Stir Casting of Aluminium and Silicon Carbide

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Abstract: The main objective of this present work is to study about the wear characteristics, microstructure and the mechanical properties of cast silicon carbide (SiC) reinforced aluminum matrix composites (AMCs). AMCs of varying SiC content with weight of SiC 0%, 3% and 7% was prepared by stir casting process. Wear performance, microstructure, hardness and tensile strength of the prepared composites were analyzed. The results were analyzed and it showed that adding SiC reinforcements in aluminum (Al) matrix increased wear resistance and tensile strength. AMC's reinforced with 7% SiC added in Aluminium matrix showed maximum wear resistance and tensile strength. Micro-structural observation revealed clustering and non-homogeneous distribution of SiC particles in the Al matrix. Pin-on-disc wear test indicated that reinforcing Al matrix with SiC particles increased wear resistance.

Keywords: Metal matrix composites; Stir casting; Microstructure; Wear Resistance;

I. INTRODUCTION

Metallic matrix composites are the components which are formed by combinations of two or more different metals, intermetallic compounds or second phases are rooted within the metallic matrix. They are formed by controlling the morphologies of the constituents to get best combination of properties. Properties of the composites depend on the properties of the constituent phases, their relative amount, and discrete phase geometry including particle size, shape and orientation in the matrix. [1, 2]

AMCs have got wide applications in our day to-day life. There are several advantages in using particle reinforced AMCs materials than unreinforced materials such as- light weight, low thermal expansion coefficient, high thermal conductivity, greater strength, high specific modulus, improved stiffness, increased wear resistance and improved damping capabilities. Reinforcing constituents can be included in the matrix in the form of particles, small fibers, continuous fibers or mono filaments. Now this is used in industrial products, aerospace, thermal management areas, automotive applications such as engine piston, brake disc etc. [3]

AMCs can be prepared by liquid state processing (squeeze casting, stir casting, infiltration etc.), semi-solid processing and powder metallurgical route. Generally nonmetallic and ceramic particles like alumina (AL_2O_3), boron carbide (B_4C), silicon carbide (SiC), graphite etc. are used as reinforcements in AMCs.

As the loads are applied externally to the composites, metal matrix transmits loads to the reinforcements and then loads are carried by discreted reinforcements that are bonded with the matrix. Strong interface link between reinforcements and matrix is necessary to attain high strength of the composites. Interface link is obtained by reaction or mutual dissolution during casting process. Hence, good wetting of the reinforcements is essential during casting process. [4]

The objective of this study is to examine the result of SiC reinforcements in Al matrix composites on mechanical properties such as tensile strength, micro-structural aspects and wear resistance.

II. EXPERIMENTAL

2.1 Materials

Al was used as matrix material and powdered form of the SiC (3 and 7 wt. %) was added as the reinforcements in the stir casting process to prepare composites in this study. [5]

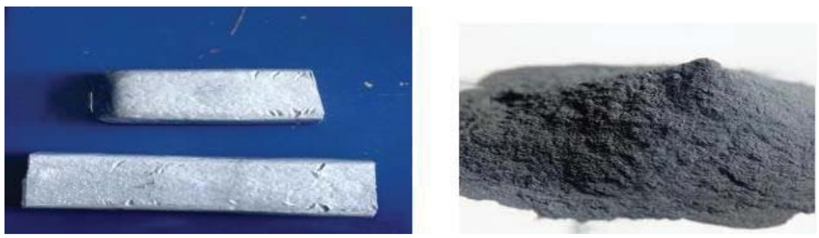

Fig1. Al metal and SiC Powder

2.2 Preparation of composites

SiC reinforced AMCs were prepared by stir casting process. Crucible made up of carbide material is used because of its high temperature resistance. First the pure solid Al was melted in furnace and when the temperature of the liquid Al reached around at 700-750^{o}C, SiC powder is added in molten Al metal. An electrical resistance furnace which was assembled with the graphite impeller used as stirrer was used for stirring purpose.

Fig 2. Stir casting furnace used for preparation of AMCs.

After that the powdered form of SiC was added and the liquid metal-reinforcement mixture was stirred for about 15-20 minutes at an rpm of 450-500. Lastly the composites were poured in preheated moulds at 670^{o}C. The melt was allowed to solidify in the mould for about 4-5 hours so as to provide enough time for cooling and then the specimens were taken out.

2.3 Experimental testing

Wear test was conducted using pin-on-disc method at room temperature and dry sliding condition. Two specimens of each composition 3% and 7% SiC-Aluminium of dimension 30mm length and 6mm diameter was prepared by machining.

SEM images of the prepared composites were observed to confess the distribution of reinforced (SiC) particles in Al matrix. An image analyzer is used to study the distribution of the reinforcement particles within the aluminum alloy matrix. The microstructures are observed using optical microscope but before doing this the samples were polished on emery paper of dissimilar grades.

Rockwell hardness of the samples was determined using RAS model Rockwell hardness testing machine. The surfaces being tested generally requires metallographic finish hence it was done with 100, 220, 400 and 600 grit size emery paper. Samples were mounted with bakelite so that samples could not move when the load was applied. A $^1/16$ ball indenter was impressed on material at a load of 100kg. To avoid the separation effect of the reinforcements in the matrix, four readings were taken for each sample.

Tensile tests are used to access the mechanical behavior of the composites and matrix alloy. Tensile test was conducted using computerized universal testing machine. The composite tensile test specimens were prepared using lathe machine and shaper machine according to the dimensions as shown in Fig 3 and Fig 4 for 3% and 7% SiC aluminum metal matrix composites. Test method IS 1608 was referred.

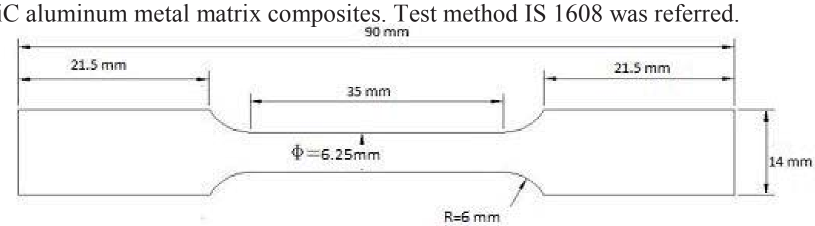

Fig. 3. Dimensions of tensile test specimens for 3% SiC - aluminum metal matrix composite

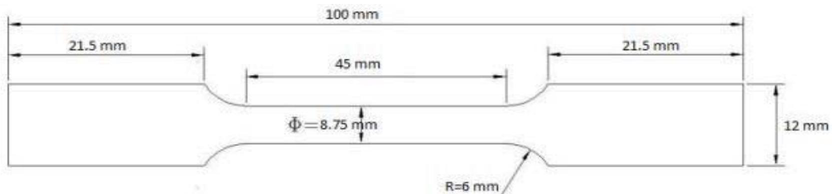

Fig 4. Dimensions of tensile test specimens for 7% SiC – aluminum metal matrix composite.

Fig 5. Tensile test specimens

III. RESULTS AND DISCUSSION

3.1 Wear test:

Table 1: Wear test results of 3% SiC-Aluminium composite

Al	3%SiC									
Load (N)	**Distance (mm)**	**Speed (m/sec)**	**Initial Weight (W_1) (grm)**	**Final Weight (W_2) (grm)**	**Weight Difference (grm) *10^-3**	**Density (g/mm^3) *10^-3**	**Vol. loss (mm^3)**	**Wear resistance *10^-3**	**Friction force (N)**	**Coef. Of friction**
9.81	**500**	**1**	**5.92**	**5.911**	**9**	**2.51**	**3.58**	**7.16**	**2.47**	**0.25**
9.81	**1000**	**1**	**5.92**	**5.898**	**22**	**2.51**	**8.75**	**8.75**	**2.46**	**0.25**
9.81	1500	1	5.92	5.897	23	2.51	9.15	6.10	2.19	0.22
19.62	500	1	6.19	6.184	6	2.51	2.38	4.77	7.27	0.37
19.62	1000	1	6.19	6.178	12	2.51	4.77	4.77	7.54	0.38
19.62	1500	1	6.19	6.173	17	2.51	6.76	4.15	7.63	0.39
29.43	500	1	6.017	6.005	12	2.51	4.77	9.55	11.82	0.40
29.43	1000	1	6.017	5.989	28	2.51	11.17	11.14	11.80	0.40
29.43	1500	1	6.017	5.977	40	2.51	15.24	10.66	11.03	0.38
39.24	500	1	6.173	6.162	11	2.51	4.37	8.75	14.21	0.36
39.24	1000	1	6.173	6.154	19	2.51	7.56	7.56	13.93	0.35
39.24	1500	1	6.173	6.147	26	2.51	10.35	6.90	13.82	0.35
9.81	500	2	6.162	6.157	5	2.51	1.99	3.98	3.90	0.40
9.81	1000	2	6.162	6.154	8	2.51	3.18	3.18	3.80	0.39
9.81	1500	2	6.162	6.152	10	2.51	3.98	2.65	3.77	0.38
19.62	500	2	6.089	6.082	7	2.51	2.78	5.57	6.85	0.35
19.62	1000	2	6.089	6.077	12	2.51	4.77	4.77	7.20	0.36
19.62	1500	2	6.089	6.071	18	2.51	7.16	4.77	7.26	0.37
29.43	500	2	6.054	6.031	23	2.51	9.15	18.31	11.47	0.39

29.43	1000	2	6.054	6.021	33	2.51	13.13	13.13	11.87	0.40
29.43	1500	2	6.054	6.010	44	2.51	17.51	11.67	11.88	0.40
39.24	500	2	6.038	6.004	34	2.51	13.53	27.07	17.25	0.44
39.24	1000	2	6.038	5.987	51	2.51	20.30	20.30	18.00	0.46
39.24	1500	2	6.038	5.973	65	2.51	25.87	17.25	16.75	0.42
9.81	500	3	6.154	6.090	64	2.51	25.47	50.95	6.40	0.65
9.81	1000	3	6.154	6.025	129	2.51	51.35	51.35	6.63	0.67
9.81	1500	3	6.154	5.994	160	2.51	63.69	42.46	6.70	0.68
19.62	500	3	5.945	5.858	87	2.51	34.63	69.26	7.35	0.37
19.62	1000	3	5.945	5.821	124	2.51	49.36	49.36	6.85	0.35
19.62	1500	3	5.945	5.783	162	2.51	64.49	42.99	6.62	0.34
29.34	500	3	6.071	5.81	261	2.51	103.90	207.80	22.25	0.75
29.34	1000	3	6.071	5.558	513	2.51	204.22	204.22	21.32	0.72
29.34	1500	3	6.071	5.304	767	2.51	305.33	203.55	21.64	0.73
39.24	500	3	5.973	5.678	295	2.51	117.43	234.87	31.23	0.80
39.24	1000	3	5.973	5.384	589	2.51	234.47	234.47	30.94	0.79
39.24	1500	3	5.973	5.000	885	2.51	352.30	234.87	30.62	0.78

The wear of pure aluminum is more; so as to reduce this sic is reinforced in matrix. The specimen with 3% and 7% SiC-Aluminium composition were tested. The loss of material of pure Aluminum was more as compared to the 3% SiC-Aluminum and 7% SiC- Aluminum. Now when comparing wears of 3% and 7% SiC-Aluminium specimens we found that the wear of 3% SiC-Aluminum composite was more than that of 7% SiC-Aluminum specimen. This indicates that when the amount of SiC reinforcement increases in the Al matrix loss of material due to wear is less. Hence, the wear resistance increases with increase in SiC. [11, 12]

Table 2. Wear test results for 7% SiC- aluminum composite.

Al	7%SiC									
Load (N)	Distance (mm)	Speed (m/sec)	Initial Weight (W_1) (grm)	Final Weight (W_2) (grm)	Weight Difference (grm) *10^-3	Density (g/mm^3) *10^-3	Vol. loss (mm^3)	Wear resistance *10^-3	Friction force (N)	Coef. Of friction
9.81	**500**	**1**	6.393	6.383	10	2.71	3.68	7.37	4.65	0.47
9.81	**1000**	**1**	6.393	6.380	13	2.71	4.79	4.79	4.36	0.44
9.81	1500	1	6.393	6.379	14	2.71	5.16	3.44	4.29	0.43
19.62	500	1	6.273	6.267	6	2.71	2.21	4.42	7.38	0.37
19.62	1000	1	6.273	6.263	10	2.71	3.68	3.68	7.28	0.37
19.62	1500	1	6.273	6.261	12	2.71	4.42	2.94	7.9	0.36
29.43	500	1	6.381	6.371	10	2.71	3.68	7.37	14.41	0.49
29.43	1000	1	6.381	6.361	20	2.71	7.37	7.37	14.31	0.48
29.43	1500	1	6.381	6.356	25	2.71	9.21	6.14	13.62	0.46
39.24	500	1	6.068	5.935	133	2.71	49.02	98.04	26.93	0.68
39.24	1000	1	6.068	5.795	273	2.71	100.62	100.62	27.61	0.70
39.24	1500	1	6.068	5.614	454	2.71	167.34	111.56	28.03	0.71
9.81	500	2	5.871	5.829	42	2.71	15.48	30.96	8.07	0.82
9.81	1000	2	5.871	5.776	95	2.71	35.01	35.01	6.83	0.69
9.81	1500	2	5.871	5.736	135	2.71	49.76	33.17	6.65	0.67
19.62	500	2	6.309	6.195	114	2.71	42.02	84.04	15.97	0.81
19.62	1000	2	6.309	6.092	217	2.71	79.98	79.98	15.72	0.80
19.62	1500	2	6.309	5.972	337	2.71	124.21	82.81	15.91	0.81
29.43	500	2	6.301	6.101	200	2.71	73.71	147.43	25.37	0.86
29.43	1000	2	6.301	5.869	432	2.71	159.23	159.23	25.63	0.87
29.43	1500	2	6.301	5.691	610	2.71	224.84	149.89	25.22	0.85
39.24	500	2	6.310	6.099	211	2.71	77.77	155.54	31.42	0.80
39.24	1000	2	6.310	5.880	430	2.71	158.49	158.49	32.56	0.83
39.24	1500	2	6.310	5.673	637	2.71	234.79	156.53	33.46	0.85
9.81	500	3	6.366	6.312	54	2.71	19.90	39.80	6.91	0.70
9.81	1000	3	6.366	6.227	139	2.71	51.23	51.23	7.67	0.78
9.81	1500	3	6.366	6.155	211	2.71	77.77	51.84	7.97	0.81
19.62	500	3	6.280	6.118	162	2.71	59.71	119.42	17.38	0.88
19.62	1000	3	6.280	5.935	345	2.71	127.16	127.16	17.58	0.90
19.62	1500	3	6.280	5.765	515	2.71	189.82	126.55	17.74	0.90
29.34	500	3	6.308	6.081	227	2.71	83.67	167.34	27.98	0.95
29.34	1000	3	6.308	5.882	426	2.71	157.02	157.02	28.06	0.94
29.34	1500	3	6.308	5.688	620	2.71	228.52	152.35	27.92	0.95
39.24	500	3	6.295	6.045	250	2.71	92.14	184.29	35.86	0.91
39.24	1000	3	6.295	5.798	497	2.71	183.19	183.19	37.61	0.96
39.24	1500	3	6.295	5.592	703	2.71	259.12	172.74	36.82	0.94

3.2 Microstructures

Fracture surfaces of the deformed test samples were analyzed with a scanning electron microscope. The Fig 5 and Fig 6 shows the SEM images of 3% and 7% SiC-Aluminium composites respectively. The distribution of SiC particles in Al MMC should be uniform but from the observations of SEM images of 7% SiC-Al composite, it is seen that there is relatively non-homogeneous distribution of SiC particles reinforced in Aluminium MMCs. This happens due to providing improper time for contact between SiC particle and Al matrix and also because of poor wetting behavior of SiC particle in molten Al. Hence these parameters should be taken care during processing of the composition.

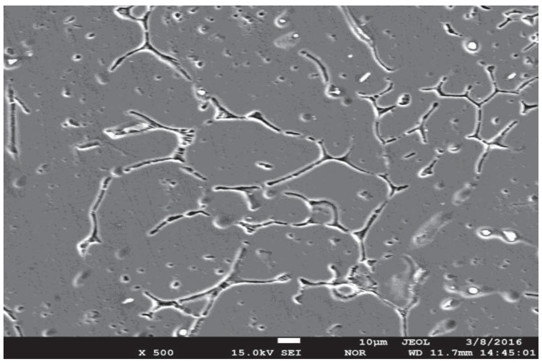

Fig 6.SEM image for 3% SiC-Al composite

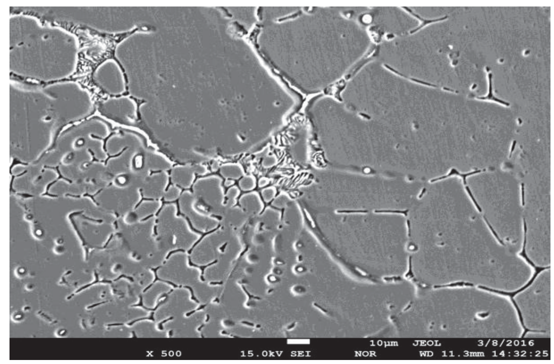

Fig 7.SEM image for 7% SiC-Al composite

3.3 Hardness

The property of material to resist against surface deformation or penetration is its hardness. [7]
The following table shows the test results of hardness test conducted for various compositions which were conducted on Rockwell hardness testing machine.

Table 3: Rockwell hardness of SiC reinforced AMCs

Sample no	Sample name	Rockwell Hardness				Mean hardness
		Trial 1	Trial 2	Trial 3	Trial 4	
1	Pure AL	56	58	59	55	57
2	Al+3%SiC	68	72	73	78	72.75
3	Al+7%SiC	92	90	95	88	91.25

Table 3 shows the Rockwell hardness values of AMCs with varying wt. % of SiC reinforcements. From the table we can see that the hardness value of Al+7%SiC is greater as compared to hardness values of Al+3%SiC and pure Al. Hence, this shows that addition of SiC Particles in Al matrix enhances the hardness value of AMCs when comparing to the pure Aluminium.

3.4 Tensile test

Tensile test:

The specimens for the tensile tests for 3% and 7% SiC-Aluminium composition were prepared as shown in Fig 3, Fig 4 and Fig 5 for testing. Below table shows the results of the tensile tests:

Table 4: Tensile strength of SiC reinforced AMCs

Sample No	Sample Name	Tensile strength (MPa)
1	Pure Al	65
2	Al+3%SiC	73
3	Al+7%SiC	84

From above table we can see that the tensile strength of 7% SiC reinforced AMC is greater as compared to 3% SiC reinforced MC and pure Aluminium. Hence, we conclude that tensile strength increases with increase in

SiC content in Aluminium matrix. This is because of the strong interfacial bonds which improves the tensile strength of AMCs. [8, 9]

IV. CONCLUSION

In our present study, AMCs were prepared by stir casting process with varying SiC content of 3% and 7% in Al matrix. Microstructural aspects, hardness, tensile strength, compressive strength and wear characteristics of the prepared composites were studied. Based on experimental estimation, we had these following conclusions:

1. Wear characteristics of AMCs resulted that increase in SiC % content in Al matrix increases the wear resistant, as it can be concluded that 7 wt. %SiC content AMC showed minimum wear loss than 3 wt. %SiC content AMC and pure Al matrix.
2. The microstructural studies revealed the fairly distribution of SiC particles in Al matrix and also porosities were observed in the microstructures.
3. The result of study suggest that with increase in composition of SiC in Al matrix the Rockwell hardness of the AMCs also increases as we had the greater hardness for 7 wt.% SiC content AMC than 3 wt% SiC content AMC and pure Aluminium.
4. With increase in percentage of SiC reinforcements in Al alloy increases the tensile strength. Here in our study and analysis we got them maximum for 7wt. % SiC content AMCs as compared to 3wt. % SiC content AMCs and pure Aluminum metal.

REFERENCES

[1] William D. Callister Jr., Materials Science and Engineering An Introduction, seventh ed., John Wiley & Sons Inc., New York, 2007.

[2] George E. Totten, D. Scott Mackenzie, Handbook of Aluminum Alloy Production and Materials Manufacturing, volume 2, Marcel Dekker Inc., New York.

[3] M K Surappa, Aluminium matrix composites: challenges and opportunities, Sadhana 28 (2003) 319-334.

[4] K.M. Shorowordi, T. Laoui, A.S.M.A. Haseeb, J.P. Celis, L. Froyen, Microstructure and interface characteristics of B4C, SiC and Al2O3reinforced Al matrix composites: a comparative study, J. Mater. Process. Technol. 142 (2003) 738–743.

[5] Dunia Abdul Saheb, Aluminum silicon carbide and aluminum graphite particulate composites, ARPN J. Eng. Appl. Sci. 6 (2011) 41-46.

[6] C.Neelima Devi, N.Selvaraj, V.Mahesh, Micro structural aspects of aluminium silicon carbide metal matrix composites, Int. J. Appl. Sci.Eng. Res. 1 (2012) 250-254.

[7] G. B. Veeresh Kumar, C. S. P. Rao, N. Selvaraj, Mechanical and tribological behavior of particulate reinforced aluminum metal matrix composites- a review, J. Miner. Mater. Charac. Eng. 10 (2011) 59-9

[8] R.Karthigeyan, G.Ranganath, S.Sankaranarayanan, Mechanical properties and microstructure studies of aluminium (7075) alloy matrix composite reinforced with short basalt fibre, Eur. J. Sci. Res. 68 (2012) 606-615.

[9] Madhu Kumar YC, Uma Shankar, Evaluation of mechanical properties of aluminum alloy 6061- glass particulates reinforced metal matrix composites, Int. J. Mod. Eng. Res. 2 (2012) 3207-3209.

[10] S. Vaucher, O. Beffort- EMPA Thun, Bonding and interface formation in metal matrix composites, volume 9, MMC-Assess Thematic Network, 2001.

[11] Madeva Nagaral, Bharath V, V Auradi, Effect of Al2O3 particles on mechanical and wear properties of 6061Al alloy metal matrix composites, J. Mater. Sci. Eng. 2 (2013).

[12] A. Vencl, A. Rac, I. Bobic, Tribological behavior of Al-based Mmcs and their applications in automotive industry, Tribol. Ind. 26 (2004) 31- 38.

[13] V. C. Uvaraja, N. Natarajan, Tribological characterization of stir cast hybrid composite aluminum 6091 reinforced with SiC and B4C particulates, Eur. J. Sci. Res. 76 (2012) 539-552.

[14] Yusuf Abdullah, Abdul RazakDaud, Roslinda Shamsudin, Mohd b. Harun, Flexural strength and fracture studies of Al-Si/SiCp composites, Int. J. Mech. Mater. Eng. 4 (2009) 109-114.