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Research Article

MICROSTRUCTURE AND MECHANICAL PROPERTIES INVESTIGATION ON ALUMINIUM HYBRID COMPOSITE BEFORE AND AFTER AGING

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ABSTRACT
In this experimental study, the metallurgical and mechanical properties are investigated for the hybrid aluminum matrix composites (AMCs) aluminum (LM25) reinforced with silicon carbide (SiCp) and graphite (Gr) particulates fabricated by sand casting process. Through previous studies, it is found that Hybrid composites containing 15 wt% of SiCp and 5 wt% of graphite reinforcements greatly improve the mechanical properties. HMMC was fabricated by sand casting process at 800 to 1000°C.The mechanical and metallurgical properties are investigated with and without aging. The casted hybrid aluminum matrix composites were heated with different temperatures of 350^0C, 400^0C, 450^0C respectively. Further these hybrid aluminum composites were examined by microstructure images. Result shows better hardness and tensile strength.

***Keywords**: Hybrid Metal Matrix Composite (HMMC), hardness, tensile, compression, microstructures.*

INTRODUCTION
Metal matrix composites are materials, which combine a tough metallic matrix with a hard ceramic reinforcement to produce composite materials with superior properties relative to conventional metallic alloys. As the matrix element, aluminum, titanium and magnesium alloys are used and the popular reinforcements are silicon carbide (SiCp) and alumina (Al_2O_3). Aluminum based SiCp particle reinforced MMC materials have become useful engineering materials due to their properties such as low weight, heat-resistant, wear-resistant and low cost. However, these materials are difficult-to-machine materials, owing to the hardness and abrasive nature of reinforcement elements. Machining of aluminium MMC, is associated with bue formation, load / force fluctuation due to encountering SiC particulates and associated tool breakage. This calls for proper selection of tool material, tool geometry and cutting conditions. Composite materials are composed of at least two phases; a matrix phase and a reinforcement phase. Matrix andreinforcement phase work together to produce combination of material properties that cannot be met by the conventional materials.In most of the composites, reinforcement is added to matrix –the bulk material to increase the strength and stiffness of the matrix. The most common composites can be divided into three main groups Polymer Matrix Composites (PMC's), Metal Matrix Composites (MMC's), Ceramic Matrix Composites (CMC's) respectively.

Among the various types of MMCs, the aluminum matrix based composites have found wide engineering applications such as cylinder block liner, drive shafts, automotive pistons, bicycle frames and even sport kits. Aluminum matrix hybrid composites are advanced engineering materials that have been developed for weight-critical applications in the aerospace, and more recently in the automotive industries as well due to their excellent combination of high specific strength and better wear resistance. The higher hardness of MMC is mainly due to harder reinforcement, dispersed over the matrix space and strength and toughness due to possible crack arresting tendency. Hosking et al. [1] reported that, SiCp were more effective than Al2O3 particles for the improvement of wear resistance of Al matrix composites due to the higher hardness, apart from chemical incompatibility. Wear resistance of Al/SiCp composite can be further enhanced by addition of graphite enhancing self lubricating, required for applications where its lubrication is a constrain [3,7]. Solid lubricant such as graphite (a layer lattice material) contained in the composite will smear over contact region and reduce the wear. However researchers have identified both experimentally and analytically that the incorporation of graphite (excess) can reduce the mechanical properties of the composites. Hence it is imperative to balance the proportion of harder SiCp particles and graphite [8]. Mechanical behavior of the Al alloy reinforced with SiCp and graphite particles have been evaluated. Details are presented in this paper.

Material properties and experimental

A. Materials used for composites

Basic matrix material, a commercial alloy Al LM 25 was obtained in bar form; silicon carbide particulates and graphite were obtained in the powder form .Table I shows the chemical composition of the aluminium metal matrix alloy and Table II shows the details of reinforcement materials.

Table I: Chemical composition of the aluminium matrix alloy

Element	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Al
Content %	0.1	0.60	7.5	0.5	0.3	0.1	0.1	0.1	0.05	0.2	reminder

Table III Details of reinforcements

Reinforcement	Average grain size [μm]	Density [g/cm^3]
SiC	45	3.21
Gr	42	2.15

B. Materials and fabrication

Al/SiCp -Gr composites were 15% of SiCp and 5%Gr by weight were prepared by sand casting technique. A measured amount of silicon carbide particles and graphite was preheated to around 800C for 2 hrs to make their surfaces oxidized to achieve better weltability and also to prevent decarburization of SiCp and Gr at higher temperature. A measured amount of Aluminium alloy (ingots) was melted in the furnace. Pre-heated silicon carbide particles and Gr were added to the aluminium melt. After that, the melt was stirred for 20 min at an average mixing speed of 300-400 rpm to make a vortex in order to disperse the particles uniformly in the melt. The SiCp particles and Gr will be uniformly distributed in the matrix when the processing temperature is around 700°C to 800°C with a hold of 10 minutes. After thorough stirring, the melt was poured into sand mould allowed to cool to obtain cast rods. Cut off this cast rods, specimens (A, B and C) were prepared by subsequent machining for different dimensions as listed in Table III.

Table IV : Machined to Specifications given

Sample	Dimensions	Specimens
A	Dia 15mm, Thickness 12mm	Micro hardness specimens
B	Dia 25mm, 100mm Long	Tensile test specimens
C	Dia 20mm, 50mm Long	Compressive test specimens

RESULTS AND DISCUSSIONS

A. Observation on microstructure

Figure1 shows typical microstructure image of hybrid composite materials before aging and fig.2 shows the microstructure images of hybrid composite materials after aging at different temperatures. The composite specimen (cast-preform) was prepared using standard hand polishing of 600, 800 and 1000-grit silicon carbide papers. The polished specimens were etched with Keller etching solution. The etch polish procedures were used to attain good microstructure. These microstructure investigations show the uniform distribution of Al LM25, SiCp and Gr in each hybrid composites.

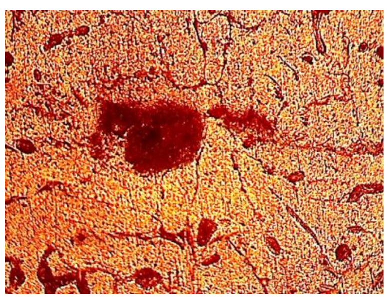
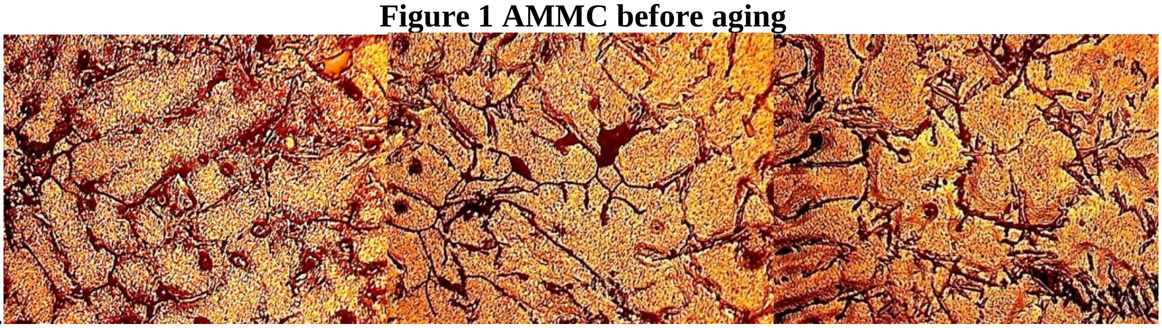


Figure 1 AMMC before aging



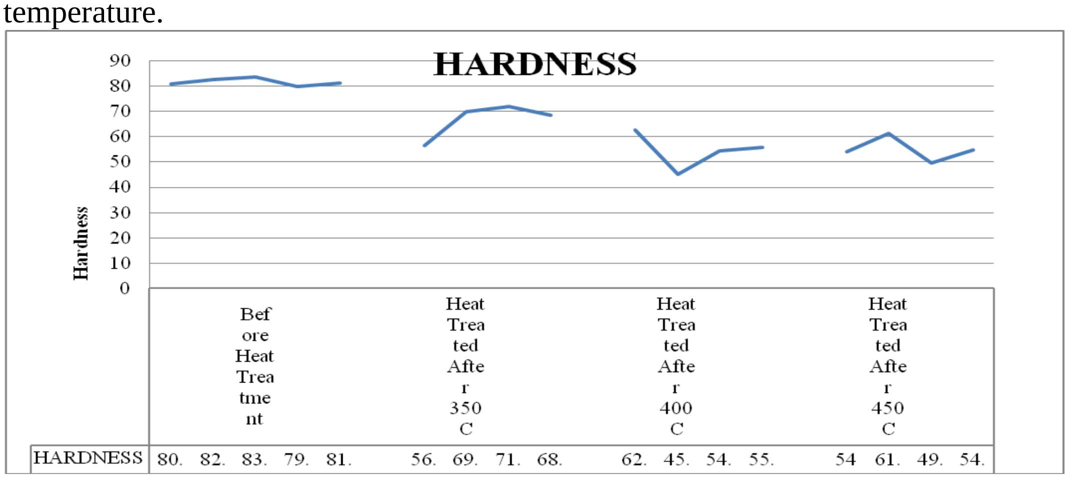
(a) AMMC at 350 ^{0}C (b) AMMC at 400^{0}C (c) AMMC at 450^{0}C

Figure 2 AMMC after aging

In figure 1 the microstructure before ageing, present fine distribution of graphite and agglomerates of SiCp. The agglomerates of SiC could be attributed to in sufficient of stirring. The aluminium silicon eutectic alloy can be seen in large elongated flakes
After preheating, in Figure 2 a) AMMC at 350^{0}C, the micro structure is different. The micro structure presents uniform distribution of SiC particulates. In aluminium solid structure, the graphite particles can be seen as spots over the grain boundary.
Figure 2 b) shows the micro structure of specimen ageing at 400^{0}C, presents uniform distribution of SiC particles to aluminium matrix (solid solution) the graphite particles can be seen over the boundary.
Figure 2 c) shows the micro structure of specimen ageing at 450^{0}C. Uniform distribution of SiCp can be seen in aluminium solid solution. Graphite can be seen over the boundary.

B. Observation on micro hardness

Figure 3 shows the evaluation of micro hardness values of specimens before and after aging process. This bar chart shows the value of specimen before aging was high. Further evaluating the micro hardness value of specimens after aging process. This shows that at 350^{0}C, it has some moderate hardness but less when compared with specimens strength / hardness drop down with ageing temperature.



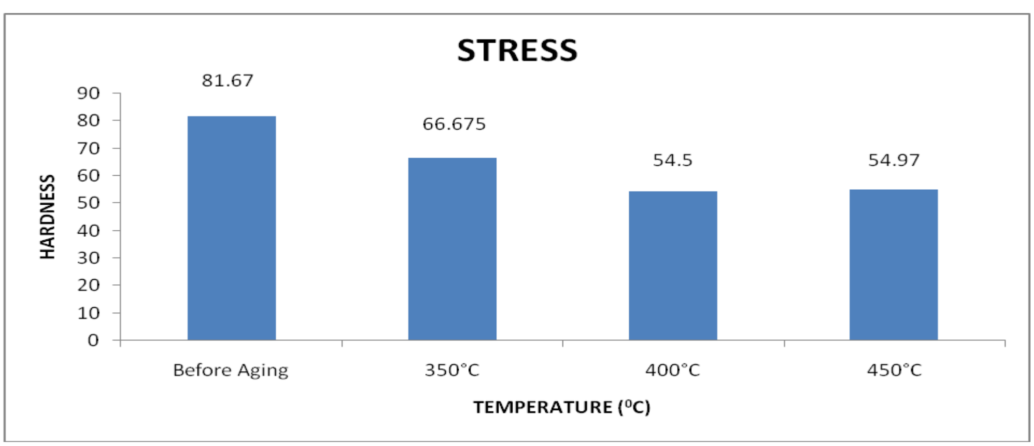


Figure 3: The evaluation of micro hardness values of specimens before and after aging.

C. Observation on Compression Test

Figure 4(a) shows the graph that compressive stress of specimen before aging process and figure 4(b) shows the graph that visualize the compressive stress variation of specimens after aging process at three different temperatures(350^0C,400^0C,450^0C). The below shown graphs clearly explains the variation of compressive stresses before after aging process.

Figure 5 shows the bar chart that shows the compressive stress values of specimens before and after aging process. This bar chart compares the compressive stress values of each specimen. At before aging condition, the compressive stress value was 336.11kN/mm^2. Further evaluating after aging specimens, it was lower than before aging specimen. After that it goes on increasing gradually. It is seen that after ageing, the micro hardness drops down. Also beyond 400^0C only a marginal change.

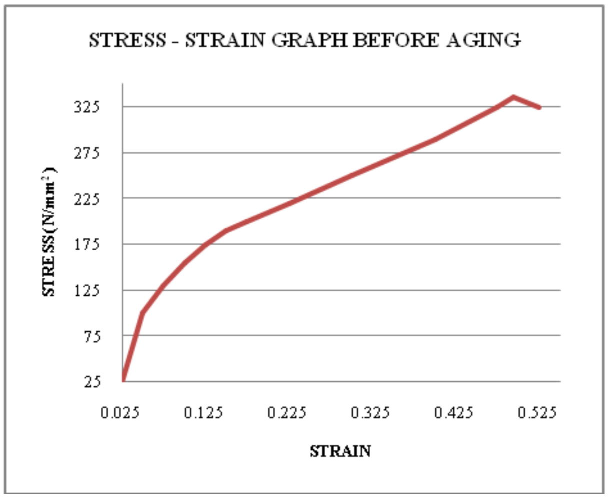


Figure 4(a) Compressive stress of specimen before aging

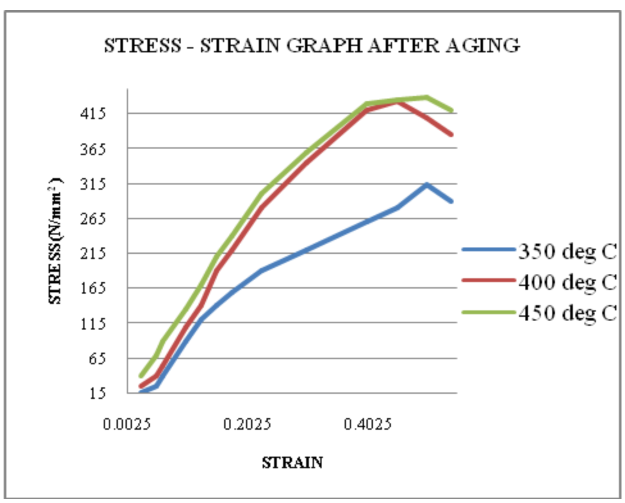


Figure 4(b) Compressive stress of specimen after aging

Al-SiCp-Gr composite specimens were exposed to compressive load. Typical monitored compressive stress characteristics of pre aged composite is illustrated in figure 4 (a). Above 125 MPa (0.065 strain), tendency to strain hardness can be seen attainable ultimate strength of 330 MPa, 0.505 strain followed by fracture / cracks.With ageing, the Al-SiCp-Gr composite exhibits a distinct variation. In 350^0C ageing, the material shows a dip in stress characteristics. Above 115Mpa (~ yield), 0.125 strain, the material experiences strain hardening, attaining an ultimate strength of ~ 315 MPa, 0.4125 strain.
Referring to the illustration, it can be seen that comparing the specimen before ageing, the specimen after ageing at 350^0C, exhibits a marginal reduction in compressive strength. This is despite higher hardness with values over 350^0C. This can be attributed to formation of lump of SiC.This could results in structural heterogeneity and consequent reduction in compressive stress with increasing ageing temperature due to better structural homogeneity and inherent enhanced compressive stress can be seen. From this it is to be inferred that MMC with casted form should undergo post treatment either in mechanical or in thermal for enhanced properties. With 450^0C ageing temperature only a marginal variation can be seen.

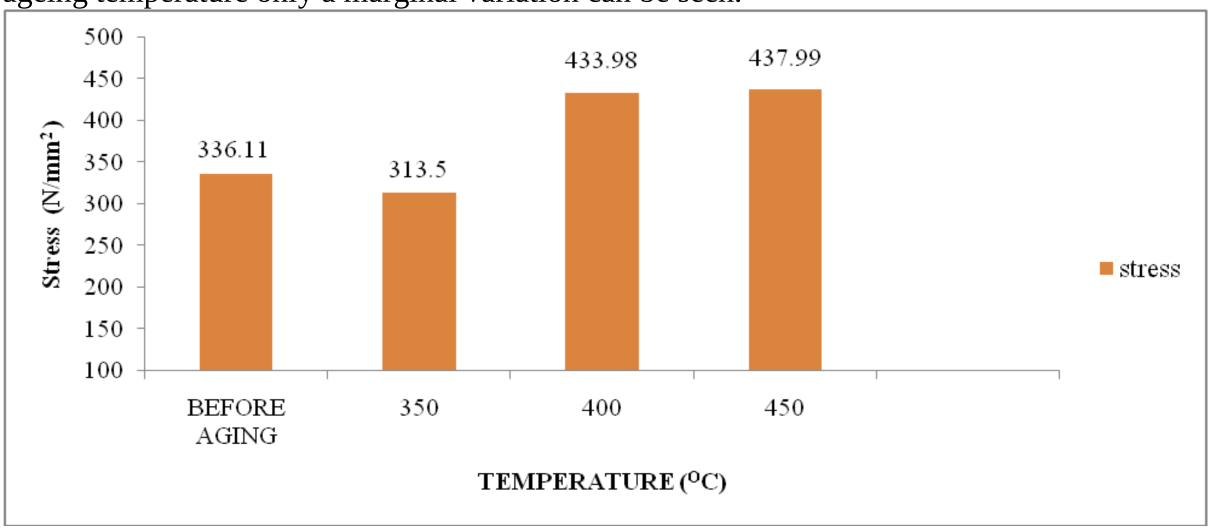


Figure 5. The compressive stress values of specimens before and after aging.

D. Observation on tensile test

Usually, the tensile stress value is inverse of the compressive stress value. Figure 6(a) shows the graph that tensile strength of specimen before aging process. It gradually increases to certain stress value and suddenly drop on particular point, that point was tensile stress for that specimen. The figure 6(b) shows that tensile stress graph variation of specimens after aging at three different temperatures respectively.
Figure 7 shows the bar chart that displays the tensile stress variation of different specimens before and after aging process. This shows the tensile stress value of specimen before aging process was much low. Further on 350^0C, the tensile stress value increases and at 400^0C, it goes on increasing. After that it becomes decreasing rate. With this bar chart, we can predict that the tensile stress value was high up to 400^0C respectively.

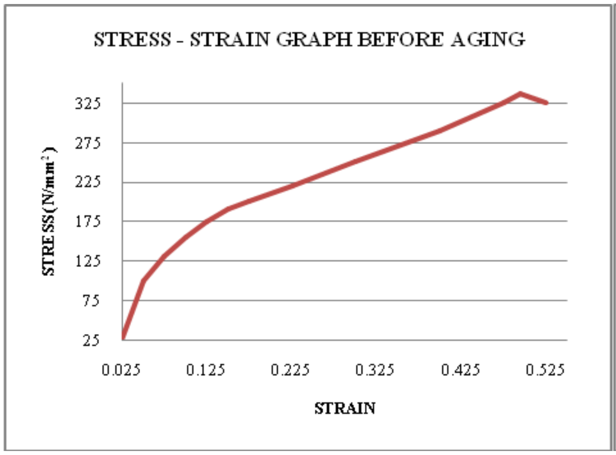


Figure 6(a)Tensile strength of specimen before aging

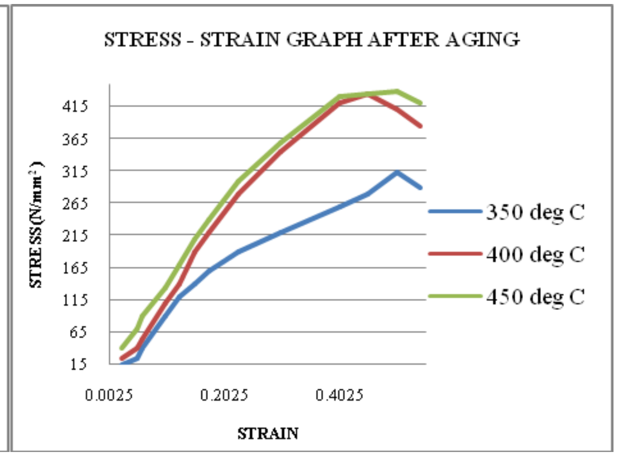


Figure 6(b)Tensile strength of specimen after aging

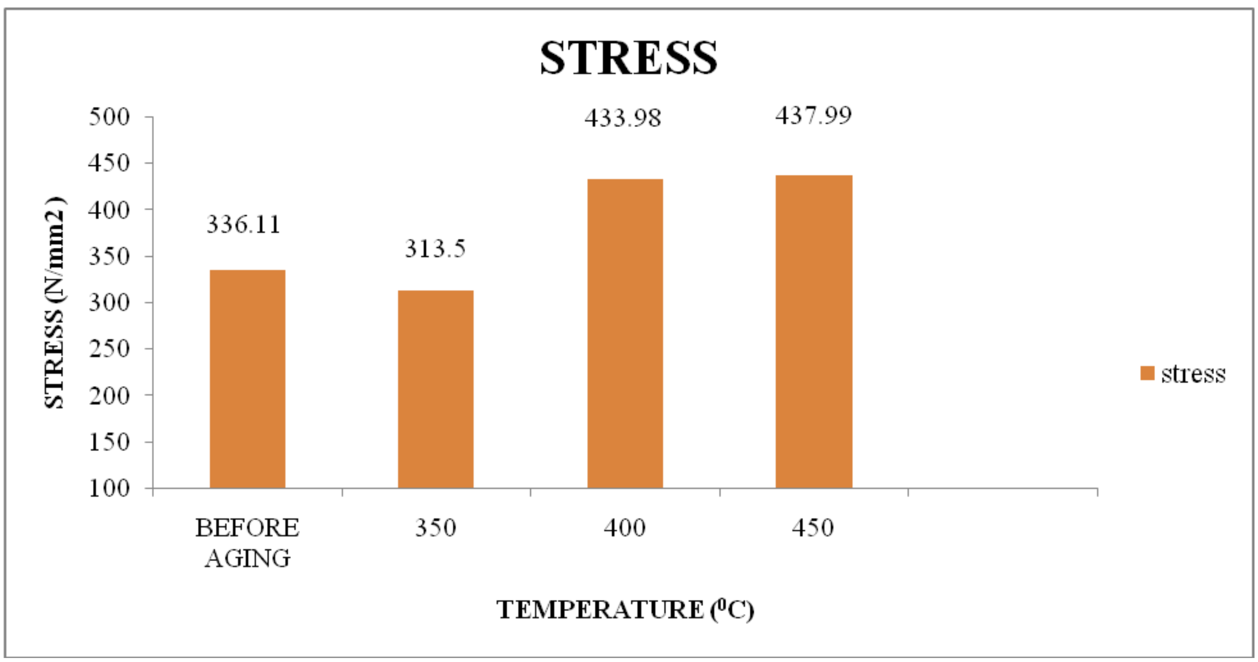


Figure 7 The tensile stress values of specimens before and after aging

Tensile load:

Typical monitored tensile stress characteristics of MMC in cast condition are shown in Figure 7. It is seen that the specimen exhibits a peak structure of around 0.04N/mm^2, at 3.2 strain, followed by a visible reduction.

Typical monitored influence of ageing of MMC on tensile strength characteristics is shown in Figure. Unless the case of compression load, MMC ageing are 400^{0}C exhibits relating higher order performance; also at 450^{0}C ageing, relating inferior performance can be seen

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