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EXPERIMENTAL INVESTIGATION AND MECHANICAL BEHAVIOR OF A356.1 ALUMINIUM ALLOY MATRIX COMPOSITE REINFORCED WITH SILICON CARBIDE

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Abstract - *Aluminium matrix composites (A**MC's)** reinforced with Silicon Carbide (SiC) particles are being used for high performance applications such as Automotive, Aerospace, Military and Electrical Industries, because of their improved physical and Mechanical properties. In this context, A356.1 Aluminium alloy was reinforced with varying weight percentages of 0, 5.0, 10.0 and 15.0 Silicon Carbide, through Stir Casting Technique. The composites were characterized by Scanning Electron Microscope (SEM). Mechanical properties such as Hardness, Impact Strength, and Wear were carried out for different conditions. The results reveal that the Metal Matrix* ***Composite (MMC'S) containing 15 weight percentage of*** *Silicon Carbide reinforcement was shown more improvement in Mechanical properties.*

Key Words: Metal Matrix Composite, SiC/A356.1 Composite, SEM

1. INTRODUCTION

Composites are the combination of two or more constituent material with significantly different physical and chemical properties with characteristics different from individual components. They commonly consist of a continuous phase called matrix and discontinuous phase in the form of fibers, whiskers, or particles called as reinforcement. Due to their characteristics of behavior with their high strength to weight ratio, Composite materials are gaining wide spread acceptance. Metal Matrix Composites (MMCs) are materials with metals as the base and distinct (Matrix) phase and typically the ceramic phases added as reinforcements to improve the mechanical properties. Excellent mechanical performance, high working temperature, wear resistance, low creep rate etc are the main advantages of MMCs. Superior combination of above mentioned properties are offered by MMCs in such a manner that today no existing monolithic material can deliver and hence they are increasingly being used in the aerospace and automobile industries.

"Metal Matrix Composites (MMCs)" are broadly refers to a composite system which is based on metal or alloy substrate, combined with metallic or non-metallic reinforcements. MMCs are widely used in aerospace industry and other high technology fields. In the past years, MMCs have been extensively studied, especially including the fabrication methods. The number of Aluminium products is rapidly growing. Since more and more Engineered Materials are meeting the global market. The continuous revolution in Metal Matrix Composites will results in the fabrication of Aluminium materials with properties and functionalities. They are going to have positive changes in the lives of our people, be it in Aerospace, Automobile, Electronics, Health, Environment or any other field [12]. Promotion of the developments of MMCs, due to their lowered cost of fabrication and enabled applications of MMCs extended from high technology to automobile industry is done by a variety of manufacturing processes, such as stir casting, semi-solid casting and spray deposition. Demand for developing metal matrix composites is much necessary for use in high performance applications such as, Aerospace, Automobiles, Electronics, and Computer industries. Aluminium alloy matrix composite attracts much attention towards manufacturing the components, due to their lightness, high thermal conductivity, moderate casting temperature etc...[6]. A significant improvement in the properties of Aluminium alloys, reduced fuel consumption, made huge demand for automobile industry because of light weight. This growing requirement of materials with high specific mechanical properties and with weight savings, as fuel significant research activities targeted primarily for further development of Aluminium based composites in recent times.

Aluminium alloy matrix is reinforced by using various kinds of ceramic material like SiC, Al_2O_3, MgO and ZrO_2 extensively. Superior mechanical properties of these materials such as refractoriness, high hardness, high compressive strength, wear resistance etc... Make them suitable for use as reinforcement in matrices of composites [7].

2. EXPERIMENTAL PROCEDURE

2.1 Materials

Present work composition of A356.1 Aluminium alloy specimens are shown in the table 1. This alloy were used as matrix Material with the reinforcement of Silicon Carbide material and is reinforced using Stir Casting Method at a stirring speed of 100 rpm.

Table 1: Chemical Composition of A356.1

Elements	Al	Si	Fe	Cu	Mg	Mn	Zn	Ni
Wt. %	91.73	7.23	0.32	0.18	0.38	0.02	0.05	0.05

2.2 Process

A356.1 Aluminium alloy was reinforced with Silicon Carbide materials at different wt. % ratios (0, 5.0, 10.0, 15.0) of samples. It was fabricated using a Resistance furnace equipped with a stirring system. Stirring process was carried out at constant speed of 100 rpm with a stirring duration of 15-30 min, and at casting temperature of 850±5°C. Specification of the stirring process including the position of ceramic coated stirrer in the molten alloy, the size and the shape of the blades of ceramic stirrer and the rate of stirrer were adopted according to the result of the literature and the previous work. Fig.1.1 Shows Schematic diagram of Stir Casting technique.

Fig 1.1: Stir Casting

Composite slurry was poured into the Cast Iron mould and samples were shaped in the form of cylindrical rod of 12 mm diameter and with the height of 170 mm. Microscopic examination were carried out using Scanning electron microscope (SEM: JEOL, Japan, JSM 840A). To study the hardness variations in longitudinal sections of the cylindrical composites, the specimens were prepared as per ASME G91 standard of dimension 12 x 8 mm cylindrical samples .The Brinell hardness values of the samples were measured on the polished sections (250 grit size papers), the hardness samples were measured on varying Wt.% reinforcements and at different temperature conditions, with a ball indenter diameter of 2.5 mm at a constant load of 187.5 Kgf. Each value of hardness for variation of Wt. % reinforcement is reported with an average of at least three randomly obtained readings. For the evaluation of wear properties of the MMC's, the cylindrical samples were machined according to the ASTM G99 standards of dimension 30 x 8 mm. Wear test is carried out on a Pin-on-disc Tribometer. The disc is made up of high carbon EN31 steel having a hardness of HRC60.The radius of the sliding track on the disk surface was 100 mm, wear test were performed under dry sliding condition and with three different varying conditions of Load, Speed, Time. Finally for the evaluation of Impact Strength of the MMC's, the cylindrical samples were machined according to the ASTM G99 standards of dimension 75 x 10 mm. Impact test is carried out on a Izod Test. The Impact strength is determined by the loss of energy of the pendulum as determined by precisely measuring the loss of height in the pendulum's swing.

3. RESULTS AND DISCUSSION

3.1 Hardness Studies

Hardness is the measure of a material's resistance to surface indentation, also it is a function of the stress required to produce some specific types of surface deformation. The Hardness tests were performed with a Brinell Hardness Tester with a load of 187.5Kgf and with a Ball Indenter Diameter of 2.5mm. The influence of Silicon Carbide material content on the hardness of various Wt. % reinforcements (0, 5.0, 10.0, and 15.0) is shown in Fig 3.1. The Fig 3.1 shows that the Hardness Number (BHN) for As cast A356.1 Aluminium alloy at room temperature (28°C) is 52, then the Hardness gradually increases to 75.4 for 5 Wt. % of SiC reinforced to A356.1 Aluminium alloy at room temperature (28°C). Similarly the Hardness Number for 10 Wt. % of SiC reinforcement is 76.58 and Hardness Number increases to 77.45 at 15 Wt. % of SiC reinforcement for the same condition.

3.2 Wear Analysis

Wear test was conducted employing a Pin-on-Disc Tribometer. Most requirements of the ASTM G99 standard on Wear Testing were followed. However, substantial modifications were considered, mainly regarding the Pin shape. Cylindrical Pins with dimension of 30 x 8 mm were made of the A356.1 Aluminium alloy reinforced with Silicon Carbide material at varying Wt. % ratios. A constant nominal area was maintained during the wear test. The counterpart disc was made of high carbon EN31 steel having a hardness of HRC60. The radius of the sliding track on the disc surface was 100 mm. Before the wear test the surface of each Pin was ground using 240,320,400,600-grit SiC Abrasive papers. Wear testing was performed in a dry sliding condition for varying Wt. % ratios with varying speed, load and Time. All worn-out Pins were cleaned in Acetone and weighed to an accuracy of ±1mg prior to testing. Wear rate and Wear weight loss was determined.

Fig 3.2 shows that Wear Rate is 60.49×10-6 g/m at a applied load of 10N for As cast A356.1 Aluminium alloy. For the same Load, 15 Wt % of SiC added to the base alloy shows decrease in Wear Rate by 35.02×10-6 g/m.
Fig 3.3 shows that Wear Rate is 70.04×10-6 g/m at operating Speed of 100rpm for As cast A356.1 Aluminium alloy. For the same operating Speed, 15 Wt % of SiC added to the base alloy shows decrease in Wear Rate by 19.10×10-6 g/m. Similarly for As cast Aluminium alloy at an operating Speed of 500rpm, Wear rate is 118.4×10-6 g/m and for the same operating Speed with 15 Wt % of SiC reinforcement to base alloy, Wear Rate Considerably decreases to 86.59×10-6 g/m.
Fig 3.4 shows that Wear Rate is 72.18×10-6 g/m at a operating Time of 300sec for As cast A356.1 Aluminium alloy. For the same operating Time, 15 Wt. % of SiC added to the base alloy shows decrease in Wear Rate by 47.78×10-6 g/m. Similarly for As cast Aluminium alloy at a operating Time of 1500sec, Wear rate is 193.8×10-6 g/m and for the same operating Time with 15 Wt. % of SiC reinforcement to base alloy, Wear Rate Considerably decreases to 156.9×10-6 g/m.
Fig 3.5 shows the graph of Wear Loss Vs Sliding Distance for all reinforcements

3.3 Impact Strength Studies

Impact Strength are used to measure the energy absorbing capacity of the material subjected to sudden loading but also to determine the transition temperature from ductile to brittle behavior. The Impact tests were performed with an Izod Test. The influence of Silicon Carbide particle content on the Impact Strength of various Wt. % reinforcements (0.5,1.0, 1.5, 2.0) is depicted in the Fig 3.6. The Fig 3.6 shows that the Impact Strength for As cast A356.1 Aluminium alloy is 60 KJ/m², then Impact Strength gradually increases to 80 KJ/m², after reinforcing 5 Wt. % of SiC to A356.1 Aluminium alloy. Similarly the Impact Strength for 10 Wt. % reinforced A356.1 Aluminium alloy is 90 KJ/m² and for 15 Wt. % of reinforcement of SiC to A356.1 Aluminium alloy results in maximum Impact Strength of 104 KJ/m².

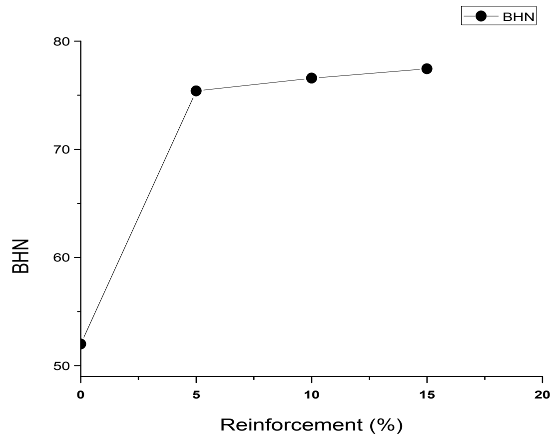

Fig 3.1: BHN Vs different Wt. % Reinforcement of SiC particles

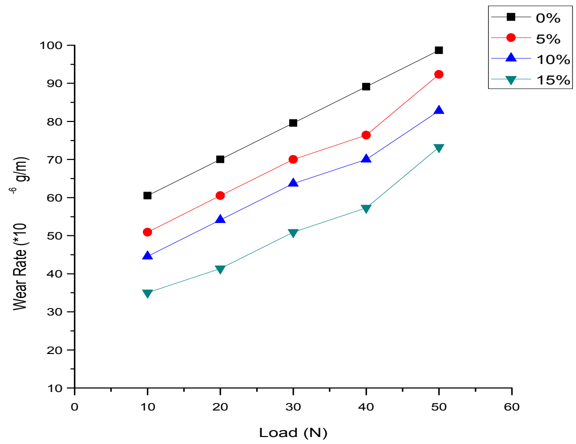

Fig 3.2: Wear Rate Vs load for at Constant Speed of 100rpm and Constant Time of 300sec

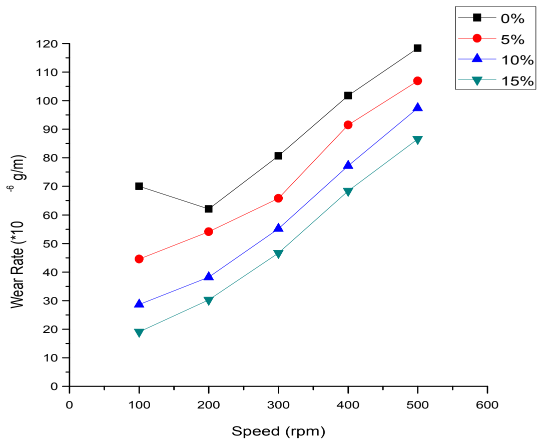

Fig 3.3: Wear Rate Vs Different Wt. % Reinforcement of SiC particles for varying Speed

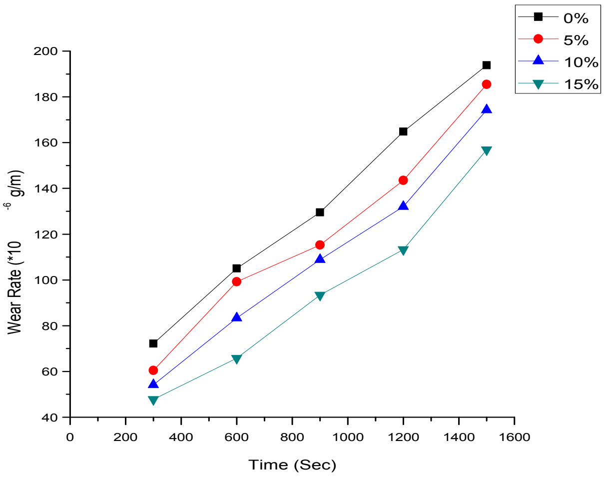

Fig.3.4: Wear Rate Vs Time at Constant Load of 30Nand Constant Speed of 300rpm

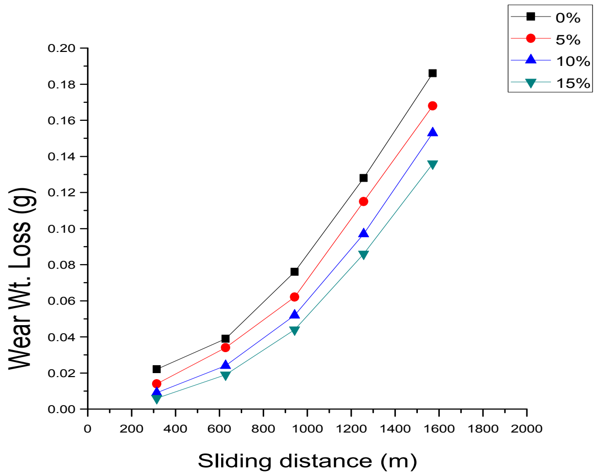

Fig.3.5: Wear Loss Vs Sliding Distance at Constant Load of 30Nand Constant Time of 300 sec

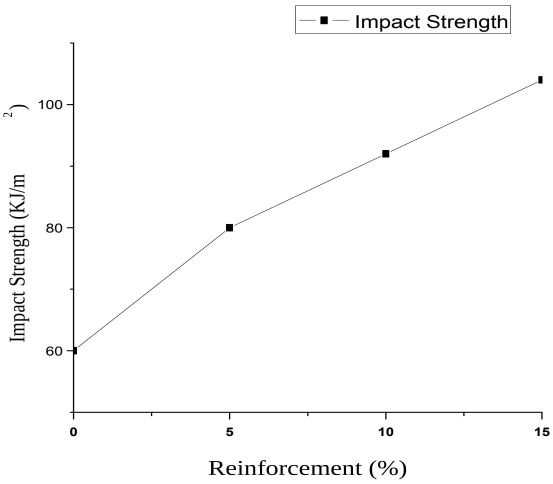

Fig 3.6: Impact Strength Vs different Wt. % Reinforcement of SiC particles

3.4 SEM

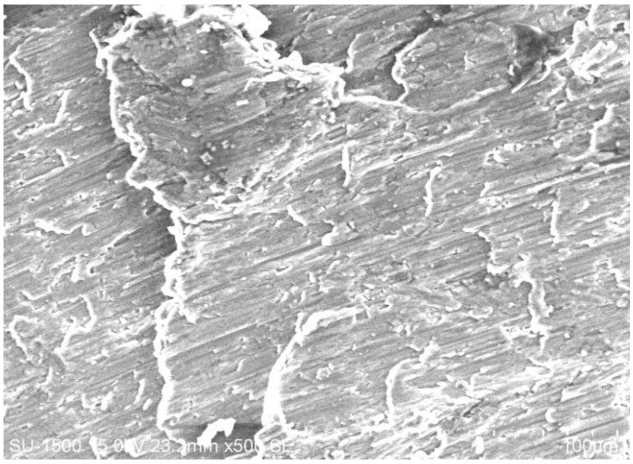

Fig 3.7.(a)

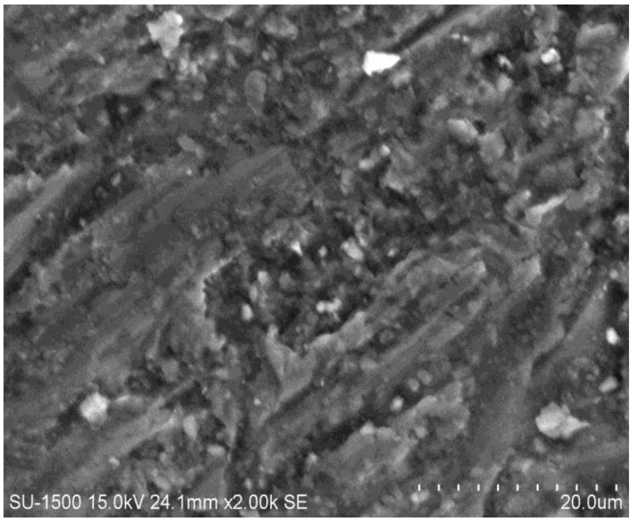

Fig 3.7.(b)

Fig 3.7.(c)

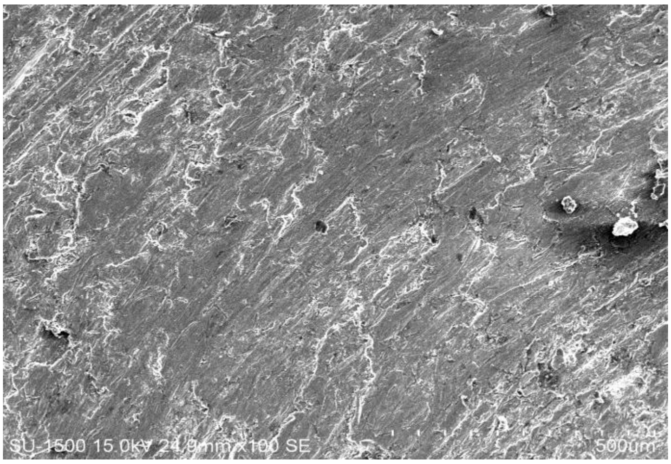

Fig 3.7.(d)

Fig.3.7.SEM Images of the A356.1 Aluminium Alloy reinforced with(a) 0 Wt.% of SiC particles at Magnification of 2500?960 (b) 5 Wt.% of SiC particles at Magnification of 2500x960 (c) 10 Wt.% of SiC particles at Magnification of 1800x960 (d) 15 Wt.% of SiC particles at Magnification of 5000x960.

4. CONCLUSIONS

In this current study, A356.1 Aluminium alloy was reinforced with Silicon Carbide (SiC) at varying weight percentages through stir casting with a stirring speed of 100rpm. Hardness, Wear and Impact Tests are carried out in order to study the mechanical properties of the Composite.

1. SEM micrographs indicate that SiC Particles are successfully reinforced with A356.1 Aluminium alloy and particles dispersed throughout the matrix.

2. The Hardness of the MMCs improved with addition of reinforcement particles. Maximum Hardness was achieved when A356.1 Aluminium alloy was reinforced with 15 Wt % of SiC particle content.

3. Wear resistance of the composite was found to be considerably higher than that of matrix alloy increased with increase SiC particle content. The hard particles resist against destruction action of the abrasive and protect the surface. So, with increase with the SiC content the wear resistance enhances. By increasing the reinforcement content of 15 Wt.%

4. Similar to the Hardness and Wear Resistance improvement, the Impact Strength of the MMCs was also increased with addition of SiC particles and maximum strength was achieved when A356.1 Aluminium alloy was reinforced with 15 Wt % of SiC particle content.

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