mixed again if the mixture has been used or new additives were refilled. For mass production, sand muller is employed to prepare green sand mixture whereas sand mixer is used for small scale production. Figure 2.5 shows a typical configuration of industrial used sand muller.

![Fig. 2.5 Schematics of continuous (left) and batch-type (right) sand muller. Plow blades move the sand and the muller wheels mix the components](Source: ME364 Manufacturing Technology lecture notes, Mechanical Engineering Department of Eastern Mediterranean University)

2.7.2 Semi-Automatic Moulding Machine

Semi-automatic moulding machine uses high static squeeze force and high dynamic squeeze force to make the mould uniformly. It can make full use of sand and maintain the quality of mould. Therefore, the mould preparation costs can be reduced when large production of casting is needed. Figure 2.6 shows a typical semi-automatic moulding machine and a set of core pattern.

![Fig. 2.6 Left; semi-automatic Machine, Right; core pattern plate](Source: ME364 Manufacturing Technology lecture notes, Mechanical Engineering Department of Eastern Mediterranean University)
2.8 Casting Defects

Defects can be as simple as broken or loose sand, or more complicated like gas bubbles. In any case, it doesn't look good, and it may make the casting part useless. Seven types of casting defects, which are developed and recognized by The International Committee of Foundry Technical Associations, are illustrated in the following; typical examples of them are shown in figure 2.7.

2.8.1 Metallic Projections

Metallic projections consist of joint flash or fins. They are very common defects in casting. It is caused by the mould somehow separated to allow metal filled between the halves, along the parting line. But it can be broken off with a hammer or pliers since the thickness of flash usually less than 3mm.

2.8.2 Cavities

Cavities consist of rounded or rough internal or exposed cavities such as blowholes and pinholes. They are produced because of gas entrapped in the metal during the course of solidification. This defect can appear in all regions of the casting.

2.8.3 Discontinuities

A discontinuities defect such as cracks often scarcely visible because the casting in general has not separated into fragments. The fracture surfaces may be discolored because of oxidation. The design of the casting is such that the crack would not be expected to result from constraints during cooling.

2.8.4 Defective Surface

Defective surface such as flow marks. It appears as lines which trace the flow of the streams of liquid metal.

2.8.5 Incomplete Casting

Incomplete casting is usually caused by the metal solidifying before it fills the cavity. It could also be a restriction: too small a sprue, gate, or not enough venting keeping the metal from going in.

2.8.6 Incorrect Dimensions or Shape

It is due to factors such as improper shrinkage allowance, pattern mounting error, irregular contraction, deformed pattern or warped casting. And the mould shift may be caused by the mismatch of mould halves at the parting line, not aligning the mould correctly. Most flasks have alignment pins to prevent this defect.
2.8.7 Inclusions

Inclusions forms during melting, solidification, and moulding, generally non-metallic are considered harmful because they are stress raisers. These defects most often appear after machining.

![Examples of common defects in castings](https://via.placeholder.com/150)

(a) flash, (b) porosity, (c) short casting, (d) mould shift, (e) inclusions

(Source: Association of Backyard Metalcasters)

3. Die Casting

3.1 Process Description

Die casting is a mass manufacturing processes for producing engineered metal components in near net shape with closed dimensional accuracy. The name “Die Casting” imply that the metal mould which are called die. The dies are normally made of special tooling steel with surface hardening treatment such that its can withstand repeated high pressure injections of molten metal. Hot chamber and cold chamber die casting are the most commonly used industrial processes for making metal components, while thixomoulding is the integration of die casting and injection moulding which is developed for producing high quality magnesium alloy components.

3.2 Hot Chamber Die Casting

Hot chamber machine is primarily designed for low melting point alloy, i.e. zinc alloy that do not attack and react with the melting furnace, cylinder and plunger. The melting furnace is accompanied with the machine which is connected together by a feeding system called gooseneck (figure 3.1).
After the die assembly close, the injection plunger move upward and allowing molten metal to fill in the cylinder, the plunger then move downward to force the molten metal into the die cavity via the gooseneck. After solidification of metal alloy, die opens and the casting is ejected. Since hot chamber machine is mainly used for producing low melting point metal components, the cycle time of one shot can be as short as a few seconds. To further enhance the productivity and reduction of cost, multi-cavities approach is normally applied.

Fig. 3.1 Schematic diagram of hot chamber die casting machine

### 3.3 Cold Chamber Die Casting

In contrast with hot chamber machine, the primarily objective of cold chamber die casting machine is utilized for producing high melt point metal part, i.e. brass and bronze, or for those alloy highly reactive with iron, i.e. magnesium and aluminum alloy. The melting furnace is separated to the casting machine and therefore robotic feeding system is normally incorporated to the machine to ladle molten metal to the cylinder, plunger then force the melts into the die horizontally to shape the parts. Likes as hot chamber process, parts can then be ejected after cooling and solidification.

Fig. 3.2 Schematic diagram of cold chamber die casting machine

(Source: Courtesy of Foundry Management and Technology)
3.4 Thixomoulding

Thixomoulding is an advance casting technology designed for producing high quality magnesium casting parts. The processes of thixomoulding is similar to plastic injection moulding machine in which raw material (clips of metal alloy) are fed into a hopper, metal clips are melted inside a heating barrel and transfer to the front of nozzle by a feeding screw. Accumulated molten metal slurry in semi-solid state is then injected into a metal die like as the processes of injection moulding, parts are ejected after solidification at the end of the processing cycle.

Since the casting temperature of melt is much lower than conventional die casting process, thixomoulded part have less shrinkage and higher dimensional accuracy comparing with die cast components. The drawbacks of thixomoulding are high investment cost for initial setup, lack of material options (i.e. Magnesium alloy only) and high material cost.

![Fig. 3.3 Schematic diagram of Thixomoulding-machine](Source: The Neue Materialien Fürth GmbH)

4. Investment Casting

4.1 Process Description

Investment casting is one of the oldest manufacturing methods producing precise metal components. It is equivalent to lost wax casting and precision casting also. Castings produced by this method are found in many applications in dentistry, jewellery, aerospace and orthopaedic surgery. As the name lost-wax casting implied, the pattern normally made by wax and which is dissolved and create a moulding cavity for metal casting.

For mass production, the wax patterns are produced by injection moulding while vacuum casting is employed if small quantity is needed. The latest Rapid Prototyping technologies such as SLA, SLS are utilized to produce scarified pattern for prototyping uses. Two different mould making methods in investment casting are shell mould and solid plaster mould. Shell mould approach is normally for
mass production whereas solid mould is for prototyping. In addition of shell mould and solid mould approach, lost foam casting is another type of investment casting which use Expandable Polystyrene (EPS) form model as the scarified pattern, and metal casting is produced by directly pouring the melt to the foam model.

![Mold to make pattern](Image)

Fig. 4.1 Schematic illustrations of investment casting processes; shell mould approach

(Source: Steel Founder’s Society of America)

### 4.2 Shell Mould

Injected/cast wax patterns attached together with a wax cluster (melt input) to form an assembly, named wax-tree, is dipped into a slurry of refractory material, then it is sprinkled with coarse ceramic particle i.e. zirconium sand, to form a layer of ceramic coating. The above steps are repeated until sufficient thickness of shell (usually 5-15mm depends on the weight of casting) achieved. Since every layer is required to be dried completely by placing inside a dehumidifying room for at least several hours, it normally takes 3-5 days for preparing the investment mould. The advance far-inferred technology is being used to speed up the drying process such that the mould drying time can be reduced to several hours;

After the cluster is thoroughly dried, it will be placed upside-down into a dewaxing furnace or autoclave for melting out the wax material. The hollowed ceramic shell is then transferred to a furnace between 870 – 1095°C for several hours for sintering. Slowly cooling down the shell to the desired temperature, melts is then poured into the cavity, after solidification, metal parts can be achieved by breaking the shell manually or pneumatic hammer.
4.3 Block Mould

Moulding material of block mould is different from shell mould which uses plaster instead or ceramic, therefore it is not suitable for high temperature metal casting, i.e. stainless steel, titanium alloy; it is suitable for non-ferrate metal casting only. The previous steps of preparing the master pattern is same as shell mould, the wax tree attached to a base and installed inside a metal flask will be placed into a vacuum machine for embedding of investment, refers fig 4.2. Weighted amount of investment powder and water are mixed together and poured into the flask, the mixing process should be carried out inside a vacuum chamber to minimize gases exist. It also works for placing again the flask into vacuum chamber for degassing if facility is not available but processing time should be well controlled since the investment slurry will be cured in about 10 minutes. The solidified solid mould is then placed into furnace for dewaxing and sintering. Time for burning solid mould is longer than shell mould, it needs to ramp up slowly (50°C per hour) from 150°C to about 700°C for completely sintering of the mould, it will be cracked if the temperature ramp up is too high. In general, the burning cycle is in between 15 – 30 hours depending on the size of mould.

![Figure 4.2](image)

Fig. 4.2  Solid plaster mould, left: multi-pattern wax tree, middle: metal flask uses for embedding of investment, right: completed casting

4.4 Lost Foam Casting

Lost foam casting is a type of investment casting process that uses foam patterns as the sacrificed pattern to produce metal parts and it is used particularly for automotive applications. LFC is a “cavities” metal casting technique since no tooling/mould is needed. Figure 4.3 shows step by step procedure of lost foam casting processes. Firstly, foam patterns, made by Expandable Polystyrene (EPS) are assembled with glue and forming a cluster like an investment casting. Then, the foam cluster is covered with a thin layer of heat resistant coating by dipping, spraying or pouring. The coating forms a barrier so that the molten metal does not penetrate or cause sand erosion during pouring. After the coating dries, the cluster is placed into a flask and filled with bonded sand, the flask need to be vibrated during filling of sand to obtain proper compaction. Molten metal is then poured into the mould, the pattern vaporizes, and the cavity is filled and replaced by metal.
5. Spin Casting

5.1 Process Description

When a short production run is required within a limited time for low melting points alloys such as pewter and zinc, spin casting process is perfect suit for this situation. The spin casting mould is made by high temperature resistant vulcanized silicone rubber which can last for 200-250 shots depending on the alloy to be cast.

Firstly, prepared master patterns, normally made by metal, are laid and arrayed circularly in a mould disc surrounding with interlocking pins. Mould release agent should be sprayed/brushed on the parting surfaces; moulding material will be stuck together after vulcanization and patterns cannot be removed otherwise.

The mould installed in a metal flame will then be placed into a hydraulic and electrically heated vulcanizer for curing. The curing time and temperature is determined by the thickness of mould, size of mould and the type of rubber to be used, common practice is 60~75 minutes per inch. Compression pressure of mould is determined by the size of mould, i.e. 2000~3000psi for 9 inch mould.
After vulcanization, mould separates, runner system and vents are cut by scalpel or sculptural knife. For common practice, the runner system will not be cut by one time. Instead, it will be modified after several shots to obtain the optimized result and air vents will be opened at the end.

The spinning speed and clamping pressure is adjusted previously according to the size and thickness of mould disc. The mould is then placed into spin casting machine, start rotating, pouring melts and parts can be removed from mould disc after solidification of melts.

6. Inspection and Testing of Casting

Quality control is very important for casting component since most casting components are designed for high-loads applications and existence of defects will reduce the parts strength significantly. A qualified metal casting is normally needed to fulfill different aspects; physical completeness, mechanical properties, dimensional tolerance, composition of alloy. The following introduces the commonly used inspection and testing techniques for casting components.

6.1 Mechanical Testing and Dimensional Inspection

After casting, metal components have to go through a series of mechanical test by 100% inspection or sampling depending on the requirement of the product. Typical mechanical tests include tensile test, hardness test, and impact test. Some foundries perform hardenability test as well as such specialized function as evaluation of wear, corrosion, fatigue and creep tests.

In addition of mechanical properties, the concentration of particular alloy element can be analyzed by the technique of atomic absorption spectroscopy (AAS). It is indeed an inspection technique widely be utilized in analytical chemistry and plating industry.

For external dimensional measurement, simply linear measurement can be performed by vernire caliper or micrometer, whereas coordinate measuring machine (CMM) is used for higher precision measurement.

6.2 Metallographic inspection

Metallographic inspection is a process employed to determine character of the microstructure, defects and segregation of alloying elements with the naked eye or under low magnification. A specimen need to be prepared by grinding and polishing the surface, special solvent is then applied on the surface for etching. After preparation, it is usually analyzed using optical or electron microscope. Figure 6.1 shows two microstructure of steel images which are captured by Scanning Electron Microscope (SEM).
6.3 Non destructive testing (NDT)

NDT is a testing approach to check the external or internal defects of a casting unnecessary to destroy the workpiece. Commonly industrial used NDT techniques include;

Dye-penetrant technique – dye penetrate is applied on the metal surface which is cleaned and dried, a developing agent is then applied to allow the penetrant to seep back to the surface. The surface is then inspected for defects, either visually or with fluorescent lighting.

Magnetic-particle technique – casting is first required to be magnetized by the application of high-amperage current. It is then put into a bin of iron powder, discontinuities (defects) on or near the casting surface generate highly localized magnetic field that attract iron powder particles to the site of discontinuities.

Ultrasonic inspection – an ultrasonic beam travels through the casting. An internal defect, such as a crack, interrupts the beams and reflects back a portion of the ultrasonic energy. The amplitude of energy reflected and the time required for return indicate the presence and location of the flaws in the casting.

Radiography inspection – it has become the major NDT method for determining the presence of internal defects of a casting. It employs X-ray to detect internal flaws or variations in the density and thickness of the part.
References

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Recommended Readings