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EFFECT OF MOLDING COMPOSITION ON ALUMINUM ALLOY (A356) SAND CASTING

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ABSTRACT

As aluminum is sensitivity with environment at high temperature foundry man are careful for molding during mold making stage. In the aluminum casting industry, the foundry manufacturers find the quality of the sand mold as important fact to achieve high quality aluminum castings that met client specification. The aim of this research is to reduce aluminum casting defects by studying the defect of proportion of water and bentonite added to a recycled sand mold. Aluminum 356 alloys was preferred for this research based on the traditional method of trial and error twelve castings were performed with the different proportion of sand, bentonite, and water. A five scale rating method has been applied to rate the casted product upon number of defects. This research has been carried out by analyzing the variance (ANOVA) by using proCAST2016 software and finally concludes with the optimum level of composition for casting to minimize defect raised due to mold for Al with the result of 90% sand, 5% bentonite, and 5% water. More time defect due to ratio of composition is directly related to the molding sand property almost 70% reflects permeability of sand casting or solidification related defects. 20% is related to moisture because gas related defect. 10% thermal cracking of mold and mold erosion. Using advanced sand casting equipment ratio of composition with small tolerance we were able to successfully cast this material part, meeting client specifications.

Keywords: *Aluminum Casting, Foundry, thermal crack, Bentonite, permeability, Optimum Level of Composition.*

I. INTRODUCTION

Aluminum casting alloys offer a range of advantages, particularly good cast ability. This includes a relatively high fluidity, low melting point, short casting cycles, relatively low tendency for hot cracking, good as-cast surface finish and chemical stability. In addition, advantages are gained by the specific alloy chosen.

Sand casting is a metal casting process which involves the use of natural sand along with adequate proportion of clay (as a binder material) to keep the sand grains together or it can use the silica sand and artificial binder pair. The mixture is then contained in a molding flask or molding box consisted of two matching parts. The mixture in the box is compressed by hand or mechanical ramming is done around the pattern. Parting sand is used between the two halves of the molding flask. When the these boxes are separated after establishing the sprue system by patterns and the dowels a negative mould shape is left behind in the molding sand. The molten metal is then poured into that hollow section or cavity. These are the basic steps of sand casting used for metal casting.

Casting Defects is an unwanted irregularity that appears in the casting during metal casting process. There is various reason or sources which is responsible for the defects in the cast metal. Here in this section we will discuss all the major types of casting defects. Some of the defects produced may be neglected or tolerated and some are not acceptable, it must be eliminated for better functioning of the parts.

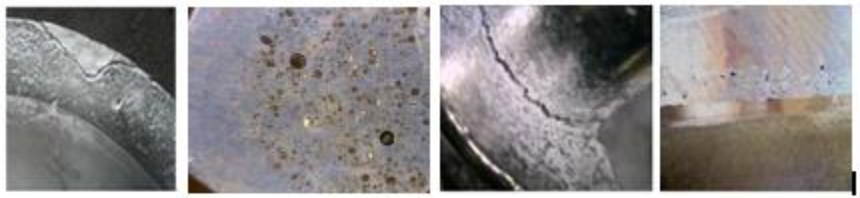

Figure 1 Defects in aluminum alloy castings [9]

Genichi Taguchi has introduced several statistical tools and concepts for quality improvement. According to him, the key element for achieving high quality and low cost product is parameter design. Through parameter design optimal levels of process parameters (or control factors) are selected such that the influence of uncontrollable (or noise) factors causes minimum variation of system performance or response. These parameters should be controlled to improve the quality of both casting process and product [2].

II. MATERIAL AND METHOD

A356 Aluminum Casting Product

Aluminum castings have played an integral role in the growth of the aluminum industry since its inception in the late 19th century. The first commercial aluminum products were castings, such as cooking utensils and decorative parts, which exploited the novelty and utility of the new metal. Those early applications rapidly expanded to address the requirements of a wide range of engineering specifications. Alloy development and characterization of physical and mechanical characteristics provided the basis for new product development through the decades that followed. Casting processes were developed to extend the capabilities of foundries in new commercial and technical applications. The technology of molten metal processing, solidification, and property development has been advanced to assist the foundry man with the means of economical and reliable production of parts that consistently meet specified requirements.

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Today, aluminum alloy castings are produced in hundreds of compositions by all commercial casting processes, including green sand, dry sand, composite mold, plaster mold, investment casting, permanent mold, counter-gravity tow-pressure casting, and pressure die casting. [8]

Material constraints that formerly limited the design engineer's alloy choice once a casting process had been selected are increasingly being blurred by advances in foundry technique. In the same way, process selection is also less restricted today. For example, many alloys thought to be unusable in permanent molds because of casting characteristics are in production by that process.

Table 1. Alloy Composition of the A356 [1]

Alloy Weight % A356	AL	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Sr
	91minimum	7.14	0.12	0.03	0.02	0.340	0.04	0.01	0.10	<0.01

Mold Material

Green Sand Molding

This process involves the use of natural sand which already has a small percentage of clay. The green sand casting process involves the following basic steps. Adequate amount of water is added to the sand. After adding water the green or natural sand is thoroughly conditioned and mixed with the help of rollers. The clay and water works as binder which holds the sand grains together. The sand is compressed around the pattern and rammed so that it becomes compact and tight. And this is known as 'Green Strength'. [4]

The properties green sand molding

The success of the casting process depends to a large extent on the making of a satisfactory mould. For this, the molding properties of the sand have to be controlled. These properties include: Porosity or Permeability 'Strength or cohesiveness, Refractoriness, Plasticity, Collapsibility and Adhesiveness Co-efficient of expansion etc. [4]

Refractoriness:- It is the ability of the molding sand mixture to withstand the heat of melt without showing any signs of softening or fusion. This property is greatly influenced by the purity of the sand particles and their size. It increases with the grain size of sand and its content and with the diminished amount of impurities and silt.

Permeability: - Permeability or porosity of the molding sand is the measure of its ability to permit air to flow through it. Molten metal always contains a certain amount of dissolved gases which try to leave it when the metal solidifies. If all these gases and vapors are not able to escape completely through the walls of the mould, they may penetrate the liquid metal where, after solidification, they form gas holes and pores. To avoid these defects, the molding sand should have good gas permeability. Again, higher the silt contents of sand, the lower its gas permeability. If the mould is rammed too hand, its permeability will decrease and vice versa.

Cohesiveness: -It is defined as the property of holding together of sand grains. Molding sand should have ample strength so that the mould does not collapse or get partially destroyed during conveying, turning over or closing. This property also enables the pattern to be removed without breaking the mould and to stand; the flow of molten metal when it rushes inside the mould. The strength of the molding sand grows with density, clay content of the mix and decreased size of sand grains. So, it is clear that as the strength of the molding sand increases, its porosity decreases;

Adhesiveness:- This is the property of sand mixture to adhere to another body (here, the molding flasks). The molding sand should cling to the sides of the molding boxes so that it does not fall out when the flasks are lifted and turned over. This property depends on the type and amount of binder used in the sand mix.

Plasticity or flow-ability: It is the measure of the molding sand to flow around and over a pattern during ramming and to uniformly fill the flask. This property may be enhanced by adding clay and water to the silica sand.

Procedure

Setting parameter

The main objective was to study effect of sand mold composition for aluminum alloy casting product mixing different proportions of molding sand, clay, moisture and grain fineness. Taguchi DOE methodology is applied in this study to assess the influence of process parameters on quality of castings. Selection of orthogonal array depends on number of parameters and their levels, here number of parameters is 'four' and number of levels is 'three' as given in Table 2.

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Table 2. Parameters and their level

Parameter	unit	Code	Levels		
			1	2	3
%Silica	%	A	85	87	89
%Moisture	%	B	4	5	6
%Clay /binder	%	C	5	6	7
`%Grain fineness no.	AFS	D	120	150	180

Determining the upper and lower limits of the mixture

The composition of molding sand, clay, moisture and grain fineness (AFS) where 85% -89%, 5-7%, 4-6% and 120-180 respectively. These proportion ranges were selected from literature and foundry. There have been performed 9 experiments separately with the different proportion of silica sand clay, moisture and grain fineness within the predefined range. Under full factorial method, number of experiments required was 3^4 = 81, using L9 (3^4) Taguchi orthogonal array (Table 3), the number of experiments are reduced to 'nine'. These nine experiments were conducted as shown in the Table 3.

TABLE 3. L9 STANDARD ORTHOGONAL ARRAY

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

Table 4. Experiment design table

Expt. No.	*%Silica sand*	*%Moisture*	*%Clay/binder*	*%Grain fineness*
	A	***B***	***C***	***D***
1.	85	4	5	120
2.	85	5	6	150
3.	85	6	7	180
4.	8	4	7	180
5.	87	5	6	120
6.	87	6	5	150
7.	89	4	7	150
8.	89	5	5	180
9.	89	6	6	120

Effect of mold composition in a356 aluminum alloy casting product of free defect product

In the entire 9 trial Al-356 tested experiment result was observed very carefully on the basis of various defects resulted on the product. Among variety of defects, defects like crack, mold break, dimension variation, scar, blow holes, pin holes, scab were the most concerning ones in our results. The defects were rated within the 6 rating scale. Then the sample no. or the product with the least average number of defects was chosen as the most defect free result. Rating, 0=no defect, 1 = very small amount, 2 = small amount, 3 = medium amount, 4 = large amount, 5 = very large amount.

Table 5. Trials conducted in nine experiments

Expt. No.	Composition in percent (%)				Casting defect								Average
	Silica sand	Moisture	Clay/ Binder	%Grain fineness	Blow	crack	Pin hole	subsurface	Scar	Dimension variation	Scab	Cold shut	Average
	85	4	5	120	1	2	4	0	2	0	1	1	1.3
	85	5	6	150	0	1	3	0	1	2	1	0	1
	85	6	7	180	0	3	5	1	3	1	0	2	1.8
	87	4	7	180	0	1	1	0	1	2	1	0	0.75
	87	5	6	120	3	4	5	1	2	1	3	1	2.5
	87	6	5	150	0	1	2	1	2	3	1	0	1
	89	4	7	150	0	0	1	0	0	1	0	0	0.25
	89	5	5	180	1	0	2	0	1	1	2	1	1
	89	6	6	120	2	1	4	3	1	4	2	2	2.35

Data analysis

Effect of parameter (mold composition), defect identification and rating

After average of S/N ratio value of each factor and level was calculated the range of each factors was determined by subtracting the larger value from the least small value within a factor, then based on the range of each factors the rank was given on the table 5 with Taguchi Analysis: Blow, crack, Pin hole, ... versus SILICA SAND, MOISTURE, CLAY.

Table 6. Response table for signal to noise ratios smaller is better

Level SAND	SILICA	MOISTURE	CLAY	GRAIN FINENESS
1	5.3880	0.2460	-3.6744	-7.6067
2	4.3813	-4.6453	-3.7943	-0.3230
3	1.3710	-6.7411	-3.6717	-3.2107
Delta	0.1170	2.9870	1.1227	7.2836
Rank	4	2	3	1

Table 7. response table for means

Level	SILICA SAND	MOISTURE	CLAY	GRAIN FINENESS
1	1.4167	0.7917	1.2083	2.0833
2	1.5000	1.5000	1.3750	0.8333
3	1.2083	1.8333	1.5417	1.2083
Delta	0.2917	1.0417	0.3333	1.2500
Rank	4	2	3	1

From the S/N ratio value response table 7 grain fineness and moisture has greatest effect and clay and silica sand content have least effect on the output of the aluminum alloy casting product.

Main effects plot for s/n ratio

Numerical experimentation predicted the effect of each selected factor using Minitab soft ware from the overall mean line of signal to noise ratio.

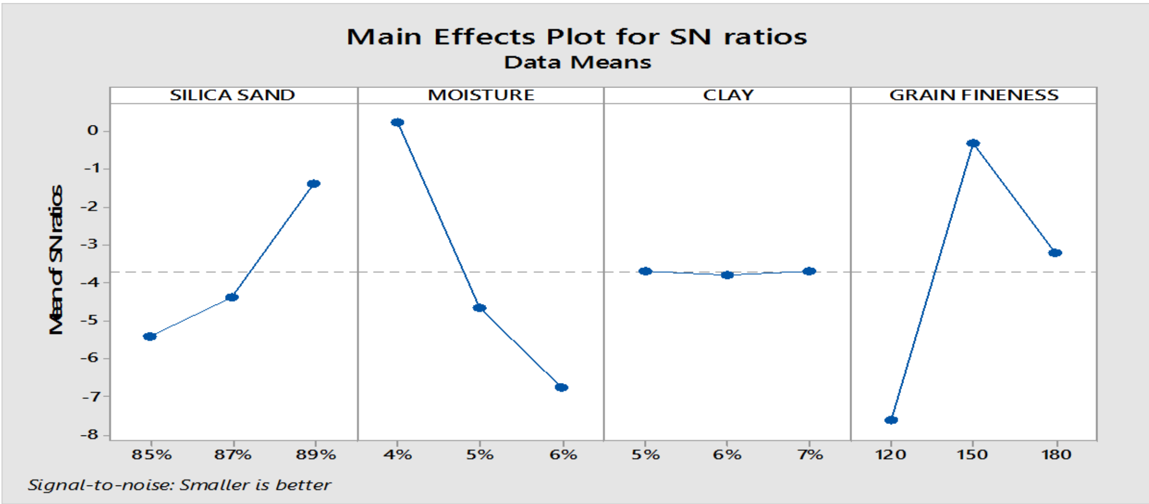

Figure 2 Main Effect of plot for S/N ratio values

Main effects plot for sn ratios

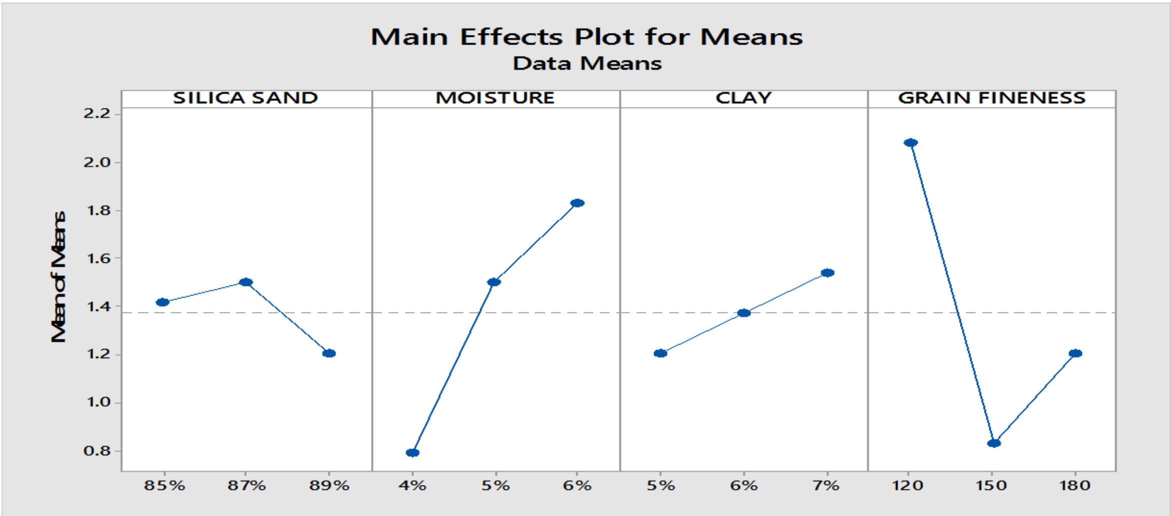

Figure 3 Main Effect of plot for S/N ratio values

Raw data analysis of experiment result

The response refers the average of value of performance characteristics for each parameter at different parameter at different level. The average value of response at each value was obtained by adding the result of all trials condition at the level considered and then dividing by number of parameter

Table 8. Eeffect of sand molding composition, defect and S/N ratios

↓	C1-T	C2-T	C3-T	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
	SILICA SAND	MOISTURE	CLAY	GRAIN FINENESS	Blow	crack	Pin hole	subsurface	Scar	Dimension variation	Scab	Cold shut	SNRA1	MEAN1
4	87%	4%	6%	180	0	1	1	0	1	2	1	0	0.00000	0.750
5	87%	5%	7%	120	3	4	5	1	2	1	3	1	-9.16454	2.500
6	87%	6%	5%	150	0	1	2	1	2	3	1	0	-3.97940	1.250
7	89%	4%	7%	150	0	0	1	0	0	1	0	0	6.02060	0.250
8	89%	5%	5%	180	1	0	2	0	1	1	2	1	-1.76091	1.000
9	89%	6%	6%	120	2	1	4	3	1	4	2	2	-8.37273	2.375

III. RESULT AND DISCUSSION

Silica (SiO_2) or silica mixed with other minerals good refractory properties capacity to endure high temperatures, Small grain size yields better surface finish on the cast part Large grain size is more permeable, to allow escape of gases during pouring Irregular grain shapes tend to strengthen molds due to interlocking, compared to round grains. Disadvantage: interlocking tends to reduce permeability. Permeability or porosity of the molding sand is the measure of its ability to permit air to flow through it. Molten metal always contains a certain amount of dissolved gases which try to leave it when the metal solidifies. If all these gases and vapors are not able to escape completely through the walls of the mould, they may penetrate the liquid metal where, after solidification, they form gas holes and pores. To avoid these defects, the molding sand should have good gas permeability. Again, higher the silt contents of sand, the lower its gas permeability. Low grain fineness number or permeability cause, crack, subsurface defect and large grain fineness number or high permeability causes pinhole defect, Scar defect, metal penetration or dimension variation defect, blowhole defect, Scab defect, and Cold shut. The experiments conducted have shown that the parameter grain fineness whether low or large are selected have significant influence around 70% cause mold related defect in A356 aluminum casting product. Moisture up to 5% activates the clay helps in bonding to add strength for the mold. But using inappropriate moisture cause defect like mold breaking defect, subsurface defect and cold shut excessive moisture in the sand must be controlled and kept at desired level if not greater than 20% of mold related defect can be caused due to inappropriate of mold moisture. Clay up to7% used A356 aluminum casting product. But in appropriate clay or binder can cause 10% of mold related defects. Increase permeability by use of vent wire or open sand with additions of a coarser silica sand, Reduce moisture to minimum, consistent with workability, Use of sand with correct moisture content and clay content to avoid mould crush we can gate defect free of A356 aluminum casting product and minimize rejection of product.

IV. CONCLUSION

Casting defect disturb the quality of the product and material performance affecting the mechanical properties and microstructure of aluminum casting alloys product. Appropriate selection of mould composition of sand, sand grain fineness number, amount of clay, amount of moisture and number of ramming are reduce the amount of defect present during aluminum alloy casting process. The experiments conducted have shown that the mold composition selected have significant influence on A356 aluminum casting product especially for mod related defect. The optimum levels for process parameters are grain fineness number 150%, amount of clay 7%, amount of moisture 4%, and sand clay 89%. Amount of parameters are grain fineness number, clay and amount of moisture are the significant control factors among the selected factors. The confirmation test results obtained for fewer defects like blow, crack, pin hole, subsurface, Scar, Dimension variation, Scab, and Cold shut. These results are found to be in confidence level. Casting defects occur because optimum conditions were not met during casting process. By this study it is concluded that the optimum mold composition are responsible to minimize defects and improve quality of aluminum alloy sand castings.

REFERENCES

1. Corrosion of Aluminum and Aluminum Alloys, J.R. Davis, Ed, ASM International, 1999.
2. ASM Specialty [2] Handbook: Aluminum and Aluminum Alloys, J.R. Davis, Ed., ASM International, 1993
3. Aluminum and Aluminum Alloys, in Metals Handbook Desk Edition, 2nd ed., J.R. Davis, Ed., ASM International, 1998, pp 417–505.
4. D.G. Altenpohl, Aluminum: Technology, Applications, and Environment, 6th ed. The Aluminum Association Inc. and TMS, 1998.
5. Aluminum: Properties and Physical Metallurgy, J.E. Hatch, Ed., American Society for Metals, 1984.
6. Taguchi G., Introduction to quality engineering: design quality into products and process, (Asian Productivity Organization, Tokio, 1986).
7. A.K. Gajbhiye, C.M. Choudhari, D.N. Raut, and B.E. Narkhede, et al., Minimization of Shrinkage Porosity in a Sand Casting Process by Simulation in AUTOCAST-X Software with Experimental Validation by Destructive testing, IJMER, Vol. 4 Iss. 5 , Mumbai, India , 2014, pp 110.
8. Hatch, J. E., Ed. Aluminum properties and physical metallurgy, American Society for Metals (1984).
9. Hatch, J. E., Ed. Aluminum properties and physical metallurgy, American Society for Metals (1984).
10. Ganesh G. Patil, Dr. K. H. Inamdar, Optimization of Casting Process Parameters using Taguchi Method, International Vol. 2, No. 2, pp. 157 – 164 (2014).
11. Achamyeleh A. Kassie1, Samuel B. Assfaw, Minimization of Casting Defects, IOSR Journal of Engineering (IOSRJEN), Vol. 3, No. 5, pp. 31-38 (2013).
12. Mekonnen Liben Nekere, Ajit Pal Singh, Optimization of Aluminium Blank Sand Casting Process by Using Taguchi's Robust Design Mrthod, International Journal for Quality research, Vol.6, No.1, pp.81-97 (2012).
13. research, Vol.6, No.1, pp.81-97 (2012).
14. Sun Z, Zhang X, Hu H, Niu X, Section thickness-dependant interfacial heat transfer in squeeze casting of aluminum alloy A443. In IOP Conference Series: Materials Science and Engineering 27: 12073 (2012).
15. Lynch RS, Olley RS, Gallaher PCJ, Squeeze casting of aluminium. AFS Trans 122:569-576 (1975). 18. Williams G, Fisher KM, Squeeze forming of aluminium-alloy components. Metals Technology 8: 263-267 (1981).