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Sand Optimization to Improve Quality of Cast Iron Pipes

Mohsin I A R Sheikh[1,] Rajat R Wahulkar[2], Harshal S. Gatkine[3], Roshan P.Sonwane[4], Shubham R. Wakodikar[5], Mr. Vaibhav Patankar[6]

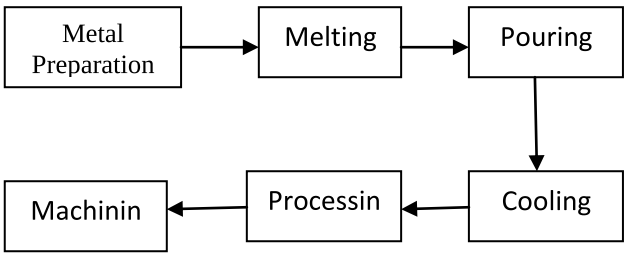
[1,6]Assistant Professor, [2-5]Students
Department of Mechanical Engineering, G.H.RIACT Nagpur, India

Abstract –*Foundry industries in developing countries suffer from poor quality and productivity due to involvement of number of process parameter. Various defects generated during the casting process of ductile iron pipes. Defects like thickness variations, pin holes, metal laps, thick/thin socket, over weight etc. are produced during the casting process of ductile iron pipe. These defects can be minimized by appropriate changing in parameters. Parameters that lead to the desired quality and yield, is important but difficult to achieve. In this study, the parameters like A.F.S Number and G.C.S of sand used during the casting process are analyzed for minimization of defects and microstructure study of ductile iron pipes. In this study, at different A.F.S Number, variations in thickness of ductile iron pipe studied. Also the defects are observed at the same G.C.S. This paper also studied that at different temperature the microstructure of the pipe varied which greatly effect on the ductility and hence quality of the pipe. An attempt has been made to optimize the parameters for manufacturing a better quality pipe and for minimizing the casting defects. The aim of this project was to optimize the proportion of sand addition, bentonite and water added to a recycled sand mould for reducing iron casting waste using the following analysis techniques: a mixture experimental design, response surface methodology, and propagation of error. The effects of variation in silica sand, betonies and water added to a recycled sand mould on the properties of the moulding sand were investigated. This project is mainly focused to maximize the American foundry society number (A.F.S. Number) and minimize material rejection. Since the grain size is an important factor in the use of sand moulding. It was observed that the grain size is directly proportional to permeability and flow density, and it is inversely proportional to quality and green compression strength.*

Keywords- ***Ductile iron pipe, optimization of parameters, minimization of Defects, Microstructure study, Bentonite, Green Compression strength, A.F.S Number.***

I- INTRODUCTION

Metal casting is a 5000 years old manufacturing process in which molten metal is poured in a mould and removed after solidification. These castings are all around us right from Simple rings to complex engine cylinders and are employed in industries varying from Aerospace, medical devices, automobiles, sanitary, electrical machineries, pipes home appliances etc. Indian casting industry with an annual production of 7.5 MT is the 2nd largest casting producers in the world after China.



Steps in metal casting.

A. Casting Process

A mould is formed into the geometric shape of a desired part. Molten metal is then poured into the mould; the mould holds this material in shape as it solidifies. A metal casting is created. Although this seems rather simple, the manufacturing process of metal casting is both a science and an art. Let's begin our study of metal casting with the mould. First, moulds can be classified as either open or closed. An open mould is a container, like a cup, that has only the shape of the desired part. The molten material is poured directly into the mould cavity which is exposed to the open environment. This type of mould is rarely used in manufacturing production, particularly for metal castings of any level of quality. The other type of mould is a closed mould, it contains a delivery system for the molten material to reach the mould cavity, where the part will harden within the mould.

B. Patterns

Expendable moulds require some sort of pattern. The interior cavities of the mould, in which the molten metal will solidify, are formed by the impression of this attern. Pattern design is crucial to success in manufacture by expendable mould metal casting. The pattern is a geometric replica of the metal casting to be produced. It is made slightly oversize to compensate for the shrinkage that will occur in the metal during the casting's solidification, and whatever amount of material that will be machined off the cast part afterwards. Although machining will add an extra process to the manufacture of a part, machining can improve surface finish and part dimensions considerably manufacture by expendable mould metal casting. The pattern is a geometric replica of the metal casting to be produced. It is made slightly oversize to compensate for the shrinkage that will occur in the metal during the casting's solidification, and whatever amount of material that will be machined off the cast part afterwards. Although machining will add an extra process to the manufacture of a part, machining can improve surface finish and part dimensions considerably.

C. Pattern Material

The material from which the pattern is made is dependent upon the type of mould and metal casting process, the casting's geometry and size, the dimensional accuracy required, and the number of metal castings to be manufactured using the pattern. Patterns can be made from wood, like pine (softwood), or mahogany (hardwood), various plastics, or metal, like aluminium, cast iron, or steel. In most manufacturing operations, patterns will be coated with a parting agent to ease their removal from the mould.

D. The Mould

When manufacturing by metal casting, consideration of the mould is essential. The pattern is placed in the mould and the mould material is packed around it. The mould contains two parts, the drag (bottom), and the cope (top). The parting line between the cope and drag allows for the mould to be opened and the pattern to be removed once the impression has been made. The core is placed in the metal casting after the removal of the pattern. Now the impression in the mould contains all the geometry of the part to be cast. This metal casting setup, however, is not complete. In order for this mould to be functional to manufacture a casting, in addition to the impression of the part, the mould cavity will also need to include a gating system. Sometimes the gating system will be cut by hand or in more adept manufacturing procedures, the gating system will be incorporated into the pattern along with the part. Basically, a gating system functions during the metal casting operation to facilitate the flow of the molten material into the mould cavity tempering the sand are important factors in regulating the degree of permeability. The significance is increase in permeability usually indicates a more open structure in the rammed sand, and if the increase continues, it will lead to penetration-type defects and rough castings. A decrease in permeability indicates tighter packing and could lead to blows and pinholes.

E. Materials Used

CASTING - Green Sand, Silica Sand, Bentonite Powder, Luston Powder, Water.
POURING METAL - Pig Iron, Turning, Foundry return, C.R.C. ,Alloy.
CORE- Silica Sand, Resin, Catalyst

SAND OPTIMIZATION

Sand optimization is the discipline of adjusting sand so as to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost and maximizing output and/or efficiency. This is one of the major quantitative tools in industrial decision making. When optimizing sand, the goal is to maximize one or more of the sand specifications, while keeping all others within their constraints.

A. Sand

GREEN SAND

Green sand is an aggregate of sand, bentonite clay, pulverized coal and water. Its principal use is in making moulds for metal casting. The largest portion of the aggregate is always sand, which can be either silica or olivine. There are many recipes for the proportion of clay, but they all strike different balances between mould ability, surface finish, and ability of the hot molten metal to degas. The coal typically referred to in foundries as sea-coal, which is present at a ratio of less than 5%, partially combusts in the surface of the molten metal leading to off gassing of organic vapours.

SILICA SAND

Silica (SiO_2) sand is the sand found on a beach and is also the most commonly used sand. It is made by either crushing sandstone or taken from natural occurring locations, such as beaches and river beds. The fusion point of pure silica is 1,760 °C (3,200 °F), however the sands used have a lower melting point due to impurities. For high melting point casting, such as steels, a minimum of 98% pure silica sand must be used; however for lower melting point metals, such as cast iron and non-ferrous metals, a lower purity sand can be used (between 94 and 98% pure).

B. Parameters of Sand

PERMEABILITY-Permeability is a property of foundry sand with respect to how well the sand can vent, i.e. how well gases pass through the sand. And in other words, permeability is the property by which we can know the ability of material to transmit fluid/gases. The permeability is commonly tested to see if it is correct for the casting conditions. The factors affecting are the grain size, shape and distribution of the foundry sand, the type and quantity of bonding materials, the density to which the sand is rammed, and the percentage of moisture used for tempering the sand are important factors in regulating the degree of permeability. The significance is increase in permeability usually indicates a more open structure in the rammed sand, and if the increase continues, it will lead to penetration-type defects and rough castings. A decrease in permeability indicates tighter packing and could lead to blows and pinholes.

MOISTURE CONTENT-Moisture content is the quantity of water contained in a material, such as sand (called sand moisture), rock, ceramics, crops, or wood. Water content is used in a wide range of logical and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation. It can be given on a volumetric or mass (gravimetric) basis. It is the amount of

AMERICAN FOUNDRY SOCIETY NUMBER (A.F.S.NUMBER)-The AFS Grain Fineness Number (AFS GFN) is a measure of the average size of particles in a sand sample. The higher the AFS number the finer is the grain size of the sand sample. It gives a rated number according to the American foundry society chart with which the quality of the sand can be obtained.

ADVANTAGES OF DUCTILE IRON PIPES

- High tensile strength, good elastic module and excellent ductility, making it suitable for high stress applications and where pressure surge may be experienced.
- High corrosion resistance.
- Excellent hydraulic flow.
- High working pressure compared to other types of pipes.
- Ease to installation.
- Long lifetime.
- Accommodate ground movement

DEFECTS ANALYSIS IN DUCTILE IRON PIPES

Foundry industries in developing countries suffer from poor quality and productivity due to involvement of number of process parameters in casting process. Even in a completely controlled process, defects in casting are observed and hence casting process is also known as process of uncertainty which challenges explanation about the cause of casting defects. Various defects which can generate during the process of centrifugal casting of ductile iron pipes are:

Metal laps, Metal Fin
Poor surface finish due to Less A.F.S. number moisture available in the sand due to the various reasons; the moisture content is calculated in percentage (%).

COMPACTABILITY-Compact ability is the ability of sand to compact in the presence of moisture in the mixture, it is denoted in the percent of the volume of sand, providing the compact range of the sand for mould and the compact ability parameter is very important for sand casting in a cast iron industry.

GREEN COMPRESSION STRENGTH-Green compression strength refers to the stress required to rupture the sand specimen under compressive loading. The sand specimen is taken out of the specimen tube and is immediately put on the strength testing machine and the force required to cause the compression failure is determined Shrinkage problem Less mould hardness, Extra time consumption on removal of excess metal , Less product hardness.

AIM AND OBJECTIVE

- Performance evaluation of existing sand
- Optimize the sand to improve the productivity Focus on reaching optimal A.F.S. Number in order to obtain better quality
- Cost reduction and time reduction Reduce the defects in casting
- Minimize rejection of products

PROCEDURE

1. The main objective was to optimize the proportional ratio of recycled moulding sand, bentonite, and water.
2. The proportional ranges of the recycled moulding sand, new silica sand, bentonite - luston, and water were 90–95%, 3-5%, 0.05–5%, and 0.05–5%, respectively. These proportion ranges were selected from literature and foundry experience.
3. The mixture experiments consisted of green sand, new silica sand, bentonite - luston and water at the range of 85%, 10%, 1% - 2% and 2 % respectively. From this mixture the A.F.S. Number obtained was 47.66.
4. The mixture experiments consisted of green sand, new silica sand, bentonite - luston and water at the range of 75%, 20%, 1% - 2% and 2 % respectively. From this mixture the A.F.S. Number obtained was 48.30.
5. The mixture experiments consisted of green sand, new silica sand, bentonite - luston and water at the range of 65%, 30%, 1.5% - 2.5% and 1% respectively. From this mixture the A.F.S. Number obtained was 52.08.

RANGE OF PARAMETERS AND CONDITIONS

Parameters (Range)	If lower than Range	If higher than Range
Compact ability (38-43 %)	Increase in moisture	Decrease in moisture
Moisture (3.5 to 4 %)	Increase in water addition	Decrease in water addition
G.C.S (900-1300 gm/sq.cm)	Increase in Bentonite	Decrease in Bentonite
Permeability (100-180)	Increase in New sand addition	Decrease in New sand addition
Active clay (8 -10 %)	Increase In Benotite	Decrease in Benotite
A.F.S.number (50-60)	Addition of new sand (High AFS no)	Addition Return Sand (Low AFS no)

Where,
According to A.F.S. Number range (50 – 55)

1. 1st and 2nd ratios A.F.S. Numbers are below range (indicated by red Colour)
2. 3rd ratio A.F.S. Number is within the range (indicated by green colour)
3. 4th, 5th and 6th ratios A.F.S. Number are above range (indicated by blue colour)

RESULT & DISCUSSION

Parameters	**Before optimization**	**After Optimization**
AFS	44.14	52.13
Cooling Time	60 min	48 min
Productivity	280 products/day	310 products/day
Material Rejection	4-6 %	2-2.5%

As the sand was optimized with A.F.S. Number as 52.43, it was observed that the parameters of the foundry improved for the best. As shown in Table 6.1, the cooling time which was previously timed as 60 minutes dropped down to 48 minutes. The productivity of the foundry increased to 320 product/day proving to be an important factor for the foundry and material rejection was reduced to merely 2 – 2.5%. The results obtained from sand optimization are promising and will be further researched for foundry application on a regular basis.

CONCLUSION

1. The optimized levels for the selected parameter is obtained by mixture experiment approach is Moisture- 4.3%, Green compression strength is 1100gm/sq.cm, compactibility- 40%, permeability-180%, AFS number- 52.43.

2. From the result of the experiment method the sand casting process improve the productivity of the casting and stable the casting process. Before application of this method defect of casting were 6.5% and after application of this method casting defects are reduced up to 3.43%.

3. Due to this experiment the casting surface finish is improved, shrinkage problem is reduced, less

machining allowances. The most important factor is time consumption which is reduced.

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