International Journal of Advanced Engineering Research and Applications (IJA-ERA) ISSN: 2454-2377
Volume – 2, Issue – 4, August – 2016

# Development of Mechanical and Metallurgical Behavior of Al-Sic Reinforced Metal Matrix Composite

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***Abstract:*** In the present investigation, Aluminium based metal matrix composite containing up to 5%, 10% and 15% weight percentage of Silicon carbide (SiC) particles along with 5% fly ash are synthesized using stir-cast method. Microstructural studies reveals that uniform distribution of reinforced particulates can be done upto 10% reinforcement of SiC after that clustering of carbide particles take place which result in uneven hardness of MMC. The composite with 10% SiC and 5% Fly ash had much better tensile strength i.e. 145.33MPa and microhardness value of 56.7HV than pure HE-9 aluminium alloy.

***Keywords:*** Metal Matrix Composite (MMC), SiC, Microstructure, SEM

## I. INTRODUCTION

Today is the time for non-conventional machining for the machining of softest to hardest materials. In the same way with the passage of time new materials are introducing day by day in various field of mechanical engineering which possess better properties including high specific strength; specific modulus, damping capacity and good wear resistance like metal matrix composites (MMCs) and polymer base composites.

Aluminium based metal matrix composite can fulfill the requirements of high strength-to-weight ratios, higher wear resistance and corrosion resistance, higher conductivity, and lower coefficient of frictions. Also, Aluminium based metal matrix composite have relatively low processing costs in comparison to other metals like magnesium, copper, titanium, zinc, etc. Improved mechanical and Tribological properties of aluminium composites had been successfully achieved and reported by a no of researchers with different reinforcements like SiC, TiC, ZrO, $SnO_2$. Interest of engineer's increasing in composites which have low density and low cost reinforcements. A number of reinforcement are available but fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of fly ash particles in aluminium alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products. Researchers studied various mechanical and tribological properties of single reinforced and hybrid reinforced aluminium metal matrix composite.

The reinforced aluminium alloys are extensively used in various fields especially in automobile and aerospace industries because of its good mechanical strength, tribological and thermal stability [1].

  

The low weight aluminium reinforced alloys lead to reduction of weight resulting in considerable economic advantages [2-5]. The wear behaviour of the reinforced aluminium MMC has been extensively studied due to their very high wear resistance compared to unreinforced metal alloys [6-7]. The aluminium metal matrix materials can be reinforced with various oxides, carbides and nitrides. The most commonly materials used as a reinforcement are SiC and Al2O3. Also B4C is used as a reinforcement but due to its high cost researches are limited for its uses [8-13]. The ceramic particulate reinforced composites exhibit improved abrasion resistance[14]. They find ap plications as cylinder blocks, pistons, piston rings, brake disks [15]. The future scope of these materials and their machining and optimization of various machining parameters is also a requirement of present industrial applications [16-19]. The present investigation has been focused on the utilization of abundantly available industrial waste fly-ash in useful manner by dispersing it into aluminium to produce composites by stir casting method and to find better mechanical properties.

## II. EXPERIMENTAL PROCEDURE

The matrix material used in the experimental investigation is aluminum. Sic used as reinforcement was supplied from Patiala chemical industries, India having grade-6615. Fly ash was supplied from thermal power plant, Yamunanagar which is further possessed to a mesh size of 45 µm according to ASTM C618 standard using ball mill. The composition of hybrid reinforcement in aluminum is shown in Table 1:

Table 1: Specimen Composition

| ***Specimen no.*** | ***Allumininium (wt %)*** | ***Silicon carbide (wt %)*** | ***Fly ash (wt %)*** |
|---|---|---|---|
| 1 | 100 | 0 | 0 |
| 2 | 90 | 5 | 5 |
| 3 | 85 | 10 | 5 |
| 4 | 80 | 15 | 5 |

### *A.* ***Processing of composite***

The synthesis of the metal matrix composite used in the present study was carried out by using stir casting method. A 3-phase electrical resistance furnace was used for heating aluminium metal to the desired super heating temperature of 900°C in graphite crucibles and inert gas is used in order to minimize the oxidation of molten metal. Reinforcement powders were preheated at a temperature of 250 C for 5 min. The Preheating of SiC particulates helpful in (i) removal of surface impurities (ii) free flow of particulates (iii) desorption of gases and (iv) altering of surface composition owing to the formation of thin oxide layer also the wettability of reinforcement with molten aluminium increases due to preheating. The preheated reinforced powder with proper weight percentages was added to molten aluminium and stirred for 5 min to form composite slurry. This composite slurry was again superheated to 750 C and again stirred for 10 min by using a mechanical stirrer to improve the uniform distribution of reinforcements. The molten composite was cast into the cylindrical shapes using sand molds.

  

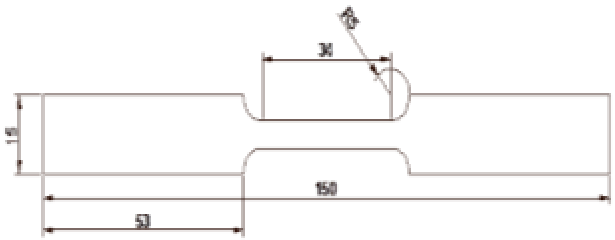

Fig. 1: Prepared specimen dimension

*B. **Characterization of composite specimens***

The hybrid composites obtained by the stir casting process were characterized for their microstructure analysis using scanning electron microscope technique (SEM). The mechanical characterizations were carried out by tensile testing and by Vickers hardness testing according to ASTM standards Microstructure investigations reveals the dispersion behavior of reinforcements in the matrix and checks for the uniform distributions. Tensile strength of composites were measured by a digital universal testing machine and Hardness of composites were measured by Vickers microhardness testing machine under load of 30 kgf.

## III. MATERIAL ANALYSIS

*A. **Structure Analysis***

The macro structural study was conducted on the as processed and machined composite castings in order to investigate distribution of elements of SiC and flyash particles retained in the aluminium metal matrix. The castings were plain turned on CNC lathe to remove 5mm of material to reveal the particle distribution on macroscopic scale. Microstructural characterization studies were conducted on unreinforced and reinforced samples. This is accomplished by using optical metallurgical microscope.

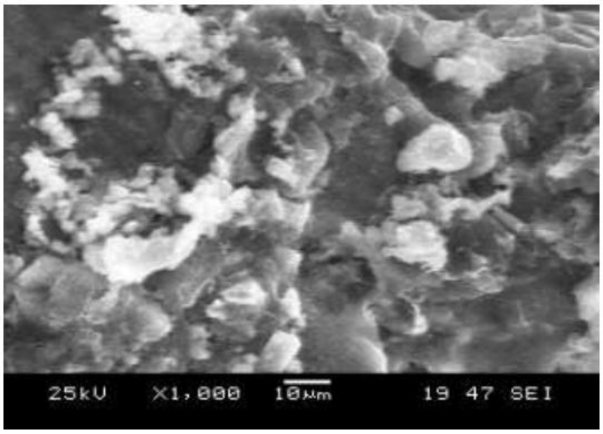


Fig. 2: SEM of unreinforced aluminium

The optical micrographs of all samples at 50x are shown in Figure 2 to 5. The presence of white particles indicates the alumina and black particles represents SiC and fly ash particles.

  

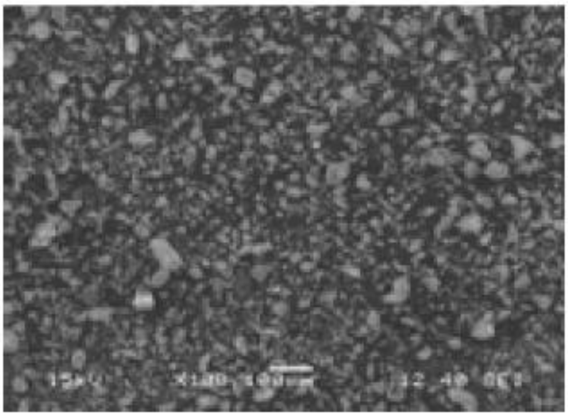

Fig. 3: AMMC with 5% SiC

The micrographs reveal that almost uniform distributions of reinforcement in the aluminum alloy matrix. It is clear from the micrographs that as reinforcement percentage increases, the area fraction covered by reinforcement in the matrix also increases. Further reinforcement starts aggregating when weight percentage of alumina increased beyond 10%. This clustering can be due to the alumina–alumina particle interactions on increasing the percentage. The SEM was used to study the interface and distribution behavior of reinforcements. The cleaned, dried, and etched specimens were prepared and subsequently mounted on a specially designed aluminum holder. These specimens were viewed under Jeol, JSM 6510 LV SEM at an accelerating voltage of 20 kV.

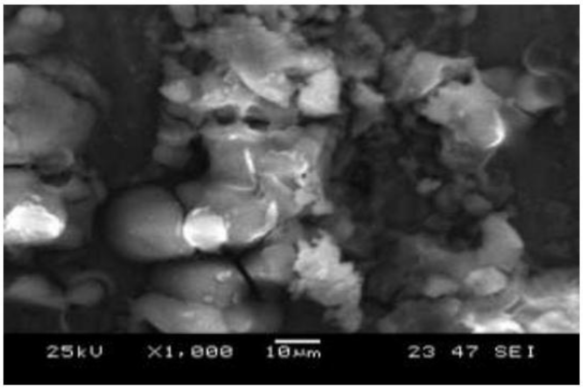


Fig. 4: AMMC (5% SiC+ 5% flyash)

The interface between alumina particle and matrix is shown in figure 3 and 4, which shows good bonding of reinforcement particles in matrix. However, agglomerations of reinforcement particles in some regions are clearly visible in higher reinforced composite specimens containing more than 10% alumina. This is due to the increased interactions of particles at higher level of reinforcements. The figure 4 also shows the clustering of particles in the matrix containing 15% alumina reinforcement. The presence of entrapped air and moisture in the reinforcement particles results in the voids/porosity after casting. Further SEM reveals excellent bonding between the matrix alloy and alumina/nanographite reinforcement particles, which is due to better wetting of reinforcement caused by preheating of powder. There was no sign of interfacial microcracking in the composites. An EDS image of alumina particle reinforced in LM6 matrix is shown in figure 5, which shows the elemental composition at that point.

  

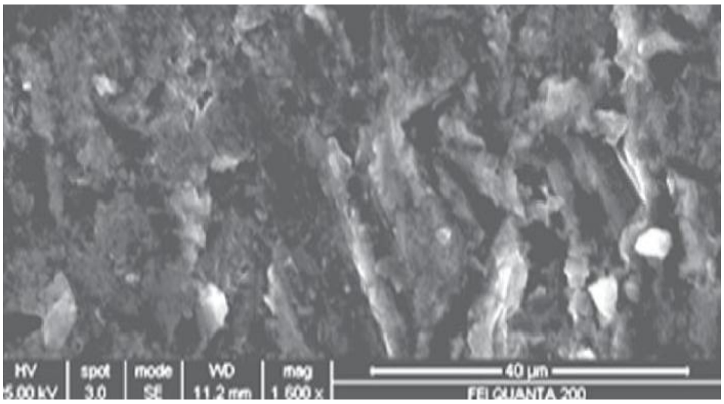


Fig. 5: AMMC (10% Sic + 5% flyash)

The microstructural analysis of the developed composites shows well-dispersed reinforcements in matrix up to 10% alumina reinforcement and SEM results reveal good wetting of reinforcements within the matrix. The mechanical characterization of composites was carried out by measuring tensile strength of composite specimen using universal testing machine. The experimental result reveals that tensile strength of aluminium increases due to reinforcement of Sic and Fly ash. The test was carried out thrice for each composition and mean of results for unreinforced and reinforced specimens is as shown in table. The tensile strength of aluminium increase with increasing weight percentage of SiC and fly ash. The maximum tensile strength obtained was of the order of 145MPa for a composition of 10% SiC and 5% fly ash reinforcement in aluminium which is much better and at relatively lower cost than HE-9 aluminium alloy. However higher amount of Sic (>10%) cause weakening of composites it may be because of clustering of carbide- carbide particle which may cause uneven distribution of reinforcement into matrix.

### *B. Hardness Measurements*

One another mechanical characterization of composites was carried out by measuring Vickers micro hardness as per ASTM E384. The tests were carried out at the microscopic level on various composites using precision diamond indenter under load of 30 kgf. The indentations were made at different five locations on unreinforced and reinforced composite specimens and means of the micro hardness values obtained are presented in Table 2.

The hardness of composites increases with increase in SiC weight percentage. However, at higher levels of SiC (>10%), the weakening effect of composite appears which may be due to increased yielding of composites with higher content of SiC or due to property of SiC to absorb aluminium particle. The micro hardness of 10% SiC with 5% flyash reinforced aluminium composite was highest with average value of 56.7 HV, which was due to the uniform distribution of SiC and flyash. The hardness is tested for all the specimens and is as shown in following table:

Table 2: Hardness Table

| Sr. no | %age of matrix and reinforcement (by weight) | | | Hardness (HV) |
|---|---|---|---|---|
| | %age of Al | %age of SiC | %age of Fly ash | |
| 1 | 100 | 00 | 00 | 32.5 |
| 2 | 95 | 5 | 0 | 35.2 |
| 3 | 90 | 5 | 5 | 43.6 |
| 4 | 85 | 10 | 5 | 56.7 |
| 5 | 80 | 15 | 5 | 54.3 |

The graph is prepared for these values to show the effect graphically as below:

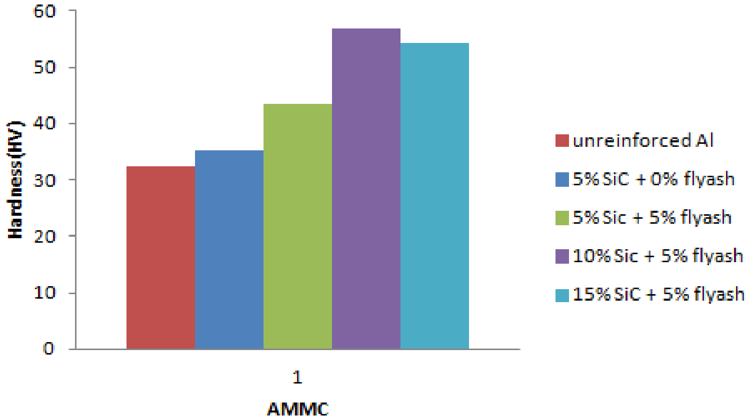


Figure 6: Hardness Graph

### C. ***Tensile Strength***

The tensile strength as tested by the help of UTM machine gives the following results:

Table 3: Tensile Strength

| Sr. No. | %age of matrix and reinforcement (by weight) | | | Tensile strength (MPa) |
|---|---|---|---|---|
| | %age of aluminium | %age of SiC | %age of Fly ash | |
| 1 | 100 | 00 | 00 | 20.82 |
| 2 | 95 | 5 | 0 | 67.65 |
| 3 | 90 | 5 | 5 | 107.23 |
| 4 | 85 | 10 | 5 | 145.33 |
| 5 | 80 | 15 | 5 | 140.02 |

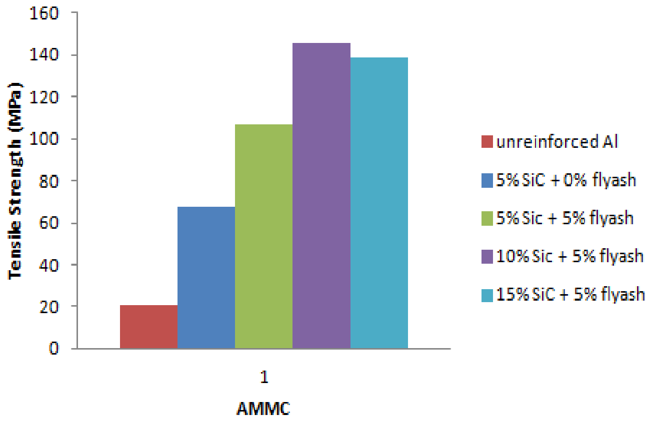


Figure 7: Tensile Strength Graph

The tensile strength of aluminium increase with increasing weight percentage of SiC and fly ash. The maximum tensile strength obtained was of the order of 145MPa for a composition of 10% SiC and 5% fly ash reinforcement in aluminium which is much better and at relatively lower cost than HE-9 aluminium alloy. However higher amount of Sic (>10%) cause weakening of composites it may be because of clustering of carbide- carbide particle which may cause uneven distribution of reinforcement into matrix.

## IV. CONCLUSIONS

The microstructural analysis of Aluminium metal matrix composite containing varying percentages of SiC and Flyash revealed uniform distributions of reinforcements and excellent bonding interface with the matrix. However, on increasing weight percent of SiC above 10%, clustering of reinforcement started due to increased interaction between particles. On varying the content of SiC from 5% to 10%, higher tensile strength and hardness of the AMMC was obtained after 10% particle accumulation started and produced uneven hard surfaces. The addition of Flyash up to 5% reduced the density of specimens resulting an increase in strength to weight ratio The addition of 10% SiC with 5% of Flyash in aluminium matrix produced the best composite having tensile strength equal to 145.33MPa and microhardness value of 56.7HV.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

**Ethical Statement:** The authors declare that they have followed ethical responsibilities.

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