

Investigation of Microstructural Features and Mechanical Properties of Al - Si Alloys (LM-13) by Horizontal Centrifugal Casting Process

Prof. J.V. Patel¹, Dr. V.B. Patel²

¹Assistant Professor, Mechanical Engineering Department, Ganpat University-U. V. Patel College of Engineering, Kherva, Gujarat – 384012, INDIA

²Professor, Mechanical Engineering Department, L. E. College, Morbi, Gujarat – 363642, INDIA

ABSTRACT - This paper attempts to investigate the effect of mold rotational speed, pouring temperature and melt treatments (with & without grain refinements and with & without modifier) on the mechanical properties and microstructural characterization of aluminium-silicon eutectic alloy (LM-13) cast by horizontal centrifugal casting process. Cast sample were tested for tensile testing, hardness and wear studies with microscopic examination. Results shows improvements in mechanical properties with melt treatment. Optimum process parameters were discussed to get maximum properties in existing examination work.

Keywords: Al-Si alloy, Al-Ti-B grain refiners, Al-Sr modifier, Horizontal Centrifugal Casting, Tensile properties, Hardness properties.

1. INTRODUCTION

Within the last few years there has been a rapid increase in the utilization of aluminium-silicon alloys, particularly in the automobile industries, due to their high strength to weight ratio, high wear resistance, low density and low coefficient of thermal expansion. Aluminium and its alloys are extensively used as the materials in transportation (aerospace and automobiles), engine components and structural applications [1]. Thus it becomes all the more vital to study the tribological characteristics of Aluminium and its alloys. Addition of Silicon to Aluminium gives high strength to weight ratio, low thermal expansion coefficient, and high wear resistance. These alloys also show improved strength and wear properties as the silicon content is increased beyond eutectic composition. Such properties warrant the use of these materials as structural components in automotive industries [2].

The commercial usage of aluminium-silicon alloys promises much larger business opportunities than the aluminium itself due to the sheer size of tribological applications. The tribological properties of Al-Si alloys are affected by shape and distribution of silicon particles, and addition of alloying elements such as copper, magnesium, nickel, and zinc often combined with a suitable heat treatment [3-5].

B. Suarez-Pena et. al. [6] studied Microstructure and mechanical property developments in Al-12Si gravity die castings after Ti and/or Sr additions. The best mechanical values were obtained when both grain refiner and grain modifier were present, in particular for the experimental composition with the higher Ti/Sr ratio. Prashantha Kumar H.G. et. al. [7] was Synthesis and characterization of Al-Si Alloy. They suggested that mechanical properties and wear resistance are increases marginally with increase in rotational speed. Mechanical properties and tribological properties of Al-Si cast alloys depend not only on chemical composition but, more important, on micro structural features such as morphologies of dendrite α -Al, eutectic Si particles and other inter-metallic that are present in the microstructure. However further studies are needed to have a deeper understanding of the relationship between mechanical properties, tribological properties and phases present in the aluminum alloys. The aim of the present work is to study the effect of casting variables of centrifugal casting process on mechanical properties and tribological properties of eutectic Al-Si alloy.

2. EXPERIMENTAL

The materials used for castings was a commercial LM 13 alloy with the following chemical composition (weight %)

Table – 1: Chemical composition of eutectic aluminium silicon alloy (LM 13)

Material	%
Si	11.980
Fe	0.750
Cu	1.040
Mn	0.390
Mg	1.460
Zn	0.250
Ni	1.120
Ti	0.020
Pb	0.030
Sn	0.020

Cr	0.010
V	0.010
Co	0.010
Al	Balance

Horizontal centrifugal casting was carried out at different parameters like pouring temperature, mold rotation speed and melt treatment were varied in range given in table

Factor	Name	Levels		
A	Pouring Temp	700	750	800
B	Mold Rotation Speed	750	900	1050
C	Melt Treatment	1	2	3

In melt treatment1 = Cover Flux+ Degassing

2 = Cover Flux + Degassing

Tablet + Grain Refiner

3 = Cover Flux + Degassing

Tablet + Grain Refiner + Grain

Modifier

2.1. Plan of Experiment

The experiments were conduct as per the standard orthogonal array. The selection of the orthogonal array is based on the condition that the degree of freedom for the orthogonal array should be greater than or at least equals sum of those of casting parameters. In the present investigation an L9 orthogonal array was chosen as shown in table.

Table - 2 L₉ Orthogonal Array

Sample ID	Pouring Temp (°C)	Mold Rotation Speed (rpm)	Melt Treatment
J1	700	750	1
J2	700	900	2
J3	700	1050	3
J4	750	750	2
J5	750	900	3
J6	750	1050	1
J7	800	750	3
J8	800	900	1
J9	800	1050	2

Figure 1 shows the horizontal centrifugal casting machine setup. The mold dimensions were shown below and mold was made of Cast-Iron. Metal was poured into the mold through tundish. Size: O.D = 160 mm. I.D = 100 mm. Length = 195 mm.



Fig.- 1 Horizontal Centrifugal Casting Machine Setup

2.2. Melting Practice

LM13 alloy was melted in induction furnace. The metal charge was melted under cover flux followed by degassing with 1 % hexachloroethane tablet. After fluxing & degassing, melt was grain refined by 1 % Al-3Ti-B and modified by 0.3% Al-10%Sr master alloy. After holding for 10 minutes, dross was removed & melt was ready to pour. Measurement of melt temperature was carried using immersion of thermocouple [8]. Thermocouple was calibrated to ensure accuracy of temperature measurement, after the melt attained the require melt temperature, the metal was poured into the horizontal centrifugal casting mold.

Before every casting, the mold was thoroughly cleaned with emery paper in order to remove mold coating and rust. It was followed by coating the preheated mold (heated up to max. 300°C) with DYCOAT 36 based graphite slurry coating. Just before casting, mold was heated to about 200°C.

2.3. Tensile Test

Tensile tests were carried out for outer section of all specimens. Tensile samples of 25 mm gauge length and 5 mm gauge diameter were prepared from Al-Si alloys. Samples were extracted from the central region of the castings. Tensile tests were conducted at room temperature on tensometer.

2.4. Hardness Measurement

The hardness values of the sample were determined using the Rockwell hardness tester on "B" scale with

1/16" inch steel ball indenter along with minor load of 10 kg and major load of 100 kg.

2.5. Preparation of Microstructure

Sample for microstructural studies cut from castings and were polished by using a series of emery papers from 1/0, 2/0, 3/0 and 4/0 grade. After specimen polished on emery papers finally polished on SYLVET cloth using fine alumina powder. Polished samples were etched with

killer's reagent. For microstructural study optical microscope was used according to standard E 562.

3. RESULTS AND DISCUSSION

Table 3 shows experimental parameters and results of mechanical properties of horizontal centrifugal casting of LM13.

Table -3 Result of Mechanical Properties

Sample ID	Pouring Temp(°C)	Mold Rotation Speed	Melt Treatment	Ultimate Tensile Strength (N/mm ²)	Elongation (%)	Location of Fracture	Hardness (HRB)		
							Inner	Middle	Outer
J-1	700	750	F+D	178.85	1.11	On GL	39	41	44
J-2	700	900	F+D+G	188.55	2.22	On GL	41	42	43
J-3	700	1050	F+D+G+M	193.67	0.74	On GL	42	44	45
J-4	750	750	F+D+G	173.31	1.38	On GL	39	40	42
J-5	750	900	F+D+G+M	188.34	0.70	On GL	41	43	45
J-6	750	1050	F+D	183.40	0.50	On GL	40	42	45
J-7	800	750	F+D+G+M	185.16	0.65	Within GL	42	43	44
J-8	800	900	F+D	162.70	0.90	Out GL	38	39	42
J-9	800	1050	F+D+G	187.10	0.76	On GL	41	42	44

3.1. Mechanical Properties of Castings:

3.1.1. Effect of pouring temperature on mechanical properties of centrifugal castings:

Three pouring temperatures have been tried for present experimental work; i.e. 700°C, 750°C and 800°C. It was not possible to try with lower pouring temperature than 700°C as melt started becoming sluggish below this temperature and castings used to get associated with cold shuts.

The mechanical properties of Horizontal centrifugal castings were seen to have its higher value when cast at 700°C as pouring temperature compared to that of castings poured at 750°C and 800°C temperature. In all the speeds of mold rotation, the higher values of hardness and tensile strength were achieved at pouring temperature of 700°C and lower values were seen at 800°C as pouring temperature. The reasons for these observations became clear from microscopic examination of castings. The volume fraction of eutectic was found to be higher in general in castings poured at 700°C compared to the casting made with pouring temperature of 750°C and 800°C. Furthermore, the castings cast at

700°C have higher rate of solidification leading to lower dendrite arm spacing under directional mode of solidification known to eliminate micro porosity under influence of centrifugal force. This also gives rise to lower level of segregation of micro constituent which ultimately contributes towards higher mechanical properties of centrifugal castings in general, at lower pouring temperature of 700°C as against the pouring temperature of 750°C and 800°C.

3.1.2. Effect of speed of mold rotation on mechanical properties of centrifugal castings:

It is observed that mechanical properties increased with increasing speed of mold rotation within the experimental range of mold rotation which was 750,900 and 1050 rpm. In this case with rpm less than 700, the castings were found to be associated with cold shuts and at rpm above 1050 rpm castings tended to tearing. Hence the chosen range of speed of mold rotation was confined to 750,900 and 1050 rpm. Highest values of mechanical properties were observed at 1050 rpm in case of vertical centrifugal castings.

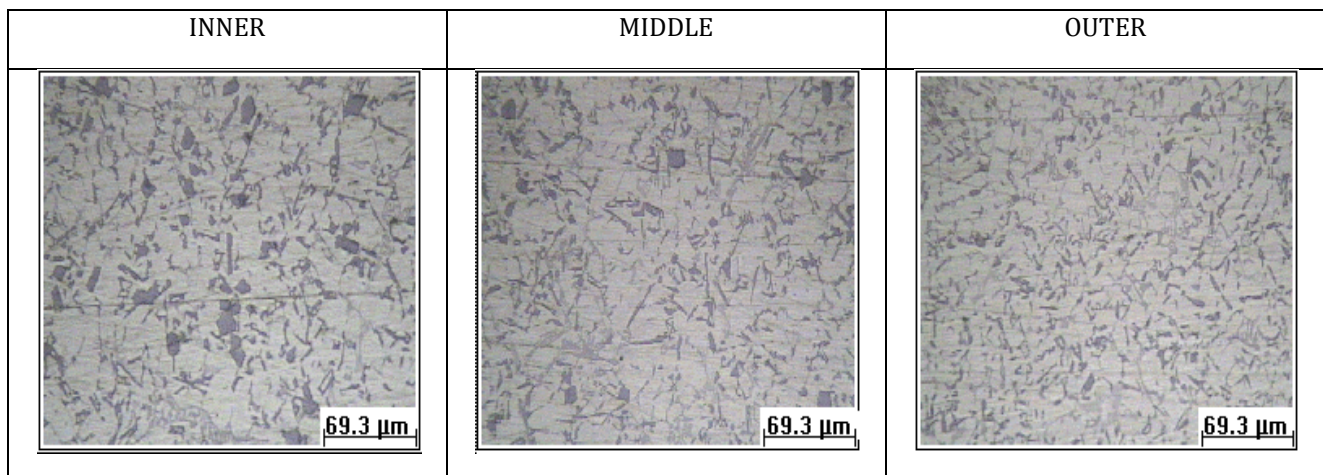
The increase in mechanical properties with increasing speed of mold rotation is clearly seen in the microstructural features of the castings. In general volume fraction of primary Si and α -Al is seen to be higher in inner casting surface and lowest at the outer surface of centrifugal castings with higher percent of eutectic being higher in outer casting surface with its lower volume fraction being in the inner casting surface with increasing speed of mold rotation. This explains the reason why increased values of mechanical properties are seen in general in centrifugal castings with increasing speed of mold rotation [9].

3.2. Microstructural Properties of Castings:

Figure 2 shows that with the increased rotational speed to 1050 rpm & 700°C as pouring temperature, the

solidification rate increases. Due to higher rate of solidification, the whole structure is seen like fine eutectic. At 1050 rpm & 700°C pouring temperature, primary silicon is found in inner section of cylinder and coarse eutectic structure is seen, as can be seen in figure (J-3). With the increasing rotational speed to 1050 rpm, the solidification rate increases due to increased centrifugal force on solidifying melt leading to better casting- mold contact and faster movement of solidification front from outer surface of casting to inner surface. As a result, fine structure is observed with lower percentage of α -aluminum dendrites compared to lower mold rotational speed. The finer eutectic structure of the casting is observed to decrease from outer to inner region.

Figure 2 for J-3 sample [HCC, Pouring Temp. 700°C, RPM-1050, (F+D+G+M)]



4. CONCLUSIONS

Al-Si eutectic alloy (LM-13) has been cast by horizontal centrifugal casting technique with varying pouring temperature, mould rotational speed and melting treatments. The effect of these parameters on rate of solidification and thus morphology of microstructures has been studied and also investigated for mechanical property. After analyzing the results, following conclusions can be drawn.

1. There exists an optimum pouring temperature (700°C) and an optimum speed of rotation of mould (1050 rpm) under given experimental conditions which result in optimization of good characteristics mechanical property (Tensile Strength & Hardness) of the casting.
2. Improved mechanical properties were found in Al-Si alloys when 1.0% Al-1Ti-3B master alloy

and 0.3% Al-10Sr master alloy were added to the melt.

3. Addition of 1.0% Al-1Ti-3B master alloy to LM-13 alloy changes coarse columnar α -Al dendrites to fine equiaxed α -Al dendrites.
4. Combined addition of grain refiner (1.0% Al-1Ti-3B master alloy) and modifier (0.3% Al-10Sr master alloy) resulted in simultaneous grain refinement and modification of LM-13 alloy. Grain modifier changes plate-like eutectic silicon into fine particles.

REFERENCES

- [1] Elwin L. Rooy "Introduction to Aluminum and Aluminum Alloys" ASM Handbook Vol-02.
- [2] Srivastava V.C, Mandal R.K, Ojha S.N, "Evolution of microstructure in spray formed Al-18%Si

- alloy”, *Materials Science and Engineering, Vol- A* 383 (2004), pages-14-20.
- [3] Yang C.Y., Lee S.L., Lee G.K., Lin J.G., Effect of Sr and Sb modifiers on the sliding behaviour of A357 alloy under varying pressure and speed conditions, *Wear*, 2006, 261, p. 1348-1358.
- [4] Harun M., Talib I.A., Daud A.R., Effect of element additions on wear property of eutectic aluminium-Silicon alloys, *Wear*, 1996, 194, p.54-59.
- [5] Dwivedi D.K., “Wear behaviour of cast hypereutectic aluminium silicon alloys, Mater”
- [6] B. Suarez-Pena and J. Asensio-Lozano, “Microstructure and mechanical property developments in Al-12Si gravity die castings after Ti and/or Sr additions”, *Materials Characterization* 57 (2006) 218-226.
- [7] Prashantha Kumar H.G, Mohan Kumar. S. & Keerthiprasad K.S., “Synthesis and Characterisation of Al-Si Alloy”, *Global Journal of Researches in Engineering Mechanical and Mechanics Engineering* Volume 13 Issue 6 Version 1.0 Year 2013.
- [8] Juan Asensio-Lozano, Beatriz Suarez-Pen, “Effect of the addition of refiners and/or modifiers on the microstructure of die cast Al-12Si alloys”, *Scripta Materialia* 54 (2006) p.943-947.
- [9] Madhusudhan, Narendranath S, G C Mohan Kumar “Properties of Centrifugal Casting at Different Rotational Speeds of the Die”, *International Journal of Emerging Technology and Advanced Engineering*, Volume 3, Issue 1, January 2013