

Aluminium Foundry Practice

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Fabrication processes are used to shape, machine and join metals. The metal which is operated is in the form of an ingot obtained by reducing or refining the metal ore. The fabrication processes are basically casting, forging, metal machining, metal joining and finishing. Fabrication of parts with other methods is time consuming. Casting is a fast way to produce the desired shape. Three steps are involved in a casting process: 1) heating metal till it becomes molten 2) pouring molten metal into a mould 3) allowing the metal to cool and solidify in the shape of the mould. Casting is used in the automobile industry to produce engine blocks or cylinder heads. Metal casting is vital to our economy and security. Different metals are cast by many different processes for different applications. Cast metal products and processes offer advantages unavailable from products made by other metal forming and fabricating techniques.

Castings are used in areas like transportation, aerospace, defense, mining, construction, maritime, fluid power, & domestic household. Some cast components include: engine blocks, suspension parts for automobiles & fluid flow components like valves, pumps, pipes, and fittings. To cut the emissions there is a need to improve the fuel efficiency and make the vehicle lighter in weight. Non ferrous metal like aluminium is lighter than steel and has density one third of that of steel. Aluminium has a lower density of 2.7 gm/cc compared to 7.8 gm/cc of steel. Aluminum and aluminum alloys are lightweight with good corrosion resistance, ductility and strength.

Aluminium castings are more expensive than ferrous based castings. The greater use of aluminum can decrease vehicle weight, improve its performance and reduce fuel costs. Pure aluminium possesses relatively poor casting features and for this reason castings are prepared from aluminium alloys. The main alloying elements are silicon, copper, magnesium, zinc, etc. Aluminium silicon alloys have good casting and corrosion resistance properties. The fluidity increases with silicon addition. The addition of copper to aluminium increases its strength and hardness. The aluminium copper alloys are heat treatable and possess good machinability.

Melting Details

The process of melting consists of - A crucible filled with metal charge is placed in a furnace and the metal is allowed to melt. The molten metal is removed from the furnace and poured into a preheated mould. Sand mould or metallic mould can be used for collecting the molten metal. Aluminium alloys can be melted in direct or indirect fuel fired furnaces or in electrically heated furnaces like - crucible furnaces, reverberatory furnaces,

pot furnaces, induction furnaces. There are various types of industrial furnaces: Oil - Fired, Gas fired and electric. The furnaces can be stationary or tilting type.

A crucible is like a vessel which is used to hold the molten metal in a furnace. The crucible used is of clay graphite or silicon carbide. Silicon carbide crucible is more popular in industry because of its higher strength and higher heat conductivity. Clay graphite crucible is cheaper than silicon carbide crucible and is used in small foundries and educational institutes. Crucibles are made from mixtures of raw materials – graphite, silicon carbide and clays. Pitches and resins are used as binders. After the crucibles are prepared they are fired. Crucibles are available in different sizes.

A crucible should withstand the high temperatures of melting and the crucible material must have a higher melting point than that of the metal being melted. The crucibles are used for melting nonferrous metals like zinc, aluminum, brass / bronze, etc. Different metals should not be melted in the same crucible as it leads to melt contamination and it will alter the properties of the castings. Crucibles should be stored in a dry area. Moisture pick up by crucible can crack it on heating. Some times crucibles crack and molten metal can leak and splash on the person and it can short the coil causing damage to the furnace and hurt the person dealing with it. New crucibles should be baked before being used.

Electrical heating furnaces offers good melt quality and absence of products of combustion. They have heating elements in the form of coils or strips. The electric resistance furnace is mostly commonly heated with metallic elements. These furnaces are insulated with ceramic fiber and are of stationary or tilt types. The coreless induction furnaces are popular and are used in small foundries to the large foundries. Low to medium frequency induction coils transfer energy directly into the melt. Low and high frequency induction furnaces are used for the melting of nonferrous metals. In induction furnace melting is fast and combustion products are absent making minimum oxidation losses. In a coreless induction furnace a graphite crucible lined with suitable refractory is used for melting non ferrous metals. The coreless induction furnace can be tilted with a hand wheel or a motorized arrangement and the melt poured in moulds.

The aluminium/alloy scrap to be melted should be clean. The scrap should be preheated to remove any moisture. The crucible used for melting should be cleaned after each melt. All tools used in melting must be clean and dry to prevent pick up of moisture by the melt. Moisture in the moulding sand will cause porosity in the casting. The sand mould must be properly dried and preheated. Combustion gases, sand, tools, etc. containing H₂O may cause hydrogen absorption. Molten aluminium/alloys absorb gases giving a defective casting after solidification. The removal of gases is an important process in the metal casting field. Aluminium is degassed by passing N₂ gas slowly in the melt. A flux is used in melting aluminium. The flux forms a protective cover to minimize oxidation and absorption of the gases. A fine grained aluminium alloy has better strength and this is done by inoculating the melt with elements which form insoluble compound particles which will help to increase the rate of nucleation. Many types of grain refiners and fluxes are available in the market.



Crucibles



Electric furnaces

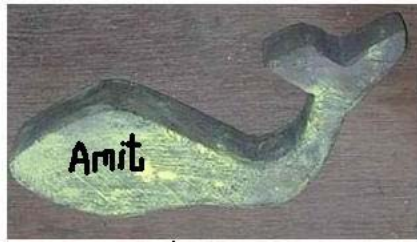
Preheated aluminium charge is added in the crucible. Once this scrap melts the remaining charge is added in the melt carefully. The fresh charge should be preheated and added carefully. If any moisture is present on the charge a steam explosion can occur. Grain refinement in aluminium alloys can be refined by adding boron, titanium to the melt. Aluminium/alloys can be cast in metallic moulds or sand moulds. The most common casting processes used are – sand casting, permanent mould casting and die casting.

Casting processes

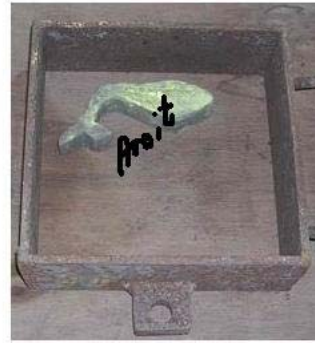
Aluminium/alloys can be cast by several processes:

1) Sand Casting

Sand casting is an important process for casting molten aluminium alloys. It can be used to prepare castings of any shape and size. Molten metal is poured into a mould cavity formed out of sand (natural or synthetic). The sand cavity is formed by using a wooden pattern. The pattern resembles the real casting part. The upper part of sand mould box is called cope and lower part is called drag. The pattern is made slightly oversize to allow for the metal contraction as it cools down. The liquid flows into the gap between the two parts, called the mold cavity. Sand castings have a rough surface and are machined later. The metal from the sprue and risers is cut from the rough casting. The riser is a reservoir of liquid metal to supply a contracting, cooling casting with make-up metal. It is used to prevent internal or external voids due to shrinkage.



Pattern



Pattern inside drag



Tools



Sand added in drag



Sand Ramming



Box filled and excess sand removed



cope and drag



excess sand removed from drag



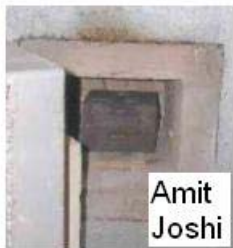
Gating cut in drag



Riser made in cope



Final cope and drag



Preheating of boxes



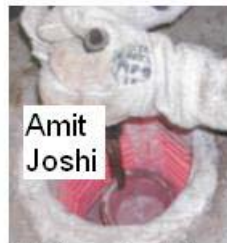
Aluminium charged in the furnace



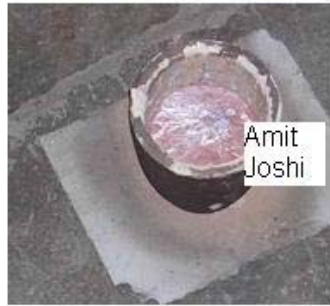
Molten aluminium



Final preheating before pouring



Molten aluminium removed from the furnace



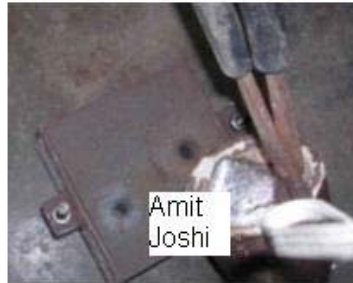
Molten aluminium in the crucible



Dross removed



Temperature measured



Pouring



Casting removed from the boxes



Final Casting



Sand Cast Aluminium Paper Weight



Aluminium paper weight (After machining)



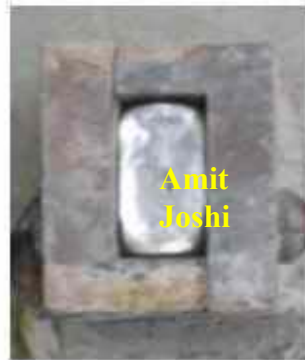
sand castings

2) Casting in metal moulds

This uses a metal mould instead of sand. The moulds are made of steel or cast iron. The mould can be of solid type or split type. In the split type mould casting removal is easy. The moulds are coated with ceramic based coating agent. The mould is dried and preheated before molten metal is poured. The crucible is removed from the furnace and the dross is removed. The melt temperature is taken and the melt is poured in the mould cavity. After solidification the casting is removed.



Mould preheated by oxyacetylene flame



Molten aluminium poured



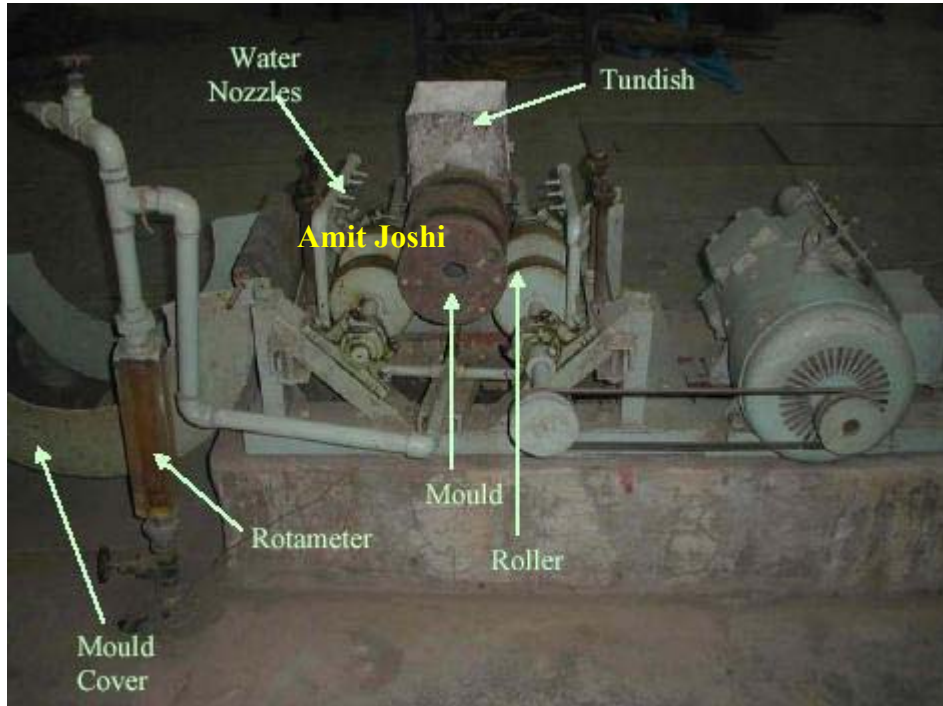
Casting removed

From the above figure shrinkage can be seen. Shrinkage happens because during solidification there is a volume contraction. The shrinkage area is machined away by cutting on a powersaw and the rest of the casting can be used. In diecasting molten metal is injected into the mould under high pressure resulting in a better part with good dimensional accuracy.

3) Centrifugal casting

The principle of originally from a patent the process was used for centrifugal casting is long established, dating taken out by A. G. Eckhardt in 1809. In this process molten aluminium is poured into a rotating mould. Molten metal is poured into the rotating mold and the metal is held against the wall of the mold by centrifugal force. The mould may be made of cast iron or steel, copper, graphite, ceramic, or dry sand. This process is suitable for the production of hollow parts, such as pipes, bearings, bushings, etc. Most metals like steel, copper/alloys, aluminum/alloys, etc can be used successfully in centrifugal casting. The impurities which segregate can be machined off. The casting is relatively free from defects. There is less loss of metal in tundish compared to that in gating and risers as in conventional sand casting. The process can be used to manufacture bimetallic pipes. Bimetallic pipe is composed of two different metal layers. Bimetal pipes are important in applications which demand outer layer to be wear resistant or inner layer to have lubricating properties. This process can be used to prepare a functionally graded metal matrix composite material. The tundish is a vessel to collect the molten metal from the crucible or ladle. The tundish has a long nose which fits into the centre hole of the

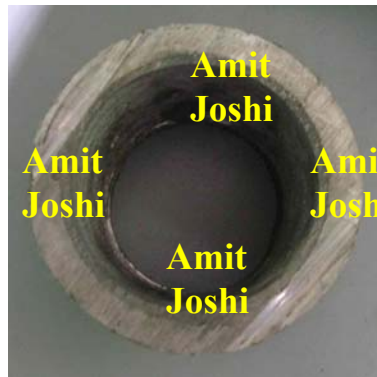
mould flange. The tundish transfers the molten metal into the rotating mould. The tundish can be made of graphite or lined with basic lining material.



The mould is driven by a belt driven motor. To avoid any splash of metal the rotating mould is covered.



Centrifugal casting



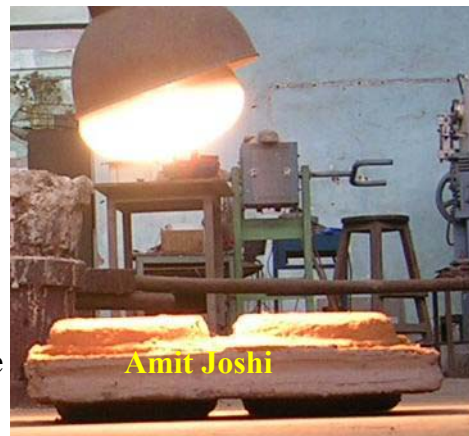
Aluminium Lead Bimetal Pipe

The above figure shows a centrifugally cast bimetallic pipe of Aluminium/Lead. The outer layer is aluminium and the inner one is lead. A trilayer metallic pipe can be cast by the centrifugal casting process.

4) Shell moulding – In this process a heated metal pattern is made to contact sand/resin mixture. This cures the resin in the mixture and it forms a rigid shell. The dump box is then turned back and all the loose sand falls off. The pattern with the sand shell is returned to the oven to harden the shell and is then removed from the pattern. The upper and lower shell moulds are clamped and molten metal is poured inside. The castings made in shell molds have excellent surface finish, dimensional accuracy and detail. Shell moulding is a used for producing simple or complex near net shape castings. The process was developed and patented by Croning in Germany during World War II and is sometimes referred to as the Croning shell process.



Shell parts on the heated pattern



Preheating of the assembled shell parts



Pouring molten aluminium in the shell mould



Final machined casting

5) Investment casting - Investment casting or the lost wax process has been known since ancient times. Wax replica of the desired casting is prepared. This is called the pattern. The pattern is attached to a sprue and then dipped in liquid ceramic slurry many times. After the ceramic becomes dry the wax is melted. Molten metal is poured and after the metal cools, the part, gate, sprue and pouring cup become one full solid casting. The outer ceramic is broken. The gating etc is machined away from the casting and the final casting is obtained.

6) Continuous casting – This process is used to prepare long castings of different cross sections like round, square, etc. The molten metal poured in the preheated tundish passes into the water cooled mould. The mould has the cross section as per the need. The metal is continuously withdrawn and a long casting can be prepared in a smaller mould. The solidified form is cooled and withdrawn at a controlled rate from the water-cooled mold by rollers and the material is cut to length with a traveling saw. Metals such as steel, copper and aluminium are continuously cast.

Casting Defects

The cast aluminium alloys are subject to:

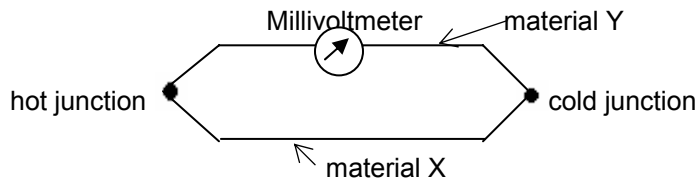
Shrinkage – Al/alloys shrink by 4–6% during solidification (depending on alloy type)

Gas porosity- Molten aluminium picks up hydrogen which is expelled during solidification giving rise to porosity. Molten aluminium picks up hydrogen from the atmosphere or from refractories. The solubility of hydrogen in solid aluminium is low and it is high with molten aluminium. To obtain good castings melts are degassed. Hydrogen has a high solubility in molten aluminium which increases with melt temperature. Hydrogen comes from water vapour in the atmosphere/from burner fuels, refractories, moist fluxes, oily/dirty scrap/foundry tools. To reduce hydrogen pickup, refractories, crucibles, tools and oily scrap should be thoroughly preheated.

Oxide inclusions- Molten aluminium exposed to air oxidizes forming an oxide which may be entrained into the casting. The other casting defects are cold shuts, hot tears, etc.

Melt Temperature

Temperature is defined as the degree of hotness or coldness measured on a definite scale. Liquid metals poured at lower temperature will give defective castings. Accurate temperature measurement is an important requirement in the casting area. Immersion thermocouple is commonly used to measure the melt temp. Optical pyrometer and radiation pyrometers are also used to measure the temperature. A thermocouple is made of two wires of two different material joined at one end. Thomas Seebeck discovered the thermocouple. He experimentally determined that a voltage exists between the two ends of a conductor when the conductor's ends are at different temperatures. If the temperature is more voltage will be higher and if its less voltage will be lower.



His discovery soon became the basis of the thermocouple, which today is one of the most popular temperature sensors. Millivoltmeter or potentiometer may be used to measure the voltage of a thermocouple circuit. Thermocouples are widely used for temperature measurement because they are inexpensive, rugged and reliable, and they can be used over a wide temperature range. Thermocouples are available in different combinations of metals. They are used depending on temperature. The different types of thermocouples are - Iron constantan, chromel alumel, platinum – platinum rhodium, etc. Type K (Ni-Cr/Ni-Al) thermocouples are widely used in the industry and can measure temperature till 1200^oC. Platinum – platinum rhodium (type R platinum-rhodium (13%)/platinum and type S platinum-rhodium (10%)/platinum) thermocouple measures high temperature. Type T Copper/Constantan is used at low temperature.

Other

Molten metal is brought in ladles from the furnace and it is later poured in the sand mould or metal mould to obtain a casting. The selection of pouring temperature depends upon the metal composition and the type of casting to be made. Improper pouring temperatures can cause casting defects. Molten metal poured at temperatures lower than the optimum causes cold shuts. If temperature of molten metal is high gas content will increase especially for molten aluminium.



Molten metal can cause severe burns if spilled or splattered upon someone. Use extreme caution when handling. Wear thick shoes, long pants, heavy gloves, and eye protection. Keep kids away from heat sources, parts, tools, and other dangerous items.