Thesis

On

DESIGN AND FABRICATION OFTHE SETUP FOR RESIN SAND RECLAMATION AND INVESTIGATE THE EFFECTS OF DIFFERENT PARAMETERS ON THE PERFORMANCE OF THE RECLAMATION PROCESS

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Submitted By

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DECLARATION

I hereby declare that the thesis entitled **"DESIGN AND FABRICATION OF THE SETUP FOR RESIN SAND RECLAMATION AND INVESTIGATE THE EFFECTS OF DIFFERENT PARAMETERS ON THE PERFORMANCE OF THE RECLAMATION PROCESS"** is an authentic record of my study carried out as requirement for the award of degree of **Master of Engineering (CAD/CAM & Robotics)** at **Thapar University, Patiala** under the guidance of **Dr. AJAY BATISH,** Professor and Head, Department of Mechanical Engineering, Thapar University, Patiala, during **July 2011 to July 2012.** The matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any other degree.

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ABSTRACT

With the increase in use of shell mouldingin variety of applications concept of reclamation of the resin sand is gaining attention. Moreover, sand disposal costs are always on the increase and many foundries are reclaiming their sand for re-use. Present work aims at design and fabrication of the reclamation setup that require less energy consumption, minimal air use and easy to install. The setup consists of electric furnace with rotary cylinder inside it. This setup is capable of performing both dry attrition and thermal reclamation of small quantity of resin sand which helps in increasing the performance of the reclamation process. Reclamation of the reclaimed sand by varying the process parameters like heating temperature at 500 °C, 550 °C, 600 °C and heating duration of 20 min., 25 min. and 30 min. is performed. Investigation of the performance of reclaimed sand obtained from experimental trials is carried out based on the properties of the sand like compressive strength, hardness and loss on ignition. Comparison of properties of mixture of reclaimed sand and resin sand in different proportion is done with the properties of fresh resin sand.

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION TO SHELL MOULDING

Shell moulding is an expendable mould casting process that uses a resin covered sand to form the mould. It is a process for producing simple or complex near net shape castings, maintaining tight tolerances and a high degree of dimensional stability. These qualities of precision can be obtained in a wider range of alloys and with greater flexibility in design than die-casting and at a lower cost than investment casting. It is a process well suited to rapid, automated, repetitive and high-volume production. The most common method for producing shell moulds is to use a dump box. [1]

Shell moulding processes was invented by Johannes Croning. The process was developed and patented by Croning in Germany during World War II and is sometimes referred to as the Croning shell process. The process was introduced in the German foundries in 1953 for making moulds and cores. The huge interest of the American foundry industry in the novel German moulding process became obvious in 1952 during the foundry exhibition in Atlanta City, on the occasion of the 56th Annual Meeting of the American Foundry men's Society, where the new technology was one of the highlights of the exhibition. Johannes Croning died suddenly and unexpectedly in Hamburg on May 12, 1957. In 1958, the shell moulding process was presented during the world exhibition in Brussels with the support of the Federal Republic of Germany. One of the first shell moulding machines designed by Johannes Croning and the first steel fittings cast with the shell moulding process were part of the exhibition of the German Museum in Munich. [2]

1.2 SHELL MOULDING PROCESS

The process of creating a shell mould consists of six steps:

1. Fine silica sand that is covered in a thin (3–6%) thermosetting phenolic resin and liquid catalyst is dumped onto a hot pattern. The pattern is usually made from cast iron and is heated to 230 to 315 °C (450 to 600 °F). The sand is allowed to sit on the pattern for a few minutes to allow the sand to partially cure.

2. The pattern and sand are then inverted so the excess sand drops free of the pattern, leaving just the "shell". Depending on the time and temperature of the pattern the thickness of the shell is 10 to 20 mm (0.4 to 0.8 in).
3. The pattern and shell together are placed in an oven to finish curing the sand. The shell now has a tensile strength of 350 to 450 psi (2.4 to 3.1 MPa).
4. The hardened shell is then stripped from the pattern.
5. Two or more shells are then combined, via clamping or gluing using a thermoset adhesive, to form a mould. This finished mould can then be used immediately or stored almost indefinitely.
6. For casting the shell mould is placed inside a flask and surrounded with shot, sand, or gravel to reinforce the shell. [1]

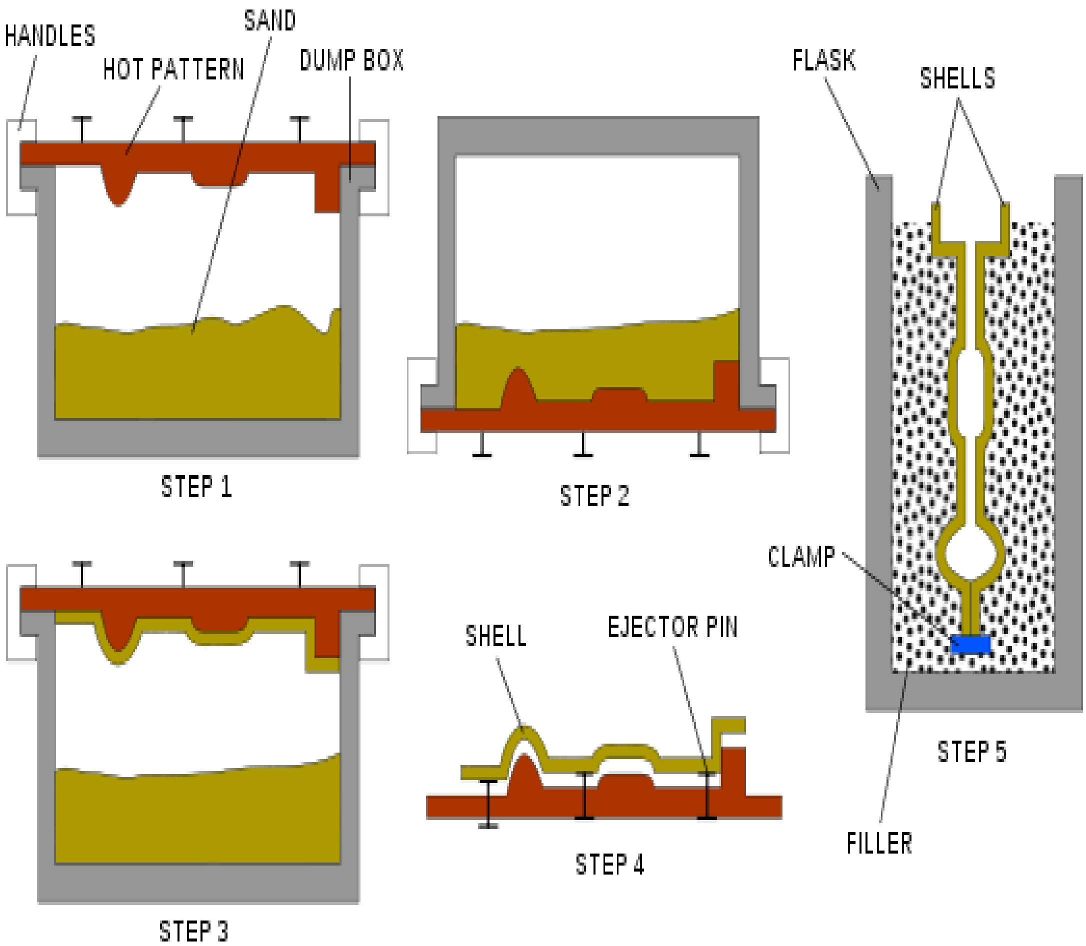

Figure 1.1 Shell moulding process [1]

Thickness of the shell formed depends on the pattern temperature and the contact time.

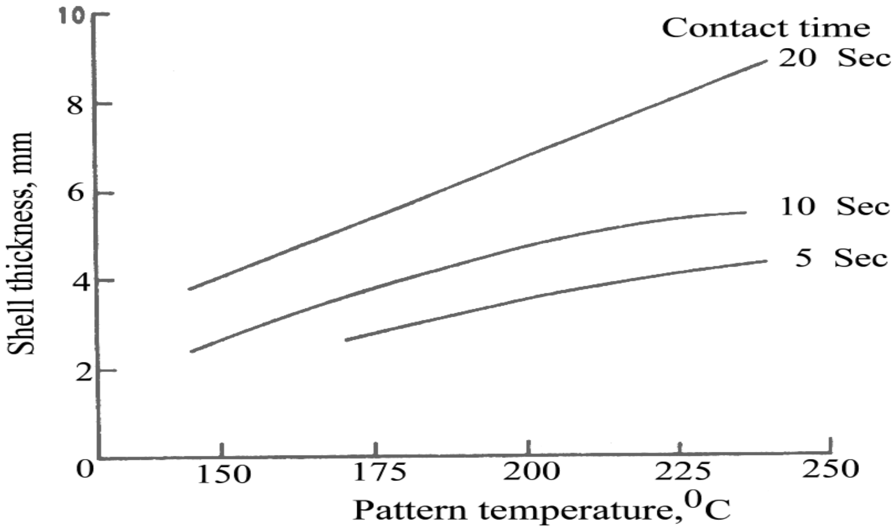

Figure 1.2 Effects of pattern temperature and contact time on shell thickness [5]

1.3 RAW MATERIALS REQUIRED FOR SHELL SAND

1.3.1 Silica sand

Silica sand is the basic material for making shell sand. The ideal silica sand for shell process should have following properties:

1. Grain Shape	Round to sub angular
2. Clay Content	0.2% max
3. Chlorides	0%
4. Carbonates	0%
5. Acid demand Value	<6 ml of KOH/100 gm of sand
6. Silica Content	98% min
7. AFS No	50-80

1.3.2 Phenol-Formaldehyde Resins

For manufacture of shell sand, phenol formaldehyde resin is used as a binder. The form of resin may be liquid or flake. Liquid resin is nothing but is a resin dissolved in alcohol. Liquid resin is used for manufacturing shell sand by either warm air process or by ignition process where as solid or flake resin is used for hot coating process. Most of Indian manufacturers of shell sand are using liquid resin, because of easiness of resins of the process. Generally following properties of resins are checked as acceptance criteria. [17]

Liquid Resin

- Clarity
- Viscosity
- PH value
- Coated sand properties at certain % age of resin.

Solid Resin

- Softening point
- Flow rate
- Particle size

1.3.3 Hexa Catalyst

Since phenol formaldehyde novolac resins are thermoplastic in nature and required formaldehyde donor to cure at certain temperature. Thus after blend of resin and hexa catalyst process becomes thermo set and formation of shell moulds and cores becomes possible. Hexa catalyst is nothing but it is a blend of hexa methylene tetra amine (formaldehyde donor) and lubricant. Lubrication helps for the flow ability of shell sand. Hexa catalyst is supplied and used in the form of fine powder. [17]

1.3.4 Additives

Shell moulds and cores mixtures are composed of sand, resin and additives. Sand provides the refractory property, the resin provides the adhesive property and additive provides the mould or core metal reaction inhibitor properties. While using additives their effect on permeability should be considered. Research on various additives has resulted in the development of shell sand with unique properties which reduce fining, increases high temperature strength and minimum exothermic effect of resin decomposition. [17]

1.4 PROCESSES FOR MANUFACTURING SHELL SAND

1.4.1 Warm Air Coating Process

First, pre weighed quantity of sand is charged into a mixer followed by hexa catalyst and mixed for 40-60 seconds. Phenolic novolac resin dissolved in alcohol (Liquid resin) is then charged and mixed for 2-3 minutes. After this alcohol solvent and water if any is driven off by flow of warm air for 4-6 minutes. During the coating process balling and built-up is observed followed by disintegration of lumps. At this stage coated sand is discharged coated sand temperature is maintained 60-65 °C, for ensuring complete evaporation of solvent/water. After disintegration and screening the coated sand is passed through cyclone where light non siliceous particles are removed and coated sand is cooled to room temperature. Cyclonised coated sand is stored in bunkers of bags. [17]

1.4.2 Hot Coating Process

The sand is heated to 120-150 °C. The resin in the form of flake or granulate is subsequently added to the mixer, melts and sand grains are coated. The hexamine is then added as an aqueous solution. A certain quantity of water is also added if required. The cooling effect produced prevents premature curing of binder. Lubricant like calcium separate is promotes collapse of the sand lumps in the mixture and serves as a partening agent in mould/core production. The water is driven off by a flow of warm air. After this, sand is discharged into disintegrator which is followed by vibratory screen for further lump braking and passed through a cyclone to remove fines and to cool coated sand to room temperature. Free flowing coated sand is stored either in bags or bunkers. [17]

1.5 ADVANTAGES OF SHELL MOULDING PROCESS

- **Excellent Surface Finish**: Shell sand process has ability to produce casting with excellent surface finish and capacity to produce fine detail.

- **Dimensional Accuracy**: The process has an ability to produce casting to tight dimensional tolerance. Due to this characteristic machining allowance can be reduced which ultimately helps for reduction in fettling and finishing cost.

- **Hollow Cores:** With the shell Sand hollow cores and thin profile moulds can be possible. This characteristic gives economics of Sand usage and ease of handling.

- **Sand to Metal Ratio**: This is the only process which given hollow cores and thin walled mould, which results in substantial weight reduction and material saving. Normally sand to metal ration is 1:1 which is much lower than other processes.
- **Ease of Handling**: Shell Sand moulds and cores are exceptionally resistance to damage through handling and storage. This happens due to high resistance to humidly. The shell cores and moulds can be stored for month without difficulty.
- **Resistant to Moisture Pickup**: The shell process is resistant to moisture pick up. The shell cores and moulds can be stored for long period even in high humid conditions. The resin used for shell process is stable and moisture resistant.
- **Simple Process**: The shell sand is supplied in the form of ready to use & thus need not require sand mixers etc where as other processes requires precise measuring and mixing of binders and catalysts
- **No Skill is Required**: Since everything is ready to use, with minimum training any worker can produce, repeatedly, precision moulds and cores.
- **Excellent Flow-Ability**: Due to the dry coating on sand, it gives better flowing ability and blowing ability than processes based on wet sand mixes.
- **Longer Shelf Life**: Shell sand has indefinite shelf life, if properly stored. Thus shell sand can be stored and used as needed by the foundry.
- **Less Inclusions and High Thermal Stability**: Shell sands are less prone to erosion by molten metal, because of high thermal stability of the phenolic resins, this characteristic of shell sand helps to reduce nonmetallic, burn in and scabs etc.
- **Little Pattern Wear**: Since patterns are made up of cast iron, very little or no wear is observed resulting longer pattern life. This helps to produce large number of casting without any dimensional problems.
- **Low Capital Investments**: Molds and cores making equipments are of moderate cost and where necessary can be added as cells. In shell process, bases sand can be easily changed to suit specific requirement of the casting. [17]

1.6 DISADVANTAGES OF SHELL MOULDING PROCESS

- **High Cost of the Process**: Phenolic resins used for the shell process are costly and at the same time % usage of resins are high compared to other processes. Hence process requires a tight control of the shell thickness otherwise competitiveness of the process will be sacrificed.
- **High Tolling Cost:** Shell process is thermoset and requires high temperature to cure, hence patterns used are of cast iron with smooth surface have very low expansion coefficient. All these results in costly affair compared to other processes.
- **High Energy Cost**: Shell process operates at around 250°C temperature which requires energy either by the way of electricity or L.P.G. The cost of energy is very high, when compared with other processes.
- **Limited Casting Weight**: Shell process in best for small intricate light weight casting. With shell process casting weight up to 80kg is produced. [17]

1.7 APPLICATION OF SHELL MOULDING

- Crankshaft fabrication
- Molded tubing fabrication
- Automotive castings (cylinder head fabrication).
- Hydraulic control housing fabrication
- cylinders and cylinder heads for air cooled IC engines,
- automobile transmission parts [17]

1.8 INTRODUCTION TO SAND RECLAMATION

In recent years foundry industry has been showing an increased interest in reclamation of system sands. One problem that confronts every foundry is that of processing an adequate supply of sand which has the properties to meet the many requirements imposed upon it in moulding and core making. The volume of sand required presents a major handling problem. Grain shape, screen analysis, chemical characteristics, as well as thermal characteristics, must be uniform to get uniform properties in today's sand mixes. These requirements can be further complicated if the use of a sand from a particular geographical location is required. While the purchase price of the sand may be the same as the local sand, the delivered cost becomes a major consideration. When transporting sand for a considerable distance, the foundry must allow for delays by maintaining a considerable stock or having a number of railcars in the circuit between the foundry and the pit. [4]

1.9 BASIC REASONS FOR RECLAIMING SAND

1.9.1 Cost reduction

The foundries desire to reduce the total sand cost which includes purchase cost, freight cost, and disposal costs. While the purchase cost of sand has gone up by more than 40% in the last 10 years, freight costs have gone up by well over 125%. The cost of 1 ton of sand is made up of purchase price, freight, unloading cost, transport cost in the foundry, and finally disposal cost. In some foundries they must not only pay for loading and unloading discard sand, but after a long distance haul they must pay a dumping fee.

1.9.2 Prevent environment degradation

It is becoming more difficult to dispose of great quantities of material into the ground. Governments want to know what chemicals are in all refuse and what amount might leach out from the sand. This interest is not only in the public dumps but on the foundry's own property. If the foundry is in a flood plain, materials they dump can have an effect on water supplies many miles away. The deposits of high quality sand will last longer if they are used more efficiently.

1.9.3 Technically

Reclamation is of interest in that in some cases binders and catalyst may be reduced in reclaimed sand. There are some indications that better castings can be made when rather large variations in impurity levels and screen analysis are minimized in an enclosed reclaimed sand loop. In many reclaim sand trials, when the sand has been cleaned to a proper level, the casting results are as good, if not better than in all new sand. On consecutive moulding pouring cycles, sand grains receive thermal shock from the pouring of molten metal into the casting cavity. Further mechanical shock is applied when the sand is impacted against the reclaimer target. The scrubbing of the individual grains occurs during transporting of the sand in the reclaimer as it moves from cell to cell. Sand grains with poor chemical structure or poor cleavage planes will fracture and the fragments in turn must be removed by dust collection. There is some data that shows repeated heating and cooling of Silica sand grains will produce a lower grain expansion. In many cases castings with better dimensional control have been made in reclaimed sand. [4]

1.10 REQUIREMENTS OF ALL RECLAMATION SYSTEMS

In any reclamation system the object is to remove a controlled amount of binder layer on the sand grain and by a dust collection system to remove the fines that are created. The requirements of any reclamation system are:

- All lumps and tramp material must remove. The lumps tend to be high in impurities and will add to rough casting surface.
- Both magnetic and non-magnetic metal must remove. The metallics are especially harmful in acid catalyzed binder systems. The acid will react with the metallic particles and a certain amount of catalyst will be used up in this reaction. This amount of catalyst will lower the amount left to react with the resin. The removal of non-magnetic is an especially difficult procedure. Either screening or some type of inertial separation is usually used.
- It must remove the inert and organic material to a low acceptable level. The acceptable level will depend on the sand used, the binder system used, the metal poured, and the sand to metal ratio. Other factors will vary from foundry to foundry.
- It must deliver reclaimed sand with a grain distribution that would be similar to the new sand specification used. The new sand was selected to give a certain casting finish. The standard practice should not be materially changed because of the use of reclaimed sand.
- Fines must remove to a uniform level. Fines are very high in impurities, whether they are organic or inorganic.
- The coating must remove from the sand grain in a uniform manner. For a new coating of binder to be of maximum efficiency the sand grain surfaces must be uniform.
- The reclaimed sand should work near equal to new sand. The casting results must be good as well as the shake-out characteristics of reclaimed sand. [4]

1.11 BASIC STEPS IN RECLAMATION

All of the reclamation units are combinations of five steps. The difference in the designs of the various systems is basically due to the order and manner in which these units are put together. The basic steps in reclamation are:

1. **Shake-out.** It is the method of separating the casting from the mould and the sand from the flask. It can be done by manual knockout, high energy impact vibrating shake-out, or by shot-blasting. The shake-out is usually the primary lump breaking unit. In the flasklessmoulding process there is no requirement to break the sand loose from the flask, but the casting must be broken loose from the sand. Although it is not considered a separate step, magnetic separation must be considered. Magnetic pulleys or magnetic overhead separators are required to remove rods, chills, and other magnetic metal.
2. **Crushing.** Crushing can be done by three different actions: The first method is by impact, in which a sharp instantaneous impingement of one moving objects against another. The hammer mill and cage mill would be examples of this type of lump breaker. Attrition or reduction of material by rubbing action. The horizontal vibrating conveyor, with louvered plate sections that allow the sand to fall through, is an example of this type of lump breaker. Process of compressing material between two surfaces. Jaw crushers are an example of this type of lump breaker. Because of the residual heat from the casting process some type of cooling is often required in a sand reclamation system. Heat is the most potent catalyst in any chemical reaction; therefore, heat will speed up the cure in the chemically cured binder systems.
3. **Cooling**

   Cooling unit can be placed before or after the scrubber and its location will affect the final design of the reclamation system. If the sand reclaimed is to be controlled closely, no residual moisture can be present in the reclaimed product. Some reclamation systems cool the sand by exhausting air through the various stages and transfer points such as elevators and belt conveyors.
4. **Scrubbing**

   Although some scrubbing is done on the sand in the shake-out and lumpbreaking process, further work is required. The form in which the scrubbing action takes place will affect the design of the equipment. Pneumatic sand scrubbers were designed to do further cleaning on the sand grains, by use of pneumatic power to transport the sand at a target and to use the impact for further binder removal. This impacting is controlled to be violent enough to knock binder loose from the sand grain surface but not hard enough to break good sand grains.

5. **Classification**

   Classification of sand is a very important step in a sand reclamation system. The reclaimed sand screen analysis should be similar to the new sand used originally. If the screen analysis varies a great deal, all the properties of the sand will vary. The coarse grains must be removed or rough casting surfaces will be produced. The fines must be removed to an acceptable level because they require high binder content for bonding and they also lower the permeability of the sand very rapidly. [4]

1.12 TYPES OF SAND RECLAMATIONS

1.12.1 Mechanical attrition

Mechanical attrition relies on the fact that the heat of the casting burns the resin binder close to the metal. Even at some distance from the metal, the sand temperature raises enough to embrittle the resin bond. Crushing the sand to grain size followed by mechanical scrubbing then removes much of the embrittled or partially burnt binder. The more strongly the sand has been heated, the more effectively is the sand reclaimed.

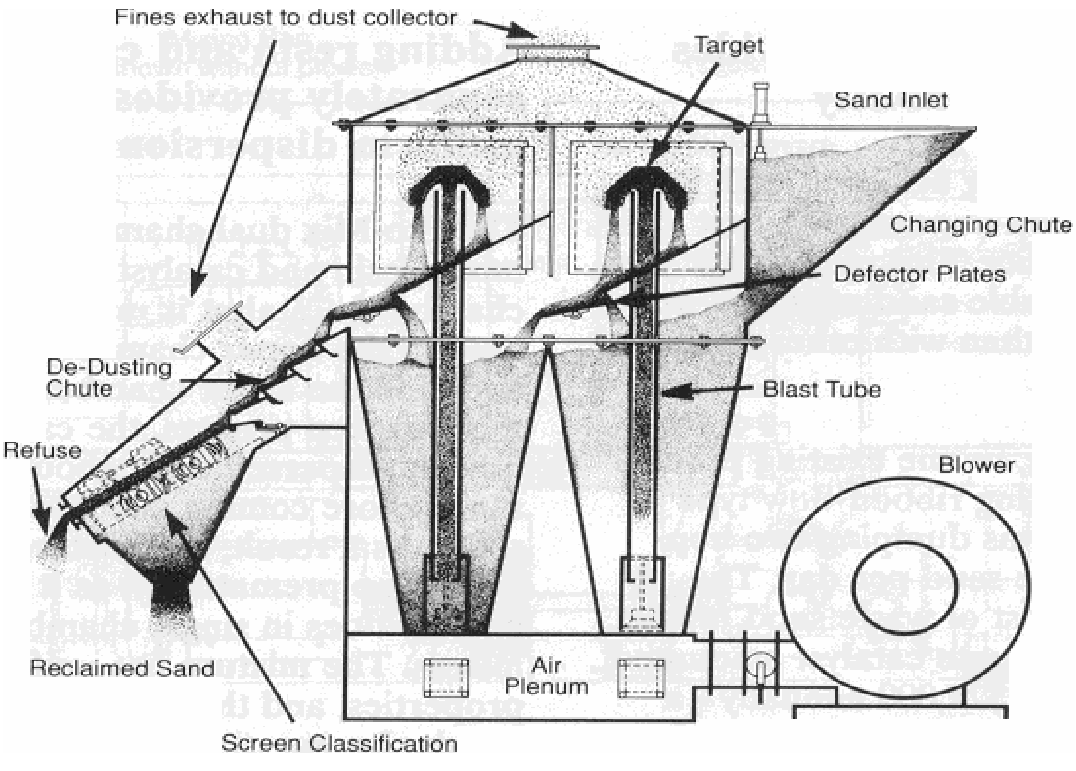

Figure 1.3 Pneumatic Scrubbing [19]

The steps in the mechanical reclamation process are:

- Breaking large sand lumps to allow the removal of metal etc.
- Separation of metal from the sand by magnet or screen.
- Disintegration of the sand lumps to grain size and mechanical scrubbing to remove as much binder as possible, while avoiding breakage of grains.
- Air classification to remove dust, fines and binder residue.
- Cooling the sand to usable temperature.
- Addition of new sand to make up losses and maintain the quality of the reclaimed sand. [19]

1.12.2 Thermal reclamation

Sand bonded with an entirely organic binder system can be 100% reclaimed by heating to about 600-700°C in an oxidizing atmosphere to burn off the binder residues, then cooling and classifying the sand. Thermal reclaimers are usually gas heated but electric or oil heating can also be used.

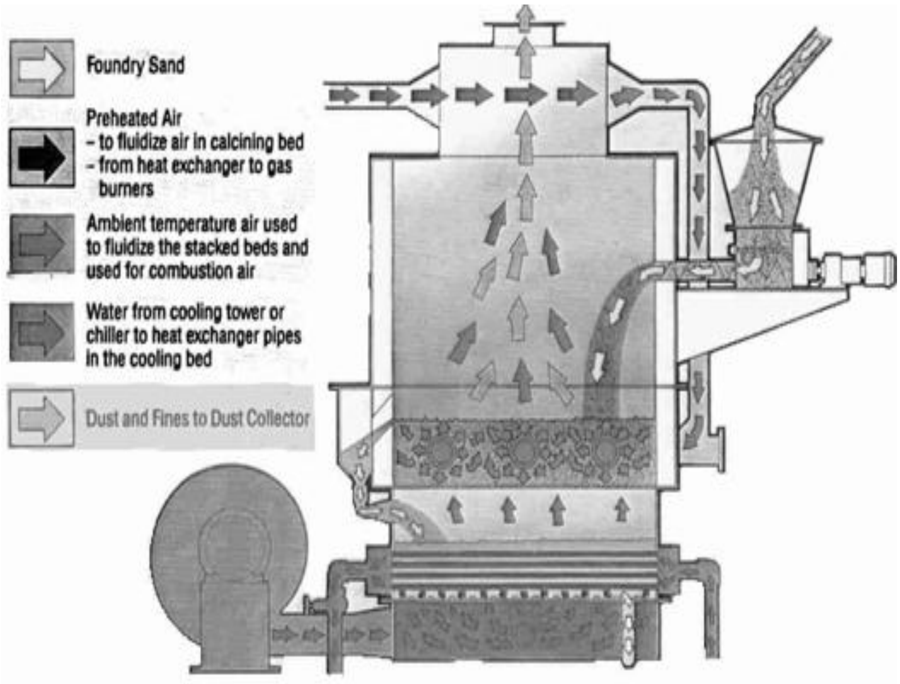

Figure 1.4 Thermal Reclamation Unit [19]

Thermal reclamation process consists of following steps:

- Lump breaking
- Metal removal
- Heating to about 600-700°C for a certain time in a fluidized bed furnace or rotary kiln.
- Cooling the sand, using the extracted heat to preheat the incoming sand or the combustion air
- Classification
- Addition of new sand to make up losses in the system.

Thermal reclamation is costly because of the large amount of heat needed and the relatively expensive equipment. The ever growing cost of sand disposal, however, leads to its increasing use. [19]

1.13 ADVANTAGES AND DISADVANTAGES OF SAND RECLAMATION

Advantages	Disadvantages
Reduced purchases of new sand	Some binder systems are not fully reclaimable
Lower waste disposal costs	Capital outlay required
Decreased binder catalyst costs	More technical controls required
Improved casting quality	Additional costs for pollution control and storage

1.14 ORGANIZATION OF THE THESIS

Chapter 1

This chapter covers the basic information of the shell moulding process and material required in shell sand. An overview of the sand reclamation process and reasons for sand reclamation process has been presented. Basic steps in the reclamation process and the type of sand reclamation processes are also described in this chapter.

Chapter 2

Presents the extensive literature review of research work which has been done by different researchers in the past .This literature is divided into three categories: method and apparatus for sand reclamation, shell sand preparation and sand reclamation.

Chapter 3

This chapter deals with design of study on the shell sand preparation, design of apparatus best suited for the reclamation process and the testing of the reclaimed sand based on different properties.

Chapter 4

This chapter is related to study on the different reclamation setups and design accordingly the setup for reclaiming the resin sand. Benefits of the setup as compared to previous processes are also described in this chapter. An overview of the setup construction and the working operation of the setup is also presented in this chapter.

Chapter 5

This chapter is related to the details of the experiments performed on the reclaimed sand and the different process parameters that were varied in the process. Composition of the resin sand used in the experimentation is also discussed. Moreover, different properties of the reclaimed sand that were compared with resin sand are also described.

Chapter 6

This chapter is related to the results of the experimental trials performed by varying the parameters of the reclamation process. Results of comparison of properties of the reclaimed sand and resin sand mixture with the properties of the fresh resin sand are also shown in this chapter.

Chapter 7

This chapter concludes results from the experimental trials performed and percentage of reclamation achieved. Future scope of the research work is also discussed is this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A large work has been done on different aspects of resin sand reclamation process. This chapter covers the literature on sand reclamation. The literature has been categorized into following sections:

(a) Method and apparatus for sand reclamation

(b) Shell sand preparation

(c) Sand reclamation

Crafton et al. [7]designed a furnace and method in which waste sand could be refined, cleaned and reclaimed, and through which metal work pieces containing sand cores could be directed for heat treatment, core removal, and sand reclamation. The system for reclaiming sand from a casting process included a chamber having an inlet, an outlet and a plurality of baffles defining a circuitous path for the sand there between. The system further included a heating element for providing heat to the chamber, and a fluidizing air distributor for agitating the sand and urging the sand through the chamber. The method included supplying waste sand to a sand reclamation unit including a chamber having an inlet an outlet and a plurality sand of baffles defining a circuitous path for the waste sand there between. The waste sand comprises sand and a binder material, fluidizing the waste sand in a fluidizing medium and heating the fluidized medium to a binder combustion temperature. As the fluidized waste sand traveled from inlet to the outlet along the circuitous path, the binder material was combusted. The characteristics of the fluidized bed were selected to achieve the desired level of sand refinement. The fluidizing medium was heated to a temperature of from about 250° C. to about 900° C. The fluidized waste sand traveled along the circuitous path for about 30 min. to about 60 min. The waste sand was supplied to the sand reclamation unit at a rate of from about 10 to 20 tons/hr.

Clayton [8] provided an apparatus and a method for reclamation of cores of bonded particulate material which was more compact and energy efficient. The apparatus comprised an outer compartment arranged substantially concentrically about an inner compartment. In one compartment there was breaking up of the bonded particulated material and other compartment was for removing the binder and for transferring broken up material from one compartment to the other. The means for removing the binder was heat at a temperature sufficient to burn off the binder. The temperature of the inner and outer compartments was controlled by heating means arranged to heat at least one wall of each compartment to heat and hold the contents of each compartment to and at a desired temperature heat. Preferably the transfer means was a weir, in a wall common to the compartments or it may also be a chute, passageway defining a path between the outer and inner compartments. The outer compartment had two or more partitions to define two or more distinct compartments. Each compartment was held at the same or at a different temperature.The inner compartment comprised an inlet and an outlet, means for fluidizing the particulate material to cause it to flow from the inlet to the outlet and means for regulating the flow of the particulate material from the inlet to the outlet to allow sufficient exposure to the heat to remove the adherent binder from particulate material.

Good et al. [9] developed a foundry sand reclamation system that requires less energy consumption, minimal air use and minimal emission volume while producing a fully cleansed sand product of any sand type. Sand reclamation apparatus was automatically operated at high volume throughput and operated to empty conditions without affecting a quick restart. The system consisted of a treatment tower having a plurality of heat conductive stainless steel tubes extending across the interior of the treatment tower. The tubes being arranged in rows and staggered with respect to each other to create close spacing there between. Fuel fired burner units stationed in the tower below the tubes to generate hot gases that quiescently rise and heat the tubes to a temperature level at or in excess of 1300° F. and there was sand feeder stationed at the top of the tower to controllably admit a predetermined supply of particulated sand to the tubes of the tower through which the sand flowed along the contours of the tubes to be heated essentially by conduction to combust the resin coating and to produce cleansed sand and a gaseous emission that leaves the sand, the cleansed sand exiting from the tower bottom.

Pohl [10] showed the process and a device for reclaiming used foundry sands. In the process the used sands were free from carbon containing materials in a first step by means of a thermal treatment. In as much as they contain organic, carbon-containing material, and are subsequently mechanically cleaned batch-wise, for which purpose wear-resistant friction elements are moved through the sand charge as a function of the degree of utilization of the respective sand batch at such a speed that the said grain of the batch was not destroyed. The device according to the invention consisted of a cylindrical housing, in which rotationally driven friction elements are provided means for the batch-wise filling of the receptacle with used sand and means for discharge cleaned sand from the receptacle being provided. The drive of the friction elements was affected as a function of the degree of utilization of the used sand and in such fashion that the quartz grain of the sand batch was not destroyed.

Oniyanagi et al. [11] provided a resin composition for a shell mould which reduces smoke generation upon moulding of a casting mould and maintains a crumbility and casting mould strength of a phenolic resin. The resin composition for the shell mould included the phenolic resin and an aromatic condensed phosphate ester. The phenolic resin was used as a binder of the resin coated sand used for producing a main mould and a core for shell mould casting of cast iron, cast steel, aluminum, and the like. The aromatic condensed phosphate ester was very effective as a crumbling agent for improving the crumbility of the casting mould after casting.

Kwata et al. [12] studied production process for a phenols novolac resin obtained by reacting phenols with formaldehydes. They were reacted in the presence of a metal compound used as catalyze for the reaction, and a chelating agent was further added in order to deactivate a catalytic action of the metal compound and a resin coated sand prepared by using the above phenols novolac resin. It was possible to provide a process for producing a phenols novolac resin having an ortho rate of 30 to 60 %, suitably 40 to 55 % at a good yield (70% or more) and resin-coated sand having a high curing property prepared by using the above phenols novolac resin. An example of Production of phenols novolac resins and the production of resin-coated sands was shown. After that flexural strength and the curing property were evaluated.

Ina [13] provided resin-coated sand which was excellent in fluidity and capable of producing a high-strength casting mould having smooth surface and also the resin coated sand which can be preferably used in multilayered mould making method. Researchers observed that resin coated sand using spherical moulding sand that was refractory particles having a specific composition and particle diameter with high sphericity and smooth surface reducing water absorption can exhibit excellent performance as moulding sand. Further, the resin-coated sand of the invention used spherical moulding sand having a smooth surface to attain excellent sand washout and to allow the surface to be coated with resin added in a smaller amount exhibit excellent adhesion to attain high mould strength. The amount of gas generated upon decomposition of resin was be reduced at the time of casting, so high-quality castings can be produced. Further, it was excellent in fluidity to allow it to be highly and uniformly filled in forming a mould. The resin-coated sand was also excellent in disintegration after casting. By virtue of these excellent characteristics it can be satisfactorily substituted for expensive zircon sand and ceramic sand used as special sand in a foundry.

Ina [14] found that resin-coated sand using spherical moulding sand that was refractory particles having a specific composition and particle diameter with high sphericity and smooth surface reducing water absorption can exhibit excellent performance as moulding sand. According to researcher there was obtained resin-coated sand which was excellent in fluidity and capable of producing a high-strength casting mould having a smooth surface. It can endure casting at high temperatures and can be used preferably in producing cast steel and cast iron. Also it was low-expanding thus preventing casting defects (veining and mould cracking) in castings attributable to expansion of sand thereby coping with the demand for dimensional accuracy of complicated castings.

Rediger et al. [15] discovered Phenolic resin binder systems for refractory materialmoulds used in metal casting which greatly improve the ability of thermally reclaimed refractory particulate material to be reused over many thermal reclamation cycles. In particular, the complete elimination of calcium compounds such as calcium stearate and calcium hydroxide, conventionally employed as a mould lubricant and as a resin curing catalyst was found to improve the quality of thermally reclaimed refractory particulate material without disadvantageously impacting the performance of the resin binder in preparing reclaimed refractory particulate material moulds. While organic residues originating from the binder were efficiently removed by thermal reclamation of the refractory particulate material used in moulds, calcium compounds were converted to calcium oxide which remains on the refractory particulate material and gradually accumulates over the course of several thermal reclamation cycles. It was believed that the accumulated calcium results in the observed decrease in the strength of moulds, over time that was made from thermally reclaimed refractory particulate material. Moreover, it was observed that the addition of aluminum-containing clay in sand clay blends exacerbates this problem due to interactions between the accumulated calcium oxide and accumulated aluminum oxide which adversely impact ability of the sand to form strong, rigid moulds. Therefore, the substantial elimination of calcium compounds from the binder system advantageously allowed for the long-term thermal reclamation of sand/clay blends for forming metal casting moulds with high tensile strength.

Okubu et al. [16] produced resin-coated sand by coating the surface of a refractory granular aggregate with a thermosetting resin and a thermoplastic resin. When using this resin-coated sand, a mould with a less rough surface was produced by a moulding apparatus. When using this mould made of the resin-coated sand, a casting with fewer gas defects was produced. Present inventors had intensively researched a laminate shaping method so as to achieve the above object and observed that the phenolic resin was merely melted by laser sintering and the curing reaction hardly proceeds, and particles of moulding sand were bonded to each other only by solidifying after the completion of laser irradiation. In this case, the phenolic resin was cured by a treatment of heating at 170 to 250° C. which was carried out after shaping by laser irradiation. Since the molecular weight of a thermosetting resin increased by the curing reaction, a thermosetting resin having comparatively low molecular weight was used before the curing reaction. Therefore, sufficient bonding strength was not obtained only by melting and solidifying the thermosetting resin, resulting in poor strength. This fact was also been founded by the present inventors and after further research it was concluded that a thermoplastic resin was employed so as to cope with poor bonding strength.

Dhumal [17] suggested two main processes used for coating the resin sand. These processes were: (1) warm coating (2) hot coating; in warm coating process, preweighed quantity of sand was charged into a mixer followed by hexa catalyst and mixed for 40-60 seconds. phenolicnovolac resin dissolved in alcohol was then charged & mixed for 2-3 minutes. After this alcohol solvent and water was driven off by flow of warm air for 4-6 minutes. During the coating process balling and buildup is observed followed by disintegration of lumps. At this stage coated sand was discharged. Coated sand temperature was maintained 60-65°C for ensuring complete evaporation of solvent. After disintegration and screening the coated sand was passed through cyclone where light non siliceous particles were removed and coated sand was cooled to room temperature. Cyclonised coated sand was stored in bunkers of bags. In hot coating process the sand was heated to 120-150°C. The resin in the form of flake or granulate was subsequently added to the mixer, melts and sand grains were coated. The hexamine was then added as an aqueous solution. The cooling effect produced prevented premature curing of binder. Lubricant like calcium promoted collapse of the sand lumps in the mixture and served as a partening agent in mould/core production. The water was driven off by a flow of warm air. After this, sand was discharged into disintegrator which was followed by vibratory screen for further lump braking and passed through a cyclone to remove fines and to cool coated sand to room temperature.

Lemon et al. [18] gave phenolic resin composition suitable for use in bonding refractory materials in the production of foundry moulds and cores. The phenolic resin composition comprised an esterified phenolic compound, a phenolic novolac resin and a base, which react to provide final cure in the presence of water or other polar solvent. The composition once reacted, will bond granular refractory materials. The esterified phenolic compound containd at least one esterified methanol group positioned ortho or para to a phenolic hydroxyl group or an esterified phenolic hydroxyl group. Included within the invention were anhydrous precursors to the reactive phenolic resin composition and also foundry moulding compositions which incorporate the reactive phenolic resin compositions. Other embodiments included methods for making foundry moulds and cores and methods for curing the reactive phenolic resin composition.

Hughes [19] looked at the different types of reclamation units available and their impact on reconditioning the sand for re-bonding. The three main types of sand reclamation were Dry Attrition, Thermal reclamation; and Wet reclamation. Dry Attrition most common system due to lower capital cost and lower running costs. Testing of sand which was reclaimed, with and without the high attrition units, revealed the following results (1) the LOI for all binder systems was reduced by 20-40% (2) alkalinity or acidity was also reduced by 15-40% and (3) there was excess dust and fines generated which must be removed. Thermal reclamation was used for the reclamation of organic based binder systems to try and achieve 95-100. The sand was heated to 600-720°C, which removed all the organic component of the binder by combustion. After thermal treatment the sand should have an LOI less than 0.3%; an acid value below 1%, and an alkalinity of less than 2%. Different types of binder systems that were being reclaimed and their limitations to achieving 100% re-use were also reviewed. Acid set furanresins compared to other self-set resin systems was of the best levels of reclamation, which was high as 95%. The LOI should be 2.5% max.The reclamation of the ester set alkaline phenolic systems, had improved with the average now being 75% with a maximum of 85%. To maintain good mould and core strengths and casting surface finish, the LOI of the reclaimed sand should be 2.0% maximum. The alkalinity should be less than 6%. Phenolic urethane self setPhenol urethane cold set system can be reclaimed up to 95% by dry attrition. It was important to keep the loss on ignition at 3% maximum as nitrogen will build up in the reclaimed sand which could cause nitrogen fisher defects. To eliminate these defects, either an iron oxide up to 3%, or a proprietary sand additive was added to the sand.

Danko [20] presented problems of scientific and development research concerning the innovative reclamation technologies of used foundry sands such as: mechanical-cryogenic reclamation and innovative thermal reclamation. Mechanical-cryogenic reclamation use extra-low temperatures as a factor intensifying the process of the waste sand mechanical reclamation. It was assumed by reducing the temperature at which the process of reclamation was carried out, the envelope of sand binder present on the surface of the sand grains should become more brittle, and the binding forces which were acting between the sand grains and the envelope of binder present on these grains should be weakened. The currently used processes of reclamation with application of extra- low temperatures were the only ones, which among all other well-known techniques of the reclamation can effectively utilize the hygroscopic behavior of moulding sands as a factor intensifying the process of releasing the sand grains from a binding material. In case of thermal reclamation modification consisted on usage of sole oxygen or air-oxygen mixture as a fluidization agent. The conducted studies confirmed that the core sand-to-core sand reclamation created a lot of technical problems. The application of oxygen enabled this time to be shortened quite considerably (by even as much as 60%), not deteriorating in any way the reclaim quality. This can be of particular importance for foundries which face some problems with throughput of the already existing thermal reclamation units, which can easily be improved without high investment outlays. At the same time, it creates the possibility of extending further the range of reclamation units which use the oxygen-enriched air to perform an even more efficient process.

Danko [21] investigated the regeneration process of mechanical and thermal carried out with the new, unconventional treatments which improve the reclaimability of used moulding sands. Some tests were made to improve the effectiveness of a mechanical reclamation process as applied to the most used type of the waste moulding sands. Compared to most of the currently used mechanical reclamation units operating under ambient conditions, the same equipment when adapted to operation at low temperatures in a short time produced the sand grains of better technological parameters. Researcher focused on an assessment of the reliability of the sand used in the technology of loose self-setting mixtures and made trials on the sand which was not burnt down, considering this type of sand much more difficult for reclamation than the burnt down material. The conducted studies confirmed that the core sand-to-core sand or green sand-to-core sand reclamation creates a lot of technical problems. So far, to perform this process, mainly thermal reclamation was used, which in industrial plants can last from about 25 to 30 minutes. The application of oxygen enabled this time to be shortened quite considerably not deteriorating in any way the reclaim quality. This can be of particular importance for foundries which face some problems with throughput of the already existing thermal reclamation units, which can easily be improved without high investment outlays. At the same time, it created the possibility of extending further the range of reclamation units which use the oxygen-enriched air to perform an even more efficient process.

Danko et al. [22] defined reclamation of spent moulding and core sands as a treatment of used moulding refractory materials, enabling a recovery of at least one of the components of properties similar to the ones of the fresh component and its reuse for production of casting moulds and cores. There was a lack of a reclaimed material assessment index, which could be applied for each type of moulding sands and reclaims. The most important criteria of the technological assessment of the reclaimed materials which should be used in order to determine the reclamation degree of spent moulding sands originated from the most often used foundry technologies were presented in the paper. All types of spent moulding sands, which means organic as well as inorganic, were subjected to a mechanical reclamation. To this end examination methods of the mechanical reclamation process were taken into account a specificity of both groups of spent moulding sands from the point of view of satisfying criteria of the reclaim assessment.

Fenyes [23]presented an overview to foundries to maximize their sand recovery. The primary topics were: (i) Primary and Secondary attrition, (ii) Thermal Reclamation.

Primary attrition process had its limitations in terms of metal cast and also the type of binder employed to maximize reclamation levels using primary attrition only, the foundry must observe characteristics like Good Sand to Metal ratio - typically 4:1 or less, Ferrous castings, and Low binder addition rate. With the above criteria in place it was possible for the foundry to reclaim up to 90% of its sand whilst maintain low loss on ignition levels that do not impact sound quality and also allow a good working environment in terms of fume liberated in the casting process. In case of Thermal reclamation, the plant should be sized according to the amount of sand that was presently being thrown away, and not the total amount that was being consumed. By doing it this way allows the foundry to use a combination of mechanical and thermal reclamation, Thereby reducing the size of the thermal plant needed and the associated capital and running costs. However it should be noted that although the sand, post thermal reclamation was typically less than 0.1% loss on ignition, it does not mean that the system was 100% efficient as there will be losses of approx. 5-8% in the system when processing the sand. Researcher suggested an alternative to thermal reclamation was secondary attrition which impart further 'work' onto the sand after primary attrition in an attempt to remove more of the binder and hence, in turn, to re-use a higher amount within the foundry. Probably the major difference in the use of secondary attrition was that because the loss on ignition was only reduced and not taken to very low levels as in the case of thermal reclamation, all the sand was processed through the plant to give an overall reduction in the loss on ignition.

Danko and Kaminska [24] performed the preliminary investigations of the mechanical-grinding reclamation of used sands from the alpha-set technology belonging to a sand group difficult for reclamation. The new testing apparatus equipped with a rotor system enabled change of intensity of grinding and crushing influences by selecting shapes of rotor elements and rotational speeds of a rotor system was applied in the mechanical reclamation. This apparatus enables the used sand reclamation in a traditional vertical system of a rotor and apparatus system or the operation in out of plumb system (from 0 to 6°). This apparatus was made in order to create comparative conditions of used sands reclamations which constitute the basis for comparative assessment of reclaimability of various sands, at not changing reclamation influences. The effects of releasing matrix grains from coatings of binding agents obtained under these conditions were more reliable and the determined effectiveness of the matrix reclamation from various used sands.

Danko et al. [25] dealt with problems of scientific and development research concerning the reclamation of used foundry sands as management of used sands generated in foundry production. Significant progress in the reclamation was related to several factors, which should be considered. The most important were: basic research supportive to searching for the sands which would be the reclamation friendly and neutral for the natural environment, striving to achieve the compatibility of mould and core technologies substantiated by the possibility of the common reclamation of spent sands in the system of mixed sands and allowing to utilize the specialist reclaimers of much simpler construction instead of very costly universal ones. Application of the proper material management in the range of moulding and core sands leading to diminishing the number of sands being used in the foundry, optimization of the existing reclamation methods by introduction of improvements and new solutions to the process.

Lucarz [26] evaluated new silica sand grains surface condition after mechanical reclamation treatment as well as on the conditions of reclaimed sand grains surface subjected to thermal and thermo-mechanical reclamation processes. In the process of thermal reclamation some elements (Pb, Cd, Fe, Cu, Mn, Zn) as well as other inorganic compounds which do not undergo combustion (for example phosphorus and potassium compounds) remain on the surface of the grains and form impurities in it as a result of the repeatedly applied process of thermal reclamation and renewed use of the same base sand grains to prepare successive batches of moulding. The impurities formed on the surface of the grains, which consist of incombustible components, can be removed by dry mechanical reclamation method and by air separation. Investigations consisted of 9 cycles of using the same silica base sand to the preparation of the green sands, obtained as a result of thermal reclamation The results of the mechanical properties tests of the sand mixture prepared of the base sand of the reclaim, as the number of the cycles of the thermal reclamation increase, showed a decrease in strength of the sand mixture prepared from the reclaimed material. The application of the mechanical reclamation after the thermal reclamation improved the mechanical properties of the new prepared sand mixture. The additionally applied treatment of the mechanical reclamation abraded the surface of the grains, which was revealed by a greater amount of impurities. It proved that the applied air separation was of small effectiveness.

Dankoand Danko [27] presented a short study of the mechanical reclamation techniques implemented in industry and of a research conducted at AGH-UST aiming at intensification and improvement of the mechanical reclamation processes by using extra-low temperature environment. In the paper, laboratory stand and the results of mechanical reclamation of used foundry silica sands with bentonite and water glass binder, carried out at both extra-low (about minus 70 °C) and ambient temperatures were presented. The obtained results were evaluated and compared with data taken from the foundry practice. Studies described here indicated that the reclamation of used moulding sands with water glass conducted in the range of extra-low and cryogenic temperatures was fully justified from the technological point of view. The mechanical-cryogenic reclamation obviously improved the reclamation output in the case of both investigated sand types, subjected to reclamation in the same reclamation unit, which has all the features of a plant of the traditional design, commonly used for the mechanical reclamation process. At this point, however, attention should be drawn to the fact that the mechanical-cryogenic reclamation of sands with either water glass or bentonite may, if not adequately controlled, lead to a much quicker wear of the sand grains and formation of large volumes of the dust.

Stuart et al. [28] investigated carbohydrate was added to sand, which was used to make foundry moulds or cores, and which was bonded using an alkaline resol phenol-formaldehyde resin, prior to reclamation of the sand by a thermal reclamation. The thermal reclamation was done in other equipment, for example, a rotary thermal reclamation unit, but was preferably done in a fluidized bed reclamation unit. The carbohydrate was preferably water soluble and was added to the used sand as an aqueous solution. The carbohydrate may be for example a monosaccharide, such as glucose, mannose, galactose or fructose, or a disaccharide such as sucrose, maltose or lactose. The carbohydrate may also be a carbohydrate derivative such as a polyhydric alcohol, a sugar acid or a polysaccharide derivative. The amount of carbohydrate used in the reclamation process was usually of the order of 0.25% to 5.0% by weight based on the weight of used sand.

2.2 GAP IN LITERATURE

After studying the literature it is concluded that a lot of work has been done on reclamation of resin sand used in the shell moulding process in one way or another. Few inventors [7], [9] have designed the fluid bed furnace with the gas fired burner for the thermal reclamation process. Some inventors [8], [10] have made heating chamber with a heating element for providing heat to the chamber. Some researchers [19], [26] have used only thermal reclamation of sand while others investigated that mechanical attrition before or after the thermal reclamation maximizes the reclamation. Some researchers [20], [21], [27] studied the mechanical cryogenics technique for the reclamation. Few researchers [22], [24, [25] have analysis the effect of process parameters (bending strength, ultimate tensile strength, loss on ignition, Acid value) on performance of reclamation process.

After observing the literature available regarding the resin sand reclamation, the literature reveals that a lot of work has been done on comparing the performance based on ultimate tensile strength, bending strength, loss on ignition and acid value, no work has been done on comparing performance based on compressive strength and hardness of the core made from the reclaimed sand. Furthermore, no work has been reported from the literature on reclamation of small quantity of sand and investigates the effects of parameters like heating temperature and duration of heating on the performance of the reclamation process and comparing the optimum result with the performance of the resin sand.

CHAPTER 3
DESIGN OF STUDY

3.1 INTRODUCTION

Based on the literature survey and the subsequent analysis of gaps the present work aims to design and fabricate setup for reclamation of 5 to 10 kg resin sand and investigate the effect of process parameters like heating temperature and duration of heating on the performance of the reclamation process and comparing the optimum result with the performance of the resin sand.

3.2 OBJECTIVES

The objectives of the study are to

- Prepare the resin sand by mixing the resin (phenol formaldehyde) and catalyst (hexa methylene tetra amine) in desired proportion with the fresh silica sand.
- Design and fabricate the apparatus for reclaiming the used sand and perform the reclamation operation.
- Evaluate the effect of process parameters (heating temperature and duration of heating) on the properties of reclaimed sand.
- Analyze the optimum result from the experimental work and compare its properties (compressive strength, hardness and loss on ignition) with the resin coated sand.

3.3 WORK PLAN

Following activities were carried out to complete the project:

1. Preparatory work
   - (a) Collect the fresh silica sand, phenol formaldehyde resin, hexa methylene tetra mine catalyst.
   - (b) Prepare the resin sand by mixing the resin and catalyst with the fresh silica sand.

(c) Prepare the core of resin sand to perform hardness and compressible strength tests on prepared resin sand.

2. Design and fabricate the setup for reclaiming the used sand.

3. Reclamation of the used sand performed by varying the process parameters (heating temperature and duration of heating).

4. Evaluate the effect of these parameters on the properties of reclaimed sand.

5. Analyze the optimum result from the experimental work and compare its properties with the resin coated sand.

3.4 STUDY ON RESIN SAND COATING

There are two processes for resin coating: warm air coating and hot air coating. Warm air coating process is used more often these days but due to the unavailability of the resin coating equipment, hot coating process was performed with some modifications. In the literature the resin coated sand comprises of following parts:

- Silica sand
- Resin (phenol formaldehyde) 3 to 6% by weight of silica sand
- Catalyst (hexa methylene tetra amine) 15 to 20 by weight of resin

In the hot air coating process first, silica sand was heated to the 120-150 °C and was transferred to a mixer and the catalyst in the powder form 1 % of sand weight was added to the mixer and mixed for 10 seconds followed by liquid resin 5% of the sand weight. The mixture was mixed for a minute which melts the resin and produced coated sand.

From the study of the literature resin as 5% by weight of silica sand and catalyst as 20% by weight of silica sand were taken in composition of resin sand for study.

3.5 DESIGN OF THE SETUP

In the literature on the reclamation of resin sand, most of the researchers used thermal reclamation instead of mechanical reclamation for the maximum reclamation results. In thermal reclamation used sand was heated at temperature above 600°C for certain period of time so the resin present in the sand get burnt and the reclaimed sand was collected at the exit.

Various types of thermal reclamations were:

1. Rotary kiln
2. Multiple hearth
3. Fluidizing bed furnace

But in the present work none of the above apparatus could be used due to the following limitations:

1. **Space**. All these apparatus require large space as they have number of parts but the present experimental setup require less space so that it can be placed anywhere in the workshop.
2. **Complicated construction**. All the above mentioned apparatus had very complicated construction. Equipment like rotary kiln had large number of moving parts which were not easy to construct and assembled together without an expert.
3. P**roblem with energy supply**. All the apparatus were gas fired or oil fired so it was difficult to manage the gas or oil as compared to the electric supply. Moreover, it was difficult to control the supply of for the proper combustion in case of gas fired or oil fired furnaces.
4. **Require a blower**. The apparatus mentioned above needed a blower to supply the air for the combustion which increased the apparatus cost and caused more energy consumption.
5. **Not suitable for small amount of sand reclamation.** These apparatus were suitable for the large amount of sand and for continuous process while for this experimental work small amount of sand needed to be handled.

In addition to the above considerations few researchers used dry attrition before or after the thermal reclamation to maximize the reclamation of resin sand. If dry attrition was done before the thermal reclamation the abrasive action cracks of the binders which helped in heating all individual grains within sand mass to the same degree in a continuous and uniform manner. Apart from the all above considerations following considerations were also considered in the design of the apparatus:

(a) The cost of energy employed in the process

(b) The amount of land that is required to support the processing equipment

(c) Governmental regulations of waste disposal

(d) Density or chemical variability of the reclaim sand preventing sand bonding for core making

Keeping in mind all above considerations a setup for the sand reclamation was designed, which was an electric furnace with rotatary cylinder which accomplish both the heating and abrasive actions.

3.6 STUDY ON RECLAIMED SAND TESTING

Researchers had studied the performance of the reclamation process on the properties like ultimate tensile strength, acid value, loss on ignition, sieve analysis and other chemical tests. The reclaimed sand was tested based on mechanical properties. These properties were:

1. Compressive Strength
2. Hardness
3. Loss on ignition

CHAPTER 4
DESIGN OF SETUP

4.1 INTRODUCTION OF THE SETUP

In the literature on the reclamation of resin sand, most of the researchers used thermal reclamation instead of mechanical reclamation to maximize the reclamation. In thermal reclamation used sand was heated at temperature above 600° C for certain period of time so the resin present in the sand get burnt and the reclaimed sand was collected at the exit.

In addition to the above considerations, few researchers used dry attrition before or after the thermal reclamation to maximize the reclamation of resin sand. If dry attrition was done before the thermal reclamation the abrasive action cracks of the binders which helped in heating all individual grains within sand mass to the same degree in a continuous and uniform manner. Moreover, the conditions like type of energy source available, space available, cost of the equipment needs to be considered.

Keeping in mind all above considerations sand reclamation setup was designed which was an electric furnace having an inclined rotating cylinder which accomplish both the heating and abrasive actions. With this setup, it is possible to perform both dry attrition and thermal reclamation which leads to maximize the reclamation. Moreover, researchers used separate equipment for the dry attrition process which increased the cost of the equipment and also the energy consumption. In addition, in the present setup there was no need of the blower for the combustion process, it also reduced the energy and equipment cost.

4.2 BENEFITS OF THE SETUP DESIGN

1. **Simultaneous Heating and Abrasion**: As the simultaneous heating and abrasion of the sand take place, during the abrasion the binder get cracked and separated from the sand and heating action burns the separated binder more quickly.

2. **Easy flow of sand**: The setup has the rotating cylinder which is inclined at an angle of 5° from the horizontal. This rotation and the inclination of the cylinder ease the flow of sand from the heating chamber to the cooling chamber. In case of fluid bed furnace there was difficulty in the flow of sand through different chambers. A vibrator was required at the base or used other means to accomplish the flow of sand.

3. **Prevents agglomerate:** There were problems in reclaiming foundry sand which was bonded with an alkaline phenol formaldehyde resin, by a thermal process, particularly when the thermal treatment was done in a fluidized bed, because the individual particles of used sand tend to re-agglomerate during the process. Due to the presence of alkali in the resin binder, the used sand contains sodium or potassium compounds and it was believed that during the thermal treatment these alkaline compounds on the surface of the sand particles decompose or melt and caused the sand particles to fuse together. Some additive must be added to prevent the fusion. But as the sand moves continuously inside the rotating cylinder problem of the fusion of the sand particles got eliminated. [28]

4. **No extra equipment required**: It performs the dry attrition process by itself before the heating process hence eliminating the need of any additional equipment to perform the dry attrition process. It helps in reduction of the cost of the equipment.

5. **Uniform heating**: In electric heating the there is slow and constant heat addition which help in heating all individual grains within sand mass to the same degree in a continuous and uniform manner.

6. **Elimination of blower**: In the fluid bed furnace the blower provided the air that required for the combustion of sand whereas in case of electric heater there is no need of the blower. Which reduces the apparatus cost.

7. **Ease of operation:** It is very easy to operate than gas fired or diesel fired furnace. Even a single person can operate it because there is no valves, moreover there is no spark needed to ignite the fuel.

8. **Safety**: There are no gas safety issues to be concerned with. In case of any short circuit it will automatically cut of the electric supply but in case of gas fired furnace there was far more risk involved any back fire can produce a blast which could be dangerous to the human being.

9. **Quietness:** The electric furnace is almost completely quiet. Gas furnaces can be very noisy and can add significantly to plant sound pollution which will be subject to increasing regulation in the future. Gas furnaces generate noise with their combustion blowers and from the burners themselves.

10. **Maintenance and Adjustment:** There are no gas burners to adjust. Electric operation is very straightforward. This is simple enough that most in house maintenance people can do this easily with the most minimal of instruction. If fuel composition changes (which can happen during winter or during fuel shortages) this may change the necessary adjustments when uniformity is a critical issue. There is very little routine maintenance on electric heater.

4.3 CONSTRUCTION OF THE SETUP

Following were the main parts in construction of setup:

1. **Refractory drum:** It is a cylinder of 480mm diameter and 1150mm height, manufactured by mild steel sheet of 3 mm thickness. It is divided into 2 parts: heating chamber and cooling chamber. Heating chamber is the upper portion of the drum. It is a chamber where the heating action takes place inside the rotary cylinder. There is refractory lining on the periphery of the chamber with help of fire bricks. Inside the chamber there is a rotating cylinder and below it there is electrical heating system which provides heat to the cylinder and the heat from the cylinder is provide to the sand inside it through conduction. The temperature inside the chamber is maintained from 450 to 600° C. Below the heating chamber is cooling chamber where the sand is cooled to the atmospheric temperature after leaving the heating chamber.

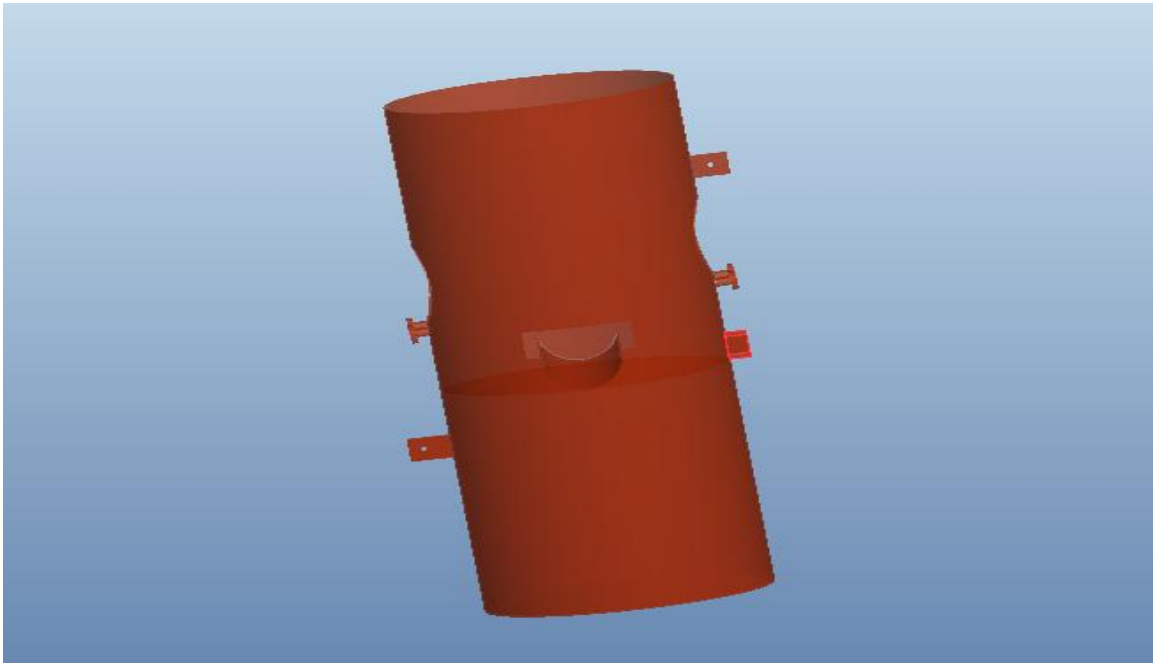

Figure 4.1 Refractory drum

2. **Rotary cylinder:** It is a cylinder of 165mm diameter and length 500mm, manufactured by mild steel sheet of 4mm thickness. The used sand is heated inside the cylinder. The cylinder is inclined at the angle of 5° to ease the flow of sand from the entrance of the sand to the exit after the heating. The cylinder is open at one for pouring of used sand through the funnel. The other end had holes on its face to exit the reclaimed sand from it. A spur gear is attached on periphery of cylinder on one end to transmit the motion from DC motor. On the other end a guide way is made within which the roller bearing rolls. It provides the smooth rotation of the cylinder. The ribs are welded inside the cylinder along the circumference for proper mixing of sand.

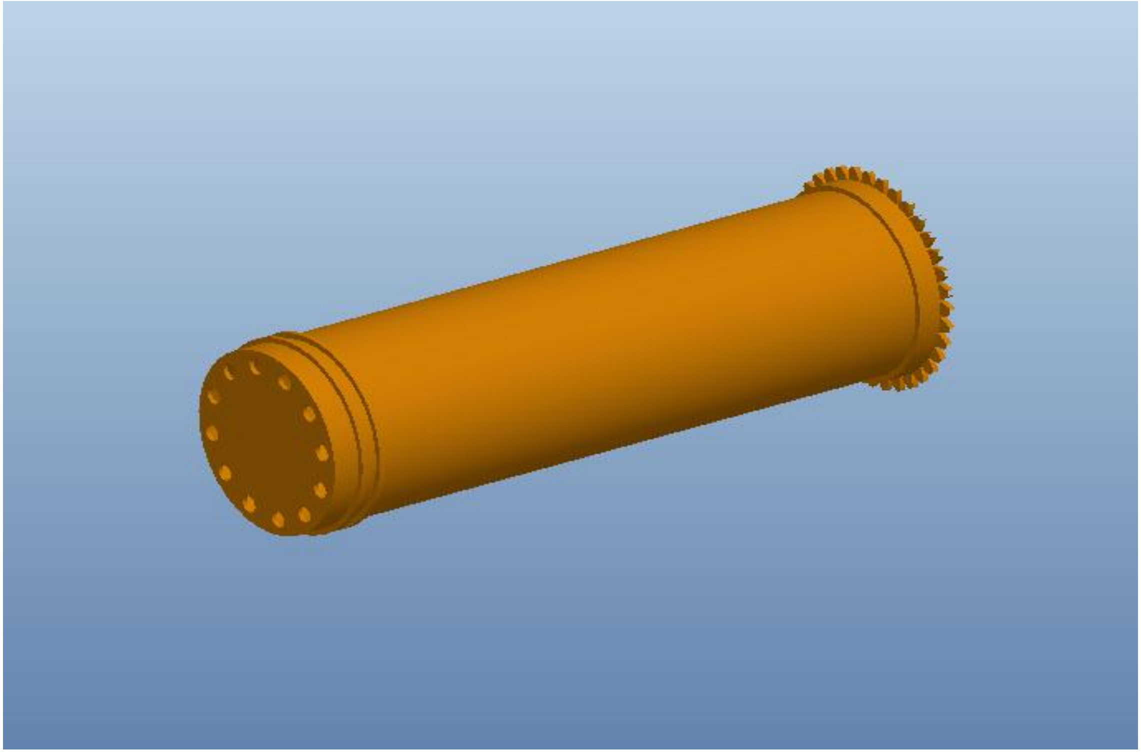

Figure 4.2 Rotary cylinder

3. **Detachable heating arrangement:** The arrangement is placed below the rotating cylinder to heat the cylinder. The whole arrangement is made detachable for the ease of repair or replacement of the heaters. The arrangement consists of a semicircular shape tray which could slide in or out the drum. A handle is welded on one end of the tray to move the tray in and outside cylinder. Two electrical heaters are fitted on a rectangular plate which is fastened on the tray. Each heater is of 2KW.

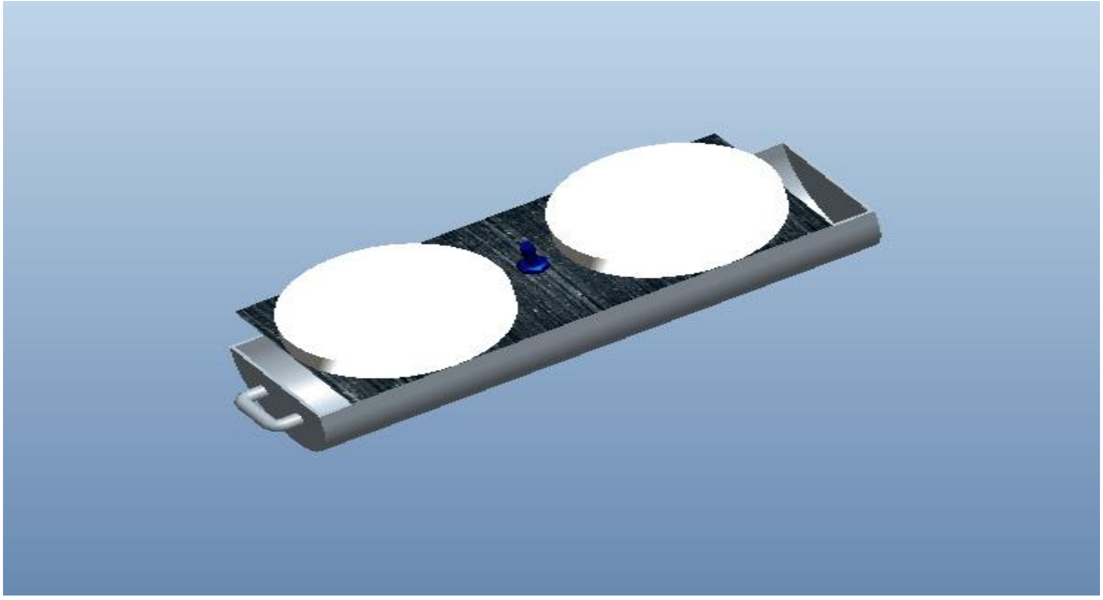

Figure 4.3 Detachable heating arrangement

4. **DC motor:** A DC motor is used to rotate the rotating cylinder. It is fitted outside the drum in line with the gear fixed on the end of the rotating cylinder. DC motor is used because it rotates at lesser rpm which is the necessary condition for proper heating of used sand. Moreover, it is small in size and light in weight so that it can be fastened to drum easily. The motor get power from the 12v battery.

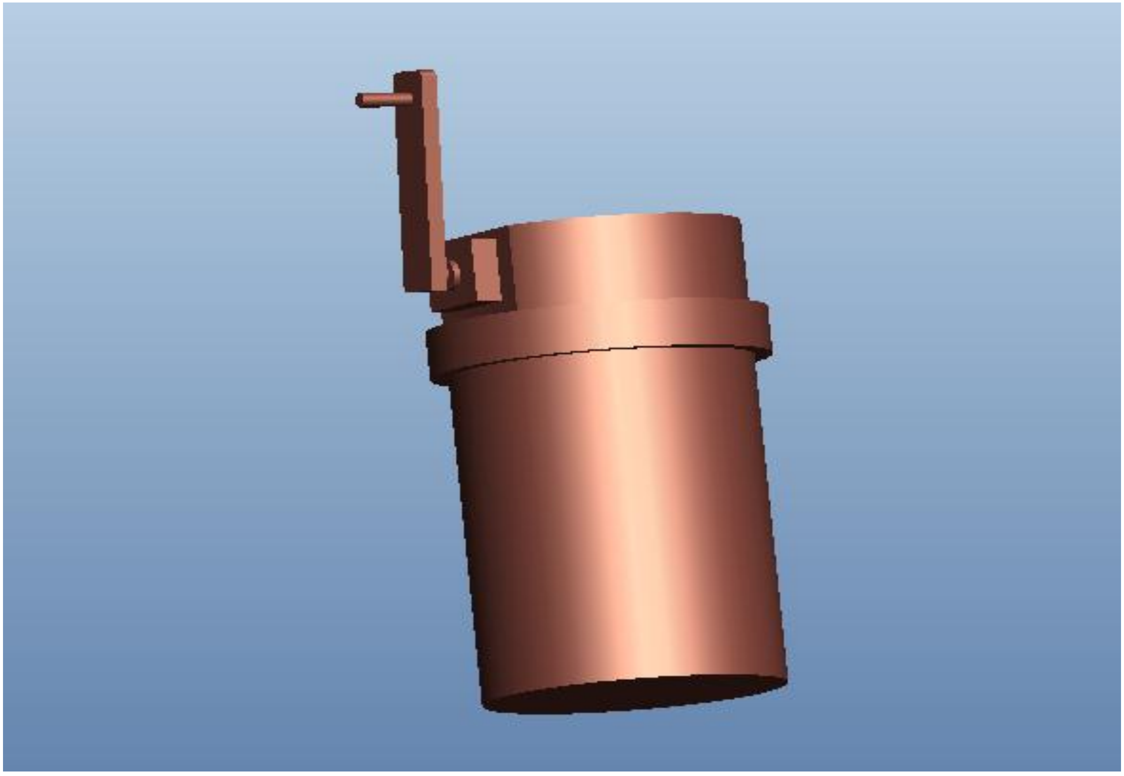

Figure 4.4 DC motor

4.4 FABRICATION AND ASSEMBLY OF THE APPARATUS

4.4.1 Fabrication of the setup

1. **Refractory drum:** A sheet of 2mm thickness was rolled and the cylindrical drum of diameter 480mm and height 1150mm was made. Circular sheet of diameter equal to the diameter of the drum was cut and welded on its base and in the center of the drum. Firebricks were placed inside the drum on its periphery with the help of fireclay. Then the circular slots were cut through the cylinder inclined at an angle of 5° to the horizontal. A passage of semicircular shape was cut above the centre on side of the drum to place the heating arrangement inside it.
2. **Rotating cylinder**. A cylindrical pipe of 4mm thickness having diameter 165mm and length 500mm was taken for making the rotating cylinder. One end of the pipe was made closed by welding a circular plate on one end. Rectangular ribs were welded inside the cylinder for the proper mixing of the sand. The holes of 15mm diameter were drilled on closed end for the exit of the sand. A cap was provided on the exit end to prevent the flow of sand from the exit during the reclamation process. Near the closed circular rings were welded end on surface of cylinder to provide the guide way for roller bearings. On the other side a spur gear was welded on its circumference to provide the rotating motion from the dc motor. After that the cylinder was placed inside the circular slot that was cut in drum at an inclination of 5° with the horizontal. Ball bearings were attached to the drum below the rotating cylinder to support the cylinder and to provide a smooth rolling motion.
3. **Heating arrangement**. A sheet of 3mm thickness was rolled and a tray of semicircular shape was made. A handle was welded on one side to hold the tray. After that a rectangular plate was cut and fastened on the top of the semicircular tray, on the top of the plate two electrical heaters (2000W each) were fitted.
4. **Hooper**. A mild steel sheet of 1mm thickness was cut and made into a funnel shape and then the funnel was brazed was brazed to a pipe of 50mm diameter which was bended at an angle to ease the flow of sand through it. The lower end of the pipe was half inside the rotating cylinder to supply the sand inside the cylinder. The whole arrangement was fastened with the drum.
5. **Exit funnel**. A mild steel sheet of 1mm thickness was cut and made into a funnel shape and then the funnel was brazed was brazed to a pipe of 50mm diameter which was bended at an angle to ease the flow of sand through it. The upper end of the funnel was placed

below the exit of sand from the rotating cylinder and the lower end of the pipe was placed inside cooling chamber to flow the sand from exit of the cylinder to the cooling chamber. The funnel was fastened with the drum with the nut and bolt.

6. **DC motor**. A DC motor was fitted below the open end of the rotating cylinder and in line with the spur gear attached on one end of the cylinder so that it can transmit rotary motion to the cylinder.

3.4.2 Assembly of the setup

All the five parts of the setup were assembled with the help of nut and bolts, no part was permanently welded with the another. In case of repair of replacement of any part it can be disassembled and assembled very easily. Both assembled and exploded view of the setup is shown below:

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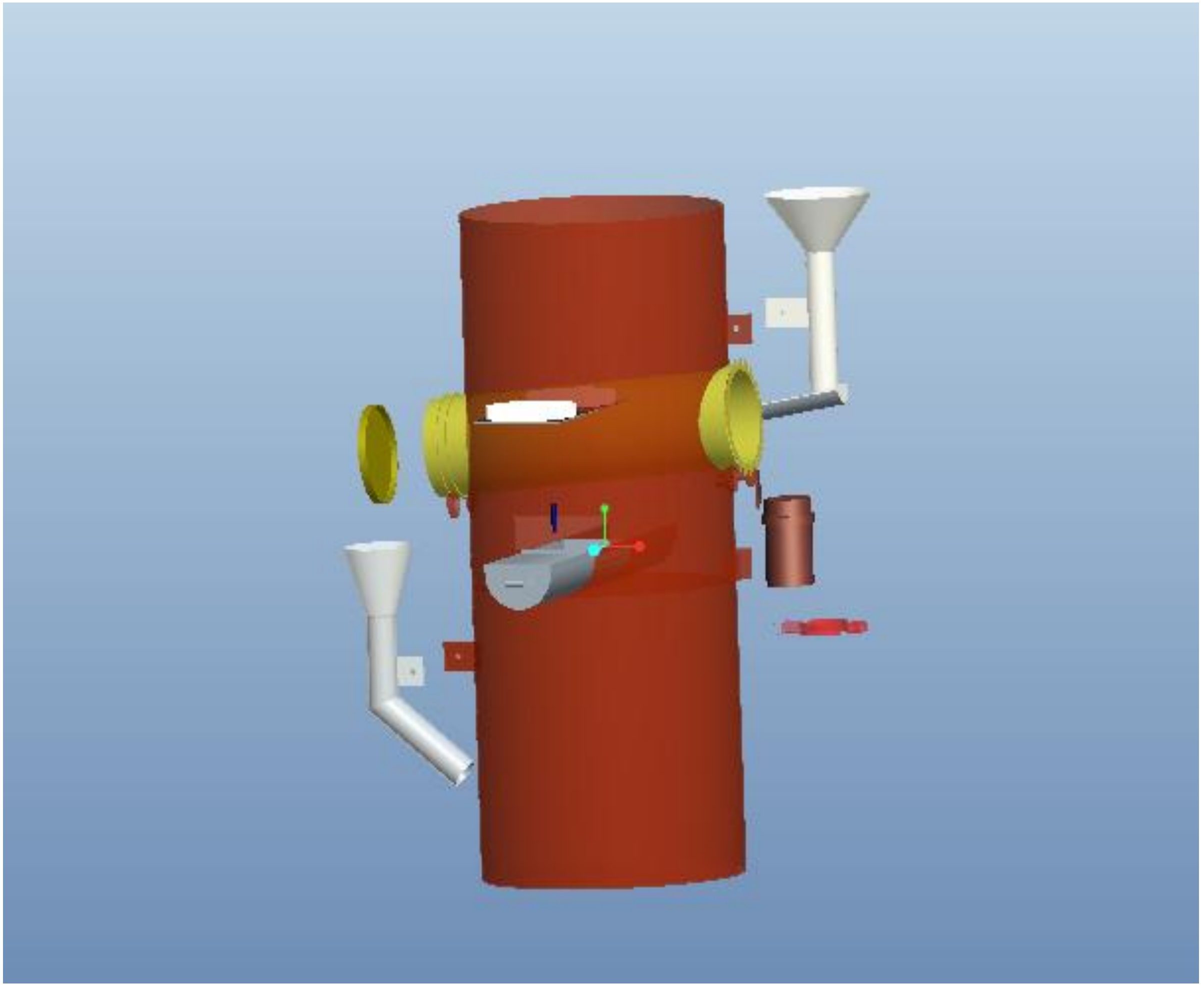

Figure 4.5 Exploded view of the setup

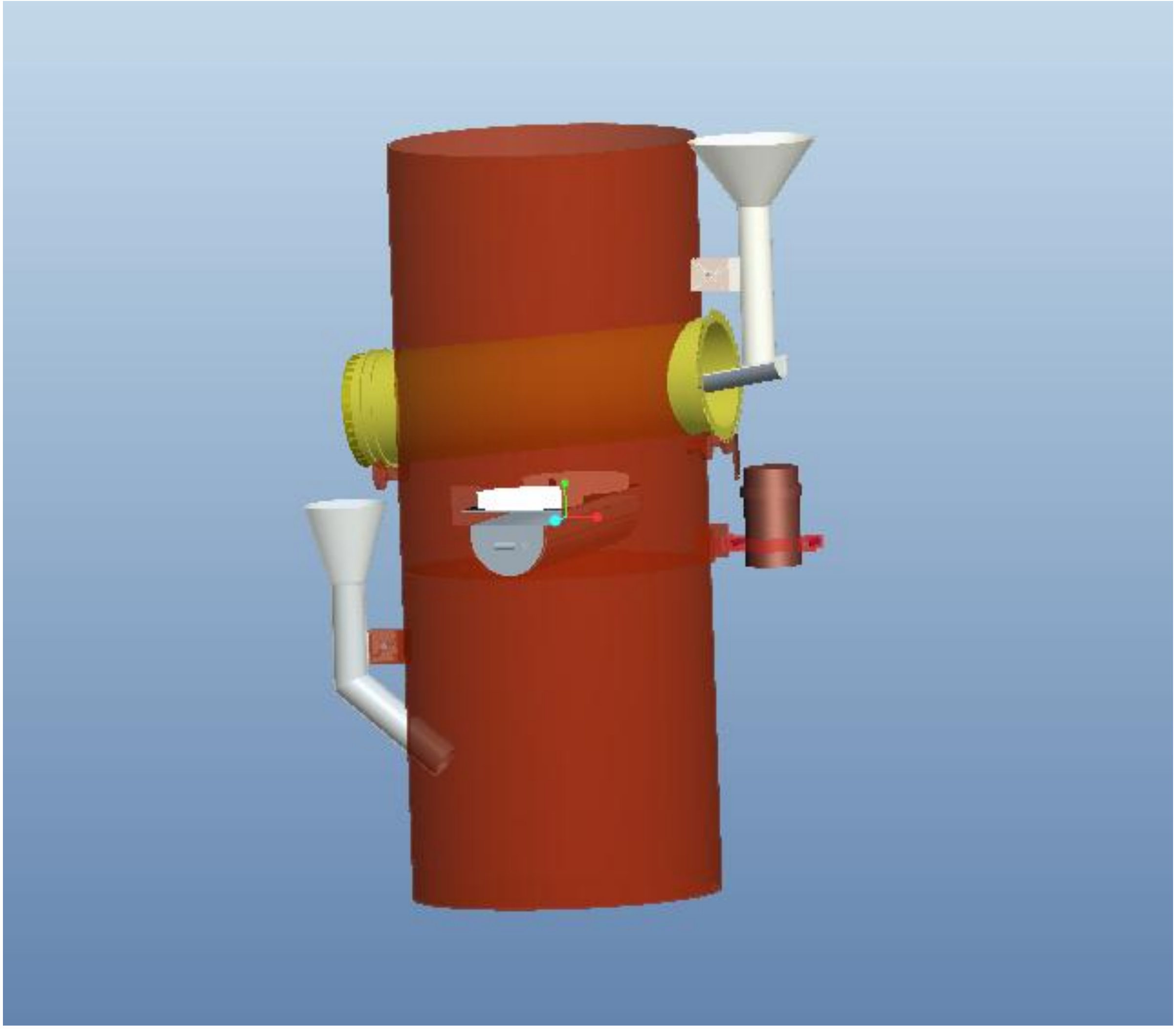

Figure 4.6 Assembled view of the set up

4.5 WORKING OPERATION

First of all, electrical heaters were switched on and the cylinder above the heaters starts getting heated. After some time when it attained the desired temperature, the sand to be reclaimed was filled in the hopper manually. From the hopper it was fed into the inclined cylinder through the circular passage. As the sand entered the cylinder DC motor was switch on and the motor transmitted the rotary motion to the cylinder through the gear which was fitted in to the rotary cylinder. When the cylinder rotated the abrasive action helped to separate the binder from the sand and as the used sand was moved inside the cylinder it gets heated by conduction. The rotation of the heated cylinder caused heating of all individual grains within a sand mass to the same degree in a continuous and uniform manner. The sand was heated at that temperature for certain period of time.

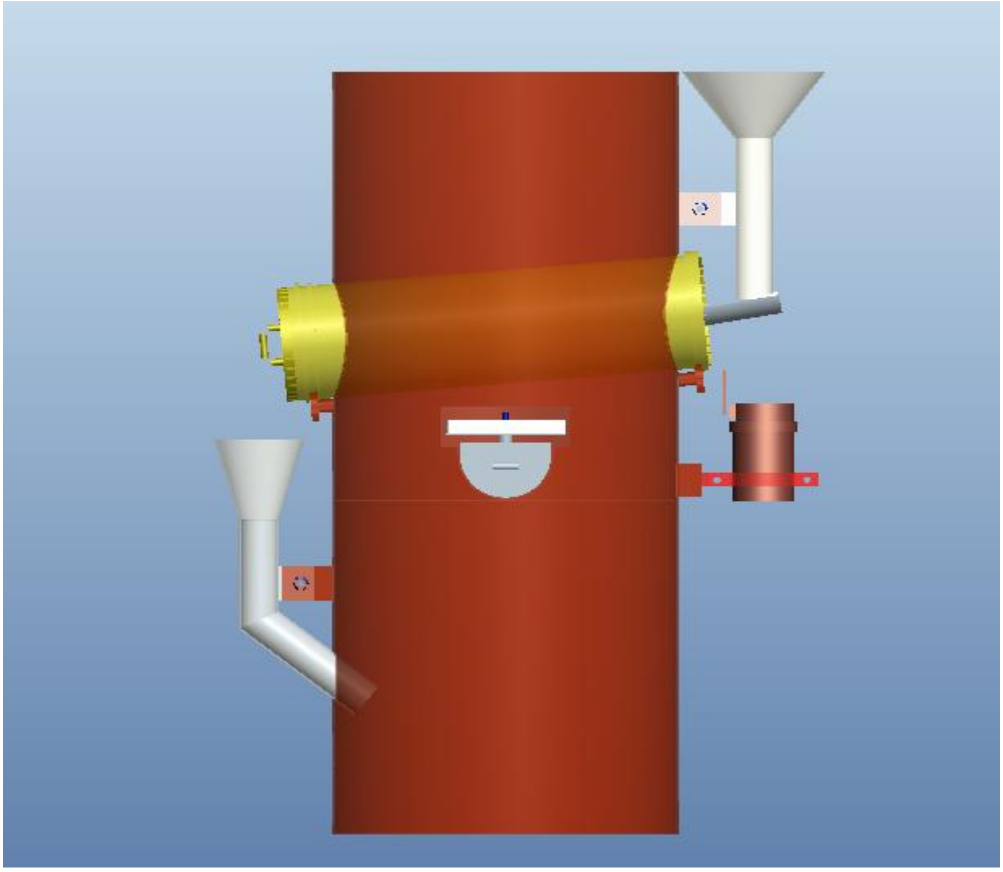

Figure 4.6 Working operation

By the heating process the resin present in the sand as binders get burnt. After that the heating was stopped and only cylinder was rotated so that the sand in the rotary cylinder easily comes out from the exit. The reclaimed sand comes out of cylinder through the holes to the funnel. From the funnel sand went into the cooling chamber where the sand was cooled at the atmospheric temperature. So the reclaimed sand at atmospheric temperature was collected fortesting.

CHAPTER 5
EXPERIMENTAL TRIALS

5.1 OBJECTIVE

The experimental work aims to investigate the effect of process parameters like heating temperature and duration of heating on the properties of the reclaimed sand and compare the optimum result from the trials with the properties of the fresh resin sand.

5.2 METHODOLOGY ADOPTED FOR EXPERIMENTATION

The experimental work performed is divided into following sub-parts:

1. Preparation of resin sand and core from resin sand and use it as specimen for testing
    a) Estimate the compressive strength and hardness of resin core
2. Reclamation of used resin sand by varying the process parameters.
3. Test the reclaimed sand after trials and find the optimum result from the trials.
4. Compare properties of mixture of reclaimed sand and resin sand with that of fresh resin sand.

5.2.1 Resin Sand Coating

Sand was coated with resin using hot air coating process. In the hot air coating process silica sand was heated to temperature 120-150 °C. The sand was put in the mixer. The catalyst in powder form was added to the mixer and mixed for 10 seconds and then liquid resin was mixed for a minute. The resin melts and gets coated on the sand. Composition of the resin sand was taken as:

- Silica sand
- Resin (phenol formaldehyde) 5 % by weight of silica sand
- Catalyst (hexa methylene tetra amine) 20% by weight of resin

Figure 5.1 Materials used in resin sand coating

Figure 5.2 Resin coated sand

This composition was used in all the experimental trials. Using this composition a 75 mm square shaped resin core was prepared as a sample for performing the following tests:

1. Compressive strength test
2. Core hardness test

Figure 5.3 Resin coated core (75 mm square) specimen for testing

5.2.1.1 Equipment Used In Resin Sand Coating

1. **Core Baking Oven:** Core Baking Oven in the Sand Testing Laboratory, Thapar University, Patiala, was used for heating the silica sand in hot air coating process and to heat the core to achieve the required strength.

Figure 5.4 Core Baking Oven

2. **Sand Muller**: Sand Muller in Sand Testing Laboratory, Thapar University, Patiala, was used in resin coating process to mix the resin and catalyst with the silica sand.

Figure 5.5 Sand Muller

5.2.2 Sand Reclamation

Sand reclamation of the used resin sand was performed in the reclamation setup by varying the process parameters like heating temperature and duration of heating. Various heating temperatures and time of reclamation used in the experimental trials are shown in the Table 5.1

Table 5.1 Temperature and time duration used for experimentation

Trial No.	Heating temp. (°C)	Duration of heating (min.)
1.	500	20
2.	500	25
3.	500	30
4.	550	20
5.	550	25
6.	550	30
7.	600	20
8.	600	25
9.	600	30

Figure 5.6 Samples of sand reclaimed at 500 °C for different time durations

Figure 5.7 Samples of sand reclaimed at 550 °C for different time durations

Figure 5.8 Samples of sand reclaimed at 600 °C for different time durations

5.2.3 Testing of Reclaimed Sand

Performance of the reclaimed sand was evaluated based on following properties:

Compressive strength

Compressive strength of 75 mm square shaped core prepared was measured on the Universal Testing Machine available in Structure Laboratory, Thapar University, Patiala. The load shown on display was divided by the area of the specimen to calculate the compressive strength in MPa.

Figure 5.9 Universal Testing Machine

Hardness

Hardness of the 75 mm square shaped core prepared was measured with the help of core hardness tester available at Sand Testing Laboratory, Thapar University, Patiala. The depth of indentation was directly measured on the scale which shows units 0 to 100.

Figure 5.10 Core Hardness Tester

Loss on ignition (LOI)

Loss of the weight of the reclaimed sand was measured using a weighing machine available at Sand Testing Laboratory, Thapar University, Patiala. Loss on ignition of the reclaimed sand was measured as percentage of weight lost after the heating of sand. Based on literature loss on ignition of the reclaimed sand should be less than 3%. Loss on ignition of the reclaimed sand was calculated as:

Loss in ignition = $\frac{weightlost\ (kg)}{originalweight} \times 100$

Figure 5.11 Weighing Machine

5.2.4 Comparison of Properties of Reclaimed Sand and Resin Sand in Different Proportion with that of Fresh Resin Sand

From the testing of the sand specimen of different experimental trials, reclaimed sand with optimum result was selected for the further experimentation. Now the selected reclaimed sand was mixed with fresh resin sand in various proportions. Various proportions in which reclaimed sand was mixed with the resin sand was shown in the Table 5.2

Table 5.2 Various proportions of reclaimed sand used with resin sand

Trial No.	Reclaimed sand used	Fresh resin sand used
1	----	100%
2	70%	30%
3	80%	20%
4	90%	10%
5	100%	----

Figure 5.12 Reclaimed sand in different proportions with resin sand

The properties of the reclaimed sand in various proportions with resin sand were tested and these results were then compared with the fresh resin sand.

CHAPTER 6
RESULTS AND DISCUSSION

6.1 INTRODUCTION

With the increase in use of shell moulding the concept of reclamation of the resin sand is gaining attention. The compressive strength test, hardness test and loss on ignition tests were conducted on reclaimed sand by varying the process parameters like heating temperature and duration of heating to evaluate the properties of the reclaimed sand with the resin sand.

6.2 RESULTS OF RECLAIMED SAND WITH VARYING PARAMETERS

The compressive strength test, hardness test and loss on ignition tests were conducted on reclaimed sand by varying the parameters like heating temperature and duration of heating to evaluate the performance of the reclaimed.

6.2.1 Results of Compressive Strength

Compressive strength of reclaimed sand after each experiment was measured. The results of the compressive strength for each of the 9 experiments are shown in the Table 6.1

Table 6.1 Results of compressive strength

Trial no.	Heating temp. in °C	Duration of heating (min.)	Compressive strength (MPa)			Mean Comp. Strength (MPa)
			I.	II.	III.	
1	500	20	1.50	1.51	1.51	1.51
2	500	25	1.53	1.52	1.55	1.54
3	500	30	1.56	1.57	1.56	1.56
4	550	20	1.60	1.62	1.62	1.61
5	550	25	1.67	1.67	1.67	1.67
6	550	30	1.66	1.66	1.65	1.66
7	600	20	1.67	1.67	1.67	1.67
8	600	25	1.73	1.74	1.74	1.74
9	600	30	1.69	1.69	1.70	1.69

From the experiments performed the mean compressive strength of the 3 samples from each trial is shown in the Figure 6.1

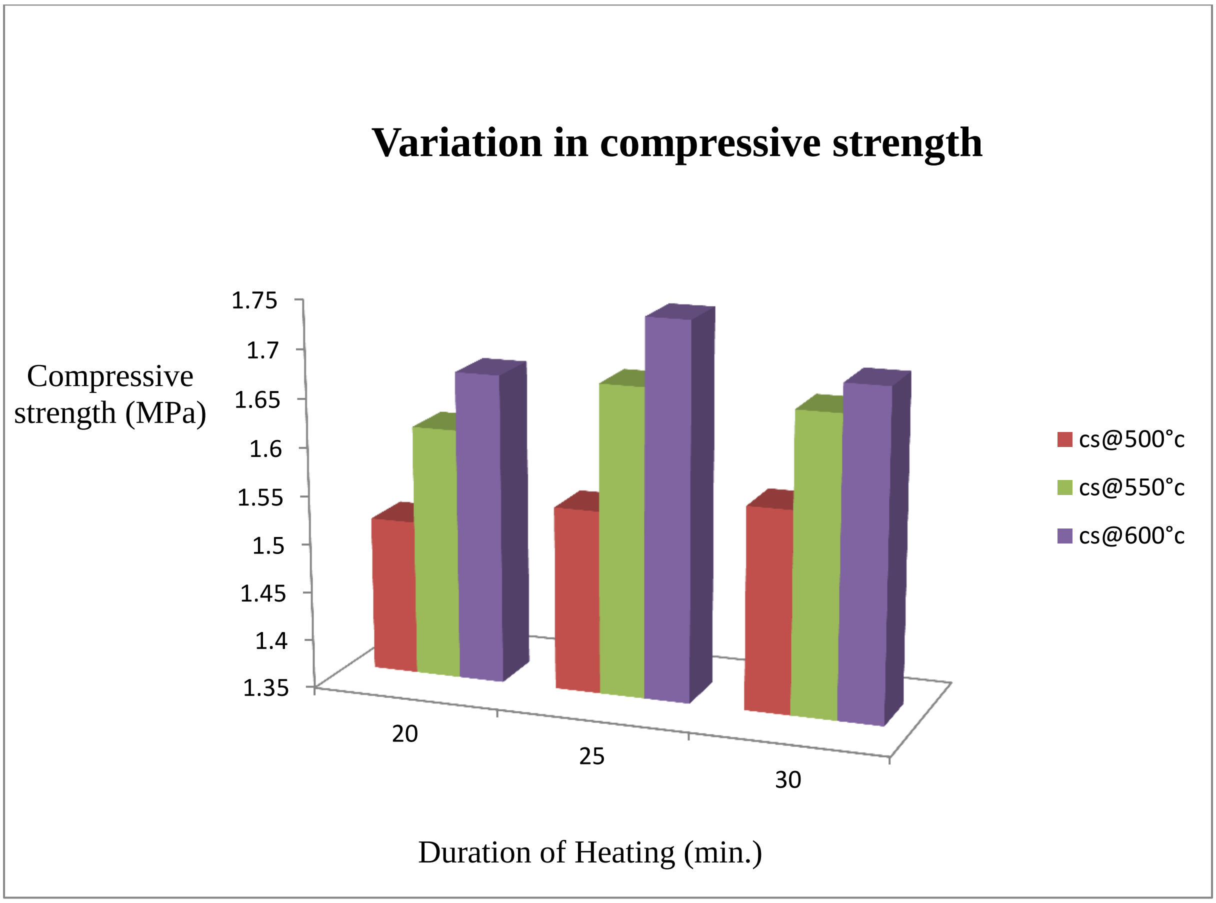

Figure 6.1 Variation in compressive strength by varying parameters

Compressive strength of the samples increased at temperature 500 °C when reclamation time was increased from 20 to 25 minutes but there was slight decrease in the strength as the reclamation time was increased from 25 to 30 minutes. When compared at 550 °C there was little increase in strength when reclamation time increased from 20 to 25 minutes but remains constant when increased from 25 to 30 minutes. Comparing at 600 °C a constant increase of strength was shown with increase in reclamation temperature.

6.2.2 Results of Hardness

Hardness of reclaimed sand after each experiment was measured. The results of the hardness for each of the 9 experiments are shown in the Table 6.2

Table 6.2 Results of Hardness

Trial no.	Heating temp. in °C	Duration of heating (min.)	Hardness			Mean Hardness
			I.	II.	III.	
1	500	20	55	50	54	53
2	500	25	60	66	63	63
3	500	30	66	68	63	66
4	550	20	61	61	64	62
5	550	25	64	69	64	65
6	550	30	64	65	65	65
7	600	20	68	64	67	66
8	600	25	69	67	68	68
9	600	30	65	68	68	67

From the experiments performed the mean compressive strength of the 3 samples from each trial is shown in the Figure 6.2

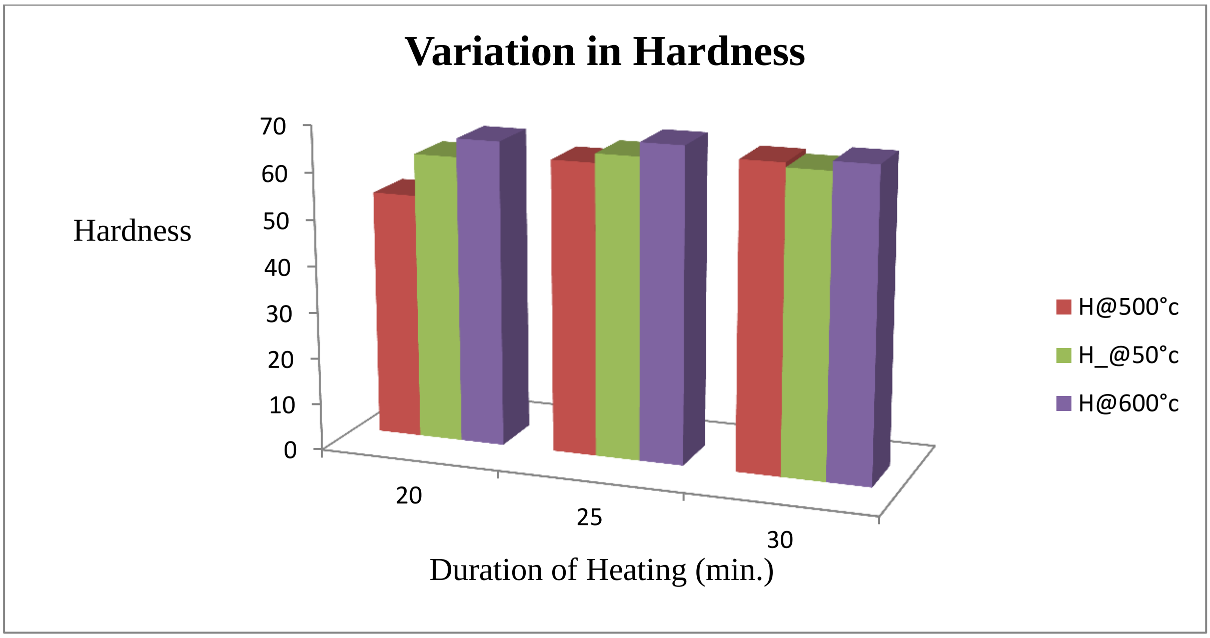

Figure 6.2 Variation in hardness by varying parameters

Hardness of the samples increases linearly at heating temperature 500 °C when reclamation time increases from 20 to 30 minutes. Comparing at 550 °C again there was constant rise in hardness but the variation was lesser as compared at 500 °C. At 600 °C there was very small reduction in hardness with increased reclamation time from 20 to 25 minutes and then small rise in hardness with reclamation time of 30 minutes.

6.2.3 Results of Loss on Ignition (LOI)

Loss on ignition of reclaimed sand after each experiment was measured. The results of LOI for each of the 9 experiments are shown in the Table 6.3

Table 6.3 Results of Loss on Ignition

Trial no.	Heating temp. in °C	Duration of heating (min.)	Loss on ignition (%age)			Mean LOI
			I.	II.	III.	
1	500	20	2.2	2.2	2.1	2.2
2	500	25	2.4	2.4	2.4	2.4
3	500	30	2.5	2.5	2.4	2.5
4	550	20	2.5	2.5	2.5	2.5
5	550	25	2.6	2.5	2.5	2.5
6	550	30	2.6	2.6	2.7	2.6
7	600	20	2.5	2.5	2.5	2.5
8	600	25	2.7	2.8	2.8	2.8
9	600	30	3.2	3.1	3.2	3.2

From the experiments performed the mean loss on ignition of the 3 samples from each trial is shown in the Figure 6.3

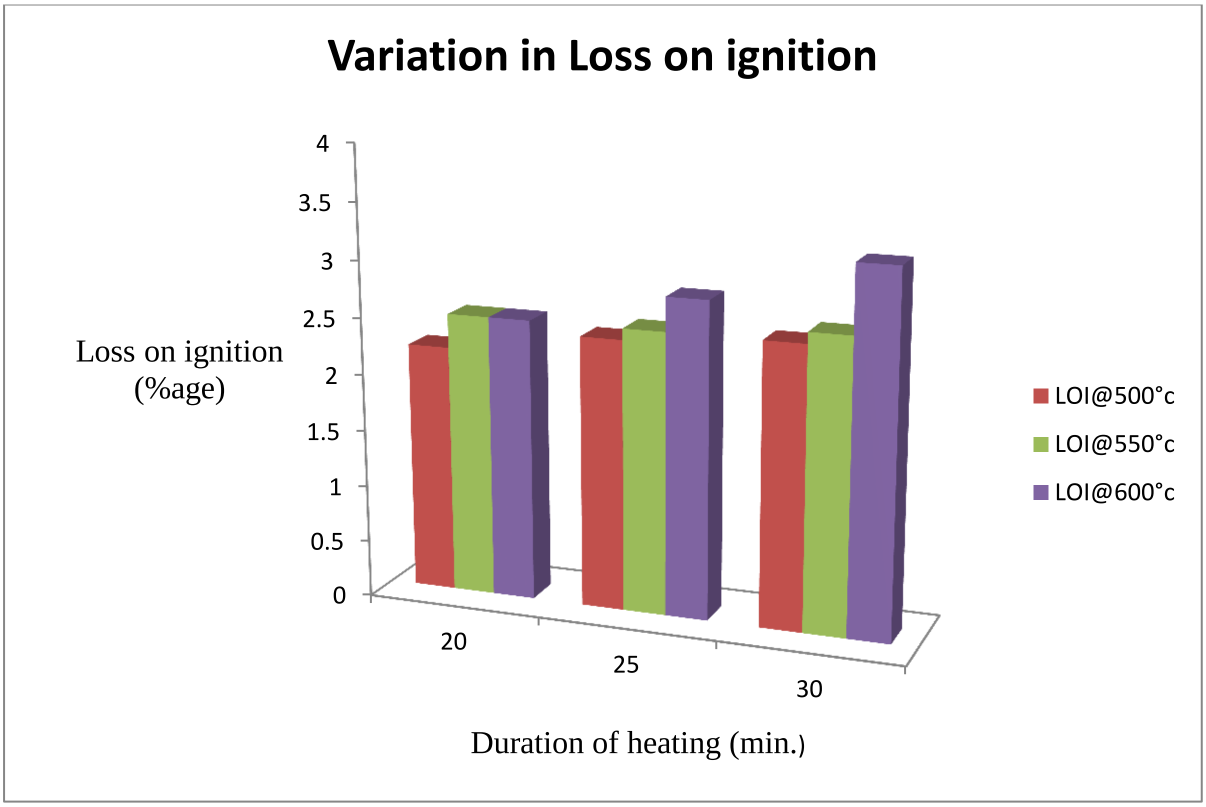

Figure 6.3 Variation in loss on ignition by varying parameters

There was gradual rise in the loss on ignition as the reclamation temperature was increased from 500 °C to 550 °C and the reclamation time was increased from the 20 to 25 minutes. But the LOI increases rapidly to a higher value when the reclamation was performed at 600 °C for period of 30 minutes.

6.3 ANALYSIS OF THE RESULTS

In the analysis of results properties like compressive strength, hardness and loss on ignition of the sand reclaimed at temperature 500 °C, 550 °C and 600 °C for the duration of 20 min., 25 min. and 30 min. were compared to get the optimum result from these parameters. Results from each experimental trial are compared with the required results. Results of the compressive strength, hardness and loss on ignition from different trials is shown in the Table 6.4

Table 6.4 Results of the compressive strength, hardness and loss on ignition from different trials

Trial No.	Heating Temp. °C	Heating duration (min.)	Compressive Strength (MPa)		Hardness		Loss on ignition (%age)		Remarks
			Reqd.	observed	Reqd.	observed	Reqd.	observed	
1	500	20	1.84	1.51	65	53	<3.0	2.2	Low comp. strength and hardness
2	500	25	1.84	1.54	65	63	<3.0	2.4	Low comp. strength and hardness
3	500	30	1.84	1.56	65	66	<3.0	2.5	hardness sufficient but comp. strength low
4	550	20	1.84	1.61	65	62	<3.0	2.5	Low comp. strength and hardness
5	550	25	1.84	1.67	65	65	<3.0	2.5	hardness sufficient but comp. strength low
6	550	30	1.84	1.66	65	65	<3.0	2.6	hardness sufficient but comp. strength low
7	600	20	1.84	1.67	65	66	<3.0	2.5	hardness sufficient but comp. strength low
8	**600**	**25**	**1.84**	**1.74**	**65**	**68**	**<3.0**	**2.8**	**observed results are closer to the reqd. compared to others trials**
9	600	30	1.84	1.69	65	67	<3.0	3.2	Comp. strength and hardness are sufficient but LOI is more than required

From the analysis of the results compressive strength, hardness and loss on ignition of reclaimed sand were compared at different the parameters like heating temperature and duration of heating. It was observed that optimum performance of the reclamation process was achieved when the sand was reclaimed at 600 °C for period of 25 minutes. In this trial Compressive strength observed was closer to the required strength compared to other trials and the hardness achieved was slightly more than the required hardness. In addition loss on ignition of the reclamation performed was 2.8% which satisfy the condition in the previous literature that loss on ignition of reclaimed sand should be less than 3%. So the sand reclaimed at 600 °C for 25 minutes was used in the further experimentation.

6.4 COMPARISON OF PROPERTIES USING DIFFERENT PROPORTION OF RECLAIMED SAND AND FRESH RESIN SAND

Reclaimed sand with optimum results from each experimental trial conducted in previous section was used in different proportions with fresh resin sand and its properties were compared with fresh resin coated sand.

6.4.1 Comparison of Compressive Strength Using Different Proportion of Reclaimed Sand and Fresh Resin Sand

The results of the compressive strength from each experiment by varying the proportion of reclaimed sand and fresh resin sand are shown in the Table 6.5

Table 6.5 Results of compressive strength with different proportion of reclaimed sand and fresh resin sand

Trail no.	Mixture of fresh resin sand and reclaimed sand reclaimed at 600 °C for 25 minutes	Compressive strength (MPa)			Mean Comp. Strength (MPa)
		I.	II.	III.	
1	100% fresh sand	1.83	1.84	1.84	1.84
2	70%reclaimed sand+ 30%fresh sand	1.80	1.81	1.80	1.81
3	80%reclaimed sand + 20%fresh sand	1.78	1.8	1.8	1.8
4	90%reclaimed sand + 10%fresh sand	1.77	1.76	1.77	1.77
5	100%reclaimed sand	1.73	1.73	1.75	1.74

From the experiments performed the mean compressive strength of the 3 samples from each trial is shown in the Figure 6.4

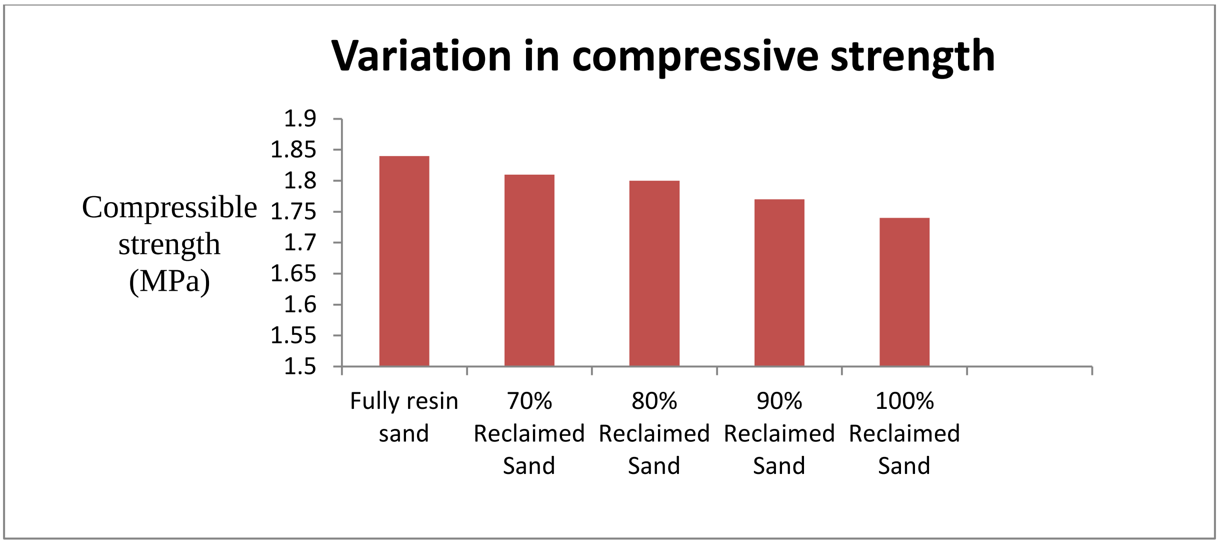

Figure 6.4 Variation in compressive strength by varying the reclaimed sand proportion

Compressive strength of the samples increased at nearly constant rate as the proportion of resin sand with reclaimed sand increased. While Compressive strength attained from the fully resin sand was maximum.

6.4.2 Comparison of Hardness Using Different Proportion of Reclaimed Sand and Fresh Resin Sand

The results of the hardness in each experiment by varying the proportion of reclaimed sand with resin sand are shown in the Table 6.6

Table 6.6 Results of hardness with different proportion of reclaimed sand and fresh resin sand

Trail no.	Mixture of fresh resin sand and reclaimed sand reclaimed at 600 °C for 25 minutes	Hardness			Mean Hardness
		I.	II.	III.	
1	100% fresh sand	66	68	62	65
2	70%reclaimed sand+ 30%fresh sand	70	65	68	68
3	80%reclaimed sand + 20%fresh sand	68	64	68	67
4	90%reclaimed sand + 10%fresh sand	65	65	64	65

5	100%reclaimed sand	62	65	67	65

From the experiments performed the mean compressive strength of the 3 samples from each trial is shown in the Figure 6.5

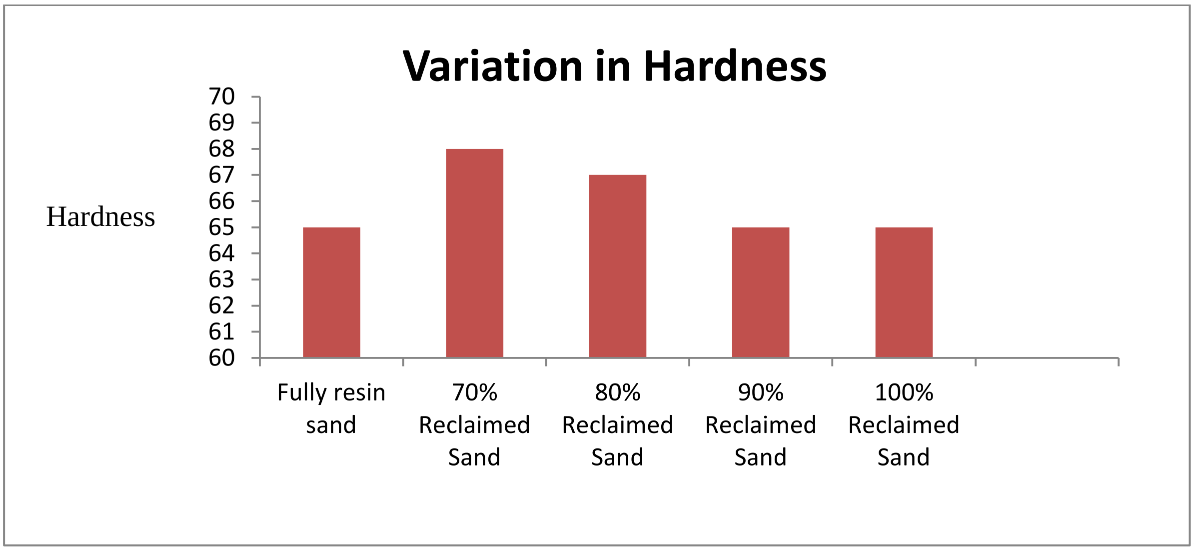

Figure 6.5 Variation in compressive strength by varying the reclaimed sand proportion

The hardness of the experiment using 70% reclaimed sand with 30% resin sand was little higher than the hardness of the 100% resin sand. When 80% reclaimed sand was used hardness of the samples drop slightly. The hardness of samples using 90% reclaimed sand and 100% reclaimed sand was same and identical with the hardness of fully resin sand.

6.4.3 Comparison of Loss on Ignition Using Different Proportion of Reclaimed Sand and Fresh Resin Sand

The results of the loss on ignition in each experiment by varying the proportion of reclaimed sand with resin sand are shown in the Table 6.7

Table 6.7 Results of hardness with different proportion of reclaimed sand and fresh resin sand

Trial no.	Mixture of fresh resin sand and reclaimed sand reclaimed at 600 °C for 25 minutes	Hardness			Mean Hardness
		I.	II.	III.	
1	100% fresh sand				
2	70%reclaimed sand+ 30%fresh	2.2	2.3	2.3	2.3

	sand				
3	80%reclaimed sand + 20%fresh sand	2.5	2.5	2.5	2.5
4	90%reclaimed sand + 10%fresh sand	2.7	2.7	2.7	2.7
5	100%reclaimed sand	2.7	2.8	2.8	2.8

From the experiments performed the loss on ignition of the 3 samples from each trial is shown in the Figure 6.6

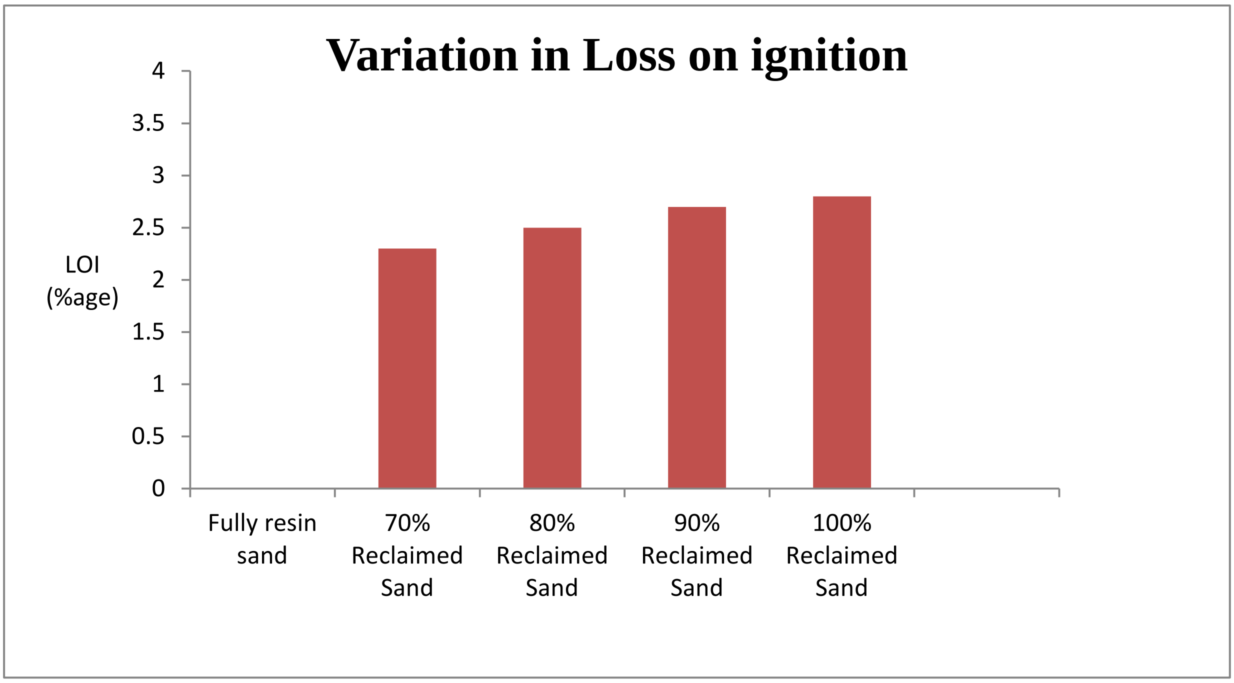

Figure 6.6 Variation in LOI by varying the reclaimed sand proportion

As shown in the figure the loss on ignition of 100% reclaimed sand used was below 3%. It drops gradually with increase in the proportion of fresh resin sand.

From investigation of results from experimental trials it was observed that for small quantity of sand, reclamation performed at temperature 500 °C, 550 °C, 600 °C and for different time durations 20 min., 25 min., 30 min. gave different values of compressive strength, hardness and loss on ignition. Reclamation performed at 600 °C and for 25 minutes of time, when compared to the properties of fresh resin sand, it gives results near to that of fresh resin sand. Compressive strength of sand reclaimed these parameters is slightly lesser where as hardness of the core was marginally higher. In addition loss on ignition of sand was within desired value. When 70% proportion of sand reclaimed at 600 °C for 25 minutes of time, is mixed with fresh resin sand it gives compressive strength very close to fresh resin sand and the hardness of the core was better than the fresh resin sand.

CHAPTER 7
CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

In the reclamation of the resin sand used in shell moulding, a sand reclamation setup was designed and fabricated and the effect of process parameters like heating temperature and duration of heating on the properties of the reclamation process was investigated and compared with the properties of the fresh resin sand. Based on the results of the present work, following conclusions were drawn:

- A new setup based on the concept of dry attrition before the thermal reclamation cracks of the binders which help in heating all individual grains within sand mass to the same degree in a continuous and uniform manner was designed for an experimental study of the reclamation process.
- The setup was tested for different combinations of temperature and heating duration to find the optimal conditions at which best properties related to the sand were obtained.
- The mixture of 70% sand reclaimed at temperature 600 °C for duration of 25 min. and 30% fresh resin sand gives core hardness better than fresh resin sand whereas compressive strength is marginally lesser. So without compromising he resin sand properties, a mixture of reclaimed sand and fresh sand can be used to lower the cost of manufacturing. The mixture proposed to be used in shell moulding process is 70% reclaimed sand and 30% fresh resin sand.
- There is a marginal drop in the compressive strength of the mixture sand as compared to fresh sand. The loss on ignition and hardness are not affected.
- The set up will be useful for small foundries that use shell moulding process to reclaim the sand. The apparatus is easy to manufacture in a workshop at low cost.
- The setup requires small space as less compared to other apparatus.

7.2 FUTURE SCOPE

1) In the present setup preheating chamber can be made above the heating chamber to utilize the heat of the heating process in preheating the sand.

2) Reclamation of the sand may be performed at temperature higher than 600 °C and for duration more than 30 minutes to increase the performance of reclaimed sand so that with lesser binder addition same compressive strength and harness can be achieved.
3) Increase in speed of the rotating cylinder of the reclamation setup may be increased for better attrition of the reclaimed sand before the heating process.
4) Experiments can be performed on sand with various grain sizes as heating temperature and duration of heating may be varied according to different grain size.

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