CASTING SIMULATION OF INSULATOR FOR QUALITY IMPROVEMENT

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ABSTRACT

In developing countries involvement of numerous process parameters leads to poor quality and productivity of foundry industries. Even in 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. To acknowledge the casting defects and problems related to casting, the study is aimed for the same in the research work. This will be beneficial in enhancing the yield of casting. Besides this, standardization (optimization) of process parameter for entire cycle of manufacturing of the critical part is intended in the proposed work. The aim of this study is to find distinct defects in casting, analysis of defect and providing their remedies with their aetiologies. In this research work an attempt has been made to enlist various types of casting defects and their root causes of occurrence. The goal of this research also comprises to provide correct guideline to quality control department to find casting defects which will help them to analyze undesired defects.

Keyword: Casting Defects, Sand Casting, Quality Tools, Casting Simulation.

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1 INTRODUCTION

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

- Melting the metal
- Pouring in to a prefabricated mould or cavity which conforms to the shape of desired components
- The molten metal is allowed to solidify in the mould.
- Removal of the component from the mould

During the process of casting, there always lies a probability of defect to occur. Minor defect can be corrected easily but high rejected rates can lead to significant change at high cost. Therefore it is mandatory for die caster to acknowledge himself about the type of defect and have the ability to identify the exact root cause, and their remedies..

2 LITERATURE SURVEY

Anicia. Dipale, and Xiaowei. Pan[3]work on quality improvement of austenitic manganese steel blades. Poor quality and low yield are major challenges to the South African foundry industry. Shrinkage porosity, gas entrapment and inclusions in the austenitic manganese scraper blades are an immense concern as they result in high rejection rate.
Causes- insufficient feed metal leads to occurrence of shrinkage defect on the cast.
Remedies- The modification of the gating and feeding system has resulted in reduction of shrinkage defects as well as the gas related defects.
Bijendra Prajapati et al. studies on the shrinkage defect prevailing in the Hand wheel casting and its remedy with the help of casting simulation software ADSTEFAN. The proposed approach reduces the rejection due to casting defects in foundries. This will especially help foundries to significantly improve their quality levels.
Causes- the shrinkage defect occurs due to the increased size of runner length.

Remedies- the Casting simulation software comprises of changes in the gating design, reduction of the runner length and placing the feeder in pattern. and introduction of this modified pattern has helped to minimise the casting defects & rejections as a whole. Modified size of runner: length reduced by 65mm. [4]

Uday A. Dabade and Rahul C. Bhedasgaonkar[15] are working on Casting Defect Analysis using Computer Aided Casting Simulation Technique and Design of experiments(DoE).For analysis of defect like shrinkage porosities computer aided casting simulation technique is the most efficient and accurate method. The quality and yield of the casting can be efficiently improved by computer assisted casting simulation technique in shortest possible time and without carrying out the actual trials on foundry shop floor. In this paper shrinkage defect can be terminated by changing the design of gating system.

Shuxin Dong[14] et al. works on shall mould cracking and its prediction during casting. due to heat The immediate inner surface of a shell mould undergoes a sudden temperature rise and by melting it attempts to expand. This thermal expansion is restrained by the other concurrent part of the mould that is still low in temperature. Consequently, compressive stress in the area near the inner surface and tensile stress in the area near the outer surface develops respectively; Filling the mould with aluminium alloy melt resulted in cracks after a short span of time.

Causes- the investigation of The cracking phenomenon of shell moulds was done during casting JIS-AC4C aluminium alloy, focusing on the thermal stress in the mould.

Remedies- Even if tensile stress occurs in the outer side of a mould, if the side is heated by melting before the stress exceeds the tensile strength, the tensile stress will be decreased rapidly and no crack will be observed.

S. Sundarrajan[10] et al**.** is performing practical to eliminate defects in casting. This paper deals with elimination of defects in aluminium alloy castings produced by gravity die casting process. The main purpose of work is to investigate the defects and improve quality of a gravity die cast component using Computer Aided Casting Simulation Software.

Remedies- Simulation showed that the new design provides a homogeneous mould filling pattern and the last filled area was transferred from part to the riser. The results of simulation are in good accordance with that of experimentation.

Anicia. Dipale, and Xiaowei. Pan[3] work on quality improvement of austenitic manganese steel blades. The prevalence of defects within the blades were investigated and categorised according to the type, size, shape and location on the castings. This study seeks to optimize the casting process of the blades using casting simulation to visualize the filling and solidification processes of the molten metal inside the mould cavity.

Causes- the blowholes occurred due to low casting temperature, insufficient venting and gas released.

Remedies- The Al content for this steel was 0.03% after sparking, which proves it acted as a deoxidizer. However, it was not adequate to completely deoxidize the Hadfield steel as the expected minimum value should be 0.04%.

Praevadee Kaewkongkha, Somkiat Tangjitsitcharoen[8] work on the factor affecting the blow holes in die casting process. the injection speed, the high starting of the position and the vacuum pressure are investigated.

Causes-defects occur due to high pressure.

Remedies-During casting of high pressure aluminium alloy type R14 low injection piston speed resulted in increased number of blow holes hence, to avoid it high injection piston speed was the solution. Low vacuum pressure, the movements of high injection speed are slow or too fast with high speed starting position plunger motion is inappropriate.

Saravanan Kumar, Dharmalingam and Pandyrajan[13] In this paper casting defects for a selected component are studied and analyzed. A non -traditional optimization approach is used to identify and mitigate the defects. It will help the quality control department of casting industries to analyse the casting defects with minimum cost and to improve the production to satisfy the customer needs. If castings are inspected using non-traditional approach, rejections in the foundry can be controlled. If this non traditional method is introduced in future, the casting defects can be reduced up to 10% by proper selection of Input parameters.

Samuel B. Assfaw, 2013 [17] In this paper the variation in result shown in literature there are many experiments needed for finding cause of shrinkage defects & gas defects. Finally, the conducted experiments it is proved that the trial of experiment 6 is better combination of the parameters like sand binder ratio, mould permeability, pouring temperature mould moisture and so on the future scope of this experiment can help in choosing the combination of process parameter which optimize defect.

3 SELECTION OF PRODUCT FOR INVESTIGATION

Figure 1: Company Products

3.1 Select Product

Product Name = Metal Part for Solid Core Insulator
Material = Spheroidal Graphite Cast Iron
Unit weight = 6.4 kg
Moulding sand = Green Sand

3.2 Green Sand

Natural or moist state of the sand is abbreviated as green sand. The other name of it is tempered sand. The sum amount of water is 6 to 10 percent to which silica sand 20 to 30 percent clay is added. Green sand moulds are prepared with this mixture. For small size casting of non-ferrous and ferrous metals green sand mould is used.

3.3 Metal Part for Solid Core Insulator

- **Use of Solid Core Insulator**

A solid core insulator used as electrical insulator is show in figure.

Figure 2: Use of Solid Core Insulator

3.4 Casting Material: Spheroidal Graphite Cast Iron.

Ductile cast iron or high strength cast iron is the other name of nodular or *Spheroidal* graphite. This type of cast iron is obtained by adding small amounts of magnesium to the molten grey iron causes the graphite form of small nodules or spheroids instead of the normal angular flakes.

Table 1: S.G Iron Material Property

Grade	SG 400/18
Minimum tensile strength (MPa)	400
Minimum percentage elongation	18
Brinell hardness number (BHN)	130-180
Predominant constituent of matrix	Ferrite
Carbon	3.1 to 3.6%
Silicon	2.1 to 2.7%
Manganese	0.15 to 0.25%
Magnesium	0.03 to 0.04%
Phosphorus	0.004 to 0.05%
Sulphur	0.004 to 0.03%

4 MODELLING AND FE ANALYSIS

4.1 Modelling

CAD is used to create 2D and 3D designs with the help of computer system. CAD system consist three-dimensional modelling and two-dimensional layout design. For generate a CAD model different software are use like an AutoCAD, SOLIDWORKS, CATIA, Pro ENGINEERING, etc.

4.2 Design Data of Casting Product

The data of casting product was collected from MODERN ENGINEERING WORKS, G.I.D.C ANKLESHWAR. They produce different types of casting products using sand casting method. There are some defects in their final product, such defects can be cost effectively eliminate using FEA and other simulation tools.

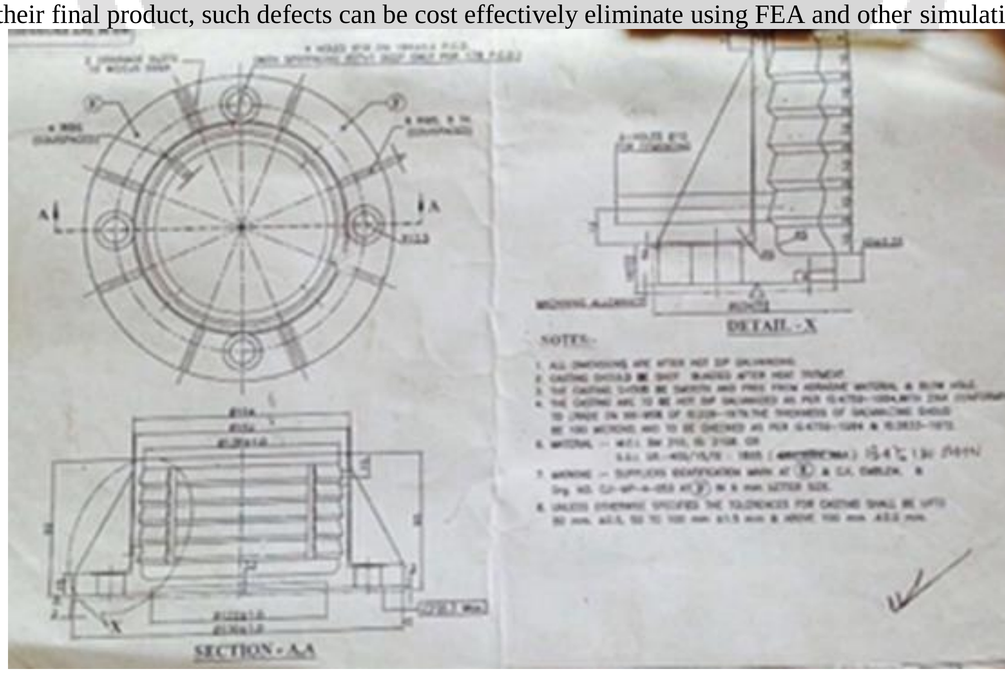


Figure 3: Design Data

4.3 Detail of Solid Core Insulator

Name of the Product: Metal Part of Solid Core Insulator
Material: Speroidal Graphite Cast Iron (SG 400/18)
Unit weight: 6.4 kg
Size of casting box:

Cope: 350mm × 350mm × 61mm

Drag: 350mm × 350mm × 139mm

Shape of the casting box: Rectangular
Type of the gating system used: Pressurized
Moulding sand: Green sand
No of core used: 1
Pouring temperature: 1300 ˚C
Type of pattern used: Cope and drag pattern

4.4 Calculate New Design of Solid Core Insulator

- Volume of casting = 787033.55 mm^3
- Surface area of casting = 4765.77 cm^2
- Part weight = volume × density
  = 6.4 kg

Pouring Time Calculation
(For ductile cast iron)

- Pouring time (t) = $k_1\sqrt{w}$

  k_1 = 2.080 for thinner section
  = 2.670 for section 10 to 25 mm thick
  = 2.970 for heavier section

  t = 2.08× $\sqrt{6.86}$
  = 5.46 sec

= 6 sec.

Design Choke Area
A_c = Choke area to be found
W = Weight of pouring metal
C = Efficiency factor (varies between 0.7 to 0.9)
= 0.85 for two runner with multiple ingates.
ϱ = Density of liquid metal = 6.9 × 10^{-6} kg / mm^3
t = Pouring time
g = Acceleration due to gravity = 9800 mm / sec^3
H = Effective height of metal head = 61

- Choke area A_c $= \dfrac{W}{c \times \varrho \times t \times \sqrt{2 \times g \times H}}$

  $$= \frac{6.4}{0.85 \times 6.9 \times 10^{-6} \times 6\sqrt{2 \times 9800 \times 61}}$$

  Choke area A_c = 167.71 mm^3
- Diameter of choke

  $A = \frac{\pi}{4} d^2$

  d = 14.61

  d ≈ 15 mm

Gating ratio
Gating ratio of a typical pressurized gating system is

Sprue : runner : ingate :: 1 : 2 : 1

Design of Runner

- Gating ratio for cast iron
  $A_c : A_r : A_g = 1.33 : 2.67 : 1$

A_c = Choke area

A_r = Runner cross section area

A_g = gate cross section area

a = 21 mm

Height of runner = 21mm

Width of runner = 21mm

Design of Ingate

$A_g = 1 \times A_c$

$= 1 \times 167.71$

$= 167.71\ mm^3$

No of ingate = 2

Each ingate area = $\frac{167.71}{2}$

$= 83.85\ mm^2$

Height of ingate = 7mm

Width of ingate = 14mm

Design of Riser

V_c = Volume of casting

S A_c = Surface area of casting = 4765.77 cm^2

- Module of casting $M_c = \frac{V_c}{SA_c}$

  $= \frac{787033.55}{191835.97}$

  $= 4.10$ mm

- Diameter of riser $D = 6\ M_c$

  $= 6 \times 4.10$

  $= 25$

4.5 Compare Existing Design with New Design

Table 2: Comparison Table

Gating System Component	Parameters	Existing Design	New Calculated Design
Sprue	Lower diameter Upper diameter Height	21 mm 39 mm 61 mm	15 mm 28 mm 61 mm
Runner	Height Width	6 mm 18 mm	21 mm 21 mm
Ingate	Height Width	6 mm 18 mm	7 mm 14 mm
Riser	Lower diameter Upper diameter Height	38 mm 50 mm 61 mm	25 mm 20 mm 61 mm

5 RESULTS

5.1 Compare Results

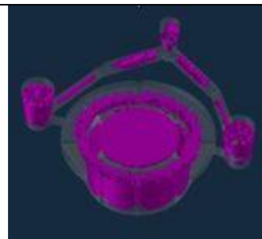
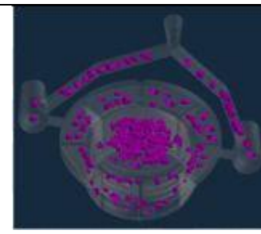
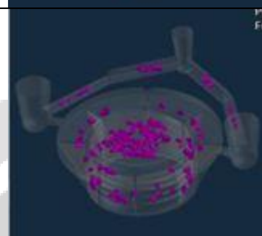
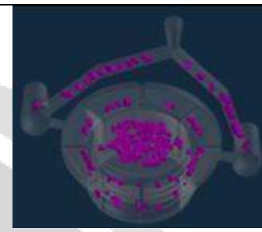
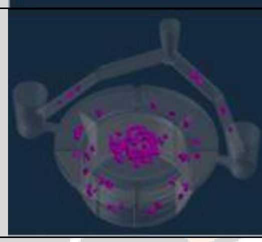
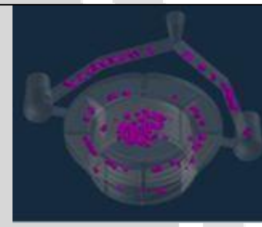
Temperature°C	Existing design	New design
1300		
1400		
1500		

Figure 4 Compare Results

5.2 Simulation Test

Table 3: Test Parameter

	Temperature (℃)	**Metal Filling time (sec)**
Simulation 1	1300	12
Simulation 2	1400	12
Simulation 3	1500	12
Calculated New Design		
Simulation 4	1300	6
Simulation 5	1400	6
Simulation 6	1500	6

5.3 Validation of New Design

For experiment on new design it is required to make a new pattern as per new design dimensions.

- **Dimension of new design**

Table 4: Dimension of New Design

Gating System Component	Parameters	New Calculated Design
Sprue	Lower diameter Upper diameter Height	15 mm 28 mm 61 mm
Runner	Height Width	14 mm 14 mm
Ingate	Height Width	7 mm 14 mm
Riser	Lower diameter Upper diameter Height	44 mm 61 mm 34 mm

5.4 Pattern making process

- Take wooden plate
- Cut wooden plate as per dimensions
- Stick wooden plate on pattern plate
- Placed runner, riser, and sprue on pattern plate.

Take wooden plate and cut it to make round shape using jipson machine.

5.5 Compare new product with existing product

Table 5 Compare Final Product

	Existing product	New product
Photo		
		
Shrinkage defect	Yes	No
Cold shut defect	Yes	No

6 RESULT & DISCUSSION

- **Result Table**

Table 6: Result & Discussion

	Hot spot	Shrinkage porosity
Simulation 1 T = 1300 ℃, FT = 12 sec	Very High	No
Simulation 2 T = 1400 ℃, FT = 12 sec	Low	No
Simulation 3 T = 1500 ℃, FT = 12 sec	Medium	No
Simulation 4 T = 1300 ℃, FT = 6 sec	High	No
Simulation 5 T = 1400 ℃, FT = 6 sec	Medium	No
Simulation 6 T = 1500 ℃, FT = 6 sec	Medium	No

- **Discussion**

The results of the existing parameters show large number of hot spots. These hot spots persists chances to generate a defect on the part. During the process of production these hot spots may generate the defects like shrinkage and cold shut, which found on the casted part resulting in the degraded quality of the cast. So it is required to change the design of gating system and change in the parameters to reduce hot spots on a part which results in improved quality of the product.

To improve the quality of the casted product the temperature of pouring metal must be changed and design of gating system should be modified to reduce the hot spots. Simulations are carried out by changing the different temperature parameters with existing design.

Results show that when temperature is increased hot spots decrease on that particular part. hence the simulation results at different temperature when temperature is taken 1500℃ and filling time is 12 seconds less hot spots are generated , and when it is compared to the new calculated design which is used for simulation, the temperature taken is 1500℃ and 6 seconds of filling time is taken where the less number of hot spots are found.

Hence this proves that the suitable parameters are, pouring temperature is 1500℃ and 6 seconds of metal pouring time with new calculated design is appropriate.

7 CONCLUSIONS

For a given specific case, it was observed that simulation allows you to visualize the progress of freezing inside a casting and identification of the hot spots. When simulation is carried out using existing design and parameters, the defect like shrinkage and cold shut are found on the final casted product. It is concluded that by changing the temperature from 1300℃ to 1500℃ less hot spots are found on the casted part.

Appropriate design of gating system helps to achieve better quality of the casting product. Using proper design of gating system which is taking parameters like 1500℃ temperature and 6 second pouring time very less hot spots are found on a part.

- **Future Scope**

Through design modification and by optimized process parameters, the defects can be minimized and quality of product can be improved.

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