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Effect of Green Sand Moulding Parameters on Hardness of LM-25 Aluminum Alloy Castings

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Abstract: *Sand casting is the oldest, basic, simple and cheapest method of casting ferrous and non-ferrous materials. The quality of sand castings is a measure of its surface finish, hardness and soundness. It depends upon the quality of various constituents of green sand and structural properties of green sand mould. The objective of the present paper is to find controllable process parameters and their optimum level to achieve best quality for Aluminum alloy (LM-25) casting. Taguchi parameters design technique with L_9 (3^4) orthogonal array is used to find out optimum level of process parameters. The different input process parameters taken under consideration in this experiment work are bentonite clay, grain fineness numbers, moisture content and metal pouring temperature. Aluminum alloy (LM-25) castings were prepared as per the Taguchi's L9 orthogonal array and their hardness was measured. Lastly optimum level of process parameters used in confirmatory experiment to check the validity of whole exercise. It was observed that a higher level of Bentonite clay, Grain fineness number and low levels of moisture is good for sand molds for obtaining best hardness from LM-25.Aluminum alloys green sand castings.*

Keywords: *Aluminum Alloy (LM-25), hardness, Green Sand, Taguchi Method, Orthogonal Array.*

1. INTRODUCTION

Sand casting is the oldest, basic, simple and cheapest method of casting ferrous and non-ferrous materials. Despite the competition from plastics and ceramics, metals still remain the dominating materials in the production of capital equipment and fabricate goods. Metal casting will continue to play a major role, as a fabricating process of significant versatility, for the predictable future. Metal casting has an old manufacturing process first used by man to produce intricate objects. Green sand Metal casting processes are extensively used all over the world for manufacturing intricate and complex parts because of its inherent capabilities viz., simplicity and versatility. It played a major role in the industrial revolution especially in aerospace components and remains at the leading edge of technology development [1]. There have been significant developments in casting processes to improve precision. This process in its fundamental form requires a mold cavity of the desired shape and molten metal to pour into the mold cavity. Casting is a process of solidification, which means the solidification phenomenon controls most of the properties of the casting. Moreover, most of the casting desert occurs during solidification, such as porosity and solidification shrinkage etc [2].

Green sand is basically a mixture of silica sand, bentonite clay, coal dust and moisture. Silica sand, bentonite clay and coal dust are dry mixed in sand Muller first and then water is added into the mixture to obtain the required strength [3]. The pouring temperature of the material should be a few hundred degrees higher than the melting point of the material to assure good fluidity, thereby avoid premature cooling, which can create porosity and voids [3]. The mixture of sand and clay is moistened with water to develop strength and plasticity of the clay to make the aggregate suitable for molding. Over 70% of all metal castings are produced via a sand casting process [4]. Green sand can be reused after adjusting its composition to replenish the lost moisture and additives. Since 1950, partially-automated casting processes have been developed for production lines. In modern foundries, this method is widely used for small size automotive castings. It is the least costly method and gives optimum quality due to low cost of sand and its ingredients and its reusability for further production. SiO_2 is mainly responsible for high refractoriness of sand at elevated temperature. The silica sand is designated by grain fineness number [5]. For present study, we have taken silica sand of 80, 90 and 100 grain fineness number (AFS number). LM-25 aluminum alloy is basically Al- 7% silicon alloy. It is supplied in cast conditions only. It possesses very good fluidity and resistance to hot tears. So, it can be easily cast in sand, pressure and gravity die casting. LM25 may be superior for castings, particularly in chill moulds, which are difficult to make to the required standard of soundness.

1.1 Taguchi design technique

Taguchi's comprehensive system of quality engineering is one of the great engineering achievements of the 20th century. His methods focus on the effective application of engineering strategies rather than advanced statistical techniques. It includes both upstream and shop-floor quality engineering. S.Guharaja et al. [3] carried out optimization of green sand casting process parameters by using taguchi method. A.Narool Haq et al. [6] optimized the parameters of CO_2 casting process by Taguchi Method. The process parameters consider in this work are weight of CO_2 gas, mould hardness number, sand particle size, sand mixing time, percentage of sodium silicate, pouring height, pouring time, pouring temperature and cooling time of poured metal. They investigated that the rejection rate of CO_2 casting process before setting optimal parameter was 7.473%, and after setting optimal parameter was 6.427%. The reduction in percentage of rejection rate of CO_2 casting process was 1.047%. The casting parameters considered in this work are moisture content, green strength, permeability number and mould hardness number. Taguchi design technique gives the optimum levels of the process parameters for minimum casting defects of spheroidal graphite cast iron. Overall casting quality mainly depends upon soundness, dimensional accuracy, metallurgical and mechanical properties of castings.

2. EXPERIMENTATION WORK

The material used for casting in this study was aluminium alloy (LM25) to investigate the effect of various parameters in a sand casting process on the properties of this alloy. A three level orthogonal array L_9 (3^4) was applied to study the effect of process parameters. The control process parameters varied were temperature of the molten metal, Grain fineness number of sand, Moisture content and Bentonite clay. The properties and quality of sand cast components are directly related to green sand and temperature of metal keeping other factors fixed for a given casting. The experimental work was performed on the basis of Design of Experiment (DOE) techniques. The process parameters levels have been decided from the literature for LM- 25 aluminum alloy castings in synthetic sand. So, an experimental layout has been set at three distinct levels for four main parameters. The parameters with their levels are given in table 1. From table 2, L_9 (3^4) O.A. has nine number of rows and is therefore selected. In the present paper surface roughness has been chosen response parameter. AFS No. of sand was determined by using sieve analysis apparatus having Sieve Nos.:40,50,70,100,140,200,270 & Pan. After conditioning of green sand mould cavity was produced using standard method. Melting of Aluminum alloy was carried out in an Open hearth furnace, Hearth size: 200×200×75 mm. Pouring temperature of molten metal was measured by thermocouple having Temp. range: 0 to 950°C. A first set of nine castings were produced as per design of experiment. Hardness was measured by Brinell hardness tester with; HBW read Scale. Indenter: 10 mm diameter hardened ball. Major Load: 1000 Kgf. Raw data average response table for main factors for hardness are shown in Table 3.

Table 1: *Process parameters and their levels*

Designation	Main parameter	Range	Level 1	Level 2	Level 3
A	Bentonite clay	4 - 6 %	4%	5%	6%
B	Grain fineness no.	80 – 100	80	90	100
C	Moisture Content	3 - 5 %	3%	4%	5%
D	Pouring Temp.	690-730℃	690℃	710℃	730℃

Table 2: *$L_9(3^4)$ Orthogonal Array with Factors and Levels.*

Exp. No.	Bentonite clay (A) %	Grain fineness no. (B)	Moisture (C) %	Pouring temp. (D) ℃
1.	4	80	3	690
2.	4	90	4	710
3.	4	100	5	730
4.	5	80	4	730
5.	5	90	5	690
6.	5	100	3	710
7.	6	80	5	710
8.	6	90	3	730
9.	6	100	4	690

Table 3: *Raw data of main factors for hardness*

Controlfactors / Levels	Control Factor Name	Level 1	Level 2	Level 3
A	Bentonite Clay	50.05	50.22	52.38
B	Grain Fineness Number	52.43	50.37	49.85
C	Moisture Content	50.02	50.82	51.82
D	Pouring Temperature	51.35	50.92	50.38

Table 4: *Raw data ANOVA table for main factors for hardness*

Source	*Sum of Square*	*Dof*	*Mean of Square(V)*	*F-Ratio*	*P%*
A	*10.1667*	*2*	*5.08335*	*18.375****	*36.75*
B	*11.2117*	*2*	*5.60585*	*20.263****	*40.53*
C	*04.8800*	*2*	*2.4400*	*8.819****	*17.64*
D	*01.4067*	*2*	*0.70335*	*2.542*	*5.08*
SST	*27.6651*	*8*			*100*

****At least significant at 99% confidence. $F_{0.99\,(2\&8)} = 8.65$*
*** At least significant at 95% confidence, $F_{0.95\,(2\&8)} = 4.46$*
** At least significant at 90% confidence, $F_{0.90\,(2\&8)} = 3.11$*

The factors shown with stars are significant as per their symbols shown below Table 4.The other factors not significant at 90% confidence are pooled as error. So, the factors A, B and C are significant at 99% confidence interval and the factor D is insignificant at 90% confidence interval and is taken as error.

The result

$\mu_{CE} = 55.4 \pm 0.5$ HBW ..... [eqn.1]

Or

$55.9 < \mu_{CE} < 54.9$ HBW

The value of average Hardness of confirmation experiment of 5 castings with 2 repetitions for Casting Hardness must lie between 54.9 HBW and 55.9 HBW. The average Hardness is 55.4 HBW and confidence interval is ±0.5 HBW. The response plots have been plotted by using Minitab software (version-16).

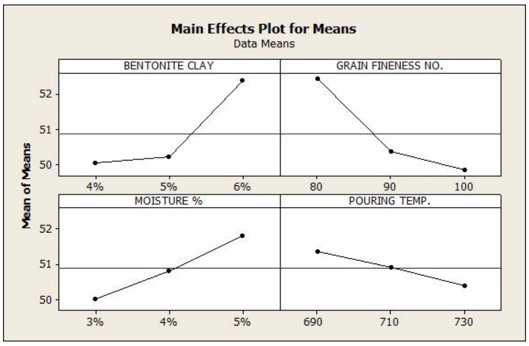

Fig 1: *Response plots for mean hardness*

The factors of LM-25 Aluminum alloy green sand castings for hardness can be classified as given below in table no. 5.

Table 5: *Summary of optimum levels for hardness*

Factors	*CONTROL FACTOR NAME*	*Level affecting average*	*Level affecting variability*
A	*Bentonite clay*	*3*	*3*
B	*Grain fineness number*	*1*	*1*
C	*Moisture content*	*3*	*3*
D	*Pouring temperature*	*-*	*-*

Confirmation test results

As part of the confirmation tests; five samples have been cast at the optimum conditions as above with hardness at position Q_1 & Q_2 are 55,55.2; 54.6,54.2; 55.5,55.1; 54.9,55.7 and 55.6,56.2 HBW. The samples have been evaluated following the same criteria used for the original experiments. The average of the sample has been found to be 55.2 HBW, which is within the confidence interval. The increase in hardness has been found to be 8.48 %.

3. CONCLUSIONS

The following parameters at level mentioned against them have been found significant for hardness of LM-25 Aluminum alloy green sand castings.

A. Bentonite clay	Level III	6%
B. Grain fineness number	Level I	80
C. Moisture percentage	Level III	5%

a) All the parameters are affecting both the average and variability of process except parameter D i.e. Pouring Temperature.

b) The improvement in hardness after confirmation experiment has been found to be 8.48 %.

c) From the above optimized parameters, we can conclude that a higher level of Bentonite clay & moisture and Low levels of Grain fineness number is good for sand molds for obtaining best hardness

d) properties from LM-25 Aluminum alloys green sand castings

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