RESEARCH ARTICLE OPEN ACCESS

Evaluation of Mechanical and Machining Properties of AL-SICP Metal Matrix Composite

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ABSTRACT

In recent times the application of Aluminum Metal Matrix Composites (MMCs) as engineering materials has exceedingly increased in almost all industrial sectors. Aluminum MMCs are preferred to other conventional materials in the fields of aerospace, automotive and marine applications owing to their improved properties like high strength to weight ratio, good wear resistance etc. These materials are of much interest to the researchers from past few decades. In this paper it is aimed to present the research findings of Al–SiC nano particles particulate metal matrix composites prepared by liquid metallurgy route (stir casting technique). The amount of reinforcement is varied from 0 to 6 % by weight. The SiC particulates were dispersed the in steps of 1.5 into the Al alloy. The prepared composites are subjected to the mechanical testing as per the ASTM standards. The Rockwell hardness of the composite was found to increase with increase in filler content in the composite. The tensile strength of the composites was also found to increase confirming the enhancement of the mechanical properties. The micro structure of the composites has been examined.

***Keywords* :–** Al, SiC, composites, hardness, tensile strength, toughness, mechanical properties, micro structure

I. INTRODUCTION

Metal matrix composites are of wide interest owing to their high strength, fracture toughness and stiffness. Among the various MMCs used in industry, the composite consisting of Al6061 matrix alloy reinforced with SiC has found wide application [1]. In the investigation of wear behaviour of Al6061 alloy filled with short fiber (Saffil) it was concluded that Saffil reinforcement are significant in improving wear resistance of the composites[2]. Self-lubricating graphite was incorporated in Al6061 alloy to prepare composites [3]. Al2O3, B4C, Ti3Al, and B2Ti in Al6061, were used to show that Mechanically Mixed Layers (MML) are generated during sliding wear condition [4]. Transition from mild to severe wear was noticed when the surface temperature reaches about 0.4 times the melting temperature of Al6061 alloy [5]. In pin-on-disc test a mechanically mixed layer (MML) six times harder than the bulk material is produced. This layer is responsible for reduction in wear rate of MMCs [6]. Friction coefficient value of the composite was also found to increase due to the presence of hard MML layer and plastic deformation of the steel disc during sliding [7]. The light metals such as Al and its alloys form superior composites suitable for elevated temperature applications when reinforced with ceramic particulates [8]. It was found that the matrix hardness has a strong influence on the dry sliding wear behaviour of Al2O3 particulate Al6061 MMC [9]. In the investigation on the tribological behavior on Al6061 reinforced with Al2O3 particles it was concluded that a characteristic physical mechanism exists during the wear process [10]. When a sufficiently high load is applied on the contact, the matrix phase is plastically deformed, and the strain is partially transferred to the particulates, which are brittle with small failure strains. It was clearly demonstrated that the effects of applied load and temperature on the dry sliding wear behavior of Al6061 alloy matrix composites reinforced with SiC whiskers or SiC particulates and concluded that, the wear rate decreased as the applied load is increased [11]. At higher normal loads (60N), severe wear and silicon carbide particles (SiC) cracking and seizure of the composite was observed in pin-on-disc test during dry sliding wear of Al2219 alloy MMCs [12]. MMCs having SiC of 3.5, 10 and 20 μm size with 15 vol. %, produced by P/M route displayed good wear resistance with increasing particle size in sliding wear [13].

II. EXPERIMENTATION

SILICON CARBIDE REINFORCEMENT in ALUMINIUM MATRIX

Silicon carbide particulates have attained a prime position among the various particulate reinforced metal matrixes composite. This is due to the fact that introduction of Sic to the aluminum matrix substantially enhances the strength, the modulus, the abrasive wear resistance and thermal stability. The density of SiCp ($3.2g/cm^3$) is nearer to that of aluminum alloy ($2.7g/cm^3$). The resistance of Sic to acids, alkalis or molten salts up to 800^OC makes it a good reinforcement candidate for aluminum based MMC. Furthermore, SiC has good wettability with aluminum alloys. Addition of alumina particle results in good wear properties and compatibility. Addition of Silicon carbide particle results in Excellent Mechanical properties this produces a very hard and strong material. The fig.1 shows the silicon carbide nano particles of size about 10 nm.

Fig.1 Silicon carbide particles

SPECIMEN PREPARATION USING STIR CASTING METHOD

The specimen with the following composition are made

I. MMC with 1.5% SiC
II. MMC with 3% SiC
III. MMC with 4.5% SiC
IV. MMC with 6% SiC

STIRRING TEMPERATURE

Aluminum generally melts at 650°C. The processing temperature is mainly influence the viscosity of Al matrix. The change of viscosity influences the particle distribution in the matrix. The viscosity of liquid decreased when increasing processing temperature and with increasing holding time and stirring time. This will accelerate the chemical reaction between matrix and reinforcement. In the present work an operating temperature of 925°C is maintained which keeps Al in liquid state.

Preheating of Reinforcement: 525°C temperature 30 min

Stirring Speed: 1025 rpm

Stirring time: 20 minutes

Fig. 2 Stir casting apparatus

Fig.3 Gravity die casting of liquid MMC

PREPARATION OF SPECIMENS USING GRAVITY CASTING

The materials are melted in the stir casting furnace (fig.2) and casted with gravity die casting machines shown in the fig.3. Specimen with 1.5%, 3%, 4.5% and 6% SiC are moulded shown in fig. 4(a) and 4(b).

Fig.4 (a) MMC with 3% SiC specimen

Fig.4(b) MMC with 6% SiC specimen

III. MECHANICAL PROPERTIES EVALUATION

The following Mechanical properties of the composites developed were evaluated experimentally are tabulated.

1. Tensile strength
2. Compression strength
3. Shear strength
4. Toughness using Charpy test& Izoid tests
5. Hardness
6. Porosity
7. Surface texture

Tensile strength: It is evaluated using Tensile testing machine
Compression strength: It is found by testing the specimen with Universal Testing machine
Shear strength: It is calculated by testing on Torsion testing machine
Toughness is evaluated using Charpy test& Izoid tests
Hardness is measured by testing on Vickers hardness testing machine
Porosity is checked with Scanning Electron microscope
Surface texture is visualized with Computerized micro scope

Table 1: Mechanical Properties of MMC

							Toughness	
S.No	**Material**	**F_t, N/mm^2**	**F_c, N/mm^2**	**F_s N/mm^2**	**HV**	**Porosity,%**	**Charpy test**	**Izod test**
1	Al	290	550	109	80	0.33	3.76	2.48
2	1.5%SiC	282	510	92.2	83	0.63	4.05	2.54
3	**3%SiC**	**278**	**450**	**84.6**	**86**	**0.57**	**4.66**	**2.68**
4	4.5%SiC	260	448	80.1	88	0.42	4.56	2.62
5	6%SiC	256	442	79.6	90	0.11	4.46	2.59
6	MS	350	1541	134.3	128	0.07	3.75	2.1

IV. RESULTS AND DISCUSSIONS

The results obtained by different tests for the MMCs developed and compared with pure Aluminum and Mild steel. The results are depicted in the histograms shown below.

Fig.(5) shows the Tensile Strength of the pure Al and MMC with 1.5%, 3.0%, 4.5% and 6.0% SiC and of MS for comparison. The results are indicating that the Tensile Strength is decreasing with the increment in % of metal matrix material. SiC Nano particles. However Mild steel is having 20% higher tensile strength compared to pure Al, (or) its MMC's. The presence of MMC is causing the material more hard and tough. However based on the results of other tests Al with 3.0% SiC MMC is seems to be a better composition for many practical purposes. Al MMC is also better than MS in specific gravity point of view even though Tensile strength is little lower.

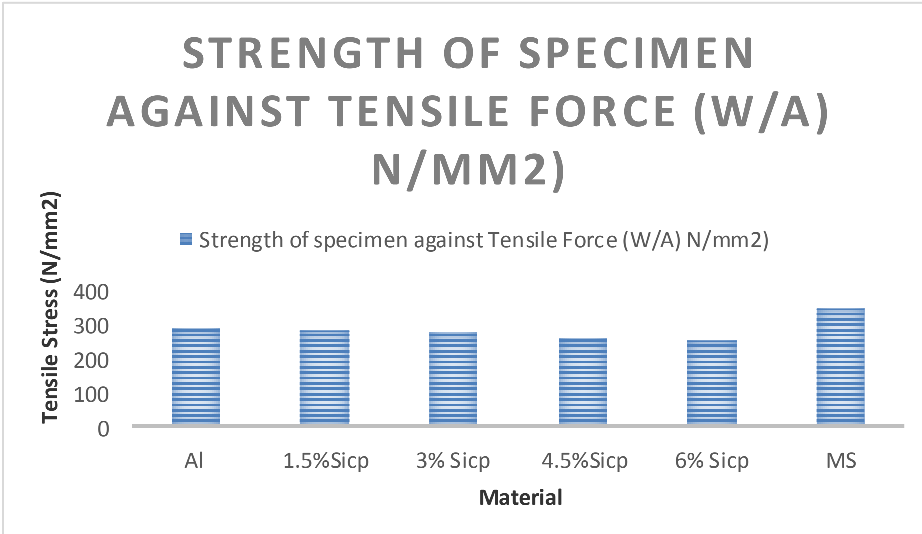

Fig.5 Tensile strength of materials

Fig.(6) Depicts the comparison of compressive strength of all the materials under present research work. Pure Al is showing 550 N/mm^2 strength and the value is declining with the increment in % of SiC. In the MMC 3% SiC MMC is having 450 N/mm^2 strength. At the higher values of SiC the compressive strength is not declining. Hence 3% SiC Al MMC seems to be a better option. However the compressive strength of MMC is un comparable with that of MS.

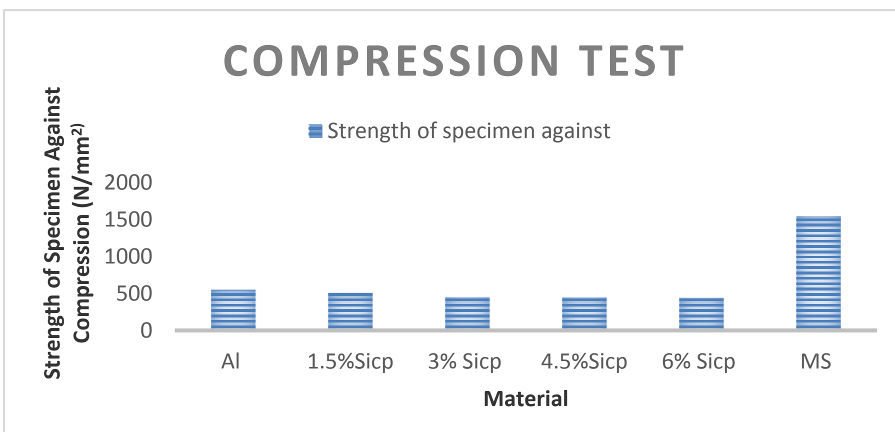

Fig.6. Compressive strength of MMC

The shear strength of the material under testing in the present research has been shown in the fig.(7). The shear strength of MMC is decreasing with the increment in the % of Nano SiC. The variation in the shear strength is observed to be 10%. 3% SiC Al MMC is observed to be better among the others and also having about 2/3rd of the shear strength of MS.

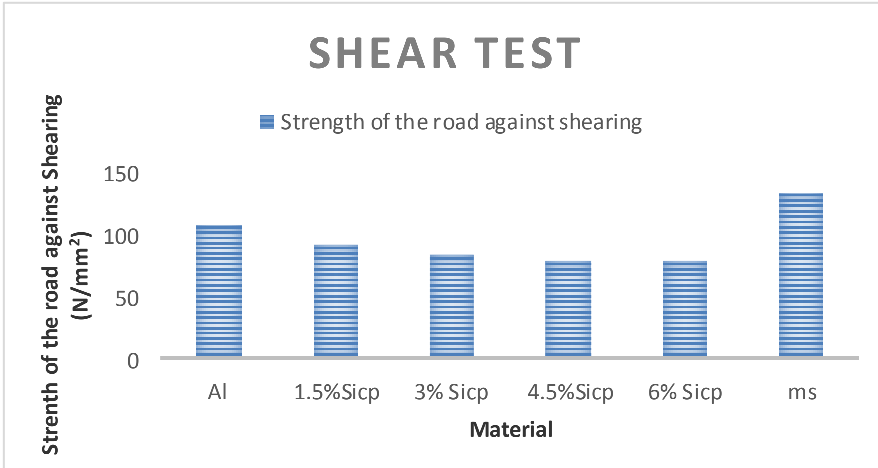

Fig. 7. Shear strength of MMC

The Hardness of the specimen under the present studies is shown in the fig. (8). Al is about the 2/3rd harder than MS. However Al hardness is found to increasing with increase in the % of SiC Nano particles in the MMC. The increment in the hardness is almost uniform. The Al SiC MMC is becoming harder and tougher than pure Al. As well as MS. The experimental results shows that 3% SiC Al will be a better option.

Fig.(9) Shows the variation in the porosity occurred in the material during casting. The results are showing that the porosity is decreasing with increase in the % of SiC in the matrix. Porosity will be useful in controlling the conductivity. 3% SiC -Al MMC seems to be having optimum mechanical properties.

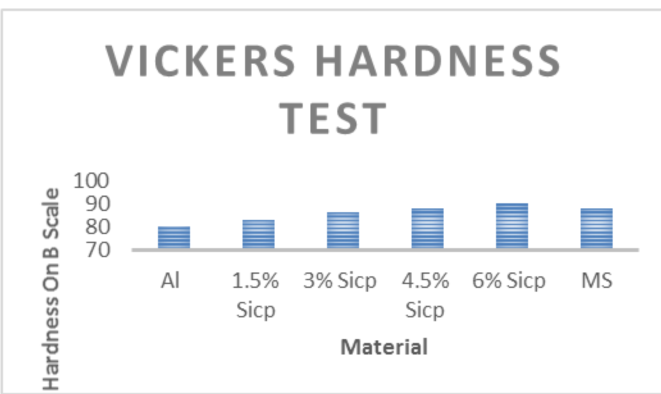

Fig. 8. Hardness of materials

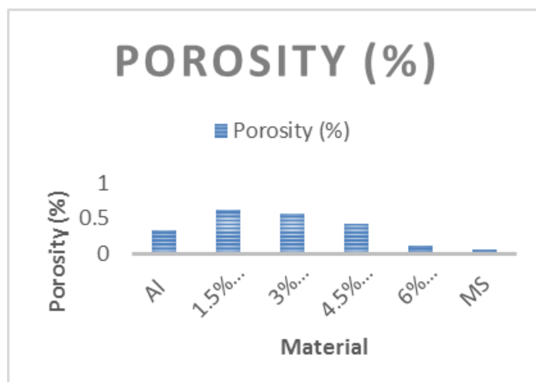

Fig.9. Porosity test results

The results of the toughness obtained for the specimen under the present study is shown in fig.(10) and (11). The toughness tested by charpy and izod tests observed to be increasing with the addition of SiC up to 3% MMC and then declined. The increment in the toughness results in decrement in the brittleness and improvement in the fracture resistance.

All the above tests reveals that the Al – 3% Sic MMC is having good mechanical strength/properties and will be useful for high strength to weight applications.

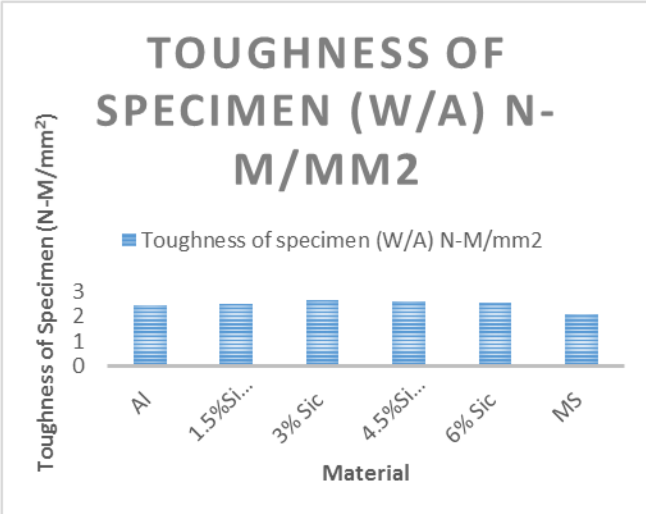

Fig.10. Izod Test results

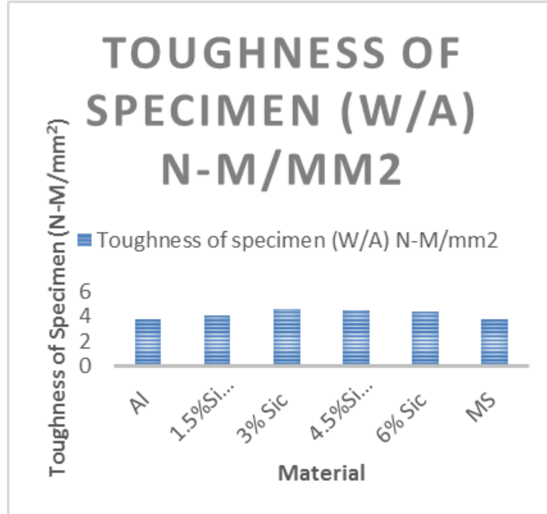

Fig.11 Charpy test results

V. CONCLUSIONS

The present work deals with the preparation and characterization of Al-SiC Metal Matrix composites. The following conclusions can be drawn.

1. The Toughness of the composite was found to be maximum at 3% SiC reinforcement compared to 6% SiC reinforcement.
2. The hardness of the composite was found to be maximum at 6% SiC reinforcement compared to 3% SiC reinforcement.
3. The compression strength and shear strength of the composite was found to be reduced compared to pure Al.
4. The properties of MMC with 3% SiC is better than the pure Al.
5. The Mechanical properties of the MMC with 6% SiC was reduced due to addition of more reinforcement was observed when compared with 3% SiC.
6. Machinability was decreased with increase in reinforcement.
7. MMC with 3% SiC is suggested to use in aviation applications due to its high Toughness.

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