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Defects Reduction of Gear Box Housing (GBI 991) through Process Improvement.

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ABSTRACT.

The Indian Foundry cluster is a key player in the production of metal castings used across various industries, including automobiles, railways, machinery, sanitary appliances, pipes, gears, earth-moving equipment, cement, electric circuits, pumps, valves, and wind turbines. Grey iron is the predominant material, constituting around 68% of all cast parts. In this context, Kolhapur plays a pivotal role in the production of diverse castings in India, primarily focusing on grey iron and SG iron castings, both of which are ferrous materials. One established foundry in Kolhapur faced stricter rejection standards for specific castings. To address these issues, a comprehensive case study was conducted to reduce rejection rates in this foundry. The primary focus of the study was on a specific casting, the Gearbox Housing, which had an initial average rejection rate of 13%. In some instances, this rejection rate spiked to as high as 18% in a single month, resulting in significant revenue losses for the company. Defects occurred in a casting of Gear box housing of foundry are categorized in to two parts. Namely methoding, filling and solidification related defects such as shrinkage porosity, hot tears, etc.& sand and mould related defects such as sand drop, bad mould, etc. In the first part casting simulation technique, analysis for shrinkage, porosity defect will perform and new gating system designed. Number of iterations will be performed using simulation software to achieve optimum design. With new gating system reduction in defects and yield improvement may observed. A new gating system was designed to enhance the casting process. In the subsequent stage of defect reduction, the Design of Experiment (DoE) tool was employed. This data-driven approach helped refine and optimize the manufacturing process to minimize defects and enhance the overall quality of Gearbox Housing castings. By implementing these strategies, the foundry in Kolhapur successfully reduced rejection rates, thereby safeguarding company revenue and ensuring the production of high-quality castings for various industrial applications.

Keywords: Casting Defects; Optimization and Analysis; Design of Experiment; Gray Relation Analysis; Sand Inclusion; Parameter optimization

1. INTRODUCTION.

Foundry operations involve the intricate process of creating castings within molds crafted from materials like sand or other substances. This time-honored production method entails crafting hollow spaces in a porous and heat-resistant material using a pattern, followed by the introduction of molten metal into the mold to shape the desired product. Among the casting methods, green sand casting stands out as the most widely employed due to its ability to produce a diverse range of castings in terms of size, its cost-effective use of raw materials, and the potential for recycling the molding sand. The versatility of green sand casting extends to accommodating metals with high melting points, such as copper and cast iron. However, the casting process is not without its challenges, as it can give rise to various defects that significantly diminish the overall casting output. Flawed castings result in substantial productivity losses. Casting defects represent deviations from meeting customer requirements in terms of (i) geometry, including issues like mismatch and swelling, (ii) integrity, encompassing problems such as porosity and inclusions, and (iii) material properties, such as segregation and the presence of hard spots.

The main objective of a gating system is to lead clean molten metal poured from ladle to the casting cavity, ensuring smooth, uniform and complete filling which results into the sound defect free casting. As this is secondary component of casting, it should be minimum in volume so as it must consume less metal and the casting yield is higher, which makes the process economical. To achieve this goal, the gating should be properly designed so as to work properly and efficiently. If gating is overdesigned it will reduce the actual casting yield, if it is undersized or not designed properly it would results into the various flow related defects such as cold shunt, misrun, blow holes, slag and sand inclusion. Hence proper design of gating system is essential for sound casting with higher yield.

The resulting consequences, including a loss in foundry productivity and a decline in customer confidence, are quite significant. Foundries, in their efforts to reduce rejection rates, initially experiment with process parameters, such as adjusting alloy composition, mold coatings, and pouring temperatures. If these measures prove ineffective, modifications are made to method design, involving changes in gating and feeding systems. When even this doesn't yield the desired results, adjustments are made to tooling design, including part orientation, parting line, and the layout of cores and cavities. The impact of any alterations to tooling, methods, or process parameters is assessed through the pouring and inspection of test castings. Design of Experiments (DoE) is a systematic and precise approach for addressing engineering challenges. It employs specific methods and techniques during the data collection phase to ensure that the resulting engineering insights are reliable, defensible, and well-supported. Importantly, all of this is achieved with minimal investments in engineering trials, time, and resources. DoE is a methodical approach aimed at establishing the connection between the inputs and outputs of a process, effectively identifying cause-and-effect relationships. This knowledge is crucial for managing process inputs and optimizing outcomes. To fully grasp DoE, it's necessary to comprehend certain statistical methods and experimental concepts. While DoE can be analyzed using various software tools, it's essential for practitioners to have a solid grasp of fundamental DoE principles for effective implementation.

2. LITERATURE SURVEY

Patil and Naik concluded that quality of castings depends on quality of sand, method of operation, quality of molten metal etc. To produce defect free casting attention have to be given towards controlling the process parameters. Most of the researchers in their study used Pareto principle and hence seven quality control tools to identify and evaluate different defects and causes for these defects responsible for rejection of components. Some of also use FMEA, Six sigma, Value stream mapping to control process. Many researchers have conducted experiments on sand process parameters using Design of experiments method such as Taguchi method and proved that the reduction in casting defects due to sand process up to 6%. Also use of simulation for simulation of component, shrinkage porosity defect gets eliminated because these are method related defect.

Dr.B.Ravi concluded that zero defect castings can be produced by collaborative design of part, tooling, methods and process parameters using a user-friendly system. At the part design phase, thickness checks enable preliminary evaluation of part manufacturability with respect to process capability. At the tooling design phase, parting line, cores and mold cavity layout can be semi-automatically designed and analysed. The methods design includes semi-automatic design and 3D modeling of feeding and gating system, followed by mold filling and casting solidification, to predict quality issues more accurately (compared to part design phase). A cost model enables comparing alternative designs. Finally, process optimization is carried out based on the results of shop-floor trials.

Patil S.S. et al Defects occurred in a casting of Gear box housing of foundry are categorized in to two parts. Namely methoding, filling and solidification related defects such as shrinkage porosity, hot tears, etc.& sand and mould related defects such as sand drop, bad mould, etc. In the first part casting simulation technique, analysis for shrinkage, porosity defect was performand and new gating system designed. Number of iterations will be performed using simulation software to achieve optimum design. Gating system must consume less metal and the casting yield is higher, which makes the process economical. To achieve this goal, the gating should be properly designed so as to work properly and efficiently. The time required is very less as compared to the conventional method of design of methoding. Visualization of mold filling phenomenon makes the process easy to understand to the user. Analysis of defects like shrinkage porosities computer aided casting simulation technique is the most efficient and accurate method .By simulation results we conclude that with change in number of ingates and its area, shrinkage tendency gets reduced and by controlling velocity of molten metal flowing through ingate, sand inclusion defect is improved by great extent. With old gating system analysis gives shrinkage nearer to middle ingate with 83% production yield whereas modified gating shows improvement in shrinkage with 85.5% of production yield of gear box housing. Thus, yield improvement with newly designed gating system is calculated and it is about 2.5 % higher than old gating system.

PROBLEM DEFINITION

Casting of an M/s Ghatge-Patil Industries Ltd Named Gear Box Housing (GBI 991) facing a problem of Heavy rejection due to casting defects developed in it since last 6 months. The rejection rate is about 15 %. Defects occurred in housing are sand inclusion (8%), Shrinkage (4%) and other defects such as cracks, mismatch etc. (3%).The monthly production of GBI 991 is 1000 units. The price for one housing is Rs.5000/-. So loss of revenue due to poor quality casting is 7.5 lakhs per month. Sponsoring organization GPI is facing loss of significance revenue due to cost of poor quality.

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Fig.4.2-Shrinkage defect in casting

Fig.4.3.Sand Inclusion in casting.

OBJECTIVES –

To achieve the reduction in rejection percentage of Gear Box Housing (GBI 991), the target should be broken down into objectives. These objectives will support the research and at the same time it will act as a scope so that research will not be off the track. Achieving all the objectives will result into reduction of defect. It will ultimately result into quality improvement for the particular component.

1. To study and analyze the casting process of selected component for identifying the defects.
2. To study the effect of parameters of gating system on defects of Gear Box Housing.
3. To modify gating system to minimize defects due to solidification.
4. To study the effect of process parameters of sand/mould on defects of casting under study.
5. To select optimum level of process parameters of sand/mould to minimise sand related defects.
6. To find reduction in defects of GBI 991 after Process Improvement.
7. Confirmation Experiment to be conducted at optimum level of process parameters

REJECTION DATA COLLECTED FROM PROCESS MAPPING-

Table 1 shows monthly rejection of casting under study for last 6 months. The average percentage of rejection for this time span is 13.02%. Data is collected from month of Aug 2016 to Jan 2017 and percentage of rejection varies from 09.58 to 18.2.

Month	Production	Total Rejection	Percentage of Rejection
Aug. 2016	793	137	17.28
Sept. 2016	1237	157	12.69
Oct. 2016	1318	137	10.39

Nov. 2016	1175	142	12.09
Dec. 2016	1033	188	18.2
Jan. 2017	1086	104	9.58
Total	6642	865	13.02

Table 1- Percentage rejection of gear box housing.

Rejection Details-

Table 2 shows rejection due to defects and their individual percentage of rejection. From data it is clear that most dominating defect is sand inclusion which is responsible higher rejection rate.

Month	Shrinkage	Sand Inclusion	Core Scab	Fettling Cracks	Other Defects	Total rejection
Aug. 2016	26	54	20	27	10	137
Sept. 2016	12	94	20	09	22	157
Oct. 2016	34	71	13	08	11	137
Nov. 2016	20	67	01	38	16	142
Dec. 2016	27	87	31	39	04	188
Jan. 2017	29	34	09	12	20	104
Total	148	407	94	133	83	865
Avg. Rej. Percentage	2.23	6.13	1.42	2.00	1.25	13.02

Table 2- Defects and Avg. rejection percentage.

Revenue lost due to rejection in month of August 2016(Sample Calculation)

Table 3 gives loss of revenue due to poor quality of gear box housing. The number of casting produced in the month of Aug. was 793.Out of which 137 were rejected. Cost of housing is Rs 5000/-. So total revenue loss in that month is 685000/- approximately.

Casting poured	Rejected castings	Cost of housing in Rs.	Total revenue lost
793	137	5000/-	685,000/-

Table 3- Revenue loss for month of Aug.

PARETO ANALYSIS FOR DEFECT CATEGORISATION-

Pareto Analysis is conducted for identification of major defects those are contributing in major rejection percentage. This tool is used to find the 20% of work that will generate 80% of the results hence also named it as a 80/20 rule. Pareto gives correct identification hence it is conducted. The average rejection percentage for housing is 13.02. Various defects are contributed in rejection of product under study. These defects along with their avg. percentage are represented on a graph, from which it is clear that which defect contributing more in rejection.

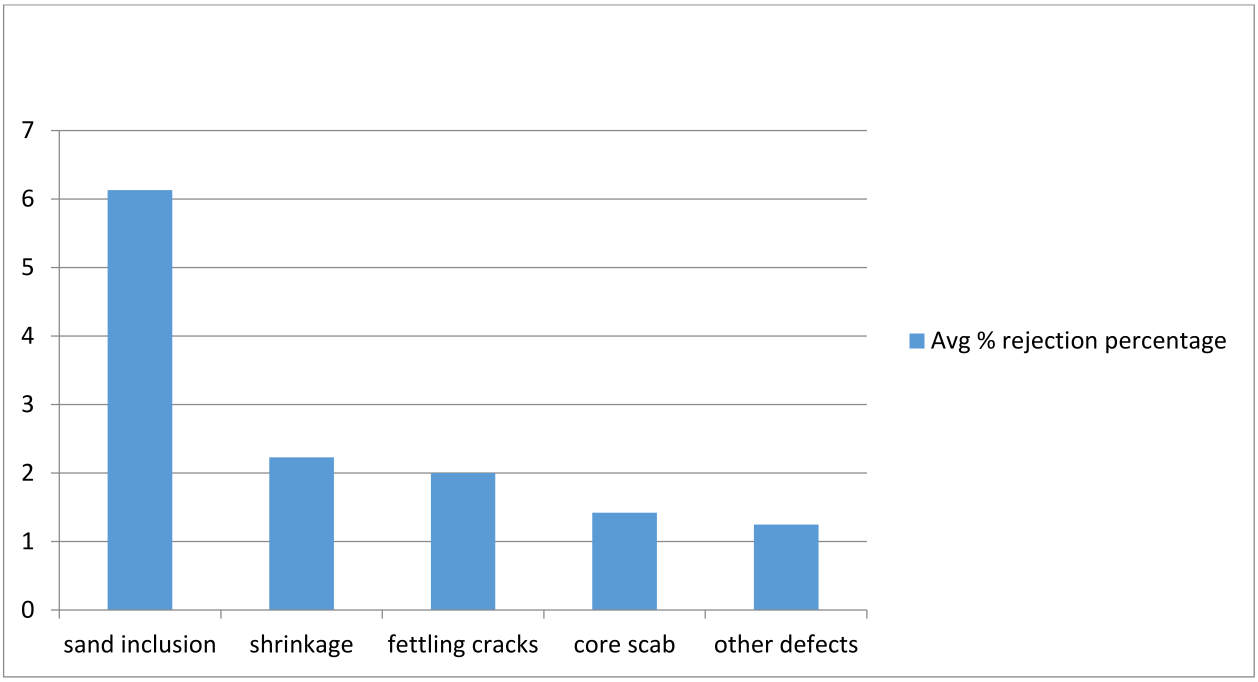


Fig 1- Pareto Analysis for defect categorization.

From fig 1 it is clear that sand inclusion and then shrinkage defect greatly affects the quality of casting and hence causes higher rejection rate. Sand inclusion and shrinkage contributing 6.13 % and 2.23 % of Avg rejection respectively out of total avg. rejection of 13.02 %.

DESIGN AND OPTIMISATION OF GATING SYSTEM

Analysis Data-

Material: CAST IRON Grade: FG-260	
Iron Composition (Weight %)	
Element	Specification
Carbon	3.15- 3.35 %
Silicon	1.45- 1.65 %
Manganese	0.80- 1.00 %
Phosphorous	0.15 % Max.
Sulphur	0.15 % Max.
Chromium	0.30- 0.45 %
Copper	0.65- 1.00 %
Weight of the casting: (kg.) =195 Kg. APPROX.	
Gross weight incl. Casting + Feeder/s + gating (kg.)= 238 Kg. APPROX.	
Mold: Green sand	
Molding process: High Pressure	
Box size:– Cope.- 1200 x 800 x 375 ; Drag.- 1200 x 800 x 350	
Sand/binder:- Bentonite	
Sand / mold temperature:- 40 ° C- 45° C	

Maximum permissible poured weight per mold: 250 kg.
Green sand molds
Water content:- 3.4-3.8%
Gas permeability:- 85-.95%
CORES – Cold Box process
Binder: Resin Part 0.85-0.95 % + Part 2- 0.85-0.95 %, Catalist.- Amine- 0.25%
Sand: Silica Sand ; Coating: water base coating
FILTER Size :- 100X100X22
Inoculation
Inoculation alloy: Fesi. ; Inoculation process: Laddle / Stream
Pouring process
Pouring temperature (°C):- 1420 ± 10 °C ; Pouring time (sec.): - 17 ± 1 SEC
Type of ladle: Teapot Spout
Dia. of press pour nozzle:- Ø38 mm.

Table 4-Details of existing casting process.

Simulation Results for old Gating System-

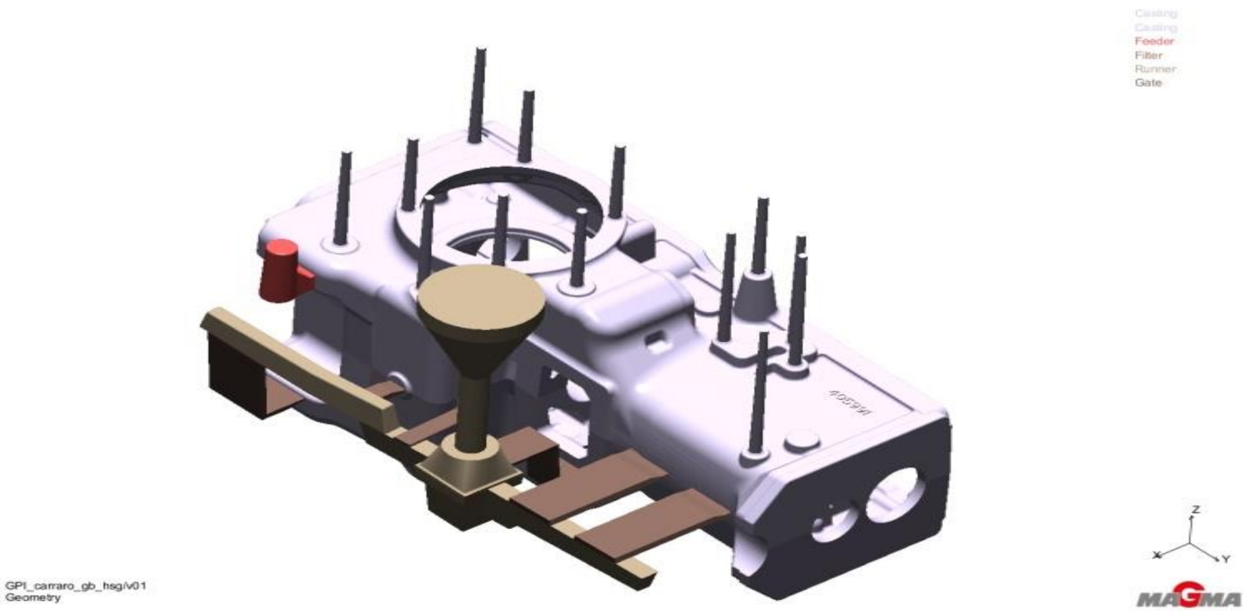


Fig 2. Casting with old gating system.

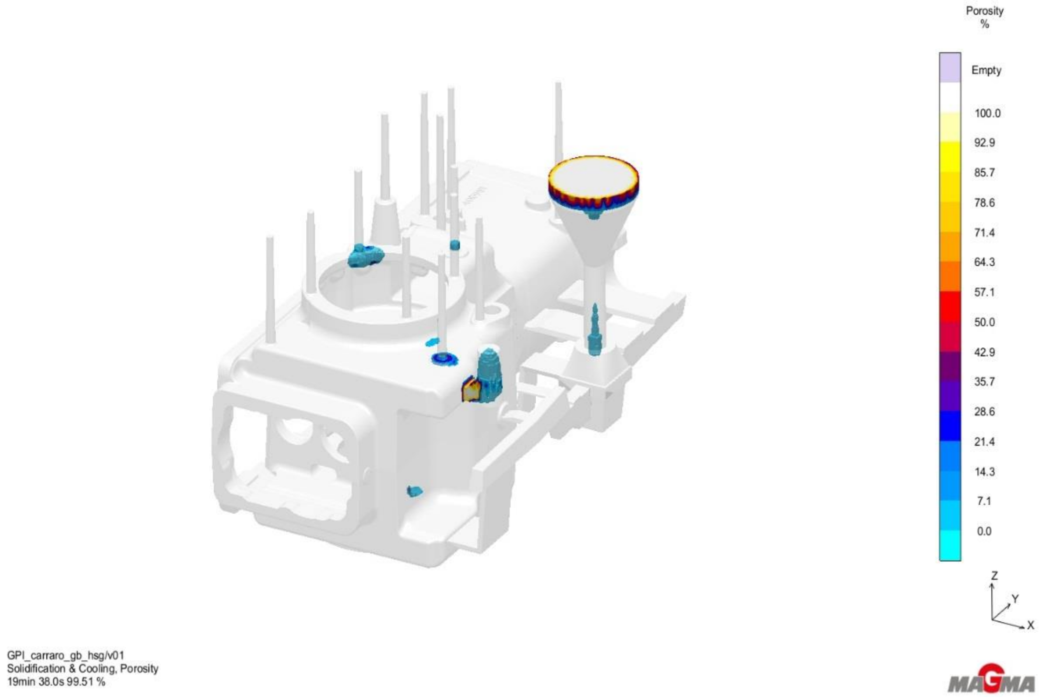


Fig 3.Shrinkage observed in casting.

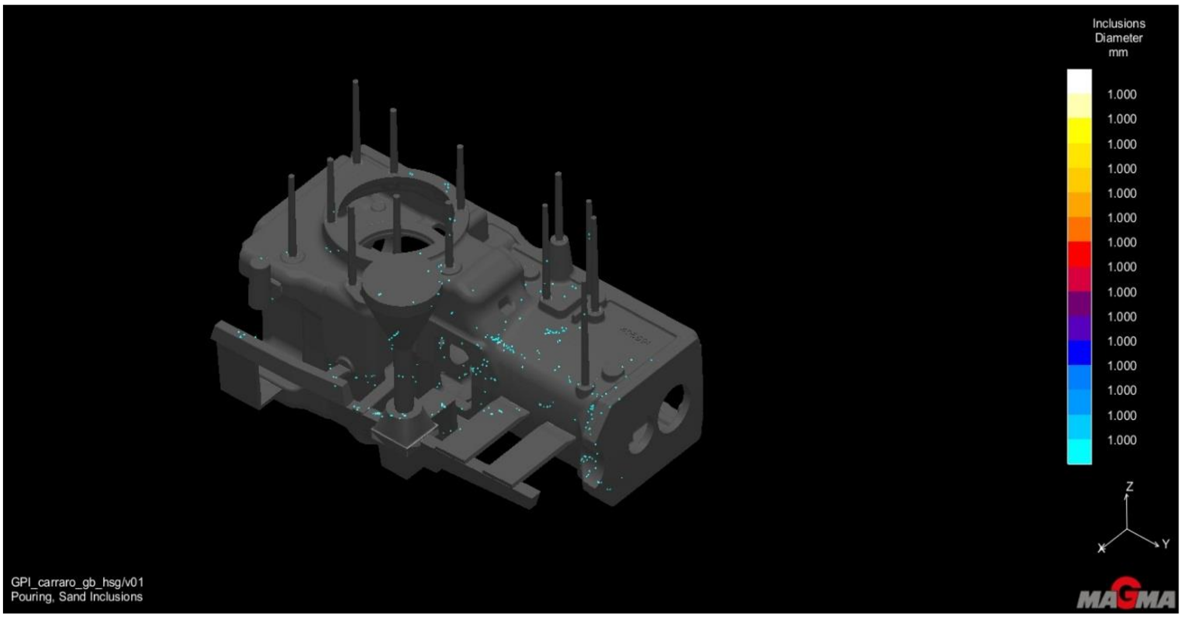


Fig.4. Inclusion observed in casting.

Design of Gating System-

1) Pouring time required to fill complete casting in sec (t) -

$$t = \frac{\text{Bunch wt.(kg)}}{\text{Flow rate fixed by press pour system. (kg/s)}}$$

Bunch weight of casting = 230 kg
Flow rate fixed by press pour = 12 kg/s

t = 230/12
t = 19 sec.

2) Sprue/Choke Area (Ac) –

$$Ac = \frac{k*\text{Bunch wt}}{\rho * t * f * \sqrt{H}}$$

where , k = thumb rule constant ,
ρ = density of metal (g/cm^3),
t = pouring time (sec),
f = friction factor and
H = effective sprue height (cm).
Where H is calculate as,

$$H = \frac{2h - a^2}{2c}$$

h = cope box height,
a = casting height in cope,
c = total casting height.

$$H = \frac{(2*37.5) - 22^2}{2*44}$$

H = 2814/88
H = 32 cm.

Putting this value of H in above said formula to calculate choke area,

$$Ac = \frac{22.6*230}{7.2* 19 *0.5 *\sqrt{32}}$$

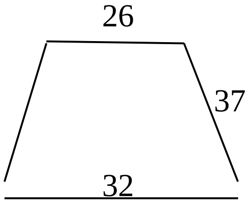
Ac = 5198/388
Ac = 1340 mm^2

Sprue bar diameter (d) is calculated as,

$Ac = \pi*d^2/4$
$d^2 = 4 * Ac/\pi$
$d = \sqrt{4 * Ac/\pi}$
$d = \sqrt{4*1340/\pi}$
d= 41mm ~ 40 mm.

3) Total runner area (Ar) = 1.4 * Sprue area (Ac)
= 1.4 * 1340
= 1876 mm^2

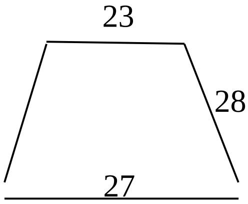
a) LHS runner area- Considered trapezoidal c/s of runner having top length 26 mm, bottom length 32 mm and height is 37 mm.



$$(Alh) = \frac{(26+32)}{2} * 37$$

$$= 1070 \text{ mm}^2$$

b) RHS runner area- Considered trapezoidal c/s of runner having top length 23 mm, bottom length 27 mm and height is 28 mm.



$$(Arh) = \frac{(23+27)}{2} * 28$$

$$= 700 \text{ mm}^2$$

4) Total ingate area (Ai) = 1.6 * Sprue area(Ac)
= 1.6 * 1340
= 2140 mm^2

a) Ingatearea on LHS(3 ingates) = (135+35+50)*6 ……(length * width)
= 1230 mm^2

b) Ingate area on RHS(2 ingates) = (70+65)*6 ……(length * width)
= 810 mm^2

5) Riser neck modulus calculation-
Casting modulus is 1.4 cm (from simulation software)
So, neck modulus required is half of casting modulus i.e. 0.7 cm
Existing riser have neck cross section (3cm*2cm)

$$\text{Modulus of neck} = \frac{\text{length} * \text{width}}{2(\text{length} + \text{width})}$$

$$\text{Modulus of neck} = \frac{3*2}{2(3+2)}$$

Modulus of neck = 6/10
Modulus of neck =0.6 cm
Modified riser has neck cross section (3.5cm*2.5cm)
With this as a cross section of riser neck neck modulus is modified & it is now 0.7 cm.

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Simulation Results for New Gating System-

Fig 5 below shows modified gating system of casting with the help of design calculations as explained above. In this gating system it is designed in such a way that it will helps in minimising shrinkage and inclusion defect of casting. In this design of gating, keeping number of runners are same as that of old gating system numbers of ingates incorporated are five out of which two ingates are on the right side of sprue and three ingates on left side of it and central ingate is removed as seen in figure below.

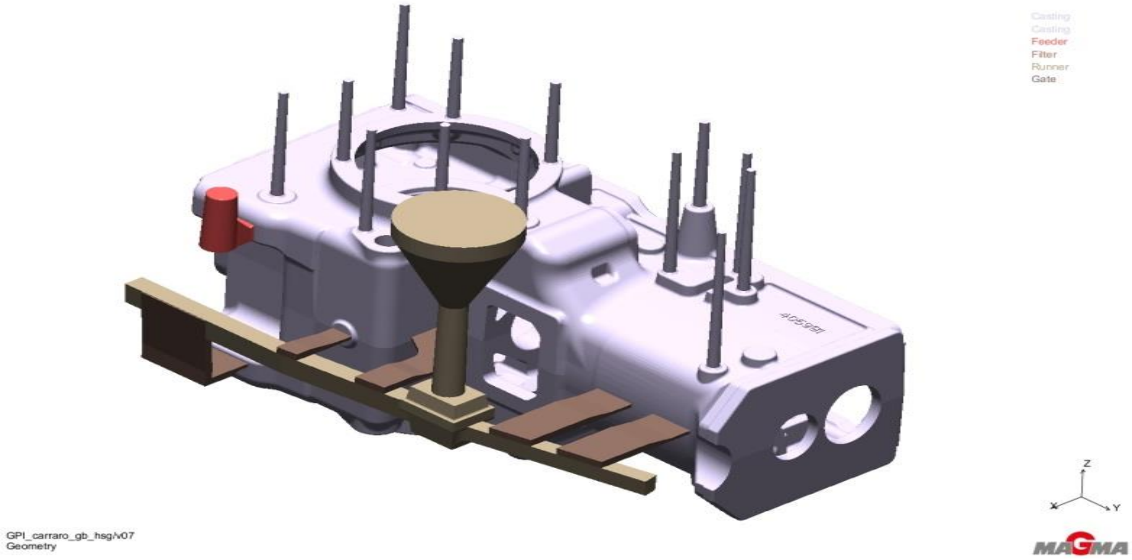

Fig 5-Casting with new gating design

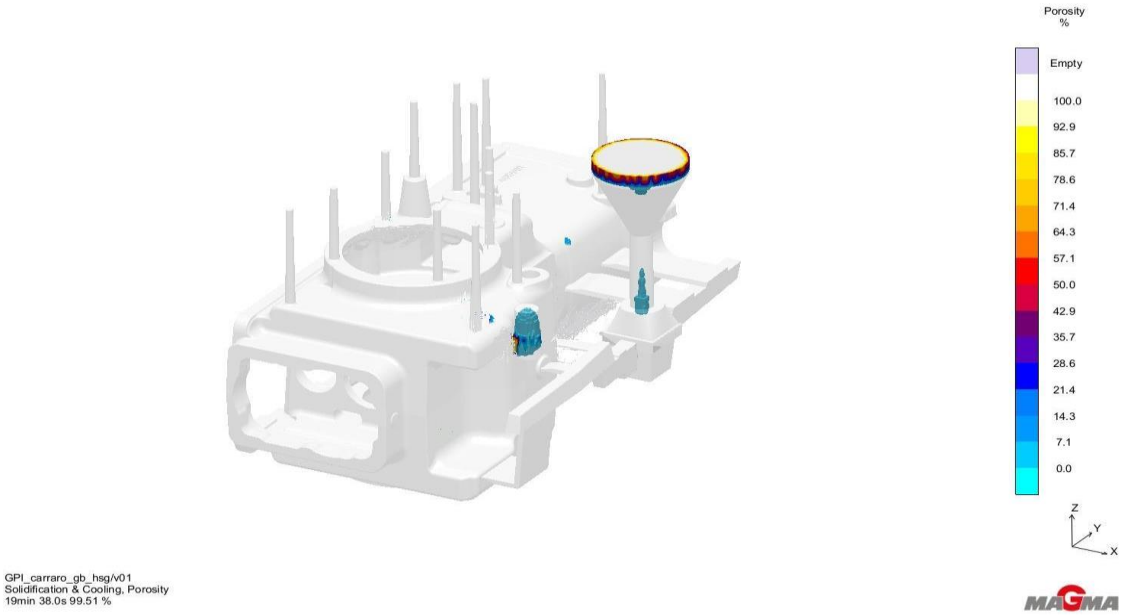

Fig 6-Improvement in shrinkage

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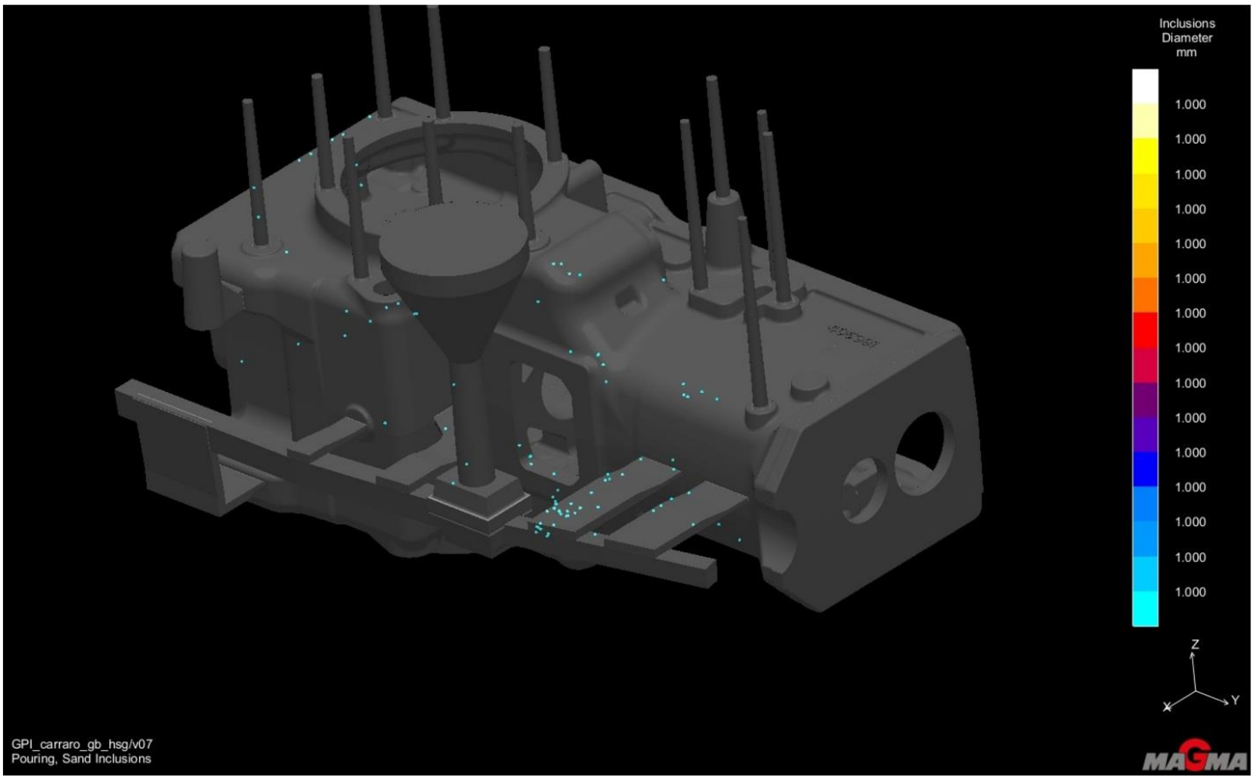
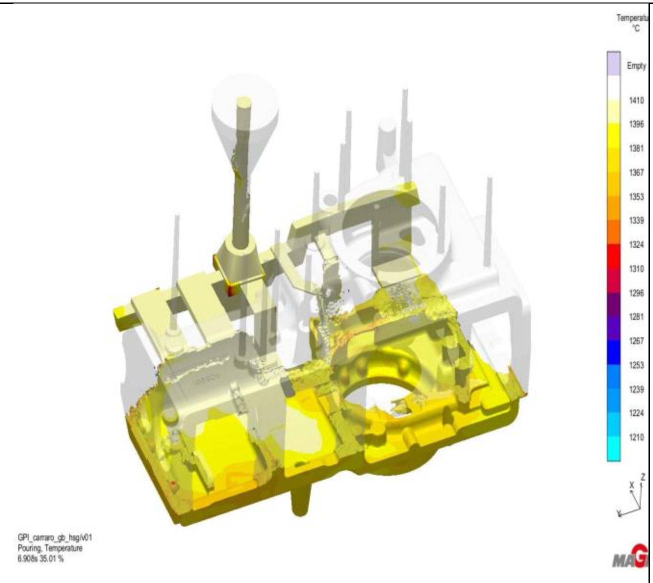
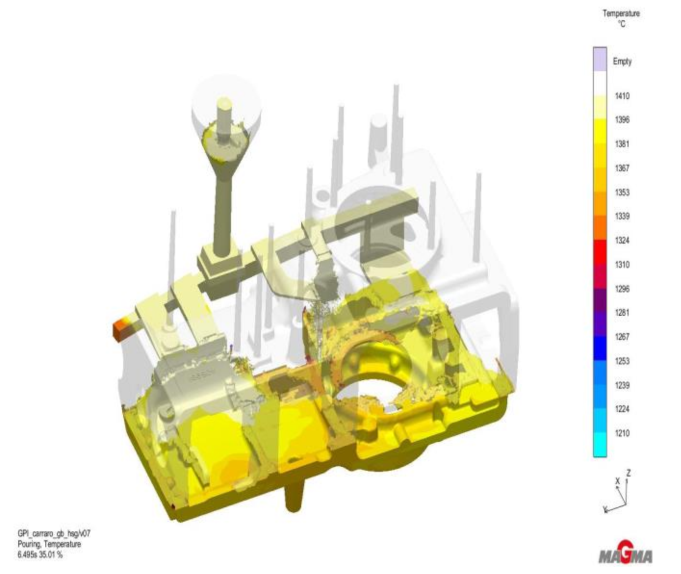
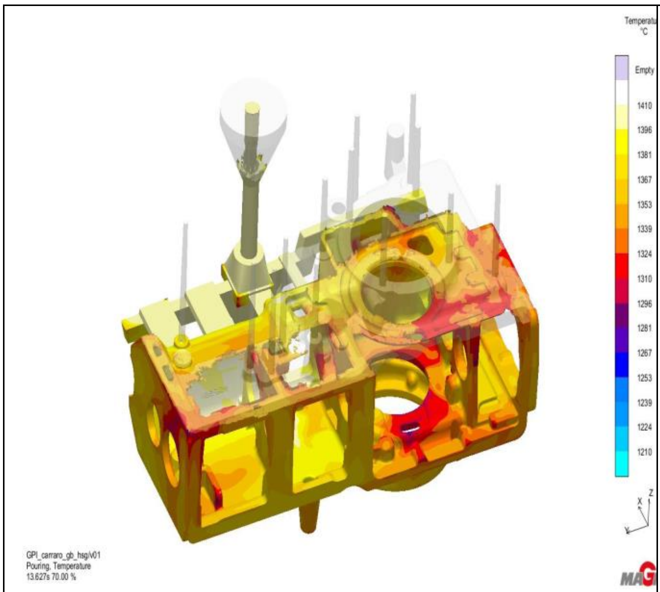
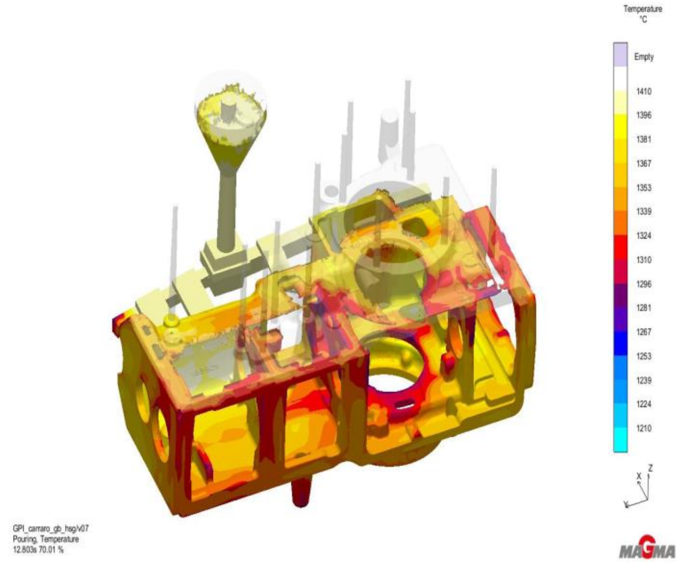
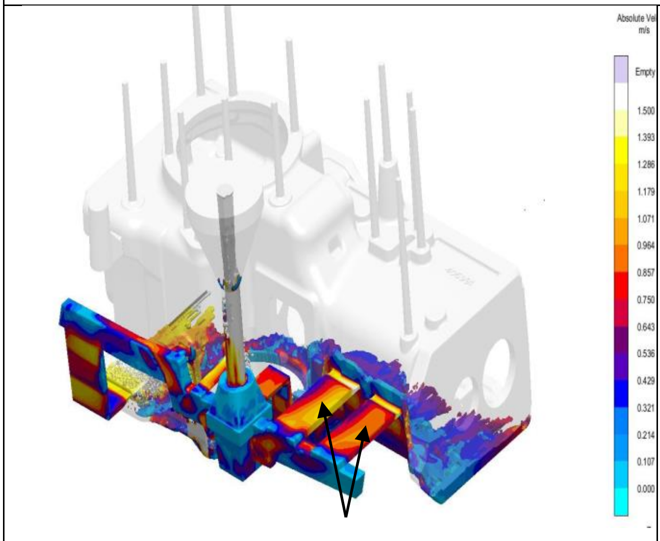
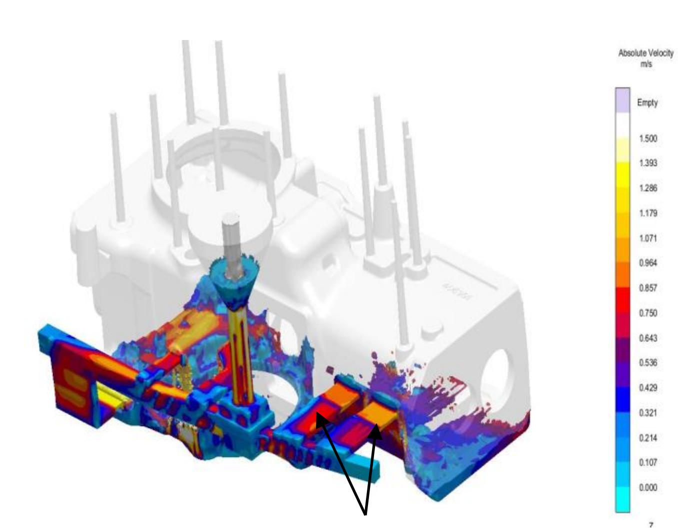
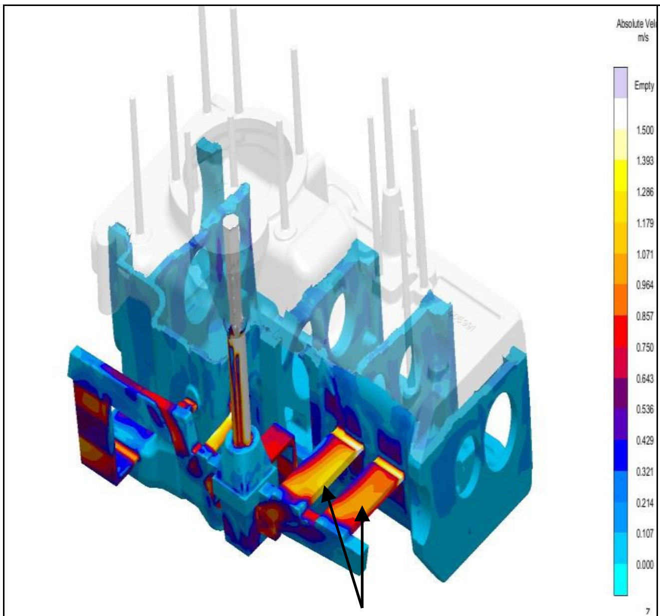


Fig 7-Improvement in inclusion.

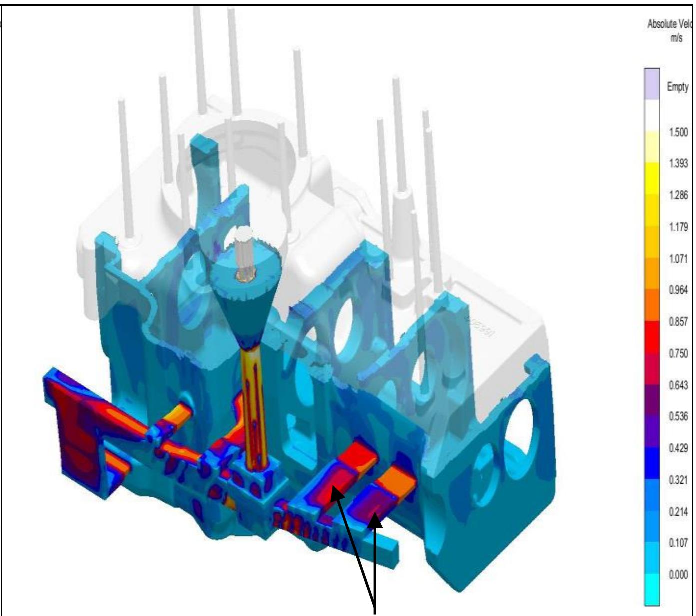
Analysis Summary-

Analysis of old gating system	Analysis of new gating system
Resulting images for temperature.	
	
No cold metal filling observed from ingates (At cavity filling of 35%)	No cold metal filling observed from ingates (At cavity filling of 35%)

 No cold metal filling observed from ingates At cavity filling of 70 %.	 No cold metal filling observed from ingates At cavity filling of 70 %.
Analysis of Old Gating System	Analysis of New Gating System
Resulting figures for velocity.	
 High velocity of metal from these two ingates. (At cavity filling of 20%)	 Smooth filling of metal from these two ingates. (At cavity filling of 20%)



High velocity of metal from these two ingates. (At cavity filling of 60%)



High velocity of metal from these two ingates. (At cavity filling of 60%)

Fig.8. Temperature and velocity resulting images of old and new gating system at same cavity filling percentage.

Detailed summary of analysis is tabulated in given below.

PARAMETERS	OLD DESIGN	NEW DESIGN
Pouring Temp.	1400-1420 ^{0}c	1400-1420 ^{0}c
Gating system weight	40 kg	34 kg
Gross weight	236 kg	230 kg
Number of gates	06	05
Cavity filling time	17	19
Yield	83%	85.5%
Shrinkage	At middle ingate.	Ingate is removed.
Sand Inclusion	At ingate face and top surface of ingate.	Improved
Number of runner bars	02	02
Filling velocity at inlet	1.5 max	1.1 max
Sprue area(Scale)	1256 mm^2 (1:1)	1340mm^2(1:1)
Runner area(Scale)	2512 mm^2 (1:2)	1876mm^2(1:1.4)
Ingate area(Scale)	1985 mm^2 (1:1.58)	2140mm^2(1:1.6)
Riser neck modulus	0.6 cm	0.7 cm

Table 5. Analysis summary.

DESIGN OF EXPERIMENT

sand parameters and their levels.

Process parameters of green sand casting that influences identified defects in casting of gear box housing with their levels are shown in below table 6

Input parameters ranges	Level		
	Level 1	Level 2	Level 3
Moisture (%)	3.0-3.5	3.5-4.0	4.0-4.6
Green Compressive Strength(gm/cm^2)	1500-1800	1800-2100	2100-2400
Permeability(Number)	65-80	81-95	95-115
Mould Hardness(Number)	80-84	84-88	88-92

Table 6 Input parameters ranges and Levels

Four parameters of their three different levels therefore L9 orthogonal array is selected for experiment. The response variable was % rejection of casting due to defects which is ratio of rejection due to considered process parameters to the quantity poured. As per orthogonal array 9 experiments were performed randomly and % of rejection in each experiment was considered as the response variable. Design Matrix Table is given in table 7.

Exp. No	Moisture	Green Comp. Strength	Permeability	Mould Hardness
01	1	1	1	1
02	1	2	2	2
03	1	3	3	3
04	2	1	2	3
05	2	2	3	1
06	2	3	1	2
07	3	1	3	2
08	3	2	1	3
09	3	3	2	1

Table 7. Design matrix table

3. RESULTS

The equations for calculating the signals to noise ratios were based on the characteristics of the response variables being evaluated; nominal the best, smaller the better and larger the better. In the present work smaller the best characteristic is used as the main aim is to reduce rejection in frames. The percentage rejection due to inclusion for each trial was evaluated and the report generated was obtained from MINITAB-17 statistical software. Sand Inclusion results are given below.

Moisture	Green Comp.	Permeability	Mould Hardness	Rejection %	SNRA1
1	1	1	1	7.0	-16.90
1	2	2	2	6.0	-15.56
1	3	3	3	5.5	-14.80
2	1	2	3	6.2	-15.84
2	2	3	1	6.5	-16.25
2	3	1	2	5.8	-15.26
3	1	3	2	6.7	-16.52
3	2	1	3	6.5	-16.25
3	3	2	1	6.3	-15.98

Table 8. Sand Inclusion DOE results

Analysis of experimental results was performed using Minitab 17 software and ANOVA and main effect plots obtained are given in Table 9 and Figure 9 respectively. ANOVA in Table 9 indicates that green compression strength and mould hardness parameters significantly influence the % rejection.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	1.53500	0.38375	8.50	0.031
MOISTURE	1	0.16667	0.16667	3.69	0.127
GCS	1	0.88167	0.88167	19.53	0.012
PERMIABILITY	1	0.06000	0.06000	1.33	0.313
MOLD HARD	1	0.42667	0.42667	9.45	0.037
Error	4	0.18056	0.04514		
Total	8	1.71556			

Table 9. ANOVA for S/N Ratio

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	7.444	0.354	21.02		

Moisture	0.1667	0.0867	1.92	0.127	1.00
GCS	-0.3833	0.0867	-4.42	0.012	1.00
Permeability	-0.1000	0.0867	-1.15	0.313	1.00
Mould Harness	-0.2667	0.0867	-3.07	0.037	1.00

Table 10 Table of Coefficients

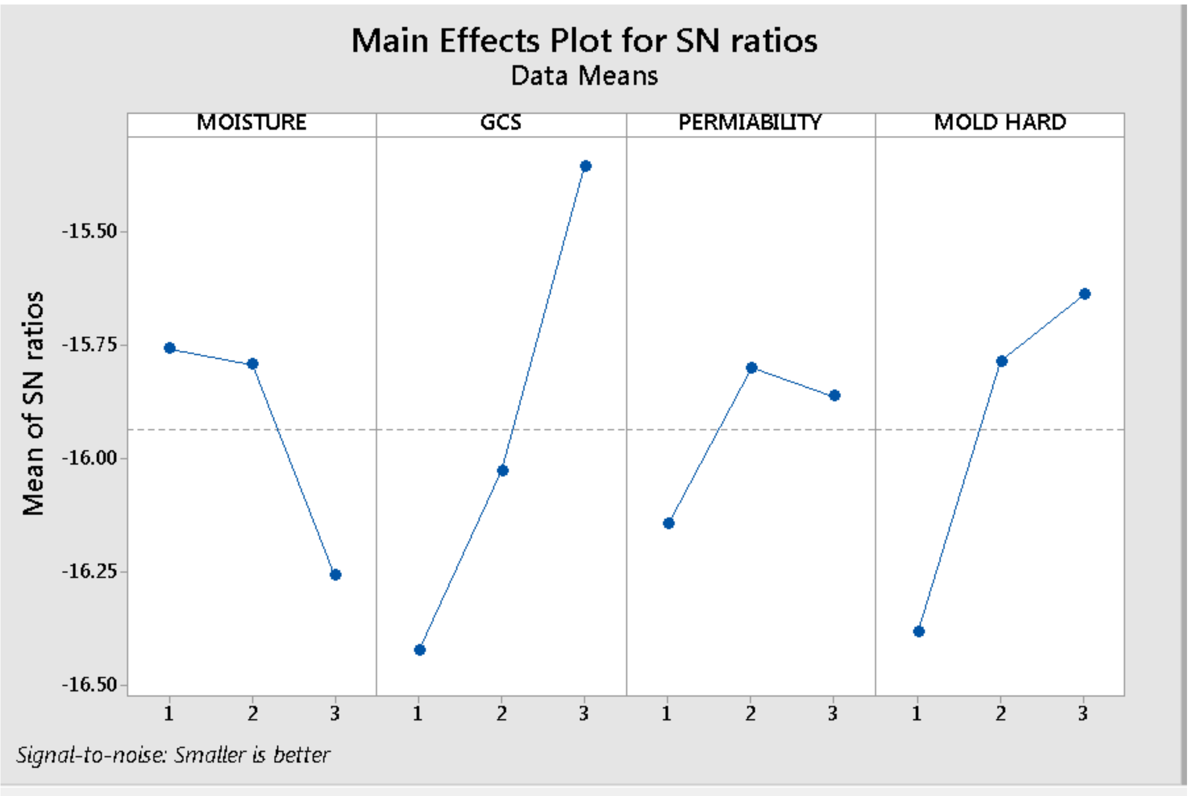


Fig 9: Main Effect Plot for SN Ratio

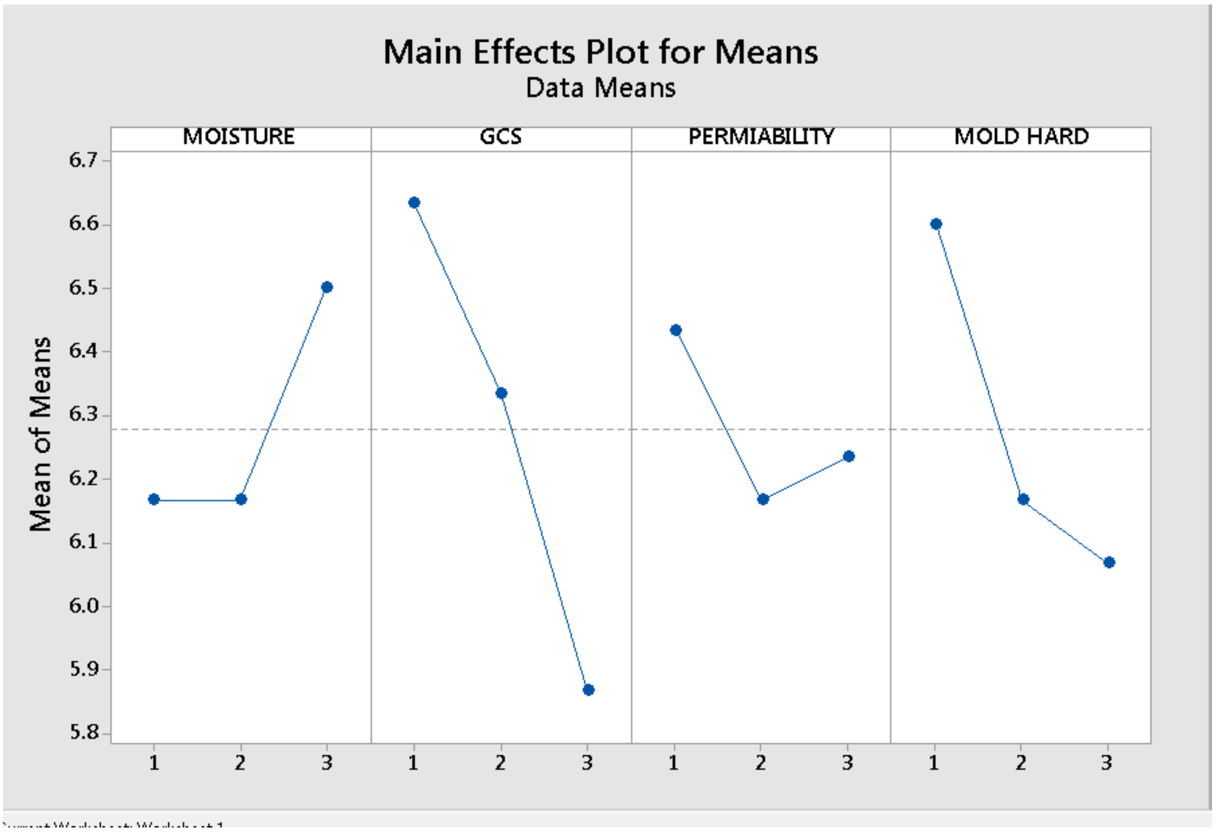


Fig 10. Main Effect Plot for Mean

The Taguchi Method is used to optimize the results obtained from each trial. In the present work L_9 orthogonal array is used for the trial purpose. The response of the S/N Ratio, contribution of different process parameters and relation between S/N ratio and the levels of different process parameters is studied and analyzed to obtain optimum process parameters. There are three categories of quality characteristics in the analysis of S/N ratio, i.e. smaller-the-better, larger-the-better, nominal-the-best. **T**he S/N ratio for each level of process parameter has been computed by using a quality characteristics smaller-the-better. From the Main effect plot shown above it can have concluded that the optimum value of Green compressive strength is 2100-2400 gm/cm^2, Mould Hardness88-92**(No),** Moisture3-3.5 % & Permeability is 81-95 (No) this combination give the optimum results.

Regression Analysis.

Linear Regression Equation for Sand Inclusion Rejection is given below,

Rejection=-7.444+0.1667 Moisture-0.3833GCS-0.1000Permiability-0.2667Mould Hardness

From the regression equation it is observed that Green Compressive Strength, Permeability and Hardness having negative effect and from ANOVA table it is seen that the value of p for Green Compressive Strength is 0.012, and Mould hardness is 0.037. And the experiments were performed with 95% confidence level, so as compared with Moisture, GCS, Permeability, Mould Hardness Green Compressive strength is more significant. Considering Loss of Optimality, Optimum parameters are tabulated in below table.8.4.

Parameters	**Optimum Value**
Compressive Strength	2100-2400 gm/cm^2

Mould hardness	88-92 (No)
Moisture	3-3.5 %
Permeability	81-95 (No)

Table 11. Optimum values of process parameters under study.

Conformation Experiments:

Three confirmation experiments were performed at the optimized settings of the process parameters, results of which are shown in Table 12. Prior to the application of Taguchi method rejection due to sand related defects for gear box housing after implementation result was 8% this is reduced to maximum up to 5.5 %.

Experiment no.	**Rejection (%)**
1	5.5
2	5.5
3	5.7
Total average of % rejection	5.56

Table 12: Results of Confirmation Experiments

4. CONCLUSION.

The casting under study facing a problem of higher % of rejection due to defects observed in it. This research uses QC tools for defects identification and categorization, Simulation tool for finding solution the solidification related defect shrinkage and DOE tool to find optimum sand/mould parameters to reduced sand related defect i.e. inclusion**.**

1) Design of experiments method such as Taguchi method can be efficiently applied for deciding the optimum settings of process parameters to have minimum rejection due to defects for a new casting as well as for analysis of defects in existing casting. The optimized levels of selected process parameters obtained by Taguchi method are: (A): Moisture content: 3-3.5 %% (B)Mould hardness:88-92 (No)(C) Green Compressive Strength :2100-2400 gm/cm^2 (No)and (D)Permeability:81-95 (No.)

2) With Taguchi optimization method the % rejection of casting due to sand related defects is reduced from 8% to a maximum upto 5.56%. This indicates that the solution is efficient. 2.24% of improvement is registered.

3) Expecting monthly casting poured are 1000 then increase in revenue by setting optimum parameter as stated above, net increase in revenue is 112,000/-INR.

4) Due to simulation on software, traditional gating system of any casting component has changed into new gating system. The time required is very less as compared to the conventional method of design of methoding. Analysis of defects like shrinkage porosities computer aided casting simulation technique is the most efficient and accurate method. By simulation results we conclude that with change in number of ingates and its area, shrinkage tendency gets reduced and by controlling velocity of molten metal flowing through ingate, sand inclusion defect is improved by great extent. Also yield improvement with newly designed gating system is calculated and it is about 2.5 % higher than old gating system.

5) Because of this improved yield increase in revenue monthly by 125,000/-INR.

6) So at the end of this dissertation it is clear that total increase in revenue is 237,000/-INR.

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