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Investigation of Mechanical Properties of Aluminium Metal Matrix Composite (AL-AL_2O_3-SIC)

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ABSTRACT: Metal matrix composite (MMC) material is one which contains two or more materials with different physical and chemical properties with two constituent parts, one being a metal and other may be metal, ceramic or fiber. Due to their light in weight, high strength and high hardness, among various MMC's, aluminium MMC is the most widely used. This paper aimed to investigate the tensile and impact properties of hybrid metal matrix composite consists of aluminium - Alumina (Al_2O_3) – Silicon carbide (SiC) fabricated by stir casting process. The composites are tested for their flexural and impact properties and the result shows that all the properties of hybrid composite are superior than base metal. The morphological analysis of the tested specimens is done using Scanning Electron Microscope (SEM).

KEYWORD: Metal matrix composite, Aluminium, Aluminium Oxide, Silicon Carbide, Morphological analysis.

I. INTRODUCTION

Ramachandra and Radhakrishna [2007] found the effects of reinforcement of flyash on sliding wear, slurry erosion wear and corrosion behavior of aluminum, Al(12% wt Si). They investigated the sliding wear behavior of MMCs by varying parameters like normal load percentage flyash and tack velocity. They also concluded that flyash reinforced material has better wear resistance with increase in flyash content, but decreases with increase in normal load, and track velocity and corrosion resistance decreases with increase in flyash content. Vijaya Ramnath et al [2014] evaluated the mechanical properties of aluminum alloy, Alumina, boron carbide, metal matrix composites. Aluminum which as better wear resistance and high strength hardness and Boron carbide which has excellent strength and fabricated by using stir casting and analysed SEM. The authors concluded that tensile strength increases with increase in aluminium while the flexural and impact strength is more in aluminium but the hardness value increases with increase in boron carbide content. Kok [2005] found the properties of aluminum alloy particles reinforced 2024 aluminium alloy composites MMCs reinforced with three different sizes Al2o3 particles up to 30% wt fabricated by vertex method and pressure is applied subsequently and concluded that decreasing size and increasing weight fraction of particles led to increase in the hardness and the tensile strength of the composites. Balasivanandha Prabu et al [2006] found the stirring speed and timing resulted in better distribution of particles, uniform hardness is achieved by 600 rpm and 10mins stirring and also concluded that with lower stirring speed and lower stirring time the clustering of the particle was more but increase in stirring speed and stirring time resulted in better distribution of particles. Ei-Sabbagh et al [2013] studied the Al 6061 and Al 7108-SiCp composites prepared by stir casting with particle size of 8 and 15µm (vf) of 0-20% by hot rolling the composites of rolled to 0.4 and concluded that hot rolling resulted in the improvement of ultimate tensile strength (UTS) for 6061 and 7108 composite and UTS of rolled composite was enhanced by T6 treatment for 6061 and 7108 composites. Srivatsan and Al-Hajri [2002] found the cyclic stress amplitude control fatigue and fracture behaviors aluminum alloy 7034 reinforced with (SiCP). The cyclic fatigue test was conducted at two different load ratios. They concluded that with a decrease in load ratio microscopic fracture of the composite was dominated by failure of the reinforcing SiC particle both by cracking and decohesion at the particle–metal-matrix interfaces. Abhishek Kumar et al [2013] fabricated and studied the characteristic of A359/Al2o3 metal motion composite of electromagnetic stir casting, such as ceramic or organic compound recently aluminum and ferrous alloy

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based cost MMCs has gained lots of popularity in all energy field engineering and technology. They also concluded that the unreinforced matrix metal has lower hardness than the MMCs and the tensile strength increases with increasing the weight fraction of Al2O3. It was found that hardness and impact strength increases with increase in weight percentage of SiC [8]. Li et al [2000] found the compressive visco plastic response of an A359/SiCp metal matrix composites and A359 Aluminium alloy matrix in the A359 matein alloy and A359/SiCp composites flow stress in compression depends that increase in strain rate the model does not incorporate the particle damage that occurs in composite it is unable to predict the changed overall strain hardening of composite material. Suryanarayanan [2013] analysed Silicate carbide reinforced Aluminum metal matrix in composites for aerospace application also found various types of reinforced material and distribution of reinforced material Al-SiC metal matrix composites with particural reference in the Aero space industry are recommended as the possible replacement for aluminium and if is seen that the exact set of properties depends on certain factors. Vijaya Ramnath et al [2013] reviewed the metal matrix composite with their applications. Siddique Ahmed Ghias and Vijaya Ramnath [2015] investigated the tensile property of Aluminium SiC Metal Matrix composite and found that hybrid composite has good strength.

II. EXPERIMENTAL DETAILS

A. MATERIALS

In this work, matrix material is aluminum while Silicon carbide and alumina in powder form are reinforced with the varying volume fractions as reinforcement. Aluminium oxide (Al_2O_3) is the combination of aluminium and oxygen which has high thermal conductivity. Silicon Carbide is one of the widely used ceramic particles due to its properties like high hardness and low coefficient of thermal expansion (4.6×10^{-6} /°C). It is used in automotive brakes and clutches. The properties of the matrix and the reinforcements are shown in table 1.

Table 1: Properties of Al, SiC and Al_2O_3

Properties	Aluminium	Silicon Carbide	Aluminium Oxide
Density (gm/cm^3)	2.70	3.30	3.98
Tensile Strength (MPa)	185	588.0	416.0
Coefficient of thermal expansion (10^{-6}/°C)	23	4.6	7.4
Modulus of Elasticity (GPa)	70	345	380

B. STIR CASTING PROCESS FOR FABRICATING COMPOSITE

Stir casting process is used to fabricate composite consists of an induction furnace with three mild steel stirrer blades. Here, the reinforcements are distributed into molten aluminium matrix by mechanical stirring. During preheating stage, the reinforcements are heated separately nearer to main process temperature of 400°C while aluminium is melted in a separate crucible at a temperature of 830°C. Now, the preheated reinforcements are mechanically mixed with the molten aluminium below their melting temperature. Then, the mixture is poured into the die and allowed to solidify. The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring speed, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added.

The weight percentage of the matrix and the reinforcements for different samples are shown in table 2.

Table 2: Composition of matrix and reinforcement in wt%

Samples	Al in %	Al_2O_3 in %	SiC in %
1	98	1	1
2	96	2	2
3	94	3	3
4	92	4	4
5	90	5	5

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III. TESTING

The following tests are performed on the aluminium metal matrix composite samples to find the influence of reinforcements on their mechanical properties. Table 3 shows various tests, their purpose and their ASTM standard.

Table 3 Various Tests

Test number	Name of test	ASTM -Standard	Purpose	Machine used
1	Flexural test	ASTM: A-370	To know the flexural property of a composite	Universal testing machine with a three point flexural setup
2	Impact test	IS: 1757	to determine the amount of energy absorbed by the samples during fracture	Charpy impact test

IV. RESULTS AND DISCUSSIONS

A. FLEXURAL TEST

The flexural test is done using UTM with three points loading- three point bending device. The flexural test results are presented in table 4. From table 4, it is observed that the flexural strength of the sample 5 is greater than other samples while the flexural strength of sample 1 is less than others. Also, Sample 1 has greater deflection than other four samples.

Table 4: Flexural properties of composites

Sample	Flexural Break Load (kN)	Maximum deflection (mm)	Flexural strength (MPa)
Sample 1	1.1	3.23	322.2
Sample 2	1.42	3.06	378.6
Sample 3	1.63	2.98	385.2
Sample 4	1.74	2.89	391.2
Sample 5	1.81	2.78	401.3

B. IMPACT TEST

The Charpy test is performed by preparing the specimen as per IS: 1757 standard. The impact properties are shown in table 5. From table 5, it is found that the sample 1 absorbs more energy than other four samples since it contains less amount of Al_2O_3 and SiC which are evenly distributed in the Aluminium matrix.

Table 5: Impact property of composites

Sample	Energy absorbed (J)
Sample 1	4.89

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Sample 2	4.71
Sample 3	4.58
Sample 4	4.61
Sample 5	4.63

V. MORPHOLOGICAL ANALYSIS

In this work, morphological analysis was done using Scanning Electron Microscope (SEM) on flexural tested specimen as shown in figure 1.

A. MICROSTRUCTURE OF THE COMPOSITES

Figure 1 shows the internal structure of sample 3 of flexural tested specimen. The white particles are aluminium and the darker particles are silicon carbide. The uneven distribution of the aluminium and the reinforcements reveals the improper stirring during the casting process which also results in the formation of porous sites and micro cracks. The fractured surface of the sample 3 is given in figure 1.

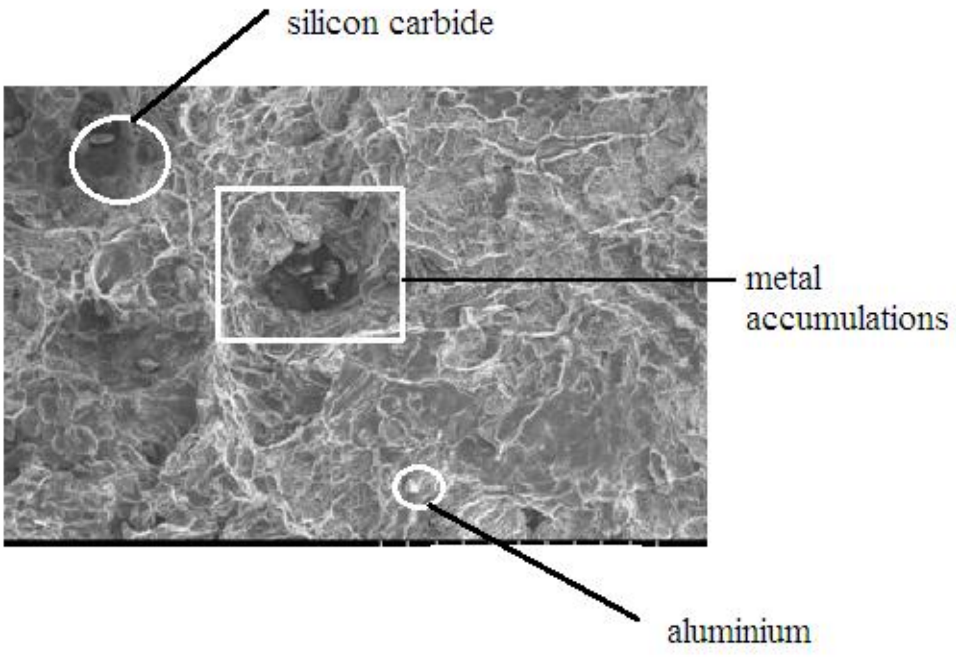

Figure 1: Flexural test specimen

VI. CONCLUSIONS

In this paper, hybrid metal matrix composite is fabricated by stir casting process with different volume fraction of alumina and silicon carbide. The following conclusions are arrived drawn after conducting mechanical tests.

1. The flexural strength of the composite increases with the-increasing wt% of the Silicon Carbide. The flexural strength of sample 5 which has more reinforcement is higher than that of the other four samples.
2. Sample 1 absorbs more energy than other samples.
3. Overall, the mechanical property of the sample 5 is superior than those of other samples.

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