

# Melt treatment in die casting industries

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## Research Article

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# Abstract

Molten aluminum metal is often contaminated with dissolved gases, inclusions, oxides, slag and insoluble materials. This results casting defects like porosity, pin holes and hard spots which reduces properties like strength, hardness, corrosion resistance and pressure tightness. The loss incurred in producing one defect casting is nearly equal to the profit gain by producing ten good castings. Hence producing defect free castings is highly economical in industries to gain profit. Proper treatment of molten aluminum metal is highly essential before casting process to achieve sound castings. This paper describes the effective cleaning methods like fluxing, degassing and addition of Strontium and Tibal alloy elements to induce grain modification and grain refinement in the alloy.

## 1. Introduction

Melting of aluminum and its alloys has been carried out by variety of furnaces such as coke fired crucible furnace, oil fired crucible furnace, gas fired crucible furnace, electrical resistant heating crucible furnace, induction melting furnace, rotary furnace and reverberatory furnace. Foundry returns, virgin ingots, risers, scrap and runners are used in furnace for melting. Pure aluminum metal melts at constant temperature of 660°C whereas aluminum alloy melts at temperature range of 590°C to 650°C (1). The principal alloying elements are Si, Cu, Mn, Mg, Zn etc. Each alloying element induces certain properties in the aluminum alloy. Addition of Silicon improves strength, hardness, flowability, corrosion resistance and resistance to hot tear. Addition of copper improves strength, corrosion resistance, machinability and helps in precipitation hardening and age hardening. Addition of manganese makes metal denser, improves strength through solid solution strengthening mechanism and retains strength at elevated temperature. Addition of magnesium improves corrosion resistance, strength through solid solution strengthening, weldable characteristics and deoxidizes with aluminum to remove impurities present in the alloy. Addition of zinc improves castability, strength, hardness and helps in precipitation hardening and age hardening. Strontium helps in grain modifier and Tibal helps in grain refiner.

After melting aluminum metal and it alloys are used for casting purpose such as sand casting, gravity die casting, low pressure die casting, high pressure die casting (2), centrifugal casting, slush casting, squeeze casting etc. Sand casting is a process in which molten aluminum metal is poured in to the mold made up of green sand mold, skin dry sand mold or no bake sand mold. The molten metal is transferred from the holding furnace to pouring basin of the mold by means of ladling. Pouring liquid metal continues till the riser, runner and cavity is fully filled with liquid metal. After freezing of metal in the die, the casting is removed from the sand mold by breaking mold itself (3). This method of casting process is known as expendable or temporary mold casting process. The mold enables for production of only one casting. For producing large number of casting from single mold other process such as die casting process is used. This die casting process is also called as permanent mold process (4).

Gravity die casting (GDC) is a process in which molten aluminum metal is poured in metallic molds made up of steel or cast iron (5). Molten metal is fills the cavity under gravitational force of metal. After freezing

of metal, the mold is open by manually or power mechanism and the casting is taken out for further deburring and finishing operations. Here the metallic mold is used for producing multiple numbers of castings. This method is used for casting housings, cylinder blocks, cylinder heads and fly wheels. The production rate is low and section thickness must be sufficiently large to fill the cavity before solidification of metal starts (6).

Low pressure die casting (LPDC) is a process in which liquid metal is flows into the steel die under low pressure in the range of 0.1 to 0.3 bars and hence the name is low pressure die casting process. The mold is fabricated with quality steel from which multiple castings are produced. After solidification of molten metal, the upper mold is open with the help of hydraulic system and the casting is ejected from the mold for further deburring and machining process (7). This process widely used for producing aluminum alloy wheels for cars and cylinder heads for two wheeler motor cycles.

High pressure die casting process (HPDC) is a process in which molten metal is laddle manually or by means of auto laddle and the die cavity is filled up with high velocity and pressure (8). The die filling time is in the range of 5 milli secons to 150 milli seconds. The pressure is in the range of 60 to 120 Mpa. Since the metal is filled with high pressure, it is called high pressure die casting process. The die is made up of high grade alloy steel to with stand high thermo-mechanical fatigue. Thin and intricate shapes can be produced by high pressure die casting process. This process is widely used for producing auto mobile componetns like engine case, crank case, shock absorber components, wheel hubs, cylindr heads, break lever, foot pedal and many more components. The surface finish, pressure tightness, soundness of the casting is excellent compare to other casting process. The rate of production is also high. Near net shape castings can be produced with no or very little machining.

Successful castings of aluminum alloys involves proper cleaning of molten aluminum metal before casting. improper cleaning results casting defects such as hard spots, slag, inclusion and gas related defects like porosity, pin holes etc. These defects significantly reduces the properties like strength, hardness,pressure tightness and increase rejection and scrap at casting stage aswell as machining stage (9). Inorder to improve productivity, quality, customer satisfaction and profit to the organization it is highly essential to keep the defects and rejection rate as low as possible.

## 2. Experimental And Results

We know that casting defects like slag, inclusions, hard spots and gas porosity results in weakening the casting properties like strength, pressure tightness, toughness and impact strength. So it is highly essential to clean the metal before going for casting process. The sources of material contamination are wet scrap, runners, risers, oily rejected castings, customer returns, field scrap etc. There are varieties of cleaning process that can be used for cleaning the molten metal before casting. The sequences of metal cleaning are

- Sorting of input material into ferrous and non ferrous metal and alloys. Segregation of these into aluminum, copper, zinc and magnesium metals and alloys.

- Fluxing
- Degassing
- Grain modifier and grain refinement

The input materials are segregated as ferrous and nonferrous with the help of magnetic conveyor. Next step is non ferrous metals are segregated by its density. All aluminum scrap is melted in induction furnace along with 60% by weight virgin aluminum ingots. In this study we selected induction furnace because induction melting ensures better mixing of scrap, virgin ingots and alloying elements by stirring action. Stirring action results in uniform and homogeneous alloy. Induction melting assists in better control of temperature of an alloy. Addition of virgin ingots improves alloy quality and reduces rejection at casting stage.

The melt temperature is increased to 670–700°C. Slag, inclusions, dirt and insoluble material floats on top of the liquid metal. At this stage fluxing operation is carried out. Sodium and potassium chloride fluxes 500 gms per 250 kgs of metal are sprinkled on top of metal and allow 5 to 12 minutes to react. Now the flux is thoroughly mixed with the floating slag with the help of dross cleaning tool. Exothermic reaction takes place, which further increases the temperature of the slag. This results in liquid metal trickle down, leaving behind black powder which is called dross on top of the furnace. The dross is skimmed off and the clean molten metal is transferred into the ladling furnace. After cleaning the metal is subjected to degassing operation.

Degassing involves purging of nitrogen gas through the rotating impeller from the bottom of molten metal in the crucible (10). Solubility limit of Hydrogen gas is more at high temperature. So the metal temperature should keep low to reduce the solubility limit of hydrogen throughout degassing process. The nitrogen degassing process takes away dissolved gases like hydrogen from the molten metal in the form of fine streams of bubbles to the atmospheric air. The rising bubbles also bring the inclusions to the top of molten metal that can be skimmed off. The time duration of degassing of is 4 to 8 minutes at the gas flow rate of 23 l/min for 250 kgs of molten aluminum. The aim is to keep the dissolved hydrogen content in the molten metal level below 0.15ml H<sub>2</sub> /100 g. This minimal Hydrogen content produces porosity free castings.

After degassing process is completed, Strontium 0.04–0.06% by weight and Tibal 0.02–0.05% by weight is added to molten alloy and stirred thoroughly with tool for uniform and homogeneous mixing with metal. This improves grain modification and refinement. Now the completely treated metal is taken for casting process.

The experimental research results are summarized in the table.1

Sl.No	Operation	Defects Before Operation	Defects After Operation
1	Fluxing and Cleaning	5%	1%
2	Degassing	10%	2%
3	Grain refinement	3%	0.4%
4	Grain modification	1%	0.2%

### 3. Results And Conclusions

After metal fluxing, degassing and grain refining process the molten metal is used for casting process. The casting defects like porosity, pin holes, inclusions and hard spots are reduced to acceptable limit in the cast components. The rejection rate is considerably reduced and helps in productivity improvement, customer satisfaction and quality. So it is very important to clean and treat the molten metal in the foundry before casting process to get sound quality castings which enhances the profitability of organization.

### Declarations

- List of abbreviations:

Not applicable

- Availability of data and materials

Not applicable

- Competing interests

Not applicable

- Authors contributions

M.Bhaskar- carried out original work

Tamil Nalluswamy- editing and drafting

P.Suresh- drafting figures and graphs

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## Figures

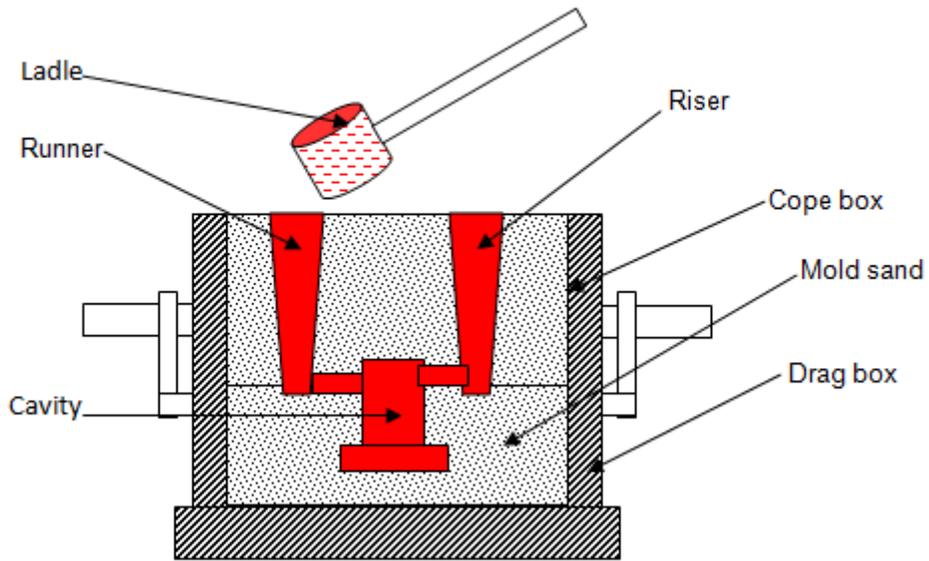


Figure 1

Sand casting process.

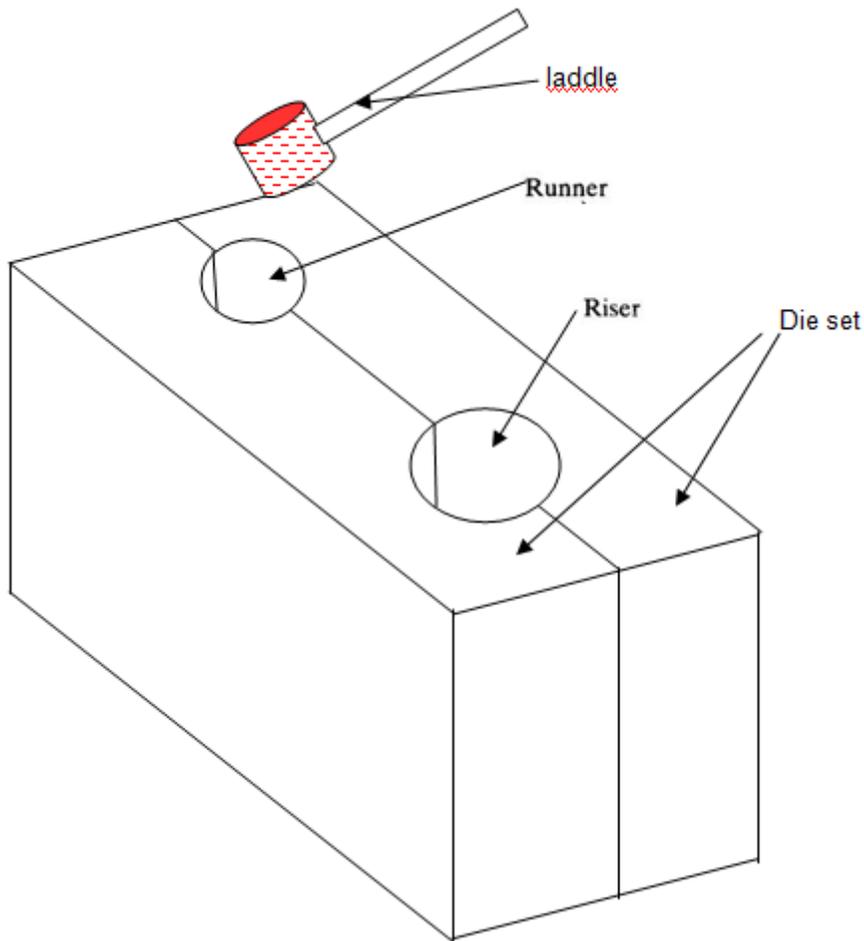


Figure 2

## Gravity Die casting

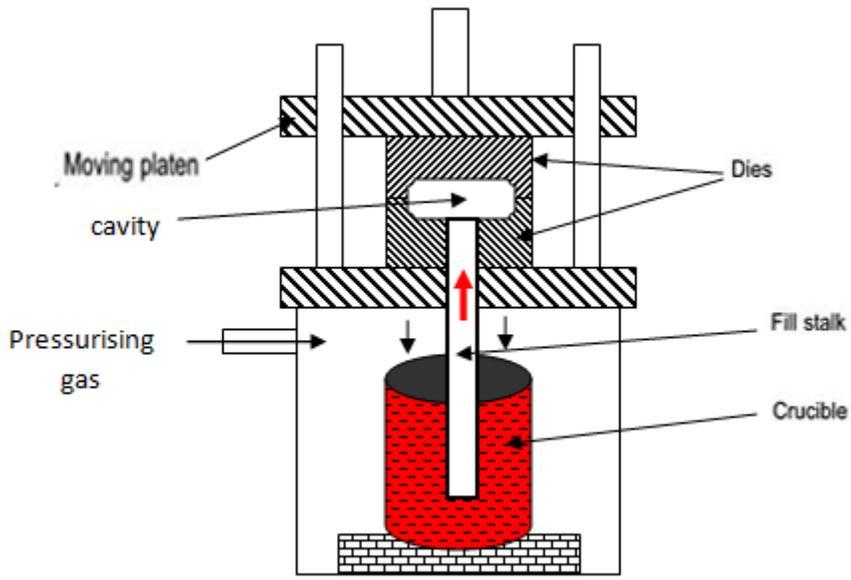


Figure 3

Low pressure die casting.

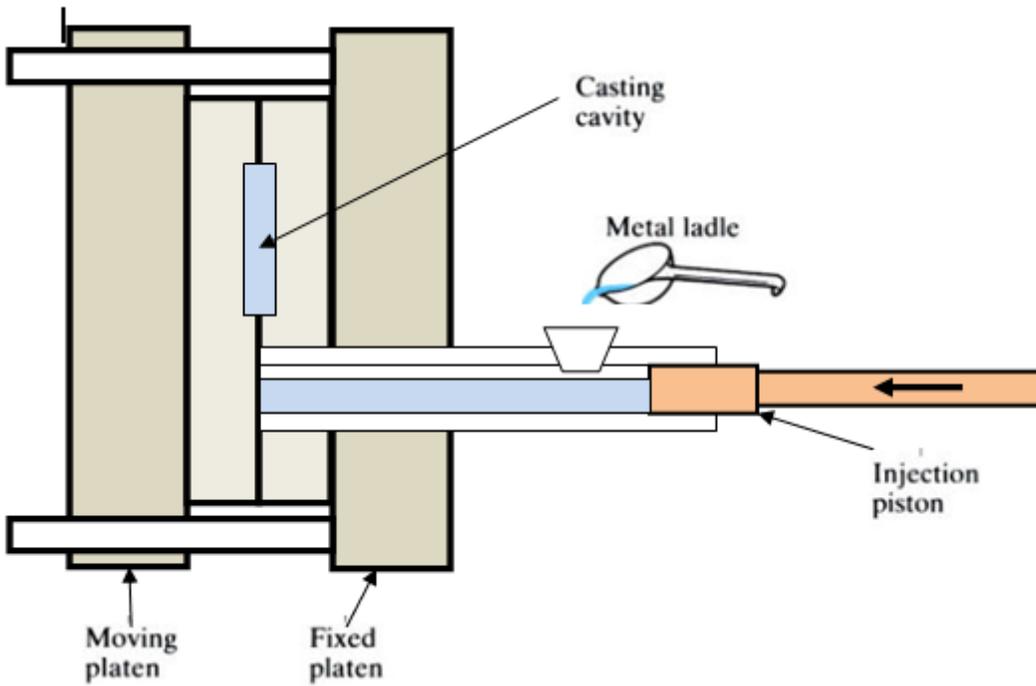


Figure 4

High pressure die casting

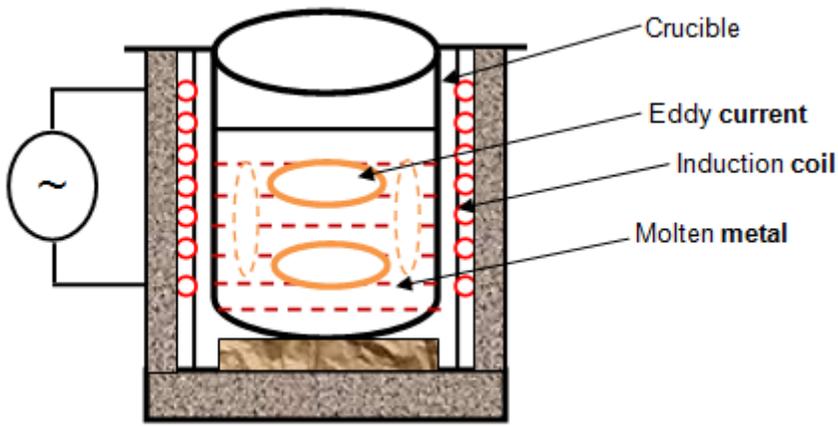


Figure 5

Induction melting furnace.

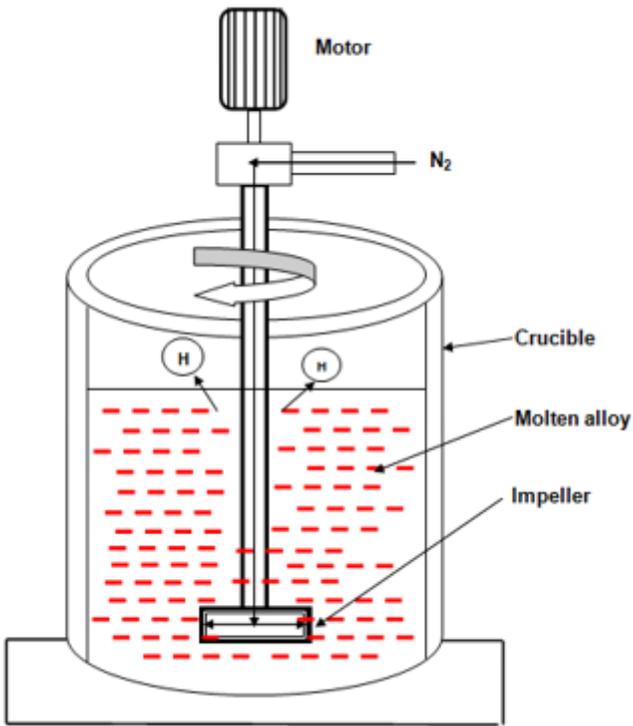


Figure 6

Rotary Degassing process

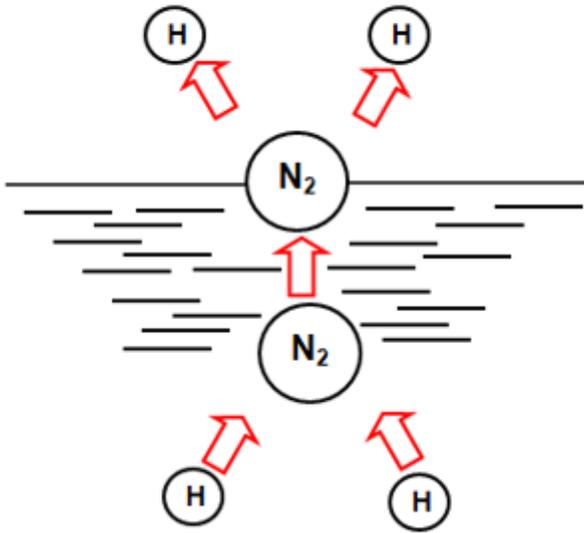


Figure 7

Degassing mechanism

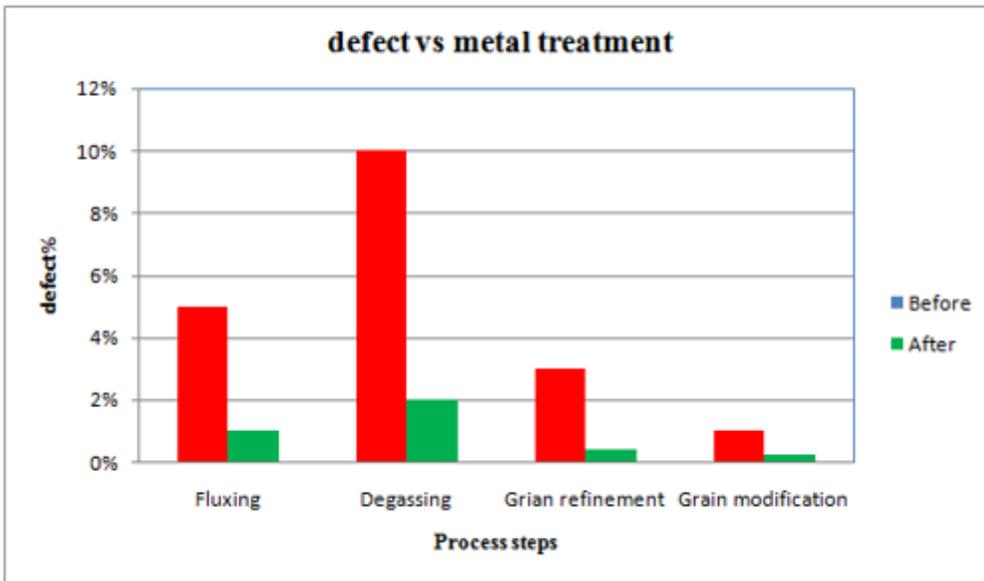


Figure 8

Defects vs metal treatment.