Investigation and Optimization of Process Parameters Affecting the Impact Strength Of LM6 Sand Cast Aluminium Alloy

Anju Chaudhary[1], Nikhil Yadav[2] and Akhilesh Sharma[3]
Dhananjay Singh[4]

[1]Anju Chaudhary/Department of Mechanical Engg / Meerut Institute Of Engineering And Technology, Meerut, India

[1]anjalich101@Gmail.Com

[2]Nikhil Yadav/ Department of Mechanical Engg / Meerut Institute Of Engineering And Technology, Meerut, India
[2] Nikmach@Gmail.Com

[3]Akhilesh Sharma/ Department of Mechanical Engg /Meerut Institute Of Engineering And Technology, Meerut, India
[3] Akhilesh15190@Gmail.Com

[4]Dhananjay Singh/ Department of Mechanical Engg / [2]Subharti Institute Of Technology And Engineering, Meerut,India
[4] Singhdhananjay2229@Gmail.Com

ABSTRACT

The work is based on the effect of various variables on the impact strength of sand casting LM 6 alloy. Various input process parameters like grain fineness number, moisture content, green strength and clay content are taken under consideration. Investigation and Optimization of various process parameters discussed above which affect impact strength of the resulting casting process is done by Taguchi technique. Preparation of casting has been done according to the Taguchi's L9 orthogonal array and the aforesaid properties are inferred. It can be inferred through graphs, that shows decremental and incremental trend of impact strength with the increment in the grain fineness number whereas it shows the incremental and decremental trend with the increase in moisture content and green strength. With the increase in clay content it decreases continuously.

Keywords — Sand Casting, process parameters, Grain Fineness Number, Moisture Content, Clay Content, Taguchi Method, L9 orthogonal array.

1. INTRODUCTION

The casting technology where cast is formed by filling liquefied metal in the cavity followed by solidification process, originated back around 3600 B.C. in Mesopotamia. It goes back to 5600 years. That time, Bronze was converted to molten form and was filled in the cavity. Al alloy casts first came into being with a phenomenon that was further tried for other metals. It is said that casting of metals was first done more than 500 years ago, when shaped casts were created into cavity of soft mineral and clay. The significant engineering attributes of Al – low melting point and ability to be casted easily showed the path to adopt currently used casting processes and development led to the improvement and variations in shapes to which the molten metal can be converted. Scope of casting of Al is quite wide and has various applications in modern industry. On estimation about 20 – 30 % of Al products produced around the world find application in contemporary world for creating moulds. There are some requirements to cast Al alloys: corrosion resistivity, good mechanical properties (such as ultimate tensile strength, yield strength and elongation) and also fine ability to cast. Defence industry, Aerospace industry, electronics industry, nuclear and Automobile industry etc. finds wide application of aluminium alloys. Examples of huge parts of Al cast parts include gaskets of electric motors, wheels of armored vehicles, tank turrets and helicopter fans hub. Zhang [2] find out the S-N curve and pore size distribution of an A713 sand moulded Al alloy, were calculated firstly, and the density and the strength of fragile links were measured afterwards. It was realized that strength distribution of weak links was more suitable property than pore distribution to calculate the behavioral changes in fatigue crack initiation of the A713 cast Al alloy. Yadav and Karunakar[3] studied the attributes of A713 alloy casts prepared by investment casting using polystyrene for pattern preparation and the plaster of paris for preparing mould. Experiments were carried out following Taguchi's L9 orthogonal array. Certain process variables like mould firing temperature, pouring temperature, firing time and mixing silica sand of different grain fineness numbers to find out their impact at the surface hardness, impact strength and tensile strength of the resulting casts. Observation of varying trends in the considered mechanical attributes was done and it was seen that higher mould firing temperature, high pouring temperature, max firing time and high grain fineness number impressively degrades the mechanical properties of A713 alloy casts prepared by the process. Raji[5] compared cast microstructures and mechanical properties of Al-Si alloy components cast by various ways. To carry out this, sand casting, chill casting and squeeze casting were done to create same products of similar shape and size from aliminium-8%silicon alloy. Increase in the grain size of the microstructures of the cast products was seen from chill casting to sand casting in comparison to squeeze casting. Inversely, the mechanical attributes of the products were better via chill casting to squeeze casting as compared to sand casting. Patel and Prajapati [7] discovered that grain refinement is one of the vital and common melt treatment method for Al–Si alloy casting. Grain-refiners are widely used in improving mechanical properties of the casts in industries, and the important benefits are also explained. Grain refinement of Al alloys avails a number of technological and economic merits, which involves less ingot cracking, improved ingot homogeneity, susceptibility to hot cracking is diminished and mechanical properties are boosted impressively. Grain refinement boosts the quality of cast by decreasing the size of primary Al grains, which will undergo solidification having coarse columnar grain structure otherwise. Merlina et al.[8] did the impact strength tests on KV sub-size Charpy samples derived from A356 Al alloy 17-inch. wheel, prepared through a low-pressure die casting. The wheels map different geometry and thermal treatment. In this research, the influences of microstructure and defects on the impact parameters are investigated. The conclusion shows that the impact energy is lesser in as-casted wheels than in T6 heat-treatment wheels. A fine microstructure always gives greater impact strength, while a direct relation between the resistance to crack propagation limits and secondary dendrite arm spacing (SDAS) also existed. Casting defects, investigated through X-ray and density calculation method, become vital while gathered around the V-notch, where they decreases the load tolerance area of charpy samples. The breakdown profile and surface of charpy samples have been examined finding out how the defect surpasses the interdendritic eutectic region where a vital fraction of deteriorated eutectic silicon and intermetallic matter is revealed.

The goal of this paper is to find the significance of different considered variables for LM6 alloy on and impact strength in sand casting. The variables that are considered are grain fineness number, moisture content, green strength and clay content. The various values of discussed variables will have affect on the impact strength of the final castings which are needed to have optimal value by the help of optimization technique. Taguchi method will be followed for the optimization of the concerned variables.

2. EXPERIMENTATION

Experiment start with material selection for casting and preparation of sand with different grain fineness number with the testing of green compressive strength of casting produced. It also clears the process of experimental design strategy. Data from experiments and graphs show the effect of process parameters on the mechanical property such as, impact strength of sand cast LM6 alloy. Sand grain fineness number, moisture content, clay content, green strength are the various parameters which involved in this.

2.1 Material Selection for Alloy

In this Experiment we have considered the LM6 (Al-Si) alloy for producing sand casting LM6 alloy which comprises as given in the Table 1:

Table-1

Cu	0.1%
Mg	0.10%
Si	10-13%
Iron	0.6%
Mn	0.5%
Ni	0.1%
Zn	0.1%
Pb	0.1%
Sn	0.05%
Ti	0.2%
Al	Remainder

Table-1: Contents of LM6 Alloy

Having good resistance to corrosion it is used under both ordinary atmospheric and marine conditions. The aluminum silicon alloys has been used to produce intricate castings of thick and thin sections. Due to large silicon content it is free from hot tearing. Due to ductility property casting can be easily changed in different shapes e.g., simple structures can be produced and later modified into complex structures. LM6 is especially suited to casting that need to be welded although special care is needed when machining.

2.2 Experimental Design Strategy

Taguchi methodology introduces Orthogonal Array (OA) for the execution of experiments. Orthogonal Arrays are generalized Graeco-Latin squares which are used to design an experiment by selecting the most suitable orthogonal array and to assign the parameters to the appropriate columns.

- To deduce the optimized condition for a product or process.
- To investigate the contribution of individual independent parameters.
- To deduce the response under the optimized condition.

Table-2

Parameters	**Level 1**	**Level** 2	**Level** 3
Grain fineness no.(A)	45	50	55
Moisture content(B)	2%	3%	4%
Clay content(C)	10%	12%	14%
Green strength (D)	74.32	61.34	46.52

Table-2: Process parameters at different levels

Taguchi's method for four factors at the respective three levels was used for the implementation of the plan of experiments. The orthogonal array L9 selected as shown in table 3, has 9 rows corresponding to the number of tests with the required columns. A particular orthogonal array is selected on the basis of the number of levels of various factors which is shown in Table 3 comprising of parameters at different levels in the respective run.

Table-3

Sr. No	**A**	**B**	**C**	**D**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table-3:L_9 Orthogonal Array

2.3 Experiment Process

In this experiment we were prepared a sand moulds according to the orthogonal L9 array which shows the different values of process parameters as per their respective levels. For temperature range 700-800 degrees Celsius in pit furnace we melt the metal. The molten LM6 alloy was then poured into mould cavity through a gating

P	Level 1	Level 2	Level 3	L2-L1	L3-L2
A	0.299	0.296	0.353	-0.003	0.057
B	0.299	0.333	0.316	0.034	-0.017
C	0.338	0.308	0.303	-0.030	-0.005
D	0.326	0.328	0.294	0.002	-0.034

system which is designed to maximize the quality of casting. After the molten metal solidification it was allowed to cool down to the room temperature. Removed gating system can be further used for casting .Cleaning operations were performed to remove sand particles stuck to the surface of casting. We performed the machining operation to prepare the different specimen used for impact test. This is repeated nine times according to Taguchi's method and data were collected for different trials.

3. RESULTS

This section shows the effect of various process parameters on the impact strength of sand cast LM6 alloy. The experiments were performed considering the L9 orthogonal array. The L9 OA with the values of impact strength according to process parameters for 9 trials is given below in the table 4.

Table-4

Trial No.	A	B	C	D	Impact strength(kgm)
1	45	2	10	74.32	0.3
2	45	3	12	61.34	0.3
3	45	4	14	46.52	0.26
4	50	2	12	46.52	0.24
5	50	3	14	74.32	0.3
6	50	4	10	61.34	0.32
7	55	2	14	61.34	0.34
8	55	3	10	46.52	0.36
9	55	4	12	74.32	0.35

Table-4: Responses

3.1 Effect of Process Parameters on Impact Strength of Castings

The average value of response (impact strength) for 4 process parameters and for 3 levels are shown in the table 5,where as S/N values for each experiment and their average values for each parameter for 3 levels are shown in table 5 and table 7 respectively.

Table-5

Table-5: Average values of responses at different levels

3.2 S/N Ratio Calculation

The S/N ratio for the individual process parameters are calculated as given below and tabulated in Table 6:

$$S/N = -10 *\log(\Sigma(1/Y2)/n)$$

Table-6

Trial no	S/N ratio
1	-10.064
2	-9.948
3	-11.540
4	-12.063
5	-10.187
6	-9.642
7	-9.503
8	-8.646
9	-8.999

Table-6: S/N ratio of Responses

Table-7

P	Level1	Level2	Level3	L2-l1	L3-l2
A	-10.517	-10.631	-9.049	-0.11	1.58
B	-10.543	-9.594	-10.06	0.95	-0.47
C	-9.451	-10.336	-10.41	-0.89	-0.07
D	-9.75	-9.698	-10.75	0.05	-1.05

Table-7: Average of S/N ratio

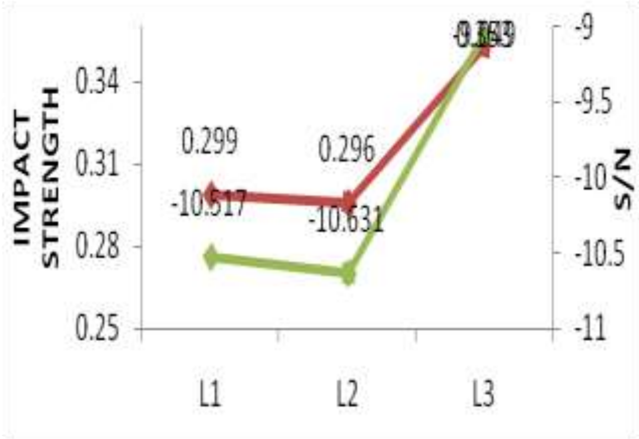

Figure 1: Variation of Impact Strength with the levels of grain fineness number

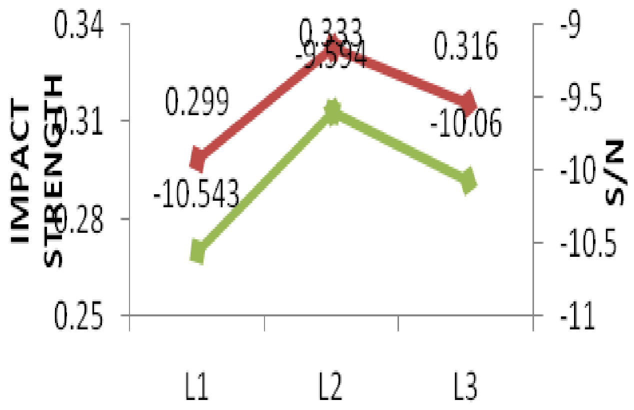

Figure 2: Variation of Impact Strength with the levels of moisture content

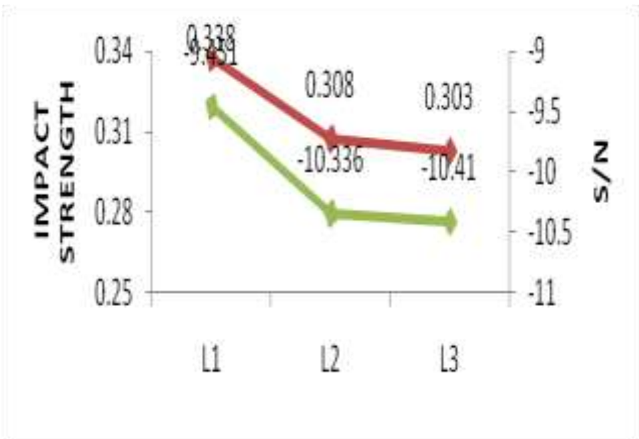

Figure 3: Variation of Impact Strength with levels of clay content

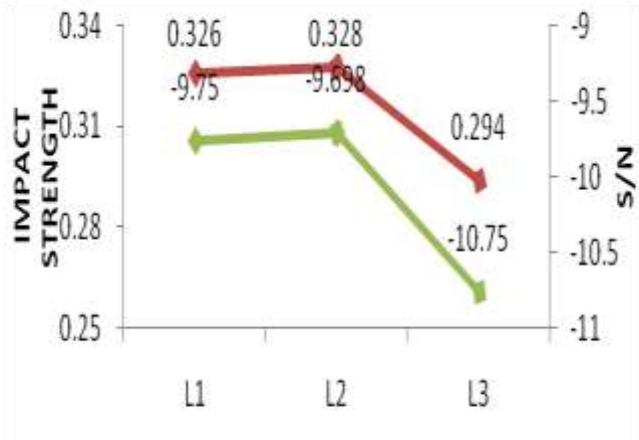

Figure 4: Variation of Impact Strength with The the levels of green strength

Figure 1-4 show the graph which represents the changes in the impact strength of the castings with the change in the levels of process parameters which are Grain Fineness Number ('A'), Moisture Content ('B'), Clay Content ('C') and Green strength ('D') respectively.

4. DISCUSSIONS

With the increase of the grain fineness number the solidification rate first decreases that make the grain grow coarser and hence the toughness is low and with the further increase of the grain fineness number the solidification rate increases that makes the grain finer and hence higher toughness. With the increase of the moisture content the solidification rate first increases that make the grain grow finer and hence the toughness is high and with the further increase of the moisture contents the solidification rate decreases that makes the grain coarser and hence lower toughness. With the increase of the clay content the solidification rate decreases that make the grain grow coarser and hence the rendering the toughness lower. With the increase of the green strength the solidification rate first increases that make the grain finer and hence the toughness is higher and with the further increase of the green strength the solidification rate decreases that makes the grain coarser and hence lower toughness.

5. CONCLUSIONS

The effect of the aforesaid process parameters on the impact strength of LM6 alloys castings was concluded and it was observed that for the process parameter A, the impact strength first decreases up to level 2 and then increases by further variation in the process parameter. At parameter B, its value increases till level 2 and slightly decreases as shown in figure 2. Figure 3 shows the effect of clay content in which its value continuously decreases from level 1 to level 3. Figure 4 Shows that the impact strength slightly increases at level 2 and then decreases up to level 3.

REFERENCES

[1] Binczewski GJ, (1995) "A History of the Aluminum Cap of the Washington Monument" - TMS *www.tms.org/pubs/journals/jom/9511/binczewski-9511.html*.

[2] Zhang Yuanbin, Xu Jianhui, Zhai Tongguang, (2010) "Distributions of pore size and fatigue weak link strength in an A713 sand cast aluminum alloy" *Materials Science and Engineering* A 527 (2010) 3639– 3644 ,30 march 2010.

[3] Yadav Nikhil and Karunakar D. B. (2011) "Effect of process parameters on Mechanical properties of the investment Castings produced by using expandable Polystyrene pattern", *International journal of advances in engineering & technology*, july 2011, (c) ijaet issn: 2231-1963.

[4] Ihom Paul Aondona, Agunsoye Johnson, Anbua Emmanuel Eric, Ogbodo Joy, (2011) "Effects of Moisture Content on the Foundry Properties of Yola Natural Sand, Leonardo". *Electronic Journal of Practices and Technologies* ISSN 1583-1078 Issue 19, July-December 2011

[5] Raji Abdulkabir, (2012) "A Comparative Analysis of Grain Size and Mechanical Properties of Al-Si Alloy Components Produced by Different Casting Methods", AU J.T. 13(3): 158-164 (Jan. 2010).

[6] Ayoola Wasiu Ajibola, Adeosun Samson Oluropo, Sanni Olujide Samuel, Oyetunji Akinlabi, (2012) "Effect of casting mould on Mechanical properties of 6063 aluminum alloy". J*ournal of engineering science and technology* vol. 7, no. 1 (2012) pp 89 – 96.

[7] Patel V.P., PRAJAPATI H.R, (2012) "Microstructural and mechanical properties of eutectic Al–Si alloy with grain refined and modified using gravity-die and sand casting", *International Journal of Engineering Research and Applications* (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.147-150.

[8] Merlina Mattia, Timelli Giulio, Bonollob Franco, Garagnania Gian Luca, (2008) "Impact behaviour of A356 alloy for low-pressure die casting automotive wheels". Journal *homepage*: www.elsevier.com/locate/jmatprotecAccepted 15 March 2008.

