Experimental Investigation of Mechanical Properties of AL 7178 Metal Matrix Reinforced with Silicon Carbide

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Abstract - Aluminium Metal matrix reinforced within silicon carbide (sic) particles are being used for a high-performance application such as automotive, aerospace, military, electrical industries and marine industries.

In the current paper aluminium alloy 7178 was taken as base metal (matrix) and silicon carbide was selected as reinforcement. Silicon carbide (sic) powder of approximately 40µm particle size was reinforced in an aluminium alloy matrix to produced composites with 3%, 6%, 9% and 12% of silicon carbide weight percentage through stir casting technique. The. fabricated composite specimen was subjected to a series of tests to evaluate the mechanical properties such as Tensile strength, Hardness and microstructures were studied under optical microscope and dispersion of the reinforced particle in the Al 7178 metal matrix.

It was observed from the results that effect on mechanical properties as Tensile strength and Hardness with the various weight percentag of reinforcement particles in the aluminium matrix. It is observed from microstructure that distribution of reinforcement particles in aluminium matrix is fairly uniform.

Keywords: Aluminium 7178 alloy, silicon carbide, metal matrix and stir casting process.

I. INTRODUCTION

With the growth of science and Technology, there is required for advanced Engineering materials which are metal matrix for high-performance application such as aerospace, automotive, electrical, military and marine. Metal matrix is a combination of Al 7178 metal (matrix) and hard particle (Reinforcement) to enhance mechanical properties. Aluminium alloy with discontinuous ceramic reinforced MMC is replaced by conventional metal matrix have high strength, lightweight and higher corrosion resistance. Aluminium alloy Particularly metal matrix have Tensile strength increases with increase in reinforcement particles size 40µm, the percentage of elongation and percentage of reduction area decreases with increase silicon carbide. Stir casting is one of the promising liquid metallurgy technique used to fabricate the composites, This process is simple and applicable for large quantity of production and development of aluminium matrix composites.

II. LITERATURE REVIEW

Metal are casted by stir casting process with various wt % of 5%,10%,.15% and 20% of silicon carbide particle with aluminium 7178. It is observed that Tensile strength of the composite material increases with increasing weight % of SiC and homogeneous dispersion of SiC particle in the Al matrix [1]. A359.1 aluminium was reinforced with silicon carbide with different wt % of SiC (o,5,10,15) of sample. The hardness of the MMC increased with addition of SiC and maximum hardness achieved at wt of 15% [2]. Aluminium metal matrix is reinforced with wt of 4%Cu and 5% SiC composites are produced by stir casting process, there mechanical properties like Tensile strength and Hardness improved[3]. Al6061 is a metal matrix and multiwall carbon (MWCNT) as reinforcement for metal matrix composites were produced by stir casting process Techniques, its hardness increased and micrograph shown strong bond between matrix and reinforcement[4]. Aluminium alloy (A536 and 6061) reinforced with various volume fraction of SiC produced by gravity casting method. It is observed that increasing SiC with increased Tensile strength, hardness, yield strength and impact strength decreased. The microstructural studies referred that uniform distribution of SiC particles in the matrix metal[5][6][7]. Al 7075 is used as matrix metal and wt % 0f Al_2o_3 is 20% and Si_3N_4 is 0.25% $ 0.75% as reinforcement composites are produced by stir casting method, here found that percentage of SiN4 is increased

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hardness of components is increased and Tensile strength is decreased.The microstructure is shown that grain boundaries, interdendritic network of Al_2O_3 and Si_3N_4 is distributed in matrix metal[8] [9][10]. AA 5083 metal matrix is reinforced with nano SiC by stir casting method using Design of experiments, The optimized value of the parameter are obtained at optimum value of hardness components [11]. Al 2024 metal is reinforced with molybdenum disulphite (MoS2) 1%, 2%, 3%, 4% $ 5% of wt% added. It is revealed that Tensile strength and hardness of components increased with increasing MoS2 up to 4% of weight and decreased further. The optimal micrograph shows that dispersion of the reinforcement in matrix [12]

Properties of Aluminium 7178 alloy (ASM data sheet) without reinforcement.

S no	Property	Metric system
1	Density	2.82g/ cm^2
2	Melting point Temperature	650°C
3	Tensile Strength	148Mpa
4	Yield strength	130Mpa
5	Elongation	10%
6	Poisson's ratio	0.33

III. OBJECTIVES AND METHODOLOGY OF WORK

A. Objectives

1. Selection criterion for Aluminium 7178 alloy as matrix and silicon carbide as reinforcement.
2. Preparation of stirrer.
3. Development of aluminium matrix composites.
4. Casting of Al-sic metal matrix composites with stir casting method.
5. Conducting Tensile test, Hardness test and microscopic analysis.

B. Methodology

Optimization composition of Al 7178 is obtained by Taguchi approach from the design of experiments. Al 7178 is reinforced with silicon carbide with different wt % of 3, 6, 9 and 12, cast with stir casting method. Casted sample was machined and tested for Tensile strength, hardness and microstructure.

IV. EXPERIMENTATION

4.1 Material

Present work composition of Aluminium 7178 alloy is shown in the table 1. This alloy is used as matrix Material with the Silicon Carbide material as reinforcement using Stir Casting Method. Table:1 shows chemical composition of Al 7178 alloy. Experiments were carried out the effect of settling the reinforcement material on Mechanical properties, Hardness and microstructure of metal matrix composites.

Table 1: Chemical Composition of Al 7178 alloy.

Elements	Zn	Mg	Cu	Cr	Si	Fe	Mn	Ti	Al
%	9.54	4.125	3	0.345	0.6	0.75	0.45	0.3	75.6

4.2 STIR CASTING PROCESS

For the melting of Al 7178 alloy to the required furnace, crucible, blower, coal and other materials. Here the furnace is heated up to 800c, melting point of aluminium 7178 is 650C .The melting was carried out in a clay-graphite crucible placed inside the resistance furnace is utilized for melting aluminium 7178 alloy and Sic, raising up to a 750oC temperature from the furnace to die and open hearth furnace is as shown in fig 1.

Fig: 1. Furnace for melting Al 7178 alloy

In this present study, aluminium alloy was reinforced with Silicon Carbide materials at different wt. % of 3%, 6%, 9% and 12% of Sic. It was produced using a Resistance furnace equipped to the stirring system, Stirring process was carried out at a constant speed of 100 rpm with a stirring duration of 10-15 min, and at casting temperature of 750±5°C. The mixing equipment for this stage consisted of a driving motor capable of producing a rotation speed within the range of 1oorpm. Balanced aluminium 7178 alloys were melted in a graphite crucible and at the same time the sic particle preheated in a muffle furnace set at temperature 900oC for approximately one hour to remove moisture surface impurities. The ceramic particle Sic was poured slowly and continuously into the molten metal and melt was continuously stirred at 100 rpm and preparing metal matrix composites by the stir casting method. Figure

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2 is shown a schematic diagram of the stir casting process.

A design and developed stirring set up shown in figure 2. Aluminium 7178 alloy was first heated 450oC before melting and added Sic powder. The furnace temperature was raised to 750oC to melt the matrix and Sic particle were added and mixed mechanically by the stirrer. Sic is used as reinforcement in the form of powder added to Al 7178 molten metal as matrix were mixed with rotating stirrer for 10 min. Now aluminium 7178 alloy was melted in a graphite crucible in open hearth furnace, mechanical mixing is carried out for about 10 min at normal speed 100 rpm and pouring temperature 750^{o}C. The composite slurry is poured into the desired die using required tools as shown as figure 5.

After some time, the molten alloy is solidified with room temperature. Now the specimen is removed from the die. This process is repeated for four trials adding various wt % of Sic 3%, 6%, 9%, and 12% and sample were shaped in the form of cylindrical rods of 25 mm diameter and 250mm length, solidified aluminium metal matrix composites are shown in figure 6.

Fig : Stir Casting tool

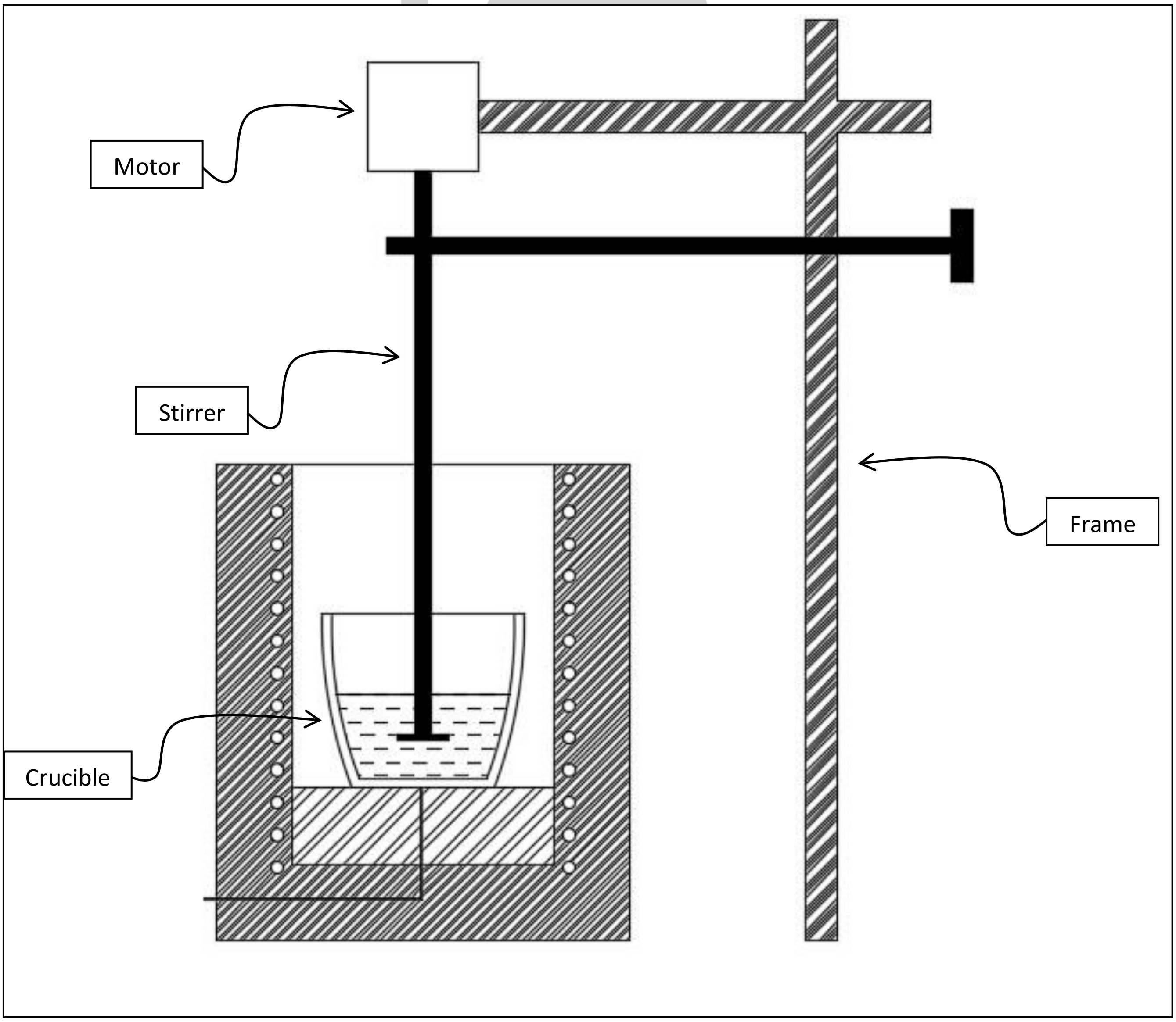

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Fig.2 Shows Schematic diagram of Stir Casting technique

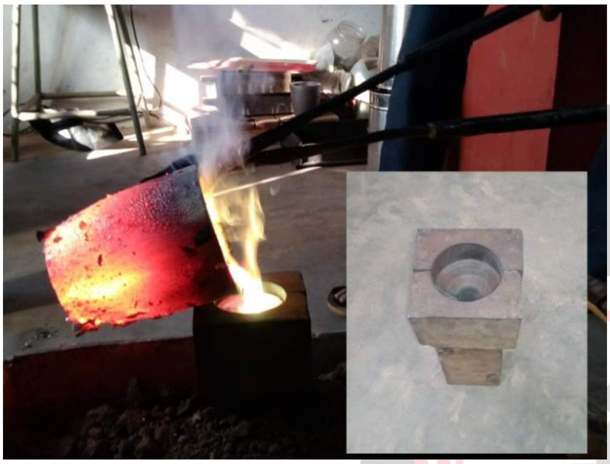

Fig 4. Stirring the molten aluminium alloy.

Fig 5. Pouring of Al 7178 alloy in required die

Fig 6. Al 7178 MMC

4.3. MACHINING

After the casting, machined according to ASTM (American Section of the International Association for Testing Materials) standards on highly sophisticated lathe.

a) For tensile test :

The tensile test uses specimens of 20 mm grip diameter, 50 mm grip length, 60 mm gauge length, 73 mm length of reduced cross-section, inner diameter of 12.5 mm and total length 200 mm and it is shown in the figure 7..

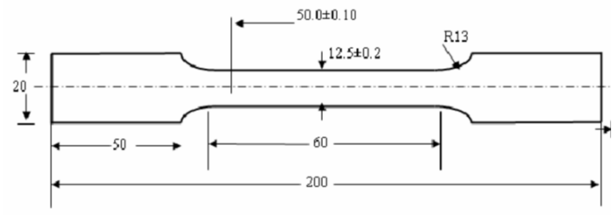

Fig 7. Dimensions of tensile test specimen.

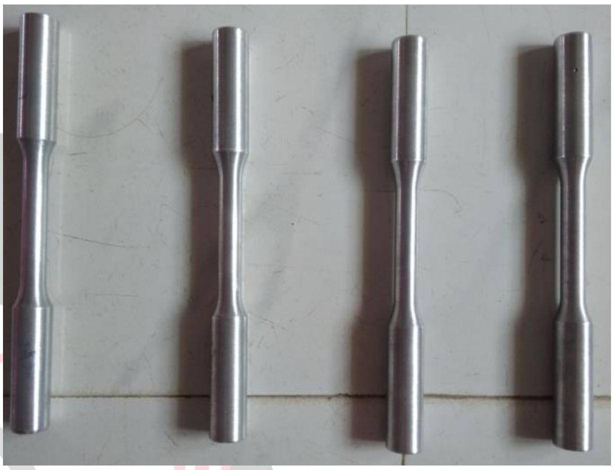

Fig 8: AMC. machined Specimens

b) For Hardness test :

c) For performing Brinnel hardness test , sample were extracted from defect-free surface region of the casted composites and minimum of three indentation were made on the sample at distance 5 mm using Brinnel hardness tester. The hardness test uses the specimen of 30mm diameter, 25mm length and it is shown in the figure 9.

Fig 9. Hardness test specimens

The microstructure test uses the small specimens which are placed in Bakelite powder by mounting press. with the dimensions of 10mm length and 15mm breadth as shown in fig 10.

- Cut the specimen into small pieces with the help of blade.
- Specimens are mounted in Bakelite powder by mounting press.

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- the specimen is filed by using belt grinding machine.
- After belt grinding, the specimen is again filed by using 80 to 1200 series emery papers.
- After the using of emery papers this specimen is again filing in the **9 micron** cloth to remove scratches of emery papers.
- This specimen is again polished by using **3 micron** cloth to remove scratches of 9 micron.
- Again polished the specimen used **1 micron** cloth to remove 3 micron scratches.
- Apply 9µ, 3µ, 1µ diamond paste to the cloth before filing.
- Clean the specimen every time of filing by acetone chemical and check whether it is clean or not.
- Finally the specimen polished by using kerosene (only for aluminium metals) to remove small scratches.
- Finally these specimen is cleaned by using the process of etching to remove final scratches in the specimen.
- Check the microstructure of specimen by using **Electronic Microscope (EM).**

Fig 10. Micro structure test specimens.

V Result and discussion

Following tests are carried out in this process

a) Tensile test

b) Hardness test

c) Microstructure

(A) TENSILE TEST

Tensile test measures the resistance of a material to a static or slowly applied force. Besides the true stress- true strain curve can also be determined with the help of the **tensile test**.

This test was conducted in DMRL (Defence Metallurgical Research Laboratory), Hyderabad, Telangana, India. And was performed in WALTER+BAI.AG Universal testing machine (UTM) as shown in fig 11. The maximum load of this machine is 200kN and maximum temperature is up to 1200C. In this test Yield strength, Ultimate tensile strength and ductility were evaluate

First holding the work piece by using bottom hydraulic gripper (BHG) and upper hydraulic gripper (UHG). In this upper hydraulic gripper is movable and bottom hydraulic gripper is constant. Adjust the settings in the DION PRO software as per requirement. Attach the sensor clip to the specimen as shown in fig 13.

After this, the machine is started and the upper gripper is moved vertically upwards with '1mm/min'. By moving upper gripper the specimen is elongated and there will be a breaking point after some time as shown in fig 14. This speed is used for first two specimens and other two specimens are conducted with speed of 0.5mm/min. And the maximum load is applied in this tests is 100kN.

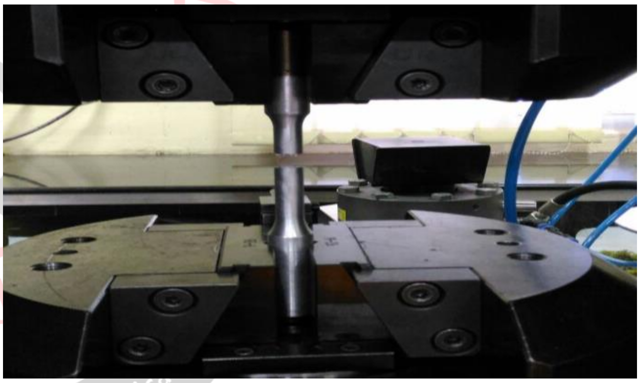

Fig 11: Broken Al-Sic MMC specimen

Fig: 12 Fractured AA 7178 specimens

Table 5.9 Tensile Test Result

S.No	Sample Designation	UTS (MPa)	Max Load (KN)	% of Elongation
1	Al-Alloy-1	110.5	11.72	0.1

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2	Al-Alloy-2	113	14.12	0.2
3	Al-Alloy-3	131.3	16.5	0.2
4	Al-Alloy-4	151.4	18.5	0.4

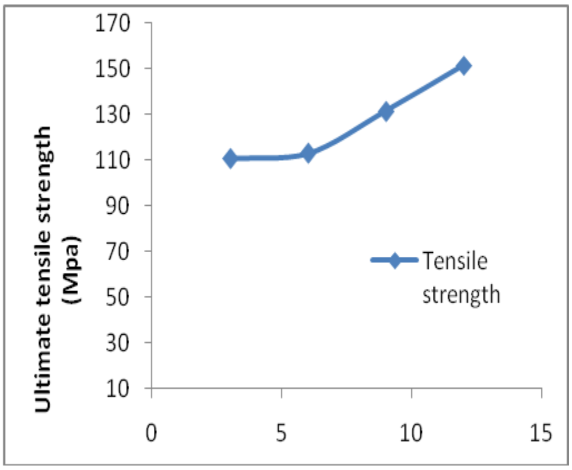

Figure 12: Effect of silicon carbide on Tensile strength of Al 7178 alloy.

Figure 12 reveal that the ultimate tensile strength of composites increases by the addition of the reinforcement(Sic).

Table 5.4: Hardness Test Result

S.No	Sample Identification	Location	Impression 1	Impression 2	Impression 3	Average BHN
1	Al-Alloy-1	On surface	128	129	128.6	128.5
2	Al-Alloy-2	On surface	130	130	130	130
3	Al-Alloy-3	On surface	132	132.4	131.2	131.8
4	Al-Alloy-4	On surface	131.2	131.8	132	131.6

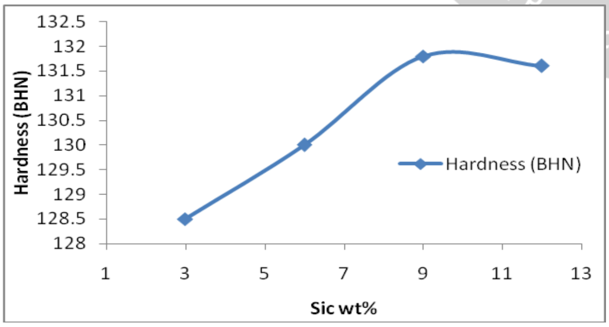

Figure 13: Effect of silicon carbide on Hardness of Al 7178 alloy.

. Figure 13 shows the Brinnel hardness value of cast composite increase as the weight percentage of Sic increases from 3% to 12 % in the aluminium 7178 alloys. Silicon carbide particles incorporated in the metal matrix up to 9% wt and the decreased on further reinforcement .The brinell hardness value of AMCs containing a varying weight percentage of reinforcement. Addition of Sic particle in aluminium matrix composites enhances

the hardness of AMC when compared with unreinforced Al 7178 alloy. The presence of harder and well bonded sic particle in Al matrix that impedes the movement of dislocation increases the hardness of aluminium metal matrix composites.

Silicon carbide content increases from 0 to 12 weight per cent. In this case, the addition of Sic to aluminium 7178 alloy matrix is increasing the ultimate Tensile strength of the composite material. It is believed that the enhancement of Tensile properties in composites is due to the distribution of silicon carbide particle and low porosity. The grain refinement and strong multidirectional thermal stresses at the Al-Sic interface are essential factors which play a significant role in the high strength of the composites and Sic particle have grain refined strengthening effect which is increased with increasing weight fraction since they act as heterogeneous nucleation catalyst for aluminium alloy.

(B)Hardness Test:

Hardness is characteristic of a material and defined as resistance to indentation and determined by measuring the permanent depth of the indentation. Brinell hardness measurement are carried out in order to investigate the influence of Sic particulate weight fraction on the matrix hardness. The applied load is 250 N and steel ball 5 mm in diameter.

(C) MICROSTRUCTURE ANALYSIS

Micro structure of sample 1.

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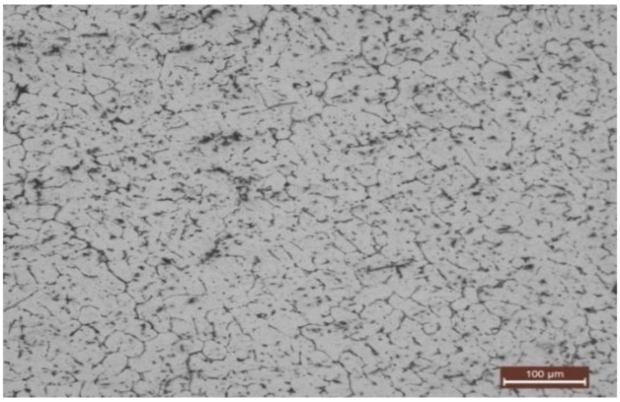

100XZOOM

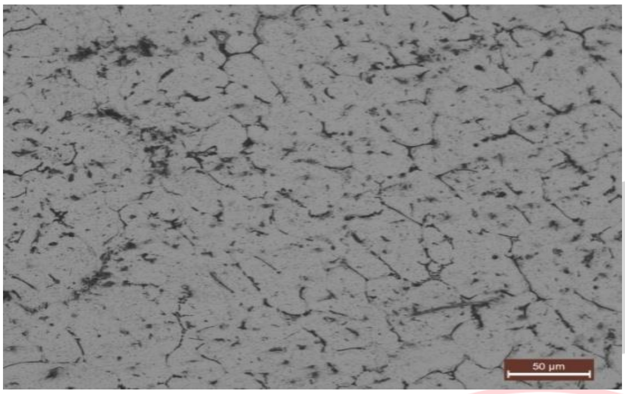

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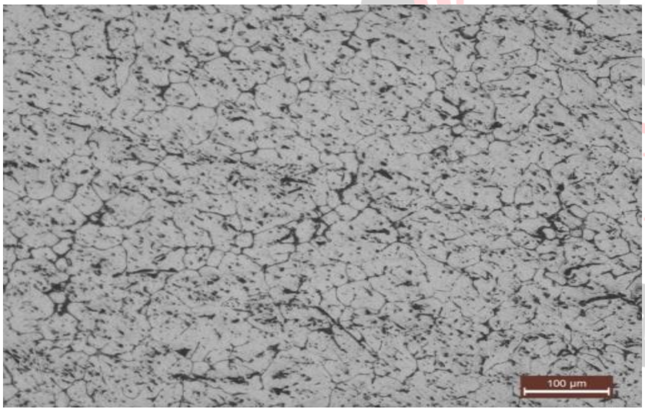
Figure 14: Optical micrograph of Al -3% sic specimen

- Micro structure of sample 2.



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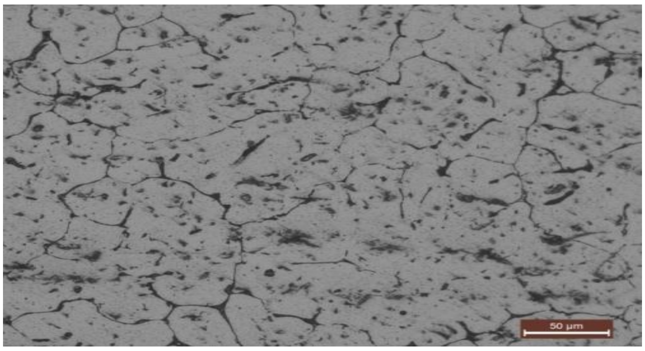

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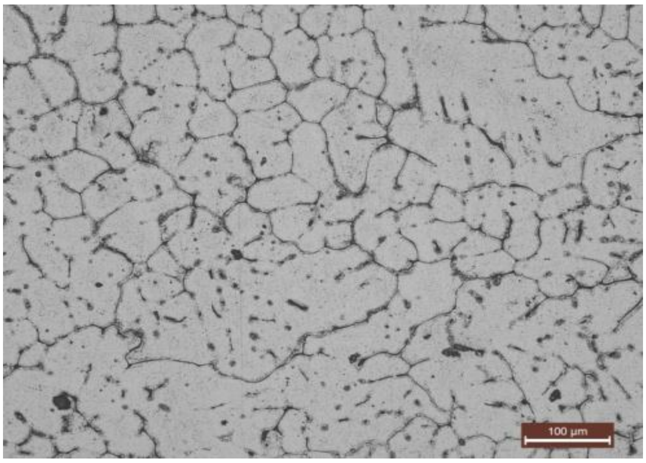
Figure 15: Optical micrograph of Al -6% sic specime

- Micro structure of sample 3.



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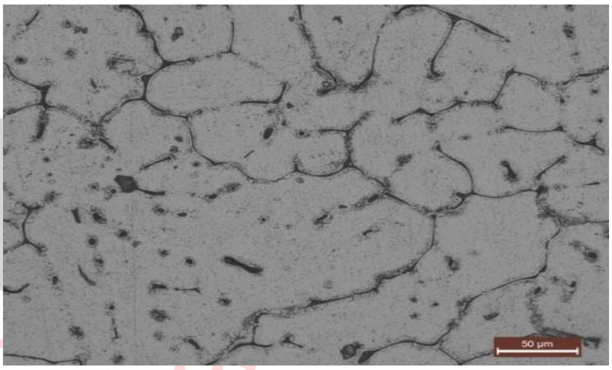

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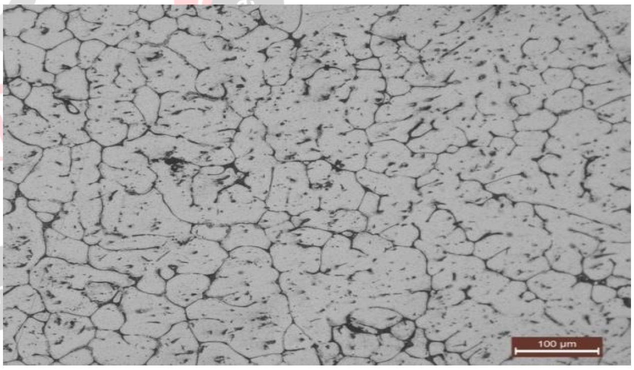
Figure 16: Optical micrograph of Al -9% sic specimen

- Micro structure of sample 4.



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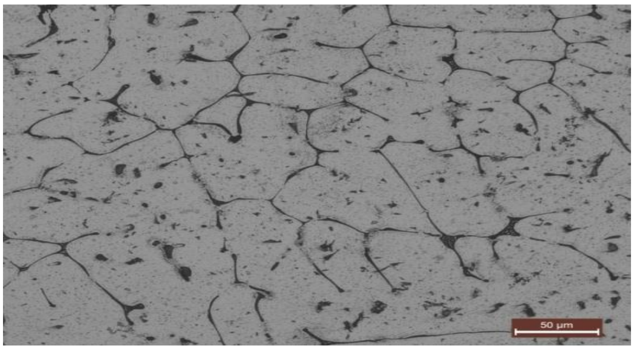

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Figure 17: Optical micrograph of Al -12% sic specimen

The optical micrographs of Aluminium composites for varying percentage of SiC are shown figures 14, 15, 16

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and 17 that SiC particles are mixed in molten aluminum alloy. The micrographs are composed of dendritic structure. It is reasonably seen that with the increase in the percentage of SiC particle the grain size reduces. The reinforcement SiC particulate induced modification in the dendritic structure and grain refinement. It is observed that the reinforcement particle are visible and the particles are fairly dispersed in composites some clusters. It is clearly shown that homogeneous distribution of SiC particle.

V. CONCLUSION

In our present study, AMCs (Aluminium matrix compositions) were prepared by stir casting process with a varying weight percentage of SiC content of 3%, 6%, 9% and 12% in Al matrix. Microstructural aspects, hardness, the tensile strength of the prepared composites were studied. Based on the experimental estimation.

1. Prepared of Al 7178 casting with reinforcement of SiC with metal matrix composites.
2. The microstructural studies revealed the fairly distribution of SiC particles in Al matrix and also porosities were observed in the microstructures.
3. By increasing the silicon carbide, Tensile strength is increased to 6% at 12 wt %
4. By increasing the silicon carbide, Brinell hardness is increased to 2.6% at 9 wt %
5. The result confirmed that stir casting formed aluminium 7178 with silicon carbide reinforced composites have superior properties of Tensile strength and hardness to base aluminium7178.
6. Microscopic views of different composites at !0X and 20X magnification observed that disperson of reinforcement particles in aluminium matrix is fairly uniform and homogenous. Micrographs of Al-Si composites are modified.
7. The micro structural studies revealed the fairly distribution of SiC particles in Al matrix and also porosities were observed in the microstructures.

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