CHAPTER 1

INTRODUCTION

1.1 CASTING PROCESSES

Casting is considered as one of the most ancient processes of manufacturing metallic components. Also, with few exceptions, it is the first step in the manufacturing of metallic components. The process involves the following basic steps;

- Melting the metal
- Pouring it into a previously made mould (or) cavity which conforms to the shape of the desired components
- Allowing the molten metal to cool and solidify in the mould
- Removing the solidified component from the mould, cleaning it and subjecting to further treatment, if necessary

The solidified piece of metal, which is taken out of the mould, is called as “Casting”. A plant where the castings are made is called “foundry”. It is a collection of necessary materials, tools, machines and equipments necessary to produce a casting. The casting process is also called as “founding”. The word “foundry” is derived from Latin word “fundere” meaning “melting and pouring”. The schematic diagram of general casting process is shown in Figure 1.1.

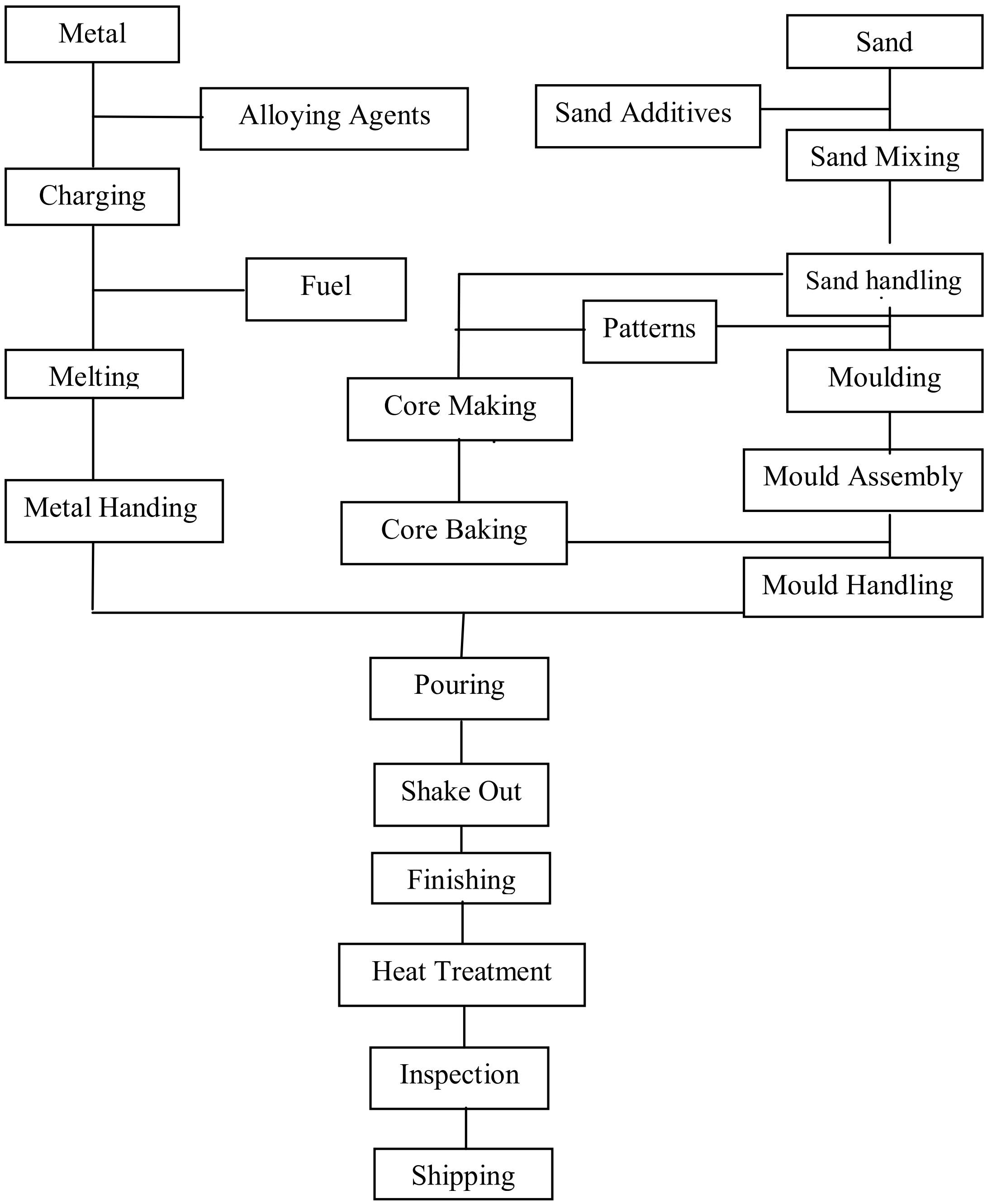

Figure 1.1 Schematic diagram of general casting process

1.2 CLASSIFICATION OF CASTING PROCESSES

Casting processes which can be classified into four categories according to the moulds are given below:

(i) Conventional Sand Moulding Processes

- Green sand moulding
- Dry sand moulding
- Flask less moulding

(ii) Chemical Sand Moulding Processes

- Shell moulding
- Sodium silicate moulding
- No-bake moulding

(iii) Permanent Mould Processes

- Gravity die casting
- Low and high pressure die casting

(iv) Special Casting Processes

- Lost wax
- Ceramics shell moulding
- Evaporative pattern casting
- Vacuum sealed moulding
- Centrifugal casting

1.3 GREEN SAND CASTING PROCESS

Green sand moulds are prepared with the use of natural moulding sands or with mixtures of silica sand, bonding clay and water. These materials are thoroughly mixed in proportions which will eventually give the desired properties for the class of work being done. Thus to make the green sand mould, the sand must be properly tempered before it can be used. If the sand is too dry, additional water is added, if too wet, dry sand is added until it attains proper temper. A handful of sand is grasped and pressure is released, and the sand is broken into two sections. The sections of sand should retain their shape, and the edge of the break should be sharp and firm.

The surface of the mould which comes in contact with the molten metal forms the most important part in green sand moulds. In order to give the casting a clean and bright surface and to prevent the sand from burnining on the face of the mould, a layer of facing sand is given surrounding the pattern. Facing sand mixtures for iron castings generally contain some finely ground bituminous coal known as sea-coal, new sand in addition to be used in moulding sand. One part by volume of sea-coal to ten parts of moulding sand is a common ratio of mixtures for the moulds for iron casting. The sea-coal aids in preventing the sand from fusing to the surfaces of the castings, whereas the new sand increases the bond in the facing mixture, and thereby prevents cutting of sand surfaces by the liquid metal. It is the common practice to coat the surfaces of sand mould with refractory material to produce a smooth skin on the castings. The materials ordinarily used for this purpose are graphite, coke, charcoal, gas carbon, plumbago, black lead, silica, mica and talc. These materials may be placed in two groups namely the carbonaceous materials known as blackings and the other materials are designated as mineral coatings. They may be applied in the wet or dry form. For use in the wet state some additive is employed like clay, gum and other substances being mixed together with water.

1.3.1 Green Sand Casting Mould Making Procedure

The procedure for making mould of the green sand casting is given below.

- The first step in making mould is placing the pattern on the moulding board
- Then the drag is placed on the board
- Dry facing sand is sprinkled over the board and the pattern to provide a non sticky layer
- Moulding sand is then riddled into cover the pattern with the fingers; then only the drag is completely filled
- The sand is then firmly packed in the drag by means of hand rammers. The ramming must be done properly. Here, it must neither be too hard or soft
- After the ramming is over, the excess sand is leveled off with a straight bar known as a strike rod
- With the help of vent rod, vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during pouring and solidification process
- The finished drag flask is now rolled over to the bottom board thereby exposing the pattern
- Cope half of the pattern is then placed over the drag pattern with the help of locating pins. The cope flask on the drag is located aligning it again with the help of pins.
- The dry parting sand is sprinkled all over the drag and also on the pattern.

- A sprue pin for making the sprue passage is located at a small distance from the pattern. If riser pin is required, it can be placed at an appropriate place.
- The operation of filling, ramming and venting of the cope proceed in the same manner as performed in the drag.
- The sprue and riser pins are removed first and a pouring basin is scooped out at the top to pour the liquid metal.
- Then, pattern from the cope and drag is removed and facing sand in the form of paste is applied all over the mould cavity and runners which would eventually give the finished casting a good surface finish.

Ultimately the mould is assembled and ready for pouring.

1.3.2 Advantages of Green Sand Casting

- Least expensive
- Less distortion than in dry sand casting because no baking is required
- Flasks are ready for reuse in minimum time
- Dimensional accuracy is good across the parting line
- Less danger of hot fearing of casting compare to other type

1.3.3 Disadvantages of Green Sand Casting

- Sand control is more critical than dry sand casting
- Erosion occurrence of the mould is common in the production of large castings
- Certain metals and some castings develop defects if poured into moulds containing moisture

- More intricate casting can not be produced
- The surface finish can deteriorate and dimensional accuracy decreases as the weight of the casting increases

1.4 CO_2 CASTING PROCESS

This process is basically a hardening process for moulds and cores. The principal of working of CO_2 process is based on the fact that if CO_2 gas is passed through a sand mix containing sodium silicate (water glass), the sand immediately turns strongly bonded as the sodium silicate becomes a stiff gel. The gel is responsible for giving the necessary strength to the mould. The chemical reaction that takes place can be represented in a simplified form as follows:

$$\mathbf{Na_2\,O(\mathit{x})\,SiO_2 + (\mathit{x})\,H_2O + CO_2 \Longrightarrow Na_2\,CO_{3+}\,SiO_2(\mathit{x})\,H_2O}$$

The sand used for the process must be dry with a maximum moisture content of 0.25 percent and clay free. It has been found that there is a rise in the strength as the grain fineness of the sand increases until about 60 mesh size. When finer sands are used, the maximum strength decreases until 120 mesh size it reduces to zero. However, the sand is thoroughly mixed with 4 to 5 percent sodium silicate liquid base binder in a muller for 3 to 5 minutes. Suitable additives such as coal powder, wood flour, sea coal and dextrin may be added to improve certain properties like collapsibility. Similarly kaolin clay, aluminium oxide and invert sugar in other forms are sometimes added for obtaining certain specific properties. The kaolin clay promotes moulds stability, whereas, aluminium oxide improves the hot strength of the bonded sand, and produces a smooth synergistic interface between the mould and the metal. Addition of invert sugar reduces the retained strength of the mould or core after pouring. Severe shakeout problems may be encountered without additions of sugar. The suitable sand mixture can then be packed around the pattern in the flask or in the core box by standard moulding machines, core blowers, or by hand.

When the packing is complete, CO_2 is forced into the mould for a pre determined length of time. The reaction precedes rapidly in the early stages of gasification and the compressive strength of the sand mixture reaches a maximum value when a certain critical amount of gas is passed. The time to harden a small or medium size body of the sand will range from 15 to 30 seconds. The weight of CO_2 gas required can be calculated if the quantity of sodium silicate is present is known. Over gassing is wasteful and results in deteriorating the sand. Gassing can be effective only if the air present in the pores of the sand mass is completely evacuated and this replaced by CO_2 gas. Gassing can be carried out by a probe having a number of holes at the bass. The flow rate of CO_2 gas depends on the depth of penetration desired. The hardness of moulds can further be increased by exposing them to free atmosphere for a short while after gassing. Patterns used in this process may be made of wood, metal or plastics. The varnish coating on the wooden pattern causes green sand to stick to the pattern. Varnish can, however, be used if a layer of cellulose lacquer applied afterwards. A more effective alternative is to provide a zinc coat of 0.05 to 0.13 mm thickness over the pattern followed by spraying a layer of aluminium or brass of about 0.25 mm thickness. Subsequent rubbing with a smooth emery paper gives good result.

1.4.1 Advantages of CO_2 Casting

The following are the advantages of CO_2 sand casting process

- Uses conventional equipment for moulding and sand mixing
- Operation is speedy
- Suitable for heavy and urgent orders
- Eliminates baking ovens and core driers
- Floor space requirements are minimal
- Semi skilled labour can be used
- Indirect labour costs are small
- High accuracy and good surface finish on castings are possible
- Reduced machining allowances are required
- The likelihood of rejections is less while productivity is higher

1.4.2 Disadvantages of CO_2 Casting

However, the following are their disadvantages

- Difficulty in reclaiming used sands
- Moulds and cores are more expensive compared to conventional process
- Bench life of sand mixtures is much shorter than for most mould and core mixes
- Moulds and cores deteriorate noticeably after being stored under normal atmospheric conditions for more than 24 hours

- Shakeout properties are poor compared to those of conventional moulds and cores
- Poor collapsibility of hardened sand normally requires special additives to improve the quality

1.5 STEPS IN MAKING SAND CASTING

Sand casting is the most widely used process for both ferrous and non-ferrous metals, and accounts for approximately 90 percent of all the castings produced. The major steps are briefly described below

1.5.1 Pattern Making

The pattern is a physical model of the casting used to make the mould. The mould is made by packing some readily formed aggregate material such as moulding sand around the pattern. When the pattern is withdrawn, its imprint provides the mould cavity, which is ultimately filled with metal to become the casting. If the casting is to be hollow, as in the case of pipe fittings, additional patterns, referred to as cores, are used to form these cavities.

1.5.2 Core Making

Cores are forms, usually made of sand, which are placed into a mould cavity to form the interior surfaces of castings. Thus the void space between the core and mould-cavity surface is what eventually the casting becomes.

1.5.3 Mould Making

Moulding consists of all operations necessary to prepare a mould for receiving molten metal. Moulding usually involves placing a moulding aggregate around a pattern held with a supporting frame, withdrawing the pattern to leave the mould cavity, setting the cores in the mould cavity and finishing and closing the mould.

1.5.4 Melting and Pouring

Preparation of molten metal for casting is referred to as melting. Melting is usually done in a specifically designated area of the foundry, and the molten metal is transferred to the pouring area where the moulds are filled.

1.5.5 Cleaning

Cleaning refers to all the operations necessary for the removal of sand, scale, and excess metal from the casting. Burned-on sand and scale are removed to improve the surface appearance of the casting. Excess metal, in the form of fins, wires, parting line fins, and gates, is removed. Inspection of the casting for defects and general quality is performed.

1.6 OBJECTIVE OF THE RESEARCH WORK

The present research work mainly focuses on the selection of optimal moulding sand and pouring metal related parametric combination for achieving minimum percentage of casting rejection in green sand casting and CO_2 casting process.

Subsequently this research work is going to identify the correct parametric combination for minimizing the percentage rejection.

Initially the optimal parametric combination is identified by using Taguchi method. The optimal parametric combination obtained by Taguchi method is further refined by evolutionary heuristics like, genetic algorithm, simulated annealing and ant colony optimization techniques. Finally, confirmatory experiments are carried out to evaluate the effectiveness of evolutionary heuristic optimal parametric combination set.

1.7 APPROACHES AND METHODOLOGIES

In this research work, the green sand casting and CO_2 casting, moulding sand and pouring metal related parameters that affect the quality of casting are identified by using questioner technique and brainstorming technique. Initially the optimal parameters are identified by using Taguchi method. Taguchi method does not perform well when the search space is too large. Due to this reason, the evolutionary heuristics like, genetic algorithm, simulated annealing and ant colony optimization techniques need to be implemented to obtain quality solutions when the search space is too large. The experimental results from the orthogonal array were used for developing the mathematical model to map the relationship between process parameters and percentage of rejection rate for casting process. The mathematical model relating the output response to input parameters was developed by using statistical analysis software the proposed mathematical model is used to formulate the objective function, which is the pre-requisite of evolutionary heuristics. The mathematical model is verified by efficacy test and comparing the predicted values with the experimental values. A set of confirmation tests with the optimum level of casting parameters is carried out to illustrate the effectiveness of evolutionary heuristics. The performance of each evolutionary heuristic technique is compared. The software codes have been developed using MATLAB 6.5 software.

1.8 ORGANIZATION OF THE THESIS

Chapter 1: This chapter presents the introduction about the green sand casting and CO_2 casting processes and the objective of the research work is discussed.

Chapter 2: This chapter provides details about the literature review related to the area of research. It also presents the limitations of the existing approaches used in parameter optimization. Also the state of art in parameter optimization and the need for further research are discussed.

Chapter 3: This chapter deals with Taguchi method and evolutionary heuristics methods such as genetic algorithm, simulated annealing and ant colony algorithm.

Chapter 4: This chapter is dedicated to the problem identification methods. Various casting defects, causes and remedies are analysed.

Chapter 5: This chapter depicts the selection of optimal moulding sand and pouring metal related parametric combination for achieving minimum percentage of casting rejection rate in green sand casting and CO_2 casting processes by using Taguchi method.

Chapter 6: This chapter analyses the mathematical model relating the output response to input parameters formulated by using Minitab15 statistical analysis software. The efficacy test is used to compare the predicted values received through mathematical model with the experimental values.

Chapter 7: This chapter discusses the selection of optimal moulding sand and pouring metal related parametric combination for achieving minimum percentage of casting rejection rate in green sand casting and CO_2 casting processes by using genetic algorithm.

Chapter 8: This chapter elaborates the selection of optimal moulding sand and pouring metal related parametric combination for achieving minimum percentage of casting rejection rate in green sand casting and CO_2 casting process by using simulated annealing.

Chapter 9: This chapter deals with the selection of optimal moulding sand and pouring metal related parametric combination for achieving minimum percentage of casting rejection rate in green sand casting and CO_2 casting process by using ant colony algorithm.

Chapter 10: This chapter entitled 'Results and Discussion' presents the comparison and analysis of the results obtained through various techniques for two casting processes.

Chapter 11: This chapter provides the contributions of this research work. This chapter also explains the final outcome of the research and various limitations of this research work. Finally the scope for further research is also discussed pertaining to parameter optimization.