The Preparation of Al- SiC Metal Matrix Composite and Evaluation of its Properties

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Abstract- Conventional materials like Steel, Brass, and Aluminium etc will fail without any indication. Cracks initiation, propagation will takes place within a short span. Now a day to overcome this problem, conventional materials are replaced by Al alloy materials. Al alloy materials found to the best alternative with its unique capacity of designing the materials to give required properties. Thus, the SiC particle reinforced aluminum matrix composites are expected to have many applications in aerospace, aircraft, automobile and electronic industries. In this project work, Al metal matrix composites containing several weight percentages of reinforcement particles were prepared by using stir casting method and powder compaction method, such as 94%Al +6%SiC, 90%Al +10%SiC, 87%Al +13%SiC. The effect of different weight percentage of aluminium and silicon carbide composites on breaking load, impact strength, and hardness and compression strength were examined. It was observed that the distribution of SiC particles was uniform. The hardness of the composites increased with increasing reinforcement element addition in it. The breaking load of the composites increased with increase in the addition of reinforcement elements. In addition, and for the purpose of verification of the present theory, other published works were also compared and found to be in very good correlation with the obtained result.

Keywords –Composites, Powder Metallurgy, Stir-casting, Tensile test, Compression test, Flexural test.

I. INTRODUCTION

Research and development on MMCs have increased considerably in the last decade due to their improved modulus, strength, wear resistance, thermal resistance and fatigue resistance and improved consistency in properties and performance in general compared to the un-reinforced matrix alloys. The reinforcements are added extrinsically. The properties of MMCs depend on the properties of matrix material, reinforcements, and the matrix-reinforcement interface. The recent recognition that addition of ceramic reinforcements enables manipulation of physical as well as mechanical properties of MMCs has led to increasingly widespread use of these materials in electronic packaging and thermal-management applications. Recent market forecasts suggest the prospect for accelerating growth of MMC use as the materials are more widely understood and are cheap, suggesting a bright future for this class of materials.

Aluminum metal matrix composites are attractive for a wide variety of aerospace and defense applications. But it has lower resistance, ductile, low strength and hardness. To overcome this problem, silicon carbide is added as a reinforcement particle to enhance the mechanical behavior of Al MMC. In this investigation, the experiments were performed on different composition of SiC, the reinforcement particles are added at 2, 4, 6 and 8 of weight percentage. The composite was prepared by both powder metallurgy method and stir casting method. The specimens were examined using the standardized tests which are Microstructure analysis, Compression test, and Rockwell Hardness test

II.MATERIAL SELECTION

Aluminum was chosen as the base material because of its wide spread engineering application and low melting point. In this work, the MMC preparation has been attempted in both ways using powder compaction technique and stir casting technique. Aluminum is suitable for either technique. Silicon carbide is used as reinforcement for its good temperature resistance and abrasive resistance, SiC as a compound increases the strength of the matrix.

III. POWDER METALLURGICAL ROUTE

Equivalent quantities of the metal powders were taken by weight. The weighing was done in a very precise weighing balance. Batches were prepared for each sample. As received aluminium and silicon carbide powders were mixed such that the volume fractions of silicon carbide in the mixtures were 2% (98% aluminium), 4%, 6%, and 8 % respectively. Electronic weighing machine is used to prepare the samples. The samples and their percentage in proportions are shown in the figure.

Table 1: Percentage composition of Al - SiC composite to make pellets.

Sample	Aluminium		Silicon-Carbide	
	Weight (gms)	% by Weight	Weight (gms)	% by Weight
A	8.312	98%	0.201	2%
B	8.143	96%	0.403	4%
C	7.973	94%	0.605	6%
D	7.803	92%	0.806	8%

A horizontal ball mill was used for mechanical alloying of aluminum and SiC particulates. The Mechanical alloying process takes place by the stirring action of an agitator which has a vertical rotating central shaft with horizontal impellers. The rotation speed of the central shaft is about 100 rpm (4.2 Hz) for about 30 minutes for each sample. The morphology of the powders is tailored when they are subjected to ball collisions. It also helps in making the powder mix uniform. Addition of the lubricants Stearicacid or zinc stearate in proportion of 0.25 % to 5 % by weight reduces friction and enhances flow ability. Powder mix corresponding to 98%Al–2%SiC, 96%Al–4%SiC, 94%Al–6%SiC and 92% Al–8%SiC were blended for all particle sizes on a ball mill to obtain a homogeneous powder blend. The powder blend was prepared on a 40ton capacity hydraulic press using suitable punch and die assembly. The compacting pressure applied was 468.393MPa, which was maintained for all composition of SiC composites. Sintering was done in muffle furnace with a high purity hydrogen (inert) environment for 2 hr. The hydrogen flow rate was 0.5 l/min. The sintering temperature was kept at 500° C. All the samples (98%Al + 2%SiC, 96%Al + 4%SiC, 94% + 6%SiC and 92%Al + 8%SiC each two) were sintered constant temperature 500°c in muffle furnace.

IV. STIR CASTING ROUTE

Table 2 Percentage composition of Al-SiC for stir casting technique

Samples	Aluminium		Silicon-Carbide	
	Weight (kg)	% by Weight	Weight (Kg)	% by weight
A	0.3045	94%	0.0023	6%
B	0.074	90%	0.00977	10%
C	0.2818	87%	0.0501	13%

The powers were put in to the muffle furnace in separate graphite crucibles. First molten liquid aluminum taken out from the muffle furnace operating at 850°C was poured into mixing pot and then the hot silicon carbide powder was dropped in to the pot. The ingredients were mixed by using steel stirrer. Steel stirrer was used because steel has high melting point, so that it will not melt during the stirring process. The stir was carried out in a proper manner to obtain a uniform distribution. Initially the die was fully cleaned by using the sand paper. The mixed molten metal was poured into the suitable die to cast them and placed in the atmosphere. It was allowed to solidify for half an hour. Then it was taken out of the die. Then work piece was processed using reamer to make it fine product. Similar process was carried out for different compositions (Aluminium94%-Silicon carbide 6%, Aluminium90%-Silicon carbide 10%, Aluminium 87%-silicon carbide 13%). The dies are shown in figure no.1,used to cast the in to rectangular plates and cylindrical rods.

Fig.1 Rectangular and cylindrical die

IV. RESULT AND DISCUSSION FOR POWDER METALLURGICAL ROUTE

The microstructure shown below in Figure no.2,(a), 2(b), 2(c) and 2(d) were from Al (6061) powder with SiC powder metallurgical product matrix. The Microstructures reveal the various percentage compositions of SiC in the Aluminum matrix and its distribution within the matrix upon compaction. The mixed powders were compacted at 15 tons/ in a closed die. The compacted sample was sintered at 500 degree centigrade for 2 Hours. The furnace was maintained in nitrogen atmosphere of 0.5 liters per minute. The percentage of SiC is 8% and the particles presence is higher than the 2, 4 and 6% mix. The particles are evenly distributed in the metal matrix. The SiC particles are dark grey in color..

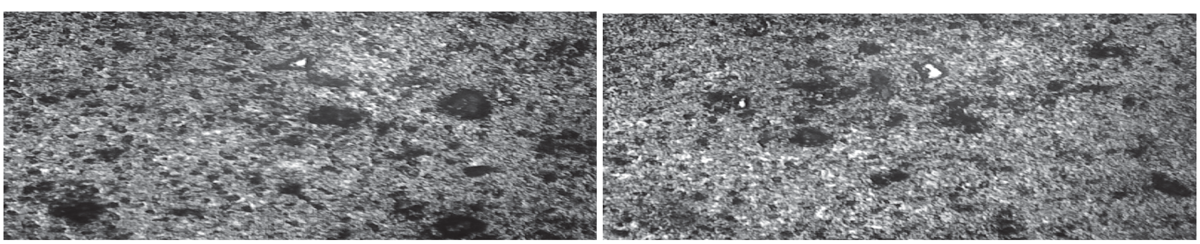


Fig.2 (a). Al - SiC – 2%

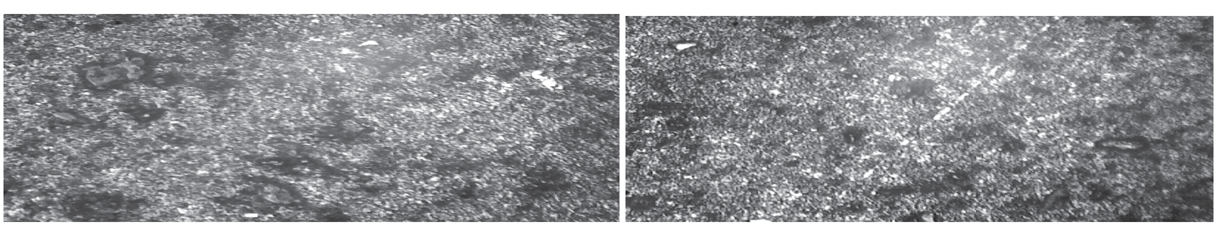


Fig 2: (b) Al - SiC – 4%

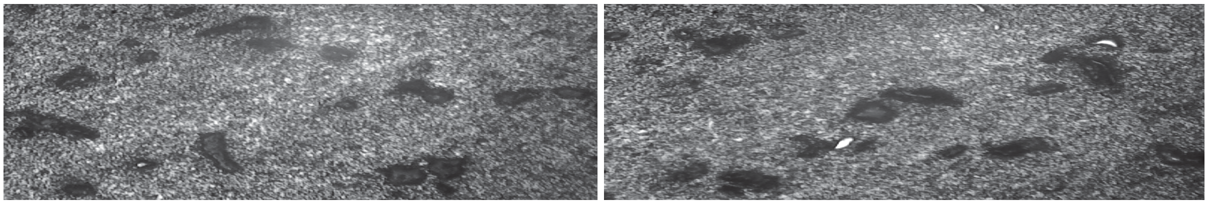


Fig 2 (c): Al- SiC – 6%

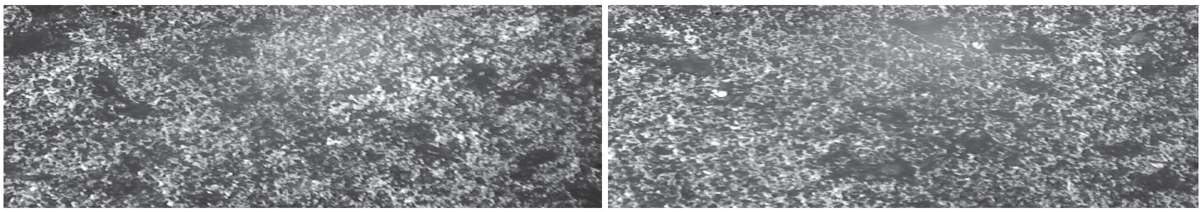


Fig 2.(d) Al- SiC – 8%

Hardness for the various compositions were tested and tabulated in Table3. The Rockwell hardness of powder metal Al-SiC composites increases with increase in weight % of SiC viz 2, 4, 6and 8 wt. % of SiC. The values shown in the graph are the average of the four readings for each composition of the composite and the scatter of the actual hardness values about the average was limited to within 5 % of the average hardness values for the Al-SiC composite samples. The hardness values for the samples vary on an average from 19 HRC to 26 HRC.

Table 3: Hardness Values of Al & SiC composite

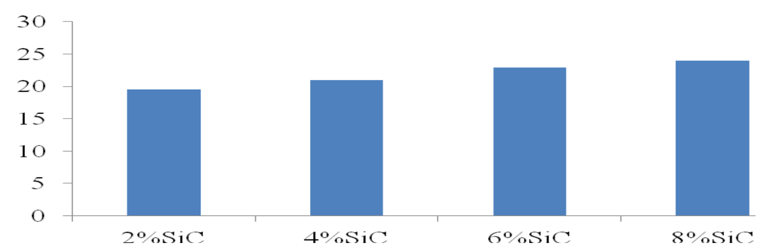


Fig 3: Hardness Vs % SiC

A relatively high variation in the hardness values, measured at different positions on the samples made by PM process, may be due to the presence of porosity. A compression test is a method for determining the behavior of materials under a compressive load. Compressive Strength is the maximum compressive stress that a material is capable of withstanding without fracture. The compression test is used to determine the elastic limit, proportionality limit, yield strength and compressive strength. Compression test is performed on four samples. The following four graphs Fig. 4(a), 4(b), 4(c) and 4(d) for the 2, 4, 6, 8%silicon carbide compositions were achieved using lab view software. X.

Scale	2%SiC	4%SiC	6%SiC	8%SiC
Rock well "C" scale	18.9	19.7	20.5	27.5
	19.2	19.2	21.1	26.7
	19.5	20.8	22.6	21.9
	21.2	23.5	25.9	28.4
	18.6	21.8	24.4	20.2

The following graphs show Load Vs Displacement characteristics for the samples with 2%,4%,6% and 8% SiC reinforcement respectively. The values for breaking load, maximum displacement, and ultimate stress are shown alongside the graphs..

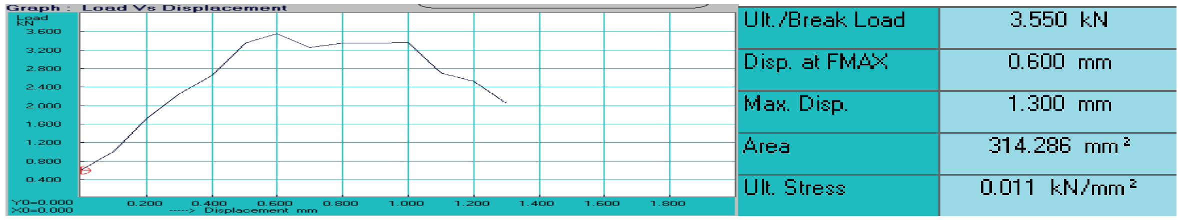


Fig 4.(a): Load Vs Displacement (2%SiC)

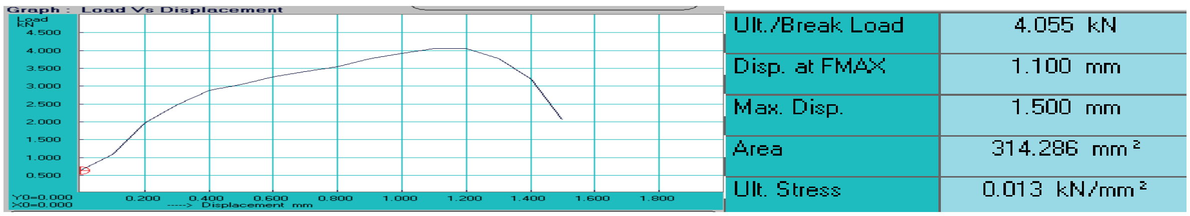


Fig 4.(b): Load Vs Displacement (4%SiC)

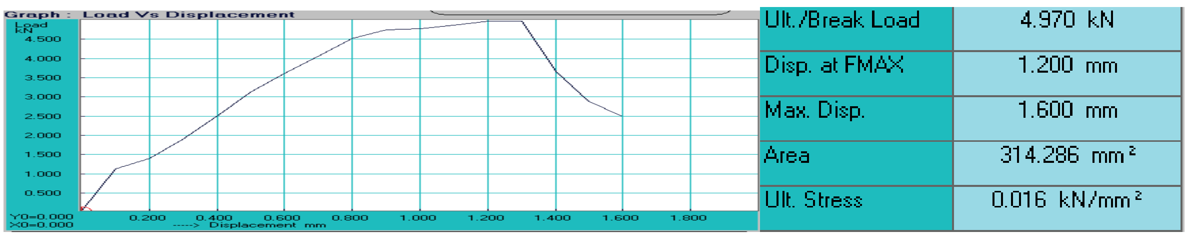


Fig 4(c) Load Vs Displacement (6%SiC)

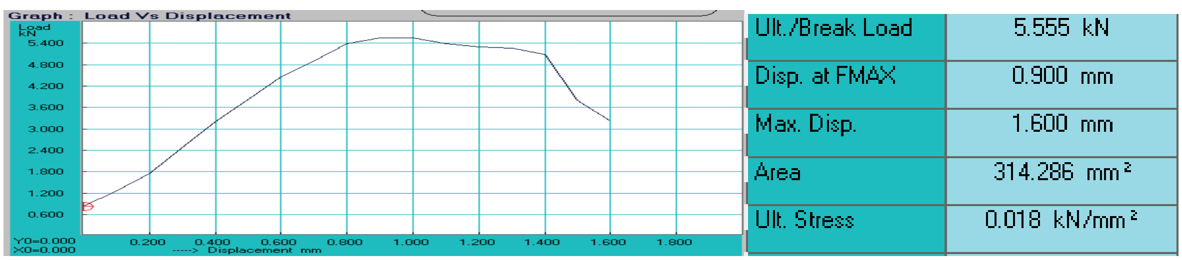


Fig 4(d) Load Vs Displacement (8%SiC)

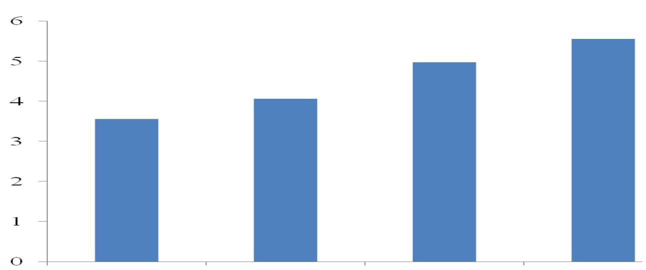


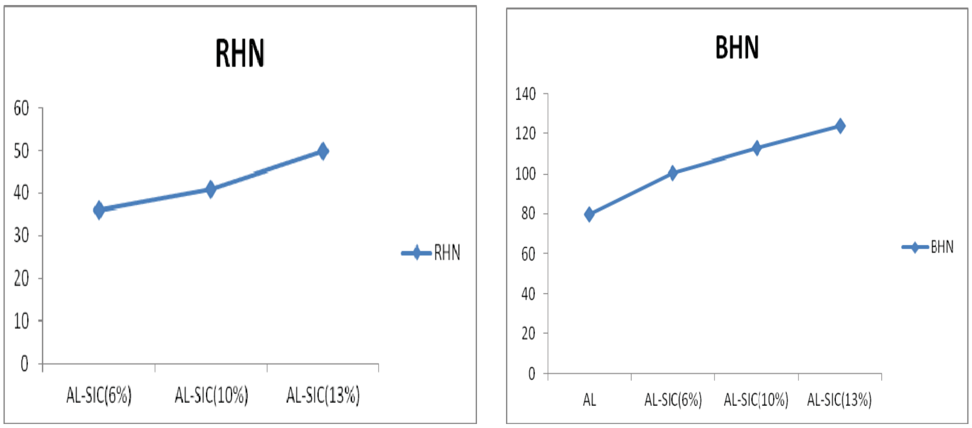
Fig 5: Breaking load Vs % in Wt of SiC

Compression test was performed on Al-SiC composite specimens with length to diameter ratio of 1.5. Tests were performed on UTM of 40 ton capacity. The sample was compressed between two flat platens and the maximum failure load was recorded. The result shows compression strength of powder metal Al-SiC composites increases with increase in weight % of SiC from 2, to 8 wt. % of SiC because Microstructure suggests proper bonding between matrix and reinforcement along their interface and Hardness of Al-SiC composite increases with increase in weight percentage of silicon carbide content.

V RESULT AND DISCUSSION FOR STIR CASTING TECHNIQUE

Table.4 Hardness Values Of Al-SiC Composites

	SAMPLE ID		
ROCKWELL HARNESS VALUES (HRC)	Al-Sic(6%)	Al-Sic(10%)	Al-Sic(13%)
	36	39	50
	37	42	51
	35	44	49
	38	48	48
	34	33	52
AVERAGE	36	41.2	50



(a) (b)

Fig.6 Hardness VS % in Wt of SiC (a) Rockwell (b) Brinell

The hardness of pure aluminum is around 30. When silicon carbide is added to aluminum material the hardness started increasing. There is a gradual increase from 30 to 36, with an addition of 6%, 10% and 13% silicon carbide. Thus the composite can be used in places where higher hardness is required, that is more hardness compared to aluminum metal. The hardness values increase when tested in Brinell hardness tester as well.

Table.5 Hardness values of a Al-SiC composites

		SAMPLE ID		
BRINELL HARNESS VALUES (BHN)	Al	Al-Sic(6%)	Al-Sic(10%)	Al-Sic(13%)
	78.25	98.24	111.43	127.47
	79.97	100.62	112.87	129.34
	80.23	102.3	106.41	120.32
	77.19	99.32	114.34	121.23
	81.42	101.71	117.45	120.57
AVERAGE	79.42	100.44	112.5	123.78

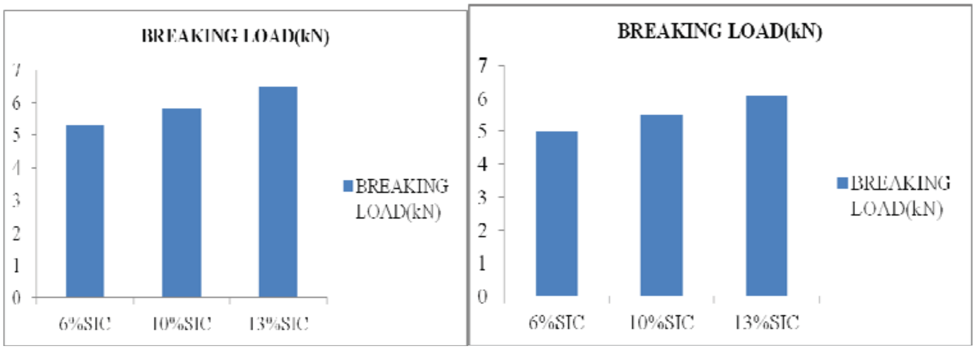


Fig.7 Breaking Load VS % Si C (a) Tensile testing (b) Flexural Testing

As we add silicon carbide to aluminum material the breaking load increases as shown above. The calculated tensile and yield strength shows that there is an increases and they are given below in Table 6.

Table.6 Properties of Al-SiC Composite (a) Tensile testing (b) Flexural Testing

Properties	Al –SiC(6%)		Al-SiC(10%)		Al-SiC(13%)	
	(a)	(b)	(a)	(b)	(a)	(b)
Tensile strength	190.25	44.52	240.88	46.12	262.35	54.62
Yield strength	135.67	38.86	178.92	40.26	189.93	47.68
% Elongation	6.67	---	4.80	----	3.18	-----

VI CONCLUSION

In PM process wastes very little material - about 90% of the starting powders are converted to product. Hardness of Al-SiC composite increases (19.48 to 23.94) with increase in weight percentage of silicon carbide content (2 to 8%). Similarly, the Breaking load of Al-SiC composite increases (3.550 to 5.555) with increase in weight percentage of SiC.

In Stir casting method, Tensile strength of aluminum silicon carbide increases (190.25kN/mm^2 to 262.3525kN/mm^2). With increase in weight percentage of silicon carbide content and Yield strength increases from 135.6725kN/mm^2 to 189.9325kN/mm^2 in tensile test. Breaking load increases from 5.29 to 6.49 kN. Similarly breaking load for compression test increases from 4.98 to 6.08kN. Rockwell Hardness of Al-SiC composite increases with increase in weight percentage of silicon carbide content (36 to 51). Brinell Hardness of Al-SiC composite increases with increase in weight percentage of silicon carbide content (100.44 to 123.78). This indicates that the Aluminum silicon carbide composite material is having less weight and more strength; it is very much useful in practical aerospace applications.

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