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# Optimization and Analysis of Aluminums A-356.0 Blank Parameters in Sand Casting Process Using Taguchi's L18 Orthogonal Array Method

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**KEYWORDS**
Optimization,
Sand casting process,
Taguchi method,
Aluminium blank,
Signal-to-noise ratio,
Analysis of variance,
Orthogonal array.

**ABSTRACT**:
In this Paper, Aluminium blank (A-356) parameters in sand (green) casting process is optimized by using Taguchi‟s L18 array approach. An attempt was made to obtain optimal settings for the sand casting processes. The casting process involves a number of parameters affecting various casting quality features of the product. In order to optimize the process seven control factors viz., pouring time, D/t ratio, sprue taper, riser surface area, type of sand mixture, quenching medium and normalizing time were selected. Each factor was considered at three levels. For this study three uncontrollable (or noise) factors viz. metal flow rate, pouring temperature and humidity were identified. To capture the effect of noise factors like surface indentation, surface roughness and geometry dimension were measured. An L18 orthogonal array was constructed for the seven factors undertaken, and performing eighteen sets of experiments with their replicates generated the data. The signal-to noise (S/N) ratios were calculated based on the design of experiments. The average values of S/N ratios for each factor at three levels were calculated and were plotted on the graph. Considering the maximum S/N ratios from the graph, the optimum levels of process factors for castings were obtained. A statistical analysis of variance (ANOVA) was performed to see which process parameters are statistically significant. A verification experiment was performed using the identified optimum conditions. The experimental results confirmed the validity of used Taguchi robust design method (L18 approach) for enhancing sand casting process and optimizing the sand casting parameters in aluminium blank casting process.

## 1. INTRODUCTION

**1.1 Casting:** Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is known as a casting. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

### 1.2 Sand Casting

Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mould material. It is relatively cheap and sufficiently refractory even for steel foundry use. A suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened with water to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The term "sand casting" can also refer to a casting produced via the sand casting process. Sand castings are produced in specialized factories called foundries. Over 70% of all metal castings are produced via a sand casting process.

#### 1.2.1 Basic Steps in Making Sand Casting:

The basic steps involved in making sand casting are as shown in fig.1:

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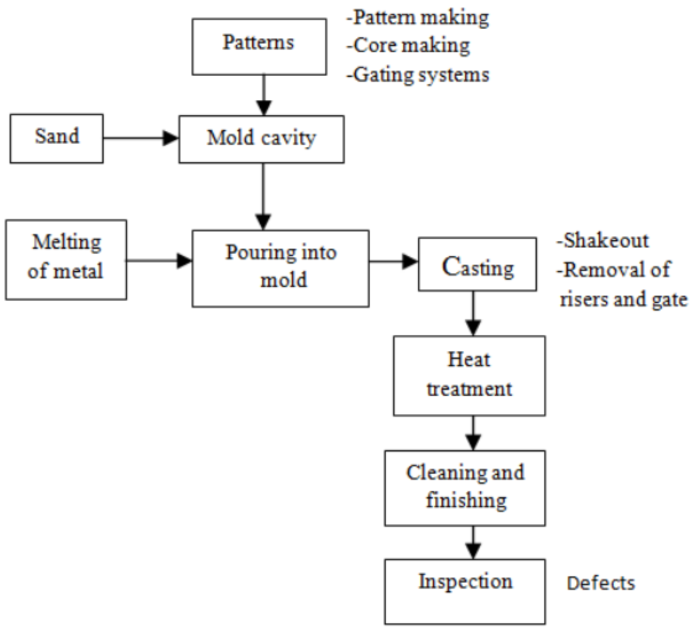


**Figure 1**

### 1.2.2 INSPECTION AND TESTING

1. Inspection and testing of castings encompasses five main categories: casting finishing, dimensional accuracy, mechanical properties, chemical composition and casting soundness.
2. Inspection follows, to check for defects in the casting as well as tonsure that the casting has the dimensions specified on the drawing and/or specifications.
3. Inspection for internal defects may be quiet involved, depending on the quality specified for the casting.
4. The inspected and accepted casting sometimes is used as is, but often it is subjected to further processing which may include heat treatment, painting, rust preventive oils, other surface treatment (e.g., hot-dip galvanizing), and machining.
5. Final operations may include electrodeposited plated metals for either cosmetic or operational requirements.

## 2. LITERATURE REVIEW

Sand casting is one of the most common production technique used for manufacturing ferrous castings. Der Ho Wu et al [2] applied the Taguchi method to optimize the process parameters for the die casting of thin-walled magnesium alloy parts in computer, communications and consumer electronics industries. The results confirmed the effectiveness of robust design methodology. Sushil Kumar et al [3] have carried out an optimization technique for process parameters of green sand casting of a cast iron differential housing cover based on Taguchi parameter design which indicated in determining the best casting parameters for differential housing cover. Muzammil et al [4] made a study for optimization of Gear Blank Casting Process by Using Taguchi‟s Robust Design Technique. In this study they demonstrated that casting process involve a large number of parameters affecting the various casting quality features of the product. The reduction in the weight of the casting as compared to the target weight was taken to be proportional to the casting defects.

A.Ballal Yuvraj P. et al [5] describes that in order to produce any product with desired quality proper selection of process parameters is essential. This paper describes use and steps of Taguchi design of experiments and orthogonal array to find specific range and combinations of turning parameters. Quality achieved by means of process optimization is found to be cost effective in gaining and maintaining a competitive position in the world market. A.Noorul Haq.et al [6] in their study demonstrates optimization of $CO_2$ casting process parameters by using Taguchi‟s design of experiments method. The effect of the selected process parameters on casting defects and subsequent setting of the parameters are accomplished by using Taguchi‟s parameter design approach. Product Quality of a casting is a measure of its dimensional accuracy, surface finish and soundness, Morgen, 1982,[7] Surface finish is the most desired characteristics to be on product surface. This is because surface finish is a predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. The measure of surface quality can be done in terms of surface roughness.S. Guharaja et al. (2004) [8] analyzed the various process parameters of the green sand casting process. They made an attempt to reach optimal settings of green sand casting process in order to acquire the optimum quality characteristics of the spheroidal graphite (SG) cast iron rigid coupling castings. Ultimately they considered the four most prominent parameters and they were green strength, mould hardness, moisture content and permeability. The effect of the selected process parameters and its effect on different level on casting defects were optimized using Taguchi‟s optimization approach.

Wisam M. Abu Jadayil (2011)[9] researched in studying the effects of varying the pouring rate on the casting defects using nondestructive testing techniques Then Al casting samples have been prepared with different pouring rate for each. Then they have been tested using the penetrant test (PT) and the ultrasonic test (UT) to describe the surface and subsurface defects respectively. It was found that when the pouring rate increases surface defects are significantly increases as the penetrant testing results showed.The Taguchi approach enables a comprehensive understanding of the individual and combined from a minimum number of simulation trials. This technique is multi – step process which follow a certain sequence for the experiments to yield an improved understanding of product or process performance [10].

Rasik Upadhye[11] discussed to optimize the sand casting process parameters of the castings manufactured in iron foundry by maximizing the signal to noise ratios and minimizing the noise factors using Taguchi method. The process parameters considered are moisture, sand particle size, green compression strength, mould hardness, permeability, pouring temperature, pouring time and pressure test. The results indicated that the selected process parameters significantly affect the casting defects in the foundry. The improvement expected in reduction of casting defects is found to be 37.66 percent.

The optimum conditions for the factors computed are:

- Moisture (%) – Level 1 – Minimum -3.5
- Green compression strength (g/cm2) – Level 1 – Minimum -900
- Permeability – Level 2 – Minimum -185
- Pouring temperature (deg. Celsius) - Level 3 – Maximum -1420

The improvement expected in minimizing the variation is 37.66 percent which means reduction of casting defects from present 6.16 percent to 3.84 percent of the total castings produced in the foundry.

## 3. METHODOLOGY

### 3.1 Identification of Process Parameters:

Process parameters identified for the experimental investigation are Pouring time(A), Sprue Angle(B), Riser surface area of contact (C), D/T Ratio(D), Type of sand mixture(E), Quenching media(F), and Normalizing time(G) with three levels of experiment are been considered.

### 3.2 Design of Experiments:

The present experiments were designed to apply the Taguchi‟s methods to establish the effects of seven casting parameters on the mechanical and dimensional properties of aluminum a-0356 during casting. The common principle of the Taguchi method is to develop an understanding of the individual and combined effects of a variety of design parameters from a minimum number of experiments.

### 3.3 Selection of Orthogonal Array:

By applying Taguchi method of approach seven three-level process parameters i.e., Pouring time(A), Sprue Angle B), Riser surface area of contact (C), D/T Ratio(D), Type of sand mixture(E), Quenching media(F), and Normalizing time(G) are being considered and their values of the cast process parameters at different levels will be considered.

## 4. PROBLEM DEFINITION

There are various physical and mechanical characteristics, which affects the geometry of the castings. The physical characters effecting geometry of the designs are life of the fluid being used, shrinkage of the component while undergoing shrinkage process,

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slag formation affinity and pouring temperatures. All of these characteristics vary amongst different properties of different alloys. Apart from physical characteristics, few mechanical characteristics too affect the geometry of the design castings. They are modulus of elasticity and section modulus. Modulus of elasticity is mainly the measurement of stiffness of the material and hence contributes to elastic properties of the material. However, section modulus is the function of shape of the material designed for casting.

**Selected Parameters:**

The Process parameters identified for the experimental investigation are Pouring time(A), Sprue Angle(B), Riser Surface area of contact(C), D/T Ratio(D), Type of sand mixture(E), Quenching media(F), and Normalizing time(G) with For each process parameter three levels are selected which define the experimental region (Table.1).

**Table.1: Process parameters with their Levels**

| FACTOR | LEVEL 1 | LEVEL 2 | LEVEL 3 |
|---|---|---|---|
| A. Pouring time (sec) | 8 | 11 | 14 |
| B. Sprue tapper(deg) | 1.4 | 1.6 | 1.8 |
| C. Riser surface area of contact($mm^2$) | 1150 | 4538 | 3527 |
| D. D/T Ratio | 3:2 | 4:3 | 6:5 |
| E. Type of sand mixture | 1 | 2 | 3 |
| F. Quenching media,(Viscosity index, min) | 42.711 | 110 | 135 |
| G. Normalizing time(min) | 35 | 40 | 45 |

## 5. RESULTS

### 5.1 Selection of Orthogonal Array:

By applying Taguchi method of approach seven three-level process parameters i.e., Pouring time(A), Sprue Angle B), Riser surface area of contact (C), D/T Ratio(D), Type of sand mixture(E), Quenching media(F), and Normalizing time(G) are being considered and their values of the cast process parameters at different levels are shown in Table 2.

As we are having the seven parameters with three different levels, using the standard array selector L18 orthogonal array is selected with 18 experimental runs and eight columns. The assigned L18 orthogonal array is shown in Table 2 and the experimental orthogonal array having their levels are assigned to columns are shown in Table 3.

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**Table.2: Orthogonal array L18 (control factors assigned)**

| Experiment Number | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | 1 | 3 | 3 | 3 | 3 | 3 | 3 |
| 4 | 2 | 1 | 1 | 2 | 2 | 3 | 3 |
| 5 | 2 | 2 | 2 | 3 | 3 | 1 | 1 |
| 6 | 2 | 3 | 3 | 1 | 1 | 2 | 2 |
| 7 | 3 | 1 | 2 | 1 | 3 | 2 | 3 |
| 8 | 3 | 2 | 3 | 2 | 1 | 3 | 1 |
| 9 | 3 | 3 | 1 | 3 | 2 | 1 | 2 |
| 10 | 1 | 1 | 3 | 3 | 2 | 2 | 1 |
| 11 | 1 | 2 | 1 | 2 | 3 | 3 | 2 |
| 12 | 1 | 3 | 2 | 1 | 1 | 1 | 3 |
| 13 | 2 | 1 | 2 | 3 | 1 | 3 | 2 |
| 14 | 2 | 2 | 3 | 1 | 2 | 1 | 3 |
| 15 | 2 | 3 | 1 | 2 | 3 | 2 | 1 |
| 16 | 3 | 1 | 3 | 2 | 3 | 1 | 2 |
| 17 | 3 | 2 | 1 | 3 | 1 | 2 | 3 |
| 18 | 3 | 3 | 2 | 1 | 2 | 3 | 1 |

**Table.3: Experimental orthogonal array**

| Experiment Number | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | 8 | 1.4 | 1150 | 3:2 | 1 | 42.711 | 35 |
| 2 | 8 | 1.6 | 4538 | 4:3 | 2 | 110 | 40 |
| 3 | 8 | 1.8 | 3527 | 6:5 | 3 | 135 | 45 |
| 4 | 11 | 1.4 | 1150 | 4:3 | 2 | 135 | 45 |
| 5 | 11 | 1.6 | 4538 | 6:5 | 3 | 42.711 | 35 |
| 6 | 11 | 1.8 | 3527 | 3:2 | 1 | 110 | 40 |
| 7 | 14 | 1.4 | 4538 | 3:2 | 3 | 110 | 45 |
| 8 | 14 | 1.6 | 3527 | 4:3 | 1 | 135 | 35 |
| 9 | 14 | 1.8 | 1150 | 6:5 | 2 | 42.711 | 40 |
| 10 | 8 | 1.4 | 3527 | 6:5 | 2 | 110 | 35 |
| 11 | 8 | 1.6 | 1150 | 4:3 | 3 | 135 | 40 |
| 12 | 8 | 1.8 | 4538 | 3:2 | 1 | 42.711 | 45 |
| 13 | 11 | 1.4 | 4538 | 6:5 | 1 | 135 | 40 |
| 14 | 11 | 1.6 | 3527 | 3:2 | 2 | 42.711 | 45 |
| 15 | 11 | 1.8 | 1150 | 4:3 | 3 | 110 | 35 |
| 16 | 14 | 1.4 | 3527 | 4:3 | 3 | 42.711 | 40 |
| 17 | 14 | 1.6 | 1150 | 6:5 | 1 | 110 | 45 |
| 18 | 14 | 1.8 | 4538 | 3:2 | 2 | 135 | 35 |

Eighteen sets of experiments are conducted as per the experimental layout by heating a metal in a cupola furnace until the metal reaches to its liquids state. Then with a proper ladle arrangement it was poured in to the eighteen moulds which were prepared in different combinations as per the selected parameters (i.e,. D/T-ratio, Sprue surface area of contact, Riser shape).

**5.4 EXPERIMENT RESULTS**

**5.4.1 S/N Ratio for Height of the Component:**

The experiments were conducted thrice for the same set of parameters using a single-repetition randomization

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technique. The height of the component that occur in each trial conditions were found and recorded. The average of the height was determined for each trial and height of the component is "lower the better" type of quality characteristics. Lower the better S/N ratios were computed for each of the 18 trials and the values are given in Table.4.

**Table.4: Representing S/N Ratio"s for Height of the component**

| Experiment Number | Height Trail Values | | | S/N Ratio |
|---|---|---|---|---|
| | Trail-1 | Trail-1 | Trail-3 | Height |
| 1 | 43.70 | 44.40 | 43.64 | -32.85 |
| 2 | 46.64 | 46.08 | 45.68 | -33.28 |
| 3 | 50.88 | 51.18 | 50.66 | -34.14 |
| 4 | 50.82 | 51.16 | 49.76 | -34.08 |
| 5 | 50.20 | 50.90 | 51.92 | -34.15 |
| 6 | 50.48 | 50.32 | 49.12 | -33.98 |
| 7 | 40.70 | 40.88 | 39.88 | -32.15 |
| 8 | 52.14 | 51.64 | 52.48 | -34.33 |
| 9 | 49.52 | 50.16 | 50.40 | -33.98 |
| 10 | 52.60 | 50.82 | 51.70 | -34.27 |
| 11 | 49.22 | 49.32 | 49.50 | -33.87 |
| 12 | 41.22 | 40.12 | 40.44 | -32.17 |
| 13 | 51.48 | 50.38 | 48.02 | -33.98 |
| 14 | 43.04 | 43.60 | 43.24 | -32.73 |
| 15 | 49.42 | 50.72 | 51.12 | -34.05 |
| 16 | 44.14 | 46.62 | 43.32 | -33.01 |
| 17 | 54.50 | 55.12 | 55.86 | -34.83 |
| 18 | 40.24 | 38.28 | 41.18 | -32.02 |

**5.4.2 Main effects of Factors and Analysis of Variance of Height:**

After the experiments are conducted, the ANOVA is used to analyze the results of the experiments. The significant factors and/or their interactions are identified, for various trial conditions and the parameters which significantly influence the height of the component. However, some more information is required to conclude with an optimum setting of parameters [16]. In applying ANOVA technique, certain assumptions must be checked through analysis of residuals before interpreting and concluding the results. It is highly recommended to examine these residuals for normality, independence, and constant variance, when using ANOVA [17]. In this paper, F ratio test is employed to check constancy of residual variance. If the F ratio test statistic is equal to or less than its corresponding critical value, the residuals have constant variance. The F-ratio value can be found using the ratio of mean square of a factor to variance of error. It can seen from the F-ratio value result that the significant factors are the control factors in the order of D (D/T ratio), C (Riser), F (Quenching media) and B (Sprue), A (Pouring time), E (Type of sand mixture), G(Normalizing time). The other control factors are pooled due to less significance and percent contribution. The expected amount of sum of squares (SS) for each factor is computed by using variance. The percent contribution (P) for each factor is calculated by using expected amount of sum of squares (SS) in Table 2. The ANOVA table after pooling until the DOF of the error term is approximately half the total DOF of the experiment is shown in Table 6.

**Table.5: Representing the Main effects of Height of the component**

| PARAMETER'S | L1 | LEVEL'S L2 | L3 | DIFFERENCE | RANK |
|---|---|---|---|---|---|
| **Pouring Time** | -33.43 | -33.83 | -33.39 | 0.44 | 3 |
| **Sprue** | -33.39 | -33.87 | -33.39 | 0.48 | 4 |
| **Riser** | -33.94 | -32.96 | -33.74 | 0.99 | 6 |
| **D/T** | -32.65 | -33.77 | -34.23 | 1.58 | 7 |
| **Types of Sand** | -33.69 | -33.39 | -33.56 | 0.30 | 1 |
| **Quenchingmedia** | -33.15 | -33.76 | -33.74 | 0.61 | 5 |
| **Normalizing Time** | -33.61 | -33.68 | -33.35 | 0.33 | 2 |

**Table.6: Representing the ANOVA analysis of Height of the component**

| Parameter | SSW | SST | VARIANCE | F – RATIO | PURE-SUM VALUE | % - Contribution |
|---|---|---|---|---|---|---|
| Pouring time | 2960542.089 | 3101773.72 | 141231.6 | 0.357785 | 0.357785 | 4.553254 |
| Sprue | 2864764.051 | 3101773.72 | 237009.7 | 0.620495 | 0.550923 | 7.641101 |
| Riser | 2331003.114 | 3101773.72 | 770770.6 | 2.479954 | 0.117353 | 24.84935 |
| D/T ratio | 1160462.949 | 3101773.72 | 1941311 | 12.54657 | 0.000628 | 62.58712 |
| Type of Sand | 3018979.139 | 3101773.72 | 82794.58 | 0.205685 | 0.816347 | 2.669266 |
| Quenching media | 2698173.772 | 3101773.72 | 403599.9 | 1.12187 | 0.351519 | 13.01191 |
| Normalizing time | 3046865.561 | 3101773.72 | 54908.22 | 0.135159 | 0.874629 | 1.77022 |

### 5.4.3. S/N Ration for the Roughness of the Component

**Table.7: Representing the S/N ratio"s for Roughness values**

| Experiment Number | Roughness Trail Values | | | S/N Ratio |
|---|---|---|---|---|
| | Trail-1 | Trail-2 | Trail-3 | Roughness |
| 1 | 70.57 | 39.55 | 33.46 | -34.07 |
| 2 | 49.14 | 26.28 | 25.63 | -30.98 |
| 3 | 61.74 | 48.30 | 62.35 | -35.24 |
| 4 | 61.76 | 79.91 | 21.79 | -35.51 |
| 5 | 59.04 | 60.61 | 32.21 | -34.37 |
| 6 | 19.12 | 44.39 | 43.77 | -31.51 |
| 7 | 69.57 | 53.73 | 54.27 | -35.51 |
| 8 | 61.49 | 72.97 | 35.36 | -35.38 |
| 9 | 57.65 | 61.43 | 68.25 | -35.93 |
| 10 | 43.26 | 41.36 | 24.49 | -31.44 |
| 11 | 73.52 | 48.37 | 38.40 | -34.88 |
| 12 | 38.39 | 34.79 | 50.53 | -32.42 |
| 13 | 47.90 | 20.87 | 59.07 | -33.17 |
| 14 | 54.32 | 40.26 | 44.75 | -33.41 |
| 15 | 20.32 | 26.11 | 26.64 | -27.79 |
| 16 | 83.62 | 73.71 | 72.08 | -37.69 |
| 17 | 89.32 | 102.00 | 98.44 | -39.71 |
| 18 | 57.93 | 57.52 | 59.16 | -35.30 |

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The experiments were conducted thrice for the same set of parameters using a single-repetition randomization technique[15]. The roughness of the component that occur in each trial conditions were found and recorded. The average of the roughness was determined by RMS Methos for each trial and Roughness of the component is “lower the better” type of quality characteristics. Lower the better S/N ratios were computed for each of the 18 trials and the values are given in Table 7.

**5.4.4 Main effects of Factors and Analysis of Variance of Roughness:**

The average effect of factors is shown in Table 8. After the experiments are conducted, the ANOVA is used to analyze the results of the experiments. The significant factors and/or their interactions are identified, for various trial conditions and the parameters which significantly influence the Roughness of the component. However, some more information is required to conclude with an optimum setting of parameters [16]. It can seen from the F-ratio value result that the significant factors are the control factors in the order of A (Pouring time), G (Normalizing time), D (D/T ratio), B (Sprue), C (Riser), F (Quenching media) and E (Type of sand mixture). The other control factors are pooled due to less significance and percent contribution. The expected amount of sum of squares (SS) for each factor is computed by using variance. The percent contribution (P) for each factor is calculated by using expected amount of sum of squares (SS) in Table 9. The ANOVA table after pooling until the DOF of the error term is approximately half the total DOF of the experiment is shown in Table 9.

**Table.8: Representing the main effects of Roughness of the component**

| PARAMETER'S | LEVEL'S L1 | L2 | L3 | DIFFERENCE | RANK |
|---|---|---|---|---|---|
| **Pouring Time** | -33.17 | -32.63 | -36.59 | 3.96 | 7 |
| **Sprue** | -34.57 | -34.79 | -33.03 | 1.75 | 4 |
| **Riser** | -34.65 | -33.62 | -34.11 | 1.03 | 2 |
| **D/T** | -33.70 | -33.71 | -34.98 | 1.27 | 3 |
| **Types of Sand** | -34.38 | -33.76 | -34.25 | 0.62 | 1 |
| **Quenchingmedia** | -34.65 | -32.83 | -34.91 | 2.09 | 5 |
| **Normalizing Time** | -33.06 | -34.03 | -35.30 | 2.24 | 6 |

**Table.9: Representing the ANOVA analysis of Roughness of the component**

| Parameter | SSW | SST | SSB | F – RATIO | PURE-SUM VALUE | %-Contribution |
|---|---|---|---|---|---|---|
| **Pouring time** | 2273.93953 | 4706.75 | 2432.81 | 8.02401 | 0.0042 | 51.6877 |
| **Sprue** | 4419.1231 | 4706.75 | 287.6341 | 0.488164 | 0.623171 | 6.111088 |
| **Riser** | 4465.905 | 4706.75 | 240.8514 | 0.404484 | 0.674385 | 5.117141 |
| **D/T ratio** | 4394.780233 | 4706.75 | 311.9769 | 0.53241 | 0.597882 | 6.628278 |
| **Type Sand** | 4610.132167 | 4706.75 | 96.62501 | 0.157195 | 0.855927 | 2.0529 |
| **Quenching media** | 4546.009967 | 4706.75 | 160.7472 | 0.2652 | 0.770574 | 3.415243 |
| **Normalizing time** | 4142.884433 | 4706.75 | 563.8727 | 1.020797 | 0.384023 | 11.98007 |

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### 5.4.5 Analysis of Variance of BHN:

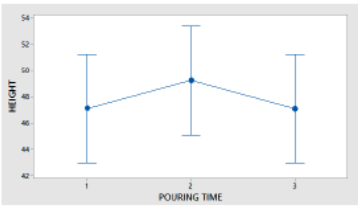
After the experiments are conducted, the ANOVA is used to analyze the results of the experiments. The significant factors and/or their interactions are identified, for single trial conditions and the parameters which significantly influence the BHN of the component. However, some more information is required to conclude with an optimum setting of parameters [16]. It can seen from the F-ratio value result that the significant factors are the control factors in the order of A (Pouring time), G (Normalizing time), E (Type of sand mixture), B (Sprue), C (Riser), D (D/T ratio),and F (Quenching media). The other control factors are pooled due to less significance and percent contribution. The expected amount of sum of squares (SS) for each factor is computed by using variance. The percent contribution (P) for each factor is calculated by using expected amount of sum of squares (SS) in Table 10.

**Table.10: Representing the ANOVA analysis on BHN**

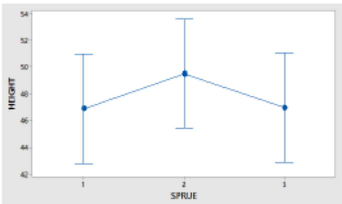
| Parameter | SSW | SST | SSB | F – RATIO | PURE-SUM VALUE | %-Contribution |
|---|---|---|---|---|---|---|
| Pouring time | 76725.5905 | 91063.0697 | 14337.39379 | 1.4014 | 0.2766 | 15.75 |
| Sprue | 85025.36 | 91063.0697 | 6037.764 | 0.5325 | 0.5977 | 6.63 |
| Riser | 86021.19 | 91063.0697 | 5041.881 | 0.4395 | 0.6523 | 5.53 |
| D/T ratio | 86799.84 | 91063.0697 | 4263.23 | 0.3683 | 0.6979 | 4.68 |
| Type Sand | 81649.46 | 91063.0697 | 9413.609 | 0.8646 | 0.4414 | 10.33 |
| Quenching media | 89094.14 | 91063.0697 | 1968.931 | 0.1657 | 0.8487 | 2.16 |
| Normalizing time | 72733.11 | 91063.0697 | 18329.96 | 1.8901 | 0.1853 | 20.12 |

**GRAPHS:**

1. **HEIGHT OF THE COMPONENT**

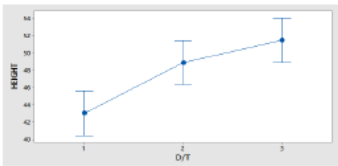



Graph.1 Height vs Pouring time

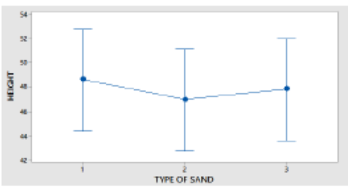



Graph.2 Height vs Sprue Tapper

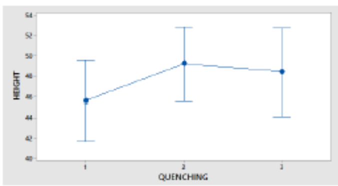

Graph.3 Height vs Riser




Graph.4 Height vs D/T ratio




Graph.5 Height vs Type of Sand




Graph.6 Height vs Quenching media

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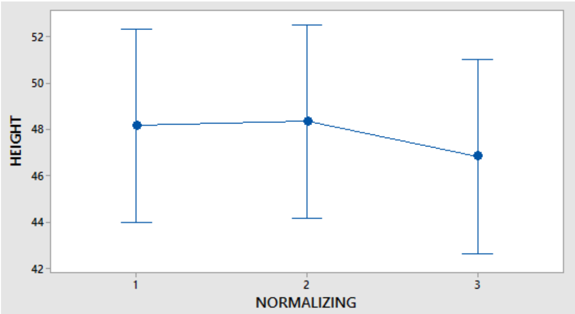


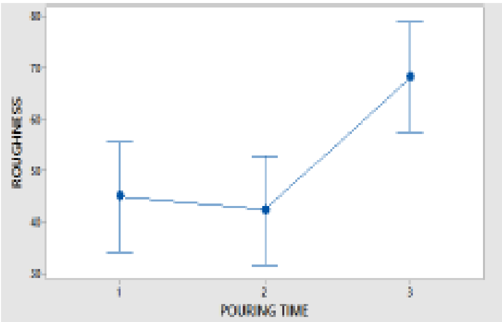

**Graph.7 Height vs Normalizing time**

From the above seven graphs it clearly states that what levels of the corresponding parameters gives the best output parameter as a dimensional accuracy.

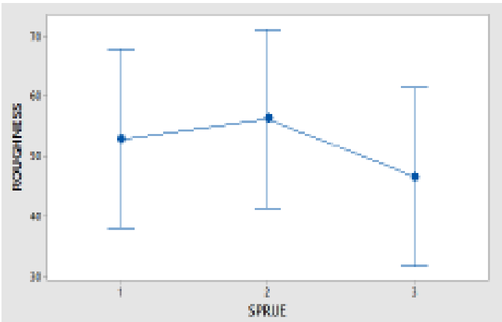
**Table.11: Representing the combination of best levels to obtain Dimensional Acuracy**

| PARAMETER | LEVEL | VALUE |
|---|---|---|
| Pouring Time | 1 | 8(seconds) |
| Sprue angle | 1 | 1.4(deg) |
| Riser Surface area | 2 | 4538 $mm^2$ |
| D/T ratio | 1 | 3:2 |
| Types of Sand | 2 | 2(Sand mixed with cast iron) |
| Quenching media | 1 | 42.711(min) |
| Normalizing Time | 3 | 45 min |

## 2. ROUGHNESS:




Graph.8 Roughness vs pouring time




Graph9. Roughness vs sprue

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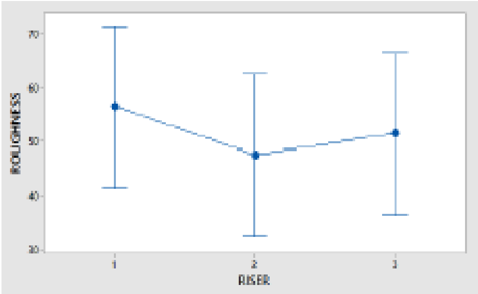
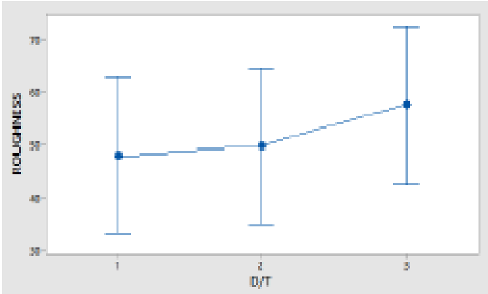
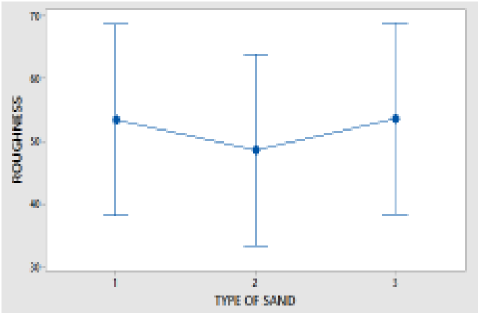


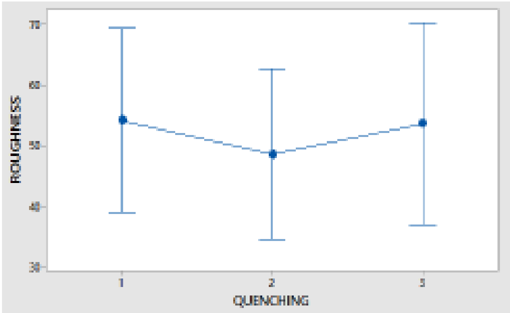

Graph.10 Roughness vs Riser



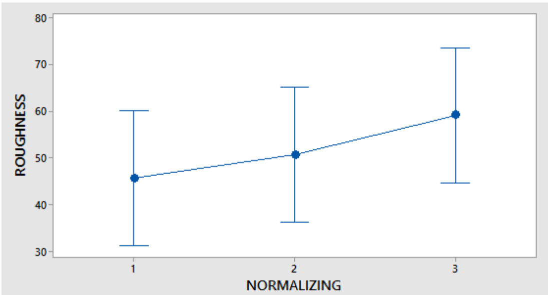

Graph.11 Roughness vs D/T ratio




Graph.12 Roughness vs Type of sand




Graph.13 Roughness vs Quenching media




**Graph.14 Roughness vs Normalizing time**

From the above seven graphs it clearly states that what levels of the corresponding parameters gives the best Roughness for the component.

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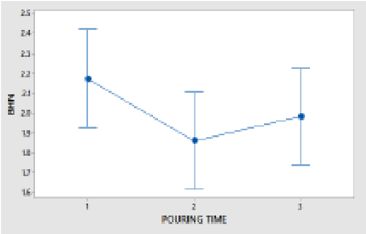
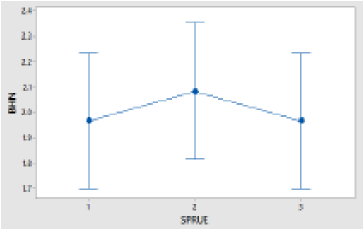
**Table.12: Representing the combination of best levels to obtain Roughness**

| PARAMETER | LEVEL | VALUE |
|---|---|---|
| Pouring Time | 2 | 11(seconds) |
| Sprue angle | 3 | 1.8(deg) |
| Riser Surface area | 2 | 4538 $mm^2$ |
| D/T ratio | 1 | 3:2 |
| Types of Sand | 2 | 2(Sand mixed with cast iron) |
| Quenching media | 2 | 110(min) |
| Normalizing Time | 1 | 35 min |

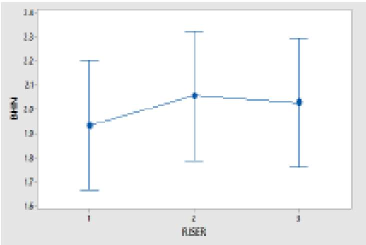
**3. BHN:**



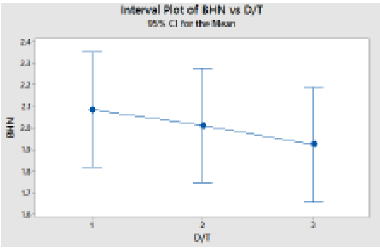

Graph.15 BHN vs pouring time



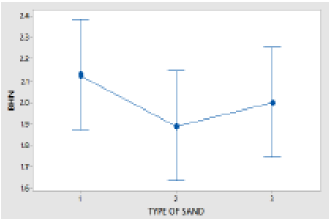

Graph.16 BHN vs Sprue



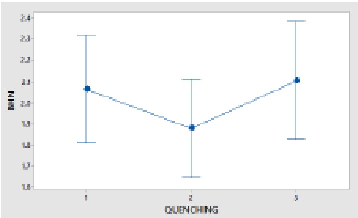

Graph.17 BHN vs Riser



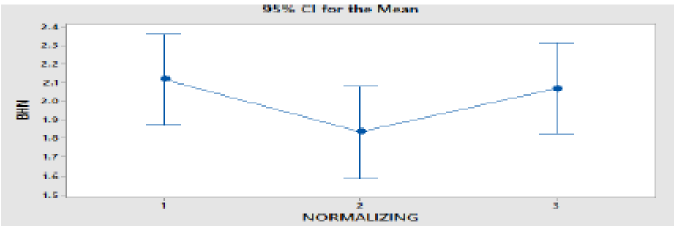

Graph.18 BHN vs D/t ratio




Graph.19 BHN vs Type of sand




Graph.20 BHN vs Quenching media




Graph.21 BHN vs Normalizing time

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From the above seven graphs it clearly states that what levels of the corresponding parameters gives the best hardened component.

**Table.13: Representing the combination of best levels to obtain Hardnesss**

| PARAMETER | LEVEL | VALUE |
| --- | --- | --- |
| Pouring Time | 1 | 8(seconds) |
| Sprue angle | 2 | 1.6(deg) |
| Riser Surface area | 2 | 4538 $mm^2$ |
| D/T ratio | 1 | 3:2 |
| Types of Sand | 1 | 2(Green Sand) |
| Quenching media | 3 | 135(min) |
| Normalizing Time | 1 | 35 min |

**CONCLUSION:**

From the results of verification experiment conducted at the optimum settings chosen the following conclusions are drawn:

- **Agreement to predictions:** The closeness of the results of predictions based on calculated S/N ratios and experimental values show that the Taguchi"s experimental robust design technique can be used successfully for both optimization and prediction in Aluminium blank sand casting process.
- **Sprue Angle** : Based on the S/N ratios and the ANOVA analysis Sprue angle is not highly influencing the cast products but for obtaining the different better output parameters different sprue angles(3 levels) are used.
- **Riser Surface area contact:** Based on the graphical analysis there is no influence of Riser surface area contact for obtaining the different output parameters but the cylindrical riser is highly influencing on Height based on the ANOVA analysis.
- **D/t ratio:** Based on the ANOVA analysis to obtain the Dimensional accuracy the D/T ratio is the main process parameter which was highly influencing and Based on the graphical analysis the 3:2 is the better dimension for obtaining any output parameter.
- **Pouring time:** It is the main and highly contributed parameter to obtain the best surface roughness
- based on the anova analysis.
- **Type of sand mixture:** To obtain the better dimensional accuracy the green sand without any mixture gives the better dimension when compared with the mixture of cast-iron chips and stainless steel chips.
- **Quenching medium:** Based on the ANOVA, S/N, Graphical type of quenching media is not influencing on any of the output parameter"s.
- **Normalizing time:** Based on the ANOVA and S/N ratio this is the main parameter which influences in obtaining the hardness of the component and dimensional accuracy.

As a result, the fundamental principle of the Taguchi method is to improve the quality of a product by minimizing the effect of the causes of variation without eliminating them. In this methodology, the design desired is finalized by selecting the best performance under conditions that produce a consistent performance. The Taguchi approach provides systematic, simple an efficient methodology for the optimization of near optimum design parameters with only a few well-defined experimental sets and determines the main factors affecting the process.

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