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Study of Functionally Graded Al-Si Alloy Fabricated by Centrifuge Casting Technique

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ABSTRACT

Functionally graded materials are plays very important role in engineering and other applications. They are class of designed materials described by a spatial variety of organization and microstructure going for controlling comparing utilitarian properties (i.e. mechanical, thermal, electrical, etc). In this paper describes comparison of FGMs of Al-Si alloys fabricated through centrifuge casting technique. Al-Si alloys are characterized good strength, less weight, low corrosive and wear resistance, good weldability etc. Here we are fabricating Al-12%Si and Al-18%Si alloys through centrifuge casting (vertical centrifugal technique) for different pouring temperature of molten metal and constant mould rotation speed. For that we conclude results based on varying the addition of silicon percentage in base metal and increases pouring temperature, for that we got better mechanical properties and good microstructure features. These alloys are useful wherever good strength, light weight of materials is required.

Key Words: *Centrifuge Casting, Al-Si Alloy, Pouring Temperature.*

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1. INTRODUCTION

"Functionally Graded Materials (FGMs) are a class of engineered materials characterized by a spatial variation of composition and microstructure aiming at controlling corresponding functional properties (i.e. mechanical, thermal, electrical, etc.)". This material shows steady progress in the microstructure as well as the composition in a definite way, the presence of FGMs, which prompts variety in useful execution inside the part through micro structural control [1]. In FGMs, the microstructure and composition fluctuate easily in space and the properties and execution performance will change from one end of the object to the other. Because of the slow variation of composition and microstructure, it maintains a strategic distance from an unexpected interface which gives smooth progress from one side to the other, local stress concentration will be avoided [2]. In this work centrifuge casting technique is used to fabricate Al-Si alloy, it has the large field of industrial application. This casting technique is normally used to create valve bodies and hoods, plugs, yokes, sections and a wide assortment of different mechanical castings. In this method centrifugal force can be utilized to make a slope creation in a metallic melt that contains another strong stage. Generally there are two different centrifugal methods for fabricating FGMs based on melting temperature of reinforcement particle.
Centrifuge casting set-up is a modified version of centrifugal casting set-up, it is purely based on centrifuge technique. This casting set-up is mainly consisting of an arm, which is centrally mounted on 0.5 HP capacity of motor shaft. One end of arm is

fixed by mould which is allowed to swing and other end is fixed by counter weight to balance the mould weight it shown in figure 1.1.

Permanent mould is used in centrifugal casting which is rotated about its axis at high speed to produce cylinder, it is an effective method to obtaining composite materials but it requires several processing parameters [3]. Processing parameters are arm rotation speed, pouring temperature of molten metal and centrifugal force.

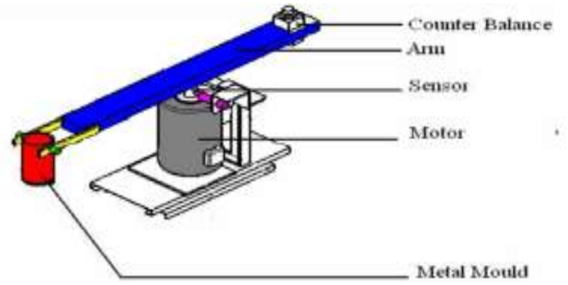


Figure 1.1 centrifuge casting set up

Position of reinforcement is usually depends on the 'G' number during solidification. Where 'G' is a centrifugal force magnitude which is given by,

$$G = \frac{(\omega^2 \times r)}{g}$$

Where,

ω = Arm rotational speed in rad/sec,
r = Radius of arm in meter,
g = Acceleration due to gravity and
G = Centrifugal force magnitude.

2. EXPERIMENTAL PROCEDURE

A. Material Selection

Nowadays Aluminum alloy usage is more in automotive industries because these alloys have high specific toughness, high specific modulus, good strength, good machinability and good wear properties. That is the reason for using these alloys in production of automotive component to save the fuel usage, improve the economy and cost. In this alloy Aluminum is base metal and other metals like Si, Cu, Mg, Mn, Fe, Zn etc. are the alloying elements. From alloying elements percentage of silicon content is more in present study. Al-Si alloys have wide range of applications like automobile industries, bearings, piston, piston heads, gears, etc. and it is light weight, having high particular quality, coefficient of thermal expansion is low, great mechanical properties, good erosion protection and good heat exchanging capacity. Al-Si alloys are used wherever friction and wear are plays important role.

Present study we selecting two materials first one is LM6 material (Al-12%Si) and second one is Al-18%Si alloy. By using of this material fabrication process is carried through centrifuge casting and evaluates the mechanical properties of all castings and comparing result to each other. Chemical composition of LM6 material is shown in table number 2.1 and chemical composition of Al-18% Si alloy is shown in table number 2.2

Table 2.1 Chemical composition of LM6 (Al-12%Si) alloy

Element	Si	Mg	Sn	Ti	Mn	Fe	Ni	Cu	Zn	Pb	Al
Percentage (max %)	11-13	0.1	0.05	0.2	0.5	0.6	0.1	0.1	0.1	0.1	Remaining

Table 2.2 chemical composition of Al-18%Si alloy

Chemical name	Percentage (max %)
Si	18
Fe	0.2
Al	Remaining

B. Methodology

Different combinations of Al-Si alloys are fabricated by centrifuge casting starts with Al-12%Si alloy and next one is Al-18%Si alloys. These two alloys are fabricated and different testing's are carried. In this technique processing parameters are plays very important role which are pouring temperature (750^{0}c and 850^{0}c) and arm rotational speed (200 rpm). Initial step is start with selecting of alloy material (Al-12%Si or Al-18%Si) and weigh with help of electrical weighing machine, take required amount of material to cast. Then Kept material inside the furnace to melt and set suitable temperatures (750^{0}c and 850^{0}c). Once that temperature is reached molten metal is ready to pour, before going to cast initial set up of centrifuge machine is carried, after that mould is fixed to one end of arm and other end is fixed with counter weight to balance, check once all the wired connections etc. Once initial set up is ready then molten metal will pour in to mould with a help of tongue, immediately after pouring set motor rotation speed up to 200 rpm and leave it for few minutes. Due to rotation of arm centrifugal force creates towards axis of rotation, due to silicon particles are light weight which comes towards top region of casted specimen, after casting process remove casting specimen from mould, repeat this process for different alloys for different pouring temperature figure 2.1 and figure 2.3 shows material before casting and after casting.

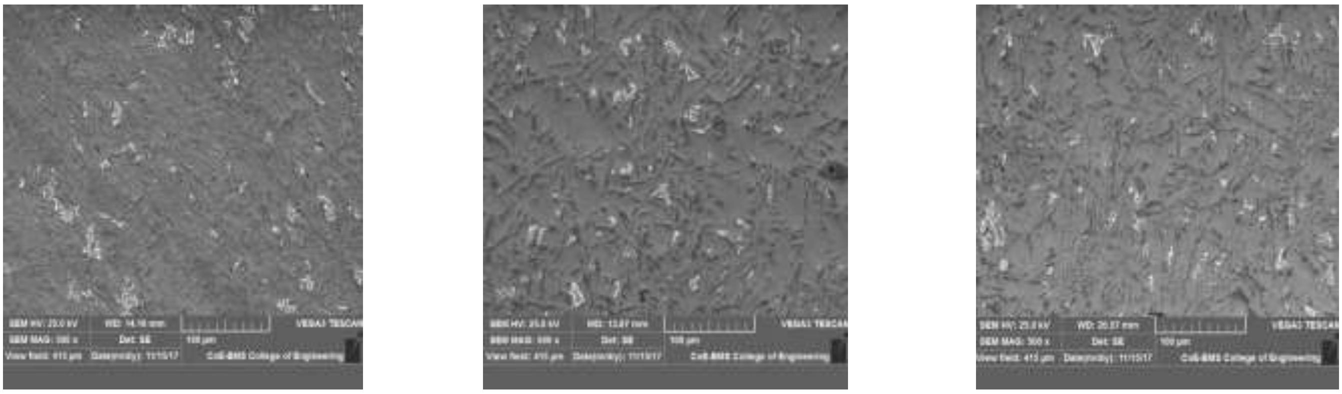
Figure 2.1 materials before casting

Figure 2.2 material after casting

Once all castings are prepared then next step is to testing all specimens, in testing part it is necessary to determine mechanical properties like tensile, hardness and wear and also we are studying the microstructural features of casted specimens. Microstructure images are obtained from SEM test (Scanning Electron Microscope). These all tests are discussed in result and discussion section.

3. RESULTS AND DISCUSSION

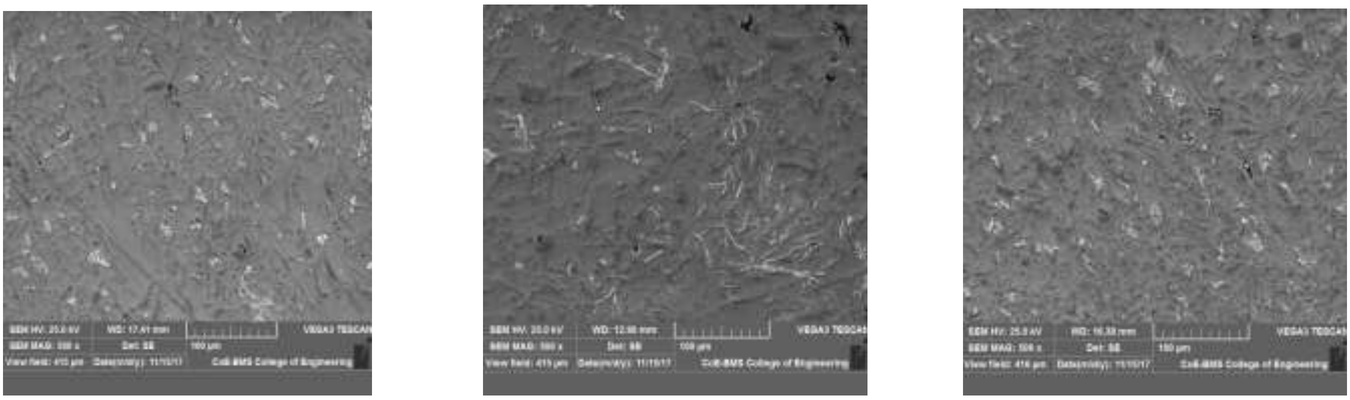
A. SEM analysis



Bottom region **Middle region** **Top region**

Figure 4.1 Microstructure of Different Region (LM6 Material Or Al-12%Si, 750^0 C Pouring Temperature)

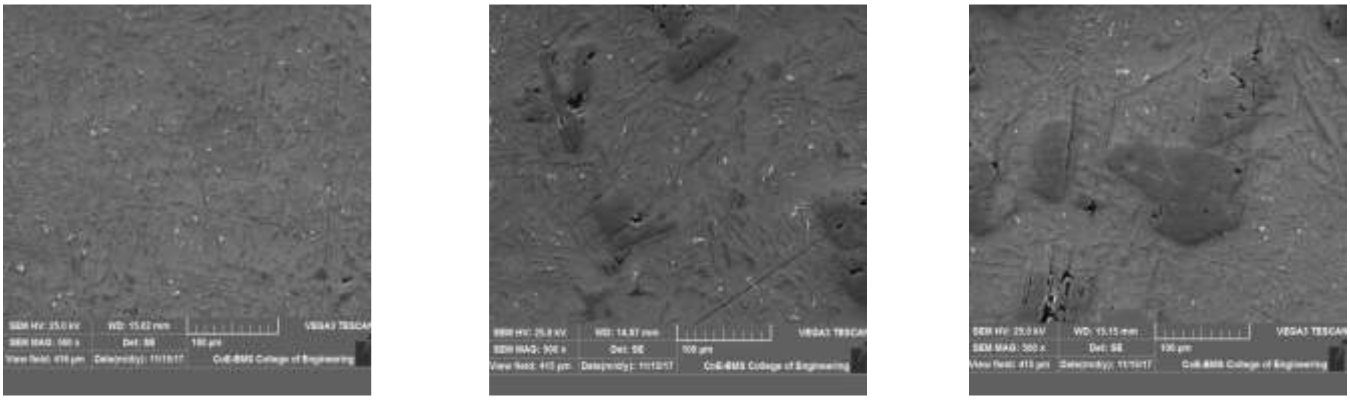
Above figure 4.1 shows microstructure images of different regions of LM6 (Al-12%Si) material obtained from SEM testing under 750^{0}c pouring temperature. In figure it shows clearly, silicon percentage is increased from bottom to top region due to action of centrifugal force.



Bottom region **Middle region** **Top region**

Figure 4.2 Microstructure of Different Region (LM6 Material Or Al-12%Si, 850^0 C Pouring Temperature)

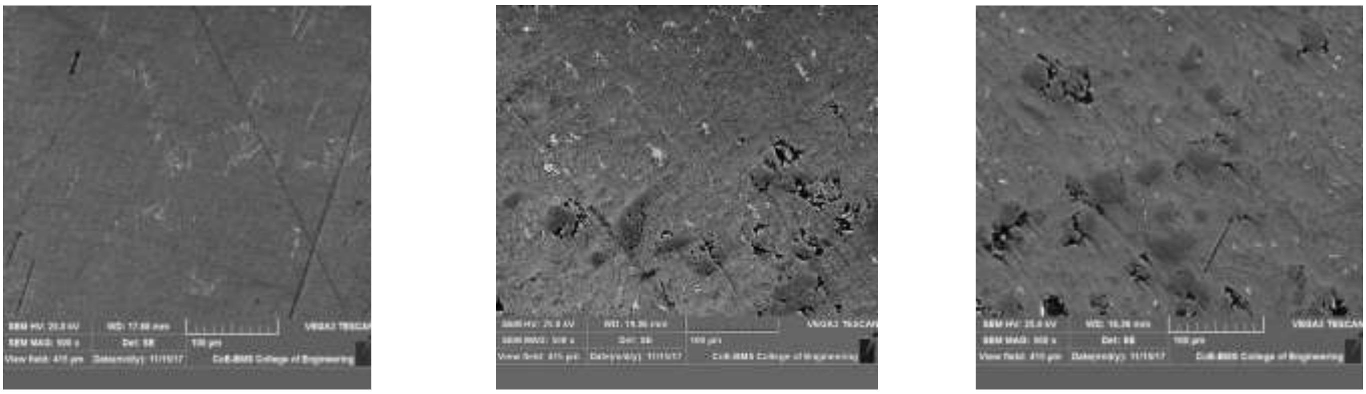
Above figure 4.2 shows microstructure images of different regions of LM6 (Al-12%Si) material obtained from SEM testing under 850^0c pouring temperature. In figure it shows clearly, silicon percentage is increased from bottom to top region due to action of centrifugal force. Difference between figures 4.1 and 4.2 is primary silicon is more at top region in figure 4.2, if we increased pouring temperature we get better results.



Bottom region **Middle region** **Top region**

Figure 4.3 Microstructure of Different Region (Al-18%Si Material, 750^0 C Pouring Temperature)

Above figure 4.3 shows microstructure images of different regions of Al-18%Si material obtained from SEM testing under 750^0c pouring temperature. In figure it shows clearly, silicon percentage is increased from bottom to top region due to action of centrifugal force. Primary silicon is more on top region and silicon particles are distributed uniformly



Bottom region **Middle region** **Top region**

Figure 4.4 Microstructure of Different Region (Al-18%Si Material, 850^0 C Pouring Temperature)

Above figure 4.4 shows microstructure images of different regions of Al-18%Si material obtained from SEM testing under 850^0c pouring temperature. In figure it shows clearly, silicon percentage is increased from bottom to top region due to action of centrifugal force. Primary silicon is more on top region and silicon particles are distributed uniformly. Comparing both 4.3 and 4.4

figures, 850^{0}c pouring temperature specimen provides better microstructure and primary silicon content is more on top region as compared to fig. 4.3

B. Tensile test

With the help of electronic tensometer, tensile tests are carried for different Al-Si alloy and pure Aluminum. From the test results it shows that there is increment in UTS (Ultimate Tensile Strength) as the silicon percentage increases in Aluminum matrix. Figure 4.5 shows the incremental of UTS from pure Aluminum to alloys of Al-12%Si and from Al-12%Si to Al-18%Si alloys there is increment in UTS. Also it is clear that as we increased pouring temperature from 750^{0}c to 850^{0}c for all materials, we get results of incremental in UTS as shown in figure.

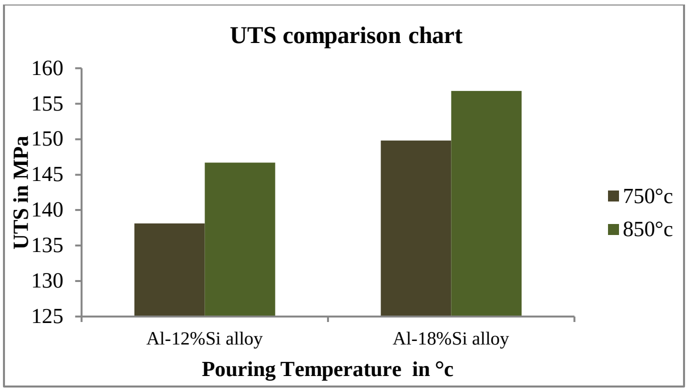


Figure 4.5 UTS Comparison Chart for Tensile Property

C. Hardness test

Hardness is an important property of material, hardness test for different alloy castings are carried at Brinell Hardness Testing machine and results are tabulated in this section. For LM6 (Al-12%Si) alloy the hardness value is increased from bottom to top and for increasing in pouring temperature, there is increment in hardness value. Related graph for both temperatures is shown in figure 4.6. It shows that incremental in silicon percentage results in an increase hardness of material. For Al-18%Si alloy hardness is increased from bottom to top region for both temperature readings is shown in figure 4.7 For comparing both alloys i.e. Al-12%Si and Al-18%Si, here Al-18%Si alloy is harder.

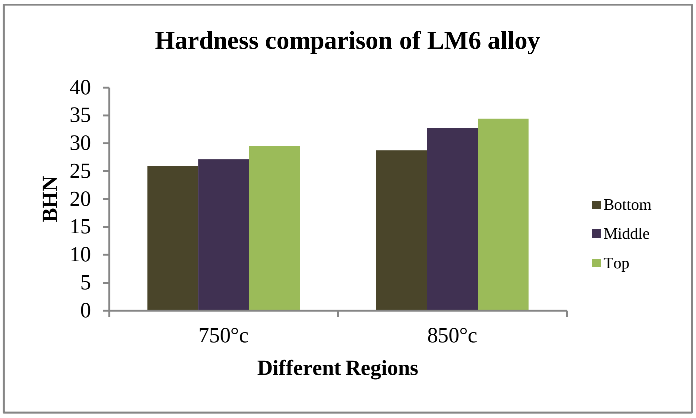


Figure 4.6 BHN Comparisons for LM6 (Al-12%Si) Alloy

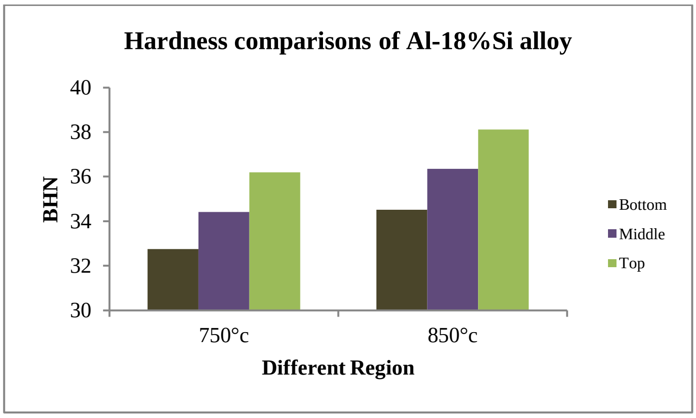


Figure 4.7 BHN Comparisons for Al-18%Si Alloy

D. Wear test

Wear test for different Al-Si alloys samples are carried at pin on disc tribometer set up and the results are tabulated, which reveals that wear decreases as percentage of silicon increases. Figure 4.8 shows clear evidence of wear properties of different samples, wear rate is more for Al-12%Si alloy and less for Al-18%Si i.e. wear property comparison chart for Al-Si alloys. These results conclude that as the percentage of silicon increases, wear decreases.

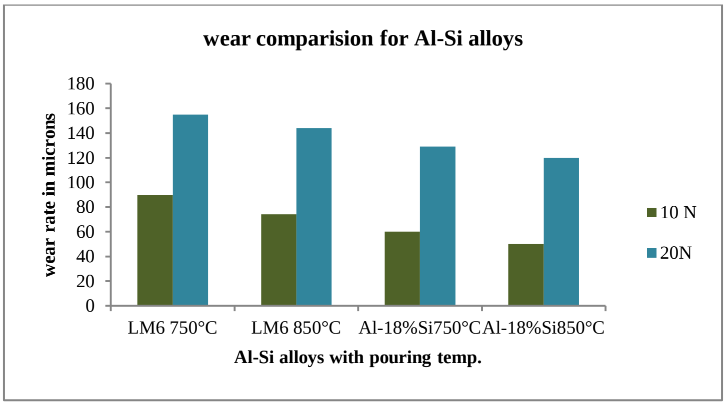


Figure 4.8 Wear Property Comparison Chart for Al-Si Alloys

4. CONCLUSION

Once all results are analyzed following conclusions can be drawn.

- Percentage of silicon is increases results in increasing mechanical properties. In tensile test we observed that improved UTS were found from LM6 alloy to Al-18%Si alloys.
- With the increase in addition of Si percentage in base metal and increase in pouring temperature, composite revealed an increase in hardness and decrease in ductility.
- Wear rate is decreases as we increased addition of Si percentage as well as pouring temperature.
- Microstructure analysis revealed homogeneous distribution of Si particle in top region of casting, as increased in addition of silicon percentage and pouring temperature.
- Increase in pouring temperature of molten metal (750°C to 850°C), results in primary silicon particles are more at top region of casting which is shown in microstructure.
- Finally conclusion can made that, as the percentage of Silicon is increases up to some level, then composite gives better mechanical properties when compared to pure Aluminum, which helps to full filling many applications where better strength is required.

5. REFERENCES

[1] M. N. D. Saiyathibrahim.A, "Processing Techniques of Functionally Graded Materials – A Review," in International Conference on Systems, Science, Control, Communication, Engineering and Technology 2015 [ICSSCCET 2015], Coimbatore, India, 2015.

[2] Kiran Aithal, Narendranath, Vijay Desai, and P G Mukunda, "Effect of L/D Ratio on Al-Si Functionally Graded Material cast through Centrifuge Technique," Trans Tech Publications, Switzerland, vol. 213 (2011), pp. 281-285, 2011.

[3] Madhusudhan, Narendranath S , G C Mohan Kumar NMIT Bangalore, "Properties of Centrifugal Casting at Different Rotational Speeds of the die.," International Journal of Emerging Technology and Advanced Engineering, vol. 3, no. 1, pp. 2250-2459, 2013.

[4] Anirudh Biswas, D.K. Bhalla and Manoj Kumar, Research Scholar, "TO STUDY THE MECHANICAL PROPERTIES OF SILICON (18%) BASED ALUMINIUM ALLOY," Bookman International Journal of Mechanical and Civil Engineering, vol. 2, no. 1, 2013.

[5] Neelima Devi. C , Mahesh.V and Selvaraj. N. "Mechanical characterization of Aluminium silicon carbide composite," INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH, DINDIGUL, vol. 1, no. 4, pp. 793-799, 2011.

[6] M. P. &. M. D. Jonathan A. Lee. NASMMarshall Space Flight Center (MSFC), "Cast Aluminum Alloy for High Temperature Applications," The Minerals, Metals & Materials Society, , Huntsville, AL 35812 USA, 2003.