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Characteristics and Property Analysis of A360Aluminium Alloy Casting Using Electromagnetic Vibration Technique

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Abstract- *The demanding problem for designers and engineers in the material science is to increase the quality of the castings. Aluminium silicon alloy A360 is an important nonferrous casting alloy. The properties of Al-Si alloy are dependent on the grain size and distribution of silicon particles which can be affected by grain refinement and modification. Different methods have been applied to improve its casting characteristics. External forces have been applied to introduce fluid flow during solidification of molten metal in casting process. In the present work, the solidifying melt is subjected to electromagnetic vibration which is considered as process parameters such as time of vibration, pulse width modulation and pouring temperature. Optimal design of experiment technique was used to conduct the experiments. It was observed that inducing vibration to the die containing molten metal resulted in fragmentation of silicon needles thereby improving the mechanical property of hardness of the alloy.*

Keywords: *Aluminium A360 alloy; Vibrational solidification process; Design of Experiments; Mechanical properties; Optical microscopic image.*

I INTRODUCTION

Worldwide the handling of aluminium alloy increases significantly in various applications. Parts of small appliances like hand tools and other machinery uses thousands of different aluminium castings, hence there is a need to improve the quality of the products. Inspection and testing of castings involve five main categories: casting ultimate, dimensional accuracy, mechanical properties, chemical substance and casting accuracy. Most of the research works are carried out to enhance casting soundness through micro structural analysis and mechanical property improvement for automobile and aerospace industries. Aluminium-Silicon alloys are one of the most commonly used alloys for foundry because they present many advantages such as good thermal conductivity, very good castability, high strength to weight ratio, corrosion resistance etc. As a result they are well suited to automobile cylinder heads, engine blocks, aircraft machinery etc. Aluminium A 360 contains lower silicon levels which results in denser castings. Grain refinement of Al and its alloys is a general practice for Aluminium casting industry, which otherwise solidifies with coarse columnar grain structure. The mechanical properties of Aluminum-Silicon alloys are related to the grain size and shape of silicon. Imposition of vibration on liquid Al-Si alloy during solidification has shown improvements like grain refinement [1], the application of vibration also causes considerable increase in wear resistance of cast alloys by falling their grain size and porosity levels [2], reduction in average size of silicon needle [3] resulting in improved properties. In earlier studies, Campbell [4] noticed grain refinement to occur and mechanical properties improved in castings due to the application of vibration during casting. Thus it is clear that subjecting the liquid molten metal to vibration during solidification promotes changes in microstructure and consequently in the properties. Various methods of suggest vibration into the molten metal like electromagnetic vibration [5], Ultrasonic vibration [6] and mechanical mold vibration [7] have been tried.

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In the present work, Electromagnetic vibration technique has been used to bring changes the properties like hardness; Impact strength and density in the alloy are studied. Process parameters likely to affect the solidification process such as pouring temperature, pulse width modulation and time of vibration have been considered.

II. Materials and Methods

A. Design of Experiments

Statistical design of experiments [8] refers to the process of planning the experiment, so that an appropriate set of data can be collected and then analyzed. In this work, optimal design of experiments with the factors set at their respective two levels has been used to develop linear relationship between the input-output parameters. In this vibration process Pouring temperature, pulse width modulation and time of vibration are the controllable parameters. So, three major factors which are having more influence in the solidification of casting under electromagnetic vibration. The chemical composition of alloy was determined by using ARL spark analyzer as shown in TABLE 1.

Table I. Composition of a 360 alloy

Elements	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Al
Wt %	0.022	0.38	8.78	0.25	0.042	0.012	0.091	0.009	0.002	0.069	Rem

Influential factors on the grain refinement associated with vibrations technique are 1.pouring temperature (°C) 2. Pulse width modulation (%) of a vibration motor 3.Vibration time (s). The following TABLE II. Ranges were accounted for each parameter to conduct optimal design.

Table II. Optimal design parameters

Parameters considered	Notations	Levels	
		Low (-1)	High(1)
Pouring Temperature	A	800°C	900°C
Pulse width Modulation	B	50 %	99%
Time of Vibration	C	6 Sec	90 Sec

B. Experimental Procedure

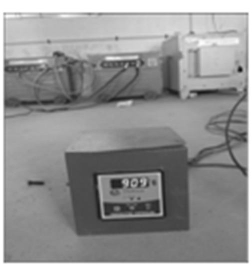

Fig 1.pouring temperature control unit

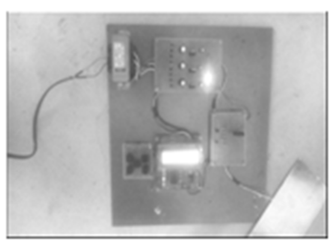

Fig 2.Electromagnetic vibration apparatus

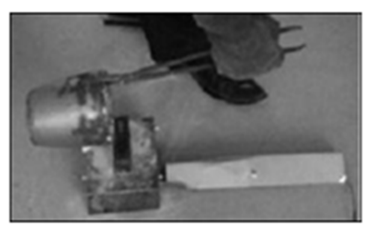

Fig 3.pouring the molten metal into die

A360 alloy were placed in a crucible and kept in an electric resistance furnace for melting. Degassing was carried out using hexachloroethane degassing tablets. The dross was skimmed off and the clean molten metal was transferred into the split die.

Following considerations were carried out for the experimentation.

- Without using grain refiner and vibration (as cast specimen)
- With considering vibration (electromagnetic)

The castings were prepared as per ASTM E18 standard having dimensions 60X10X10mm. The microstructural examination was made

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on the middle part of the castings by using optical microscope. The mechanical characteristics were measured by conducting various tests such as Rockwell hardness, Izod Impact strength and Density. The RHN hardness of the specimen was obtained with a 10mm ball indenter and applying 3000kgf load. The impact strength of the ASTM E23 standard specimen was obtained by using Izod impact testing machine. The density test was obtained by using Archimedes's principle.

III. Results and Discussions

The prediction of hardness, impact strength and density of A 360 aluminium alloy by varying parameters such as pouring temperature (A),pulse width modulation(B) and time of vibration(C) is listed in the table.

From the TABLE III it can be observed that the maximum hardness value of 104 RHN is attained for the pouring temperature of 900°C, 50% PWM and 6 sec for vibration time compared with as cast specimen without vibration. The hardness value decreased when the decrease in temperature and increase the vibration time. The impact strength is decreased when increasing the pouring temperature and decrease in time. From the observations it can be noted that the hardness property is inversely proportional to the impact strength. Reviewing the effects of subjecting solidifying Al and its alloys to various sources of vibration on the resulting casting quality, a simple inexpensive technique for inducing vibration resulting in enhanced density [9].But there is no major change in the density when varying the process parameters during electromagnetic vibration process.

Table III. Optimal design property values

Ex. No	A	B	C	Izod impact j/m^2	Rockwell Hardness RHN	Density g/c^3
1	800	0	0	1.9	84	2.642
2	800	50	6	2	89	2.589
3	800	50	6	1.5	91	2.609
4	900	50	6	1.4	102	2.684
5	900	50	6	1.5	104	2.58
6	859.5	79.4	6	1.3	96	2.65
7	800	99	6	1.2	95	2.6
8	800	99	6	1.5	96	2.64
9	822	68.62	24.9	2.1	92	2.59
10	900	99	35.4	2.2	96	2.5
11	899.5	69.11	41.7	1.4	71	2.6
12	854.5	85.77	51.9	2.2	95	2.73
13	859.5	50	55.98	1.2	92	2.68
14	859.5	50	55.98	1.1	94	2.552
15	800	79.16	56.4	2.2	96	2.73
16	800	50	90	2.1	93	2.56
17	800	50	90	1.2	87	2.65
18	800	67.15	90	1.1	92	2.586

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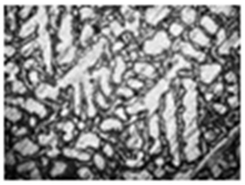
19	842.5	69.36	90	1.1	81	2.624
20	835	99	90	2.3	96	2.652
21	900	99	90	2.5	92	2.73

A. Microstructural Examination



4. Optical photomicrograph at 200X magnification without vibration

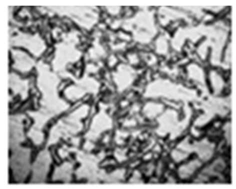


Fig 5. Optical photomicrograph at 200X magnification (800º C, 50%, 6sec)

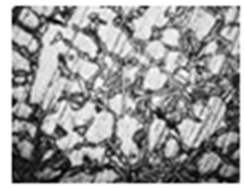


Fig 6. Optical photomicrograph at 200X magnification (900º C, 50%, 6sec)

Fig 4. Shows structure of the as cast A 360 alloy (without inducing vibration).It is observed that the structure of the alloy is comprised of coarse aluminium matrix and by large and needle shaped Si particles near the grain boundaries.

The results of microstructure examination of samples cast are shown in Fig 5. and Fig 6. An alloy A 360 is of slightly hypo - eutectic composition and solidifies with a small amount of primary aluminum as seen in the micrographs. It reveals that the grain size of the alloy was densely packed predominantly by increasing the vibration. Also there is a microstructure changes from its normal dendrite structure.

The increasing vibration makes the inter structure densely packed. It was a columnar dendrite in the natural solidification and after the vibration it has been changed. These microstructure changes make the property changes of the alloy.

IV Mechanical Behavior

B. Hardness Test

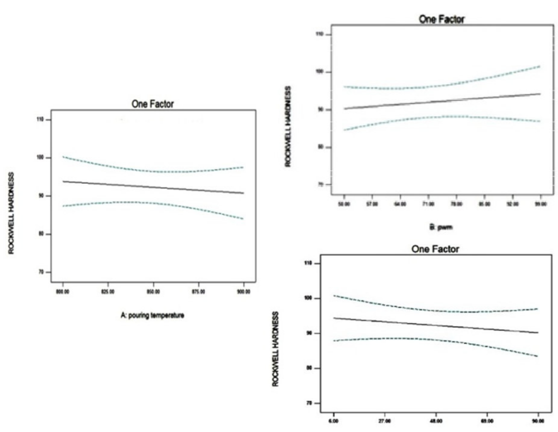


Fig 7.Graphical chart of Rockwell Hardness

Fig 7. Shows that the variations of hardness values with electromagnetic vibration, it can be seen that a maximum of RHN value is observed in specimen is subjected to the combined effect of pouring temperature, pulse width modulation and time of vibration. An improvement of 20% is seen with the combined effect of 900˚ C temperature, 50% pulse width modulation and time of vibration as 6 sec with as cast specimen.

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C. Impact Strength

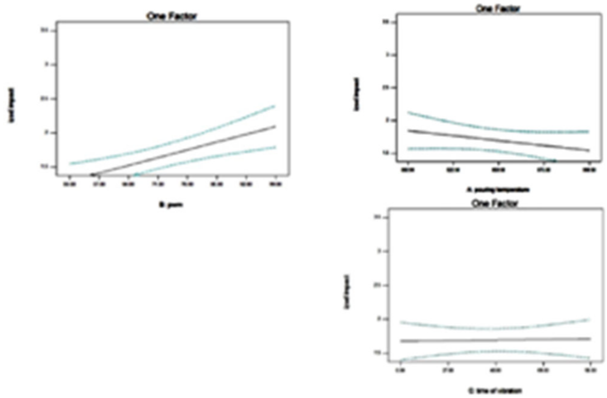

Fig 8.Graphical chart of Izod impact

Fig 8. Shows that the impact strength value of the specimens under electromagnetic vibration process. It is observed that the value decreased when the increase in the pouring temperature and decrease in vibration time. Compare all the result values conclude that the hardness property is inversely proportional to the impact strength.

D. Density Test

Fig 9. Shows that the density value maintains at constant during change in pulse width modulation. So only depends upon two variables the density value changes slightly. There is no major change in the density when varying the process parameters.

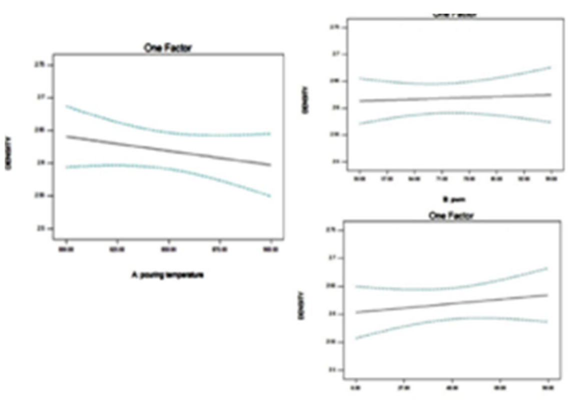

Fig 9.Graphical chart of Density

V Applications

The enhancement of mechanical properties due to the Electromagnetic vibration during the process of solidification has been widely applied in aerospace, automobile and industrial products. The composite materials are used in marine applications such as the construction of hull, connecting rod, and so on.

VI Conclusion

The experimental result shows that the grain refinement of A 360 is more effective when it is treated electromagnetically compare as cast specimen without vibration. Applying vibration to the solidifying A 360 alloy leads to microstructural changes to both the dendritic structure and growth of eutectic silicon. Vibration successfully broke the dendritic structure into small islands of Aluminum. Inducing vibration also resulted in fragmentation of silicon needles and uniform distribution of silicon flakes resulting in improved properties. Result show that the 20% hardness value is high and more effective when it is treated 50% of pulse width modulation with pouring temperature of 900°C for 6 sec.

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