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Optimization of Process Parameters of Green Sand Casting in Small Scale Foundry

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Abstract--*In this research work present the design of experiment based approach which is adopted to obtain an optimal setting of moisture content, grain particle size and temperature of pouring metal related parameters of green sand casting in SUSHA FOUNDERS AND ENGINEERS at G.I.D.C PANDESARA, SURAT. The casting parameters identified for green sand casting process are moisture content, green strength, mould hardness, permeability, sand particle size, pouring temperature ramming pressure, cooling time. For defect analysis, the possible causes are grouped into design, material and process parameters. The effect of suspected cause parameters on casting quality is ascertained through simulation. Based on the results and their interpretation, the optimal values of the parameters are determined to eliminate the defects.*

I. INTRODUCTION

A. Sand Casting

Casting is one of the oldest manufacturing process dates back to 4000 B.C. when copper arrowheads were made. Casting produced by foundry as per customers' specifications, their quality level otherwise the casting is termed as defective. If casting is defective then it is rejected. Rejected parts contributed to the wastage and loss of value to the foundry. To improve the cast metal yield, we need to optimize the gating system design, optimize mould filling, avoid shrinkage defects, voids, hot tears etc. casting simulation tools are very helpful to achieve above objectives. With advent of modern computing facilities, application of commercial software's, packages such as casting simulation tools, enable the foundry industries to accomplish successful casting design.

B. Need and Importance

Sand casting is the casting process that has the longest history. Sand casting still accounts for the largest tonnage of production of shaped castings. This is due to the fact that sand casting is economical and possesses the flexibility to produce castings of any material, and the weight of castings can range from tens of grams to hundreds of tons. Advanced high technology sand casting process, with improved sand quality and mould rigidity, enables this method to produce high precision cast products with better as cast surface finish that reduces the cost of after-cast touch up. This will enhance the capability of sand casting to produce 'near net shape' products and improve its competitiveness.

C. Basic Steps of Casting

The basic steps are as following:

Melting the metal.

Pouring it in to mould cavity which previously made as desired shape of component.

Allow the molten metal to cool and solidify in mould.

Remove the solidified parts from mould, cleaning it and further go for secondary treatment if it needed.

The solidified part is metal which is out from the mould is called Casting. A plant where casting is made is called foundry.

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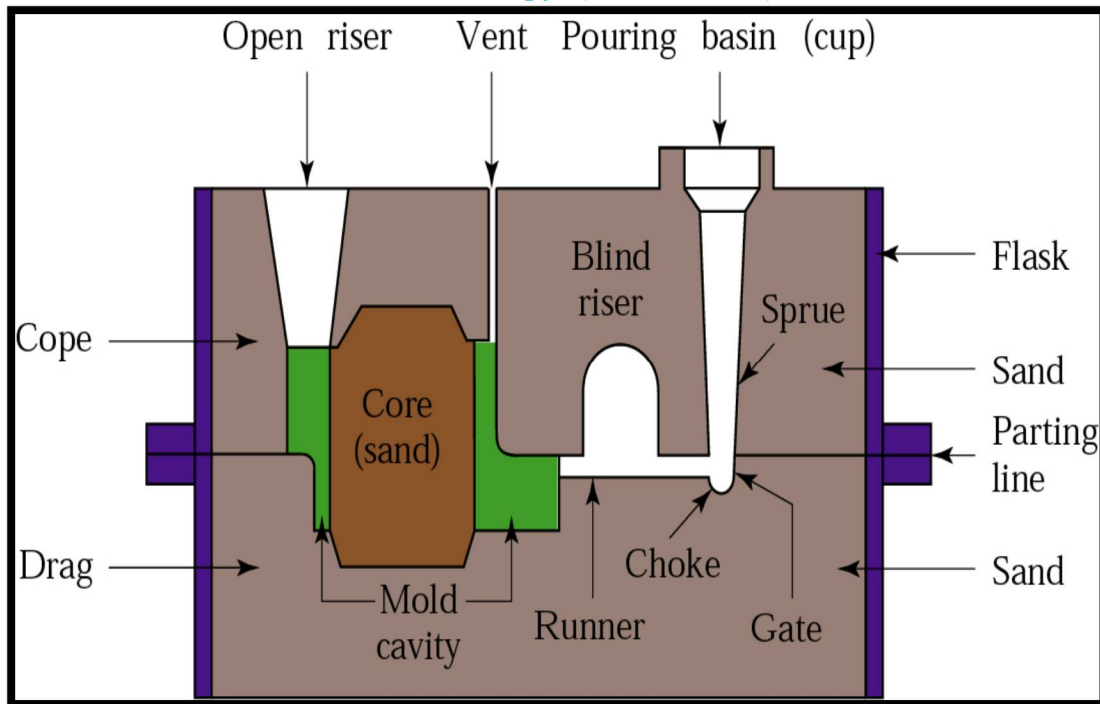


Figure: 1.1 Sand Casting

D. Classification of Casting Process

Classification of casting process according to the moulds as given belows:

- 1) *Conventional Sand Moulding Processes:* Dry sand moulding
Green sand moulding
Flask less moulding
- 2) *Chemical Shell Moulding Processes:* Shell moulding
Sodium silicate moulding
No-bake moulding
- 3) *Permanent Moulding Processes:* Gravity Die Casting
High And Low Die Casting
- 4) *Special Casting Processes:* Ceramic Shell Moulding
Centrifugal Casting
Lost Wax
Evaporative Pattern Casting
Vacuum Sealed Moulding

E. Green Sand Casting Procedure

Green sand casting procedure as given below:

First step making mould is placed in pattern on moulding the board

Then drag is placed on the board

Sand is sprinkle over the board and non sticky layer is provided on pattern

By fingers, moulding sand is provided over the pattern and the drag is completely filled

Then, ramming must be done properly

After the ramming, excess sand is removed by straight rod

Then , vent holes are made by vent rod to the full depth of flask for removed of gases during pouring and solidification process

The finishing drag flask is turn over the board and then pattern removed

Cope half of the pattern is placed in drag then cope is placed on the drag

The dry parting sand is sprinkled over pattern and drag

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A sprue pin is located at required distance from the pattern for making the passage, if riser pin required, it is located at required distance.

the filling, rammimg and venting of cope same as drag

First sprue and riser pin removed and pour basin is scooped at top for pouring the molten metal

Then pattern is removed from drag and cope, sand in form of paste is applied all over the cavity and pattern

Finally mould is assemble and ready for pouring

F. Advantages of Green Sand Casting

Flasks are ready for reuse in minimum time

Less distortion compare with dry sand casting because of no baking needed

Dimensions accuracy is good

Least expensive

G. Disadvantages of Green Sand Casting

More intricate casting cannot produced

The dimensions accuracy is decrease with increase the weight of casting

Some casting develops defects if moulds contain moisture

Sand control is difficult to compare with dry sand casting.

II. LITERATURE REVIEW

UdayA.Dabade et al^[1] combination of design of experiment and casting simulation technique to analysis the sand and methodology defects in green sand casting. In first session, using Taguchi based orthogonal array use to purposed of experiment and analysis of variance (ANOVA) indicates in selected parameter and percentage of rejection. In second session shrinkage porosity analysis by using simulation technique using new gating system designed. Result indicates new gating system and feeder reduction in porosity about 15% and yield improvement 5%.

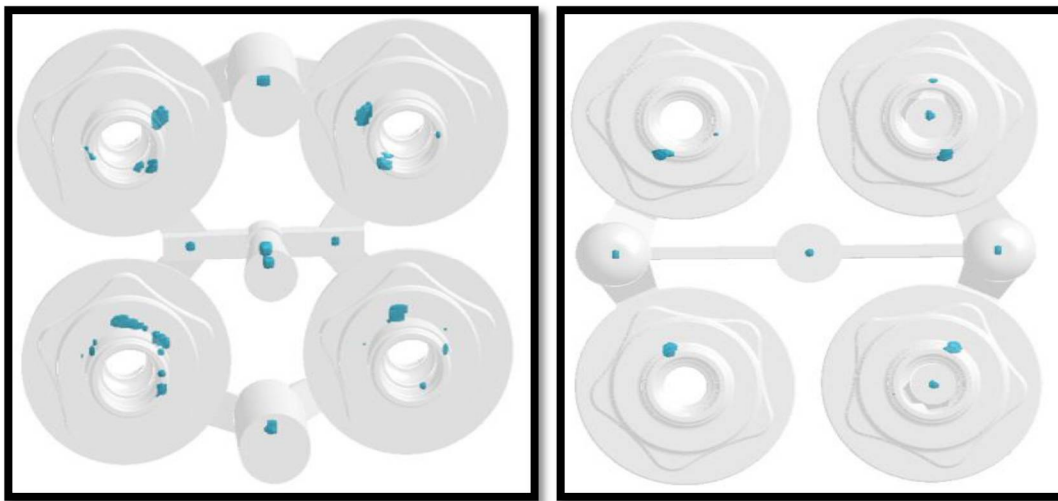


Figure: 2.1 a) Shrinkage porosity b) Shrinkage porosity with new gating design.

Lakshman singaram^[2] for improving the process performance, yield and productivity, the Taguchi method is most powerful technique. Green sand casting process involved many parameters which affected the quality of final casting. Using Taguchi method leads to improved process parameter performance by optimization of green sand casting, also reduction in process variability and casting defects. Also ANN (Artificial neural network) model indicates the relation between process performance and quality characteristic.

Manu khare et al^[3] analysis of significant parameter of green sand casting of fly wheel which is cast iron alloy [FG 260]. He take parameters are green strength, clay content and pouring time. Result indicates that green strength is significant parameter while clay

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content and pouring temperature are non-significant parameter.

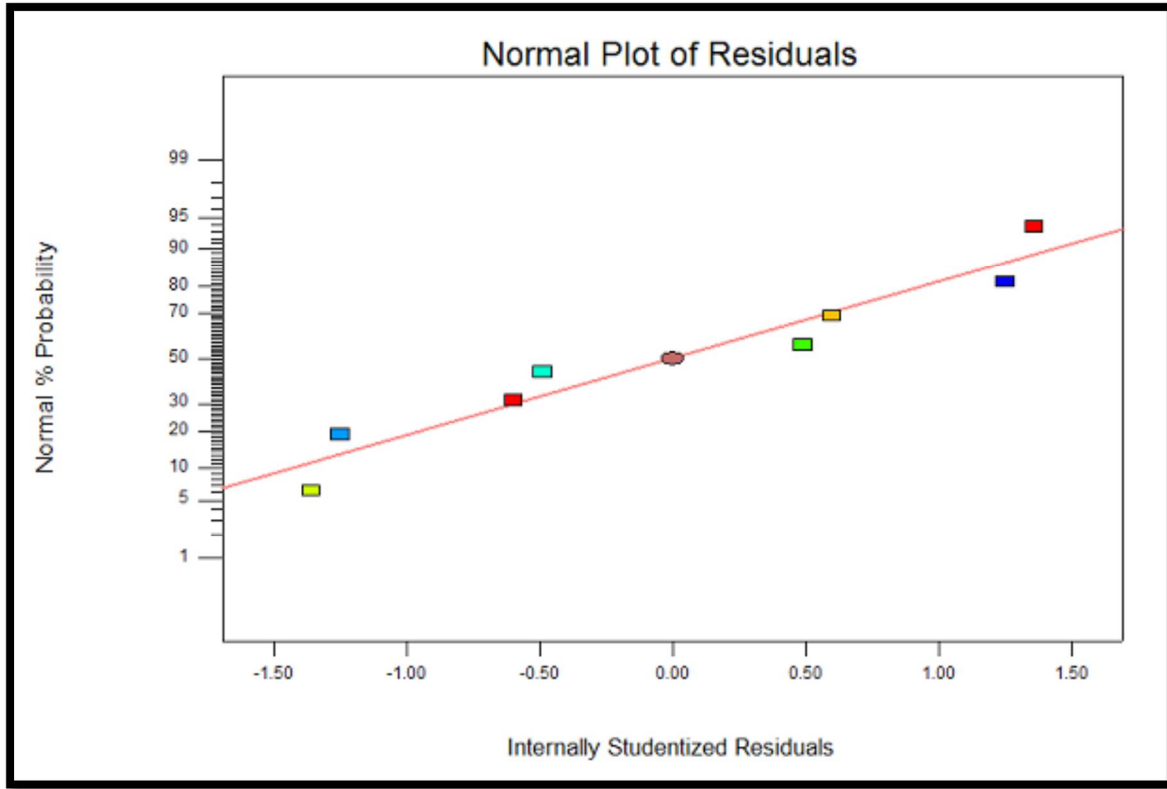


Figure: 2.2 Normal Probability plot of Residuals for Percentage.

Rasik a. Upadhya *et al*^[4] to optimized sand casting process parameter of the casting manufactured iron foundry by maximized the s/n ratio (signal to noise ratio). Also minimized the noise factors by Taguchi Method. Taken process parameters are moisture, sand particle size, green compression strength, mould hardness, permeability, pouring temperature, pouring time and pressure test. Result show the process parameters are affected on casting defects in iron foundry. Improvement in reduction in casting defects is to be 37.66 %.

Table 2.1 Optimum Condition and Performance.

	FACTORS	LEVEL DESCRIPTION	LEVEL	CONTRIBUTION
1	Moisture %	3.5	1	0.987
2	GCS g/cm ²	900	1	1.574
3	Permeability	185	2	0.508
4	Pouring Temperature	1420	3	0.856
	Total contribution from all factors current grand average of performance expected result at optimum condition improvement expected			3.924 -15.544 -11.619 37.66%

C.M. Choudhary *et al*^[5] found the major role of shrinkage porosity in the rejection of components in foundry. Take LM6 casting

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material and doing experiment work and seen the defect of shrinkage porosity and when solidification completed, the last region of solidify hot spot are there. So using methoding and simulation technique, feeding aids help to us to gating the hot spot completely shifted in feeder. Simulation technique help the in improvement in yield and quality of casting component.

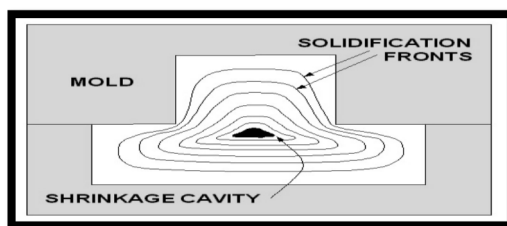


Figure: 2.3 Typical Solidification Process

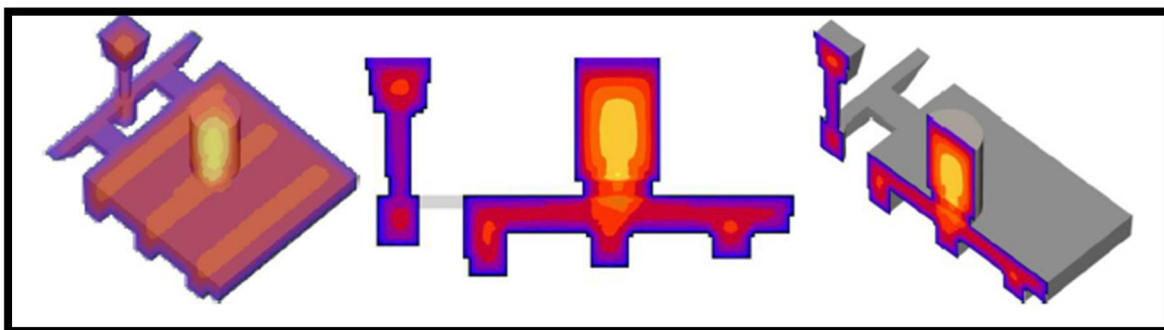


Figure: 2.4 Casting Solidification Simulations

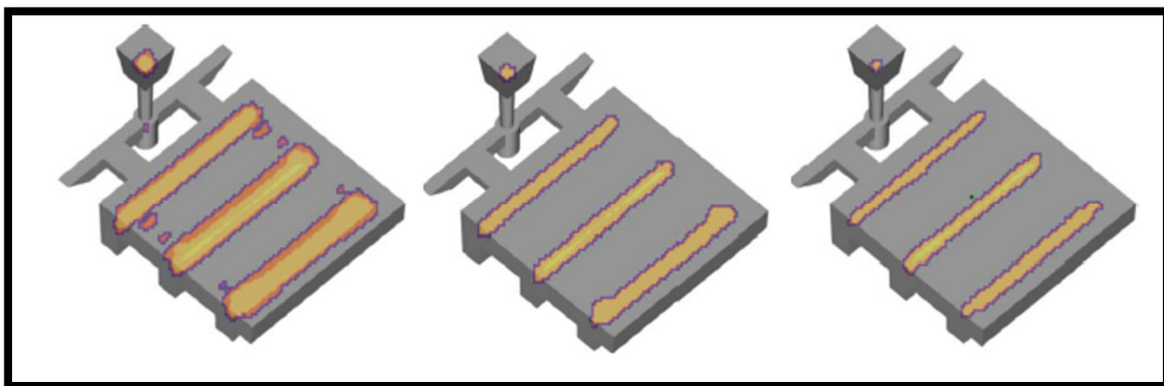


Figure: 2.5 Progressive Convergences of Hotspots Indicates Last Solidify Region.

III. PROBLEM DEFINITION AND REASERCH METHODOLOGY

A. Data Collection and Analysis

Primary data includes the rejection rates of casting for the past few years and its major problem and causes which are obtained from rejection report of foundry. Secondary data are obtained from journals, literatures and websites.

B. Historical Data of Foundry

To find the rejections in castings, data for occurrence of defects for one year was collected from one of leading Al alloy wheel casting industry. Using historical data analysis, check sheets have been prepared which helps to identify occurrence defects in HOUSING castings. Using check sheets data collection is simple and it also helps in spotting problem areas by frequency of location, cause and type of defects. The details are shown in Table 3.1

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TABLE: 3.1 DEFECTIVE FACTOR CHECK SHEET OF HOUSING PRODUCT

SR NO.	REJECTION DEFECT	REJECTED QUANTITY
1	Mis-run	12
2	Inclusion	17
3	Distortion	10
4	Shrinkage porosity	39
5	Other defects	9

Total quantity: 580 annually

Rejection parts: 87

Percentage (%) rejection: 15%

IV. EXPERIMENTAL WORK

Experiments were performed in a medium scale ferrous foundry producing ductile iron cast components. The proposed method of casting defects analysis involves two techniques, therefore according their requirements; different castings with different defects were identified by rejection analysis.

A. DoE Method for Casting Defects Analysis

Process parameters of green sand casting that influences the identified defects in casting pipe turbocharger with their levels are shown in table.

Table 4.1 Factors And Their Levels.

FACTORES DESIGNATION	FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
A	Moisture Content (%)	2	3.5	5
B	Sand Particle Size (AFS GFN)	46	48	50
C	Pouring Temperature (⁰ c)	1330	1360	1410

Out of four selected process parameters, one parameter is at two levels and other three are at three different levels. therefore using full factorial method for ptimization. Each experiment was performed thrice and average % of rejection in each experiment was considered as the response variable.

Table 4.2: Data obtained from measurement.

Sr no.		Factor 1	Factor 2	Factor 3	Response
Run	Block	A:Moisture content	B:Sand Particle Size	C:Pouring Temperature	Porosity
		%	AFS	C	%
1	Block 1	2	46	1330	6.91
2	Block 1	3.5	50	1360	5.02
3	Block 1	2	48	1360	6.4
4	Block 1	3.5	48	1410	5.09
5	Block 1	2	50	1360	6.26
6	Block 1	2	50	1410	6.22

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7	Block 1	2	48	1410	6.39
8	Block 1	3.5	46	1330	5.21
9	Block 1	5	46	1330	4.6
10	Block 1	5	50	1330	4.09
11	Block 1	5	48	1360	4.2
12	Block 1	5	50	1410	4.08
13	Block 1	5	46	1360	4.59
14	Block 1	3.5	48	1360	5.1
15	Block 1	2	46	1410	6.89
16	Block 1	2	48	1330	6.41
17	Block 1	5	46	1410	4.55
18	Block 1	5	48	1330	4.22
19	Block 1	2	50	1330	6.29
20	Block 1	5	48	1410	4.21
21	Block 1	2	46	1360	6.9
22	Block 1	3.5	46	1360	5.21
23	Block 1	3.5	48	1330	5.12
24	Block 1	5	50	1360	4.08
25	Block 1	3.5	46	1410	5.2
26	Block 1	3.5	50	1410	5.02
27	Block 1	3.5	50	1330	5.03

B. Analysis of Experimental Results

Analysis of experimental results was performed using Minitab 16 software and ANOVA and AOM plots obtained are given in Table and Figure 3 respectively. ANOVA in Table indicates that moisture content, grain particle size and pouring temperature parameters significantly influence the % rejection at 95% confidence level.

Source	DOF	Sum of square (SS)	Mean of square (MS)	F	P
A:Moisture content	2	22.8517	11.4258	1162.56	0.000
B:Sand Particle Size	2	0.9404	0.4702	47.84	0.000
C:Pouring Temperature	2	0.0029	0.0015	0.15	0.862
Error	20	0.1966	0.0098		
Total	26	23.9916			

ANOVA was used to identify the optimal process parameter levels so as to minimize casting defects.

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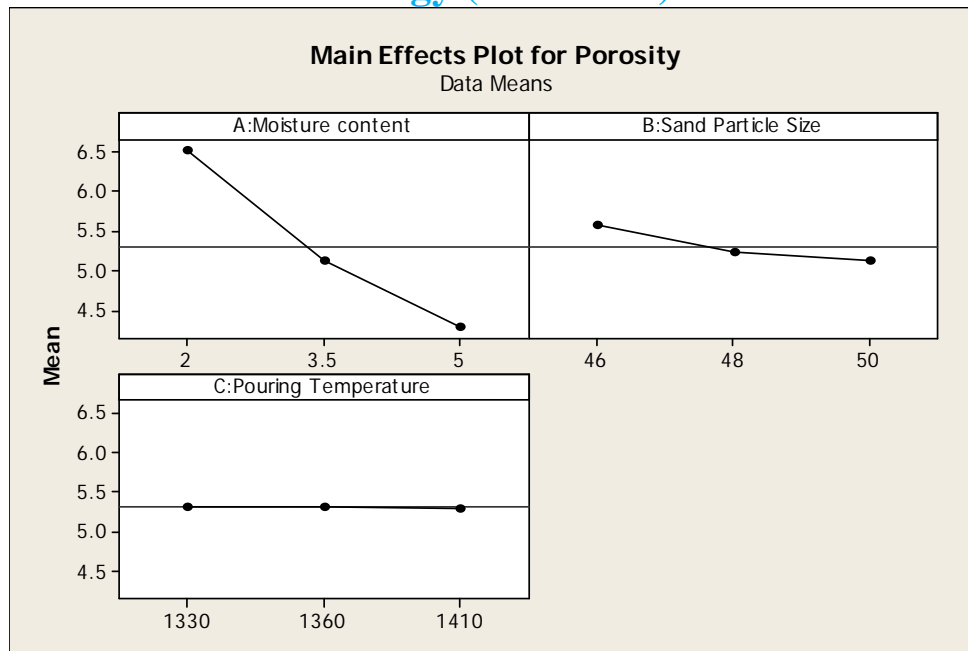


Figure 4.1: Main effects plot for porosity.

Figure 7.1 clearly suggests a dominant influence, in a quantitative sense, pouring temperature is Constance and, moisture content and sand particle size are more sensitive.

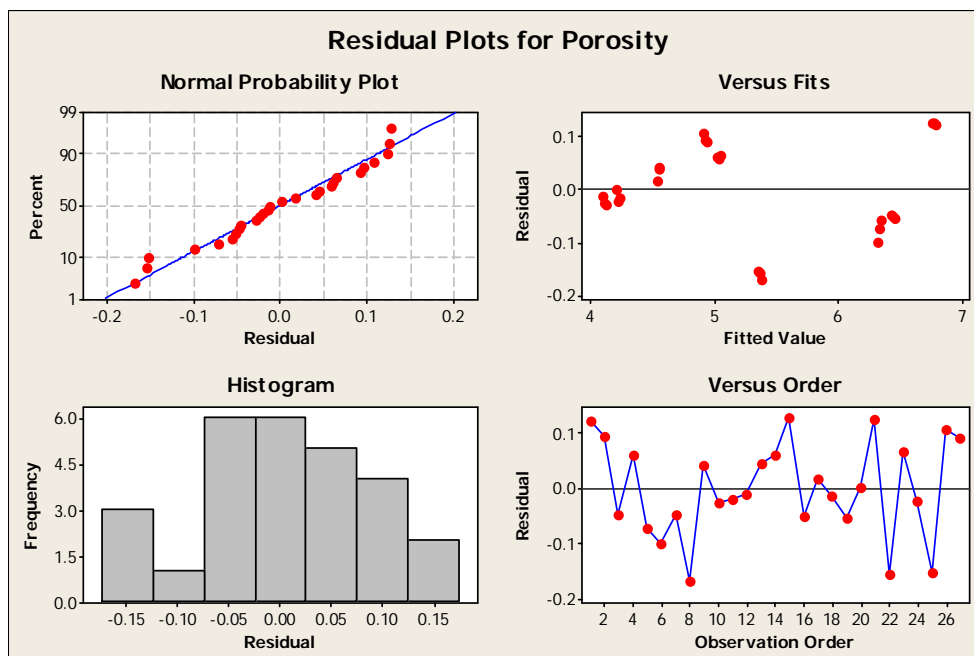
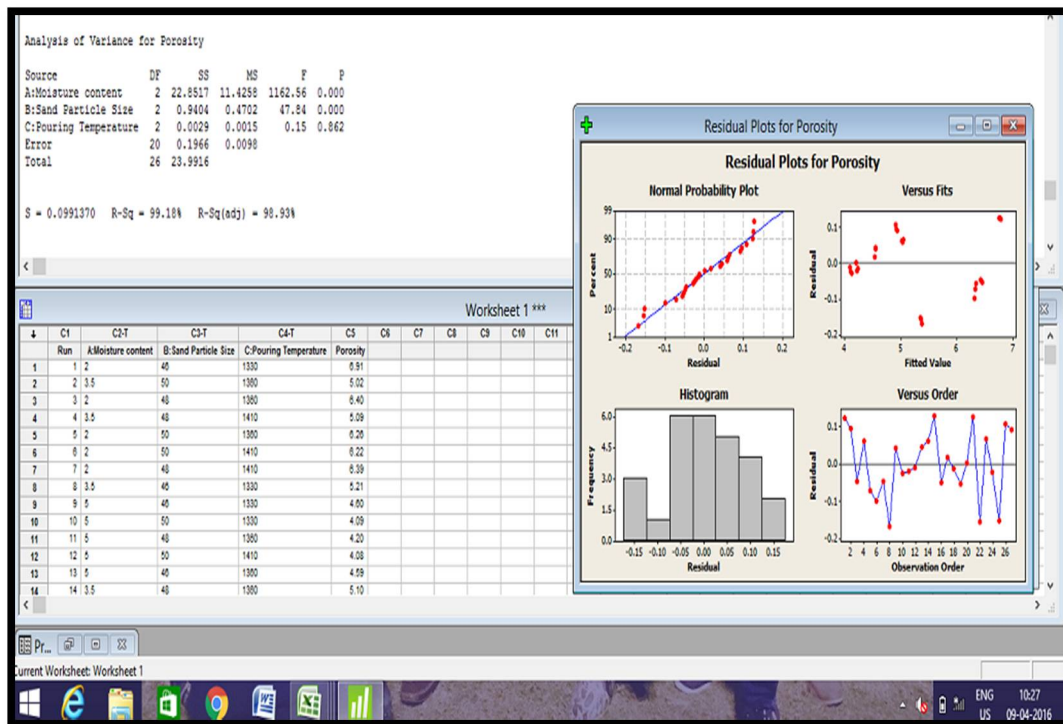


Figure 4.2 Residual plots for porosity

The result of ANOVA represented in response diagrams shown in Figure 4.1 suggest that the optimal combination of process parameters, which gives the optimum value of the Moisture content (A) A2, sand particle size (B) B2, pouring temperature (C) C2. The normal probability plot of the residuals is shown in Fig.4.2. The normal probability plot indicates whether the residuals follow a normal distribution or not, if the residuals follow a normal distribution mostly points will fall on a straight line except some moderate scatter even with normal data. Fig.4.2, revealed that the residuals generally fall on a straight line implying that the errors are distributed normally. Residuals versus the predicted response plot for surface roughness is shown in Fig.4.2.2. It tests the

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assumption of constant variance. The plot should be a random scatter. Fig4.2, revealed that they have no obvious pattern and unusual structure. This implies that there is no reason to suspect any violation of the independence or constant variance assumption.



4.2 Optimization results.

The result of ANOVA represented in response diagrams shown in Figure 7.1 suggest that the optimal combination of process parameters, which gives the optimum value of the Moisture content (A) A2, sand particle size (B) B2, pouring temperature(C) C2.

III. CONCLUSION

In this paper, a study has been carried out to investigate the effect of sand casting parameters on casting defects during casting of FG400. An attempt has also been made to optimize the casting parameters to obtain minimum defects using response surface methodology. The experimental study has led to the following conclusions.

The full factorial method of ANOVA technique is an effective tool for investigating the influence of various machining parameters on surface roughness.

The results clearly illustrate that defects decreased with increasing the grain particle size.

The casting defects is significantly minimized (5.1%) when the moisture content 3.5 %, grain particle size 48 AFS GNF and pouring temperature at 1360 degree centigrade

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