Chapter 1

Introduction

In any casting process, work cycle at every stage is very important. The most important cycle in any casting process is melting followed by pouring molds. Preparation of molds, gating systems, core placements, melting, pouring, shake-out, de-burring, shot blasting, welding defects, heat treat, dimensional inspection of key features are some of the key operations in the casting process. Also handling of castings throughout these processes is also a key parameter for large castings. Main concern in the current scenario of casting industry is maintaining a steady cycle of process with high quality, consistency and safety of the personnel involved. Automation is therefore has started to prove its importance in most important manufacturing process.

Investment casting process is widely used for highly precision as cast products mostly in aerospace and automotive industries. Process is also known as lost wax casting process. The investment casting process consists of making wax patterns, making wax trees, put first coat of zircon silica followed by back up coats of shell, de-waxing, preheat of shells and metal pouring followed by finishing processes. Main important areas in investment casting process are shelling of wax patterns and pouring. Pouring consists of melting of alloy in Induction furnace, preheating mold shells and then pouring molds. Pouring in investment casting is done in open environment or in Vacuum chamber depending on types of alloys used and end use requirements of the cast parts. Main type of current pour methods in investment casting methods are hand pour by simple ladle, tea pour type of ladle or using tilting type lip ladle. Bottom pour of certain metal alloys is used regularly in casting industries for large casting. Good quality castings are produced as flow control and clean metal flow (as slag/slurry) float on the top) is possible for large size castings.

Metal slag related issues are also avoided resulting in less inclusion defects. For many years bottom pour using stopper rod or sliding strip mechanisms are used for alloys which can hold a molten metal stage for a long period of time and have a slow cooling curve allowing more time for useful pour. e.g. most of the Cast iron grades, Aluminum or Copper alloys. It is proven that this method if used correctly is much easier to operate and gives consistent quality castings. The reason being consistency of important parameters of
pouring like Pour height, Flow rate of metal, Temperature range of pour can be optimized simply and quickly. So far this system is used only in large foundries and a mass of molten metal in ladle over and above 3 Tons on average. It is not used for smaller masses of molten metal currently due to heat loss issues related to small mass of metal and early solidification of the same. This typical situation occurs in Investment casting process due to size of castings and main alloys used are mild steel or stainless steel grades with faster cooling curves. If bottom pour with modification to current available bottom pour systems, cranes, superior temperature measuring systems in place, the effect of quality, cost savings i.e. Cost of Quality, improvement in safety environment need to be studied for investment casting process.

For the purpose of this study, it is necessary to find out a refractory composite that will reduce the heat transfer through molten metal to ladle composite material. Also currently for ladle preheating mainly oil furnaces are used. Oil heating gives lower heating temperature and emits non healthy gases and this heating should be replaced with another equivalent or better source. Also using a smaller ladle for bottom pouring will need some modification as the stopper system used will be smaller compared to conventional bigger size ladles (generally > 1500 Kg thermal mass). In investment castings, pouring process mainly involves an unique phenomenon of pre heating molds also that is molds made from zircon silica layered shells. Currently, most of the investment casting foundries use firing ovens to heat these shells with sensors for overall inside heat at only certain locations but it is not a consistent process. Reason to say that is even sensor in oven shows the overall temperature has reached the desired temperature value, the location of shells in the oven and size of shells are observed to be at different temperature after any certain amount of time. Therefore a need of system needs to be in place to make sure that shells are taken out of the oven only at optimized temperature.

If bottom pouring method used with all above modification and is successful for investment casting process, it will definitely prove to be a new trend for improved quality.

1.1 Conventional Metal Pouring Process

When literature review was done for currently used pour processes in various types of casting processes, it was found that bottom pour method which is good for flow control, and reduction of inclusions due to slurry (impurities, foreign materials in molten metal) is only restricted to cast iron or silicon based non-ferrous (Aluminum, Copper etc.) alloys. It is not used in investment casting industry as discussed before due to main reason of use of alloys with rapid cooling from melt to solid phase and size of the castings involved. Some commonly used pouring methods or practices are discussed in brief as below.
1.1.1 Typical Metal Pour Types

Metal pour is the most important process in any casting process. It is an important process to decide the quality of castings. There are many types of pour methods which are used depending on size of castings to poured, metal alloy to be poured, size and capacity of foundry to invest in the process of automation’s etc. Some of the commonly used metal pour processes are shown in fig. 1.1 through fig. 1.6 below

Figure 1.1: Hand pour by lip ladle [63]

As seen in fig. 1.1, for smaller castings/molds, in sand casting process pouring is done by hand and it limited up to maximum of 40 kg. This is purely a manual process and is dependent of human effort consistency. But it is most economical method for smaller casting. Fig. 1.2 shows the lip pour using bigger ladle but with gear box for handling large masses of metal for large castings usually ranging from 300 kg - 800 kg. Now this method is similar to the process in fig. 1.1 but automation makes it possible to use it for larger castings and special with more consistency of pour rate and assisted by gear box mechanism.

Figure 1.2: Mechanical pour by lip ladle [64]
Fig. 1.3 shows the direct pour into large molds, usually in green sand castings to avoid heat loss during pour from furnace to ladle and then to molds but it is kind of unsafe due to rapid movement required on molds from underneath the crucible. Fig. 1.4 shows the current bottom system used for large cast iron or aluminum foundries where advantage is taken to keep slag on top of the molten metal and flow control. Same advantages are discussed in detail in chapter 2.
Fig. 1.5 shows the patented Counter Low Pressure Air process used (Hitchiner Castings) for Investment casting process. It uses vacuum to suck molten metal into the investment shell and after cavities are filled with molten metal it releases the vacuum sending back all the metal from runner and gates back to molten metal sink giving high efficiency process saving extra metal in runner and gates. Fig. 1.6 shows a typical system in die casting pour method. It uses pressure plunger to force the metal in metal molds making sure the cavity is filled without gas entrapment and with right density of solid metal without any shrinkage.

1.1.2 Bottom Pour Casting Process

Bottom pour of certain metal alloys is used regularly in casting industries (Fig.1.4). Good quality castings are produced as flow control is possible for large volume castings. Metal slag related issues are also avoided resulting in less inclusion defects. For many years bottom pour using stopper road or sliding strip mechanisms are used for alloys which can
hold a molten metal stage for a long period of time and have long range of temperature and superheat before solidification starts e.g. most of Cast iron grades. It is proven that this method if used correctly is much easier to operate and gives consistent quality castings. The reason being consistency of important parameters of pouring like Pour height, Flow rate of metal, Temperature range of pour can be optimized simply and quickly. So far this is been used only in large foundries and a mass of ladle over and above 3 Tons on average. It is not used for smaller masses of molten metal currently due to heat loss issues related to small mass of metal and early solidification of the same. The basic sketch of bottom pour using stopper rod is as shown in fig. 1.7a and example of actual practice in fig. 1.7b respectively. It consists of a stopper rod with a stopper nozzle made of graphite, ceramic or similar material that does not adhere, react or melt with the respective metal alloy to be poured.

![Concept sketch](image1.png)  ![Actual process](image2.png)

Figure 1.7: Bottom pour [61]

Advantages of Bottom Pour:

1. Constant flow as required. Pour time can be controlled.
2. Slag floats on the top of ladle and is not poured into the mold.
3. Easy to operate with less efforts.
4. Large thermal masses can be easily poured with alloy having Slow cooling curve i.e. can retain pour ability for a longer time e.g Cast iron, Brass, Copper, Bronze etc.
5. Good for continuous pour of large casings.

Disadvantages of Bottom Pour:

1. So far, only used of high thermal masses with low cooling curve currently.
2. Usually only used for heavy castings,
3. High maintenance.
1.2 Problem Description

As seen so far, bottom pour is used only for typical alloys and for thermal masses. It is due to the fact of the alloys used in investment castings like low carbon steels that have Nickel or Chromium giving high strength, high corrosive resistance parts but are hard to pour due to their rapid cooling rate from molten to solid state. Also size of most of the investment casting shells are less compared to large cast iron casting processes where bottom pour is time efficient and economical. Bottom pour is also less labor intensive compared to current conventional manual pouring process in investment casting process. It can be changed a semi-automatic ladle pour. If it can be assisted with crane system and some good measurement of preheated shell temperature, it will certainly save some time and cost of quality due to rejections for defects. So the study is proposed to use bottom pour with aid of overhead crane to operate the modified bottom pour ladle and non-contact laser gun to control preheat temperature of shells and study results of this new pour system with SS 304 alloy. Experimentation results to be analyzed for feasibility of such bottom pour systems in Investment casting process and discuss advantages and disadvantages of the same.

1.3 Aims and Objectives

1.3.1 Aims

1. Study of small and middle scale investment casting industries for current standard process methods and amount of automation currently used for improvement of quality and lead time.

2. Derive low cost automation methods for small or medium scale investment casting foundries to improve consistency of key processes involved.

3. Focus on major areas for relatively simple semi-automation techniques compared to existing high technology systems using fully automated methods and control systems.

4. Use these low cost, easy to operate automation techniques for regular production and optimize the key parameters mainly in pouring areas of investment casting process giving consistent and predictable quality for variety of products involved.

1.3.2 Objectives

1. To improve quality and to reduce cost due to scrap in casting industry using economical automation techniques and optimize critical variables.
2. To prove the feasibility of bottom pour technique into small scale or large scale investments casting industry to get same advantages of the technique in other casting manufacturing methods.

3. To determine the correlation of pour variables and related quality related parameters for investment casting process using a modified pouring method for SS 304 alloy.

After reviewing most of the conventional pouring processes, common defects are reviewed. Study investment casting process was done in detail. Major defects in small scale casting industry were discussed. Bottom pour practicability for investment casting process is discussed for small thermal masses of steel to achieve same advantages achieved by conventional bottom pour process. Some modifications to current bottom pour process are also discussed. Details of the same are discussed in the next chapter.