International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

Vol. 3. Special Issue 8, August-2017

The Properties of an Aluminium Metal Matrix Composites: A Review

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Abstract

Now a days aluminium matrix composites setting a trend in its usage in various sectors especially in the areas of space, automobile, marine applications due to its less density as well as improved mechanical and tribological properties. The usage of aluminium is restricted due to its limited strength and hardness. In order to improve those properties aluminium is added with other elements, one such popular example is the aluminium metal matrix composites. There is a significant improvement in strength, hardness, wear resistance, creep and fatigue properties of aluminium matrix with the addition of various reinforcements. An attempt has been made to summarize the effect of various reinforcements on aluminium matrix on mechanical and tribological properties which are processed under various casting techniques. This paper presents the overview of the effect of addition on different reinforcements in aluminium alloy highlighting their merits and demerits.

Keywords:*Aluminium alloy, MMC's, Stir casting, Hardness, Reinforcements*

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1. INTRODUCTION

Necessity is the mother of invention, and today's most important demand of an automobile industry is to reduce energy consumption and pollution in an automobile. Aluminium alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for varieties of applications. Among several series of aluminium alloys, heat treatable Al6061 and Al7075 are much explored, among them Al6061alloy are highly corrosion resistant, exhibits moderate strength and finds much applications in the fields of construction, automotive and marine applications. Aluminum alloy 7075 possesses very high strength, higher toughness and are preferred in aerospace and automobile sector [1]. Metal Matrix Compositesare fabricated with help of introducing ceramic/ reinforcement particles in the matrix of any metal. In common words these particles increases the properties like abrasive, hardness, wear resistance, stiffness, strength to weight ratio and many thermal properties[2]. Therefore, aluminium-matrix composites have been used in aircraft, automobile and other transport vehicles successfully such as engine piston, brake drums and electronic packaging and so forth, and further application is expected with development of low-cost processing methods [3]. Based on the stated potential benefits of MMCs, this paper discusses the effect of different types of reinforcement materials on the mechanical behavior of the Aluminium based MMCs.

2. LITERATURE SURVEY

Prashant S N et.al.[4] succesfully developed composites containing 6061Al with 6, 9 and 12wt% of Graphite particulates using stir casting. The addition of Graphite has resulted in increase in tensile strength. The tensile strength is a function of volume fraction of reinforcement. As volume fraction increases tensile strength of composite increases. However, addition of graphite has resulted more improvement in tensile properties. The wear rate of the 6061Al-Graphite composite found to decrease upto 6wt% but thereafter tends to increase.

Daljeet Singh et.al[5] conducted an experiment on Experimental investigation of Mechanical behavior of Aluminum by adding SiC and alumina. Tensile test, hardness test, impact test performed on these samples which are produced by stir casting. The results confirmed that stir formed Al alloy LM6 with SiC/Al2O3 reinforced composites is clearly superior to base Al alloy LM 6 in the comparison of tensile strength, Impact strength as well as Hardness. But at the same time elongation decreases and the behavior of material changes from ductile to brittle.

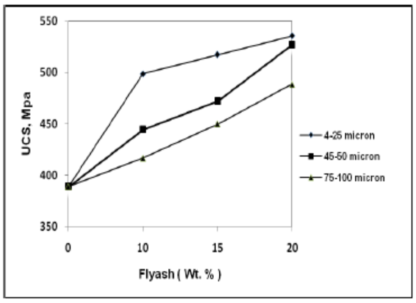
Vikram Singh and R.C. Prasad[6] succesfully fabricated aluminum MMC by liquid metallurgy route. This study shows that the mechanical properties of metal matrix composites after hot rolling were not significantly improved due to the presence of shrinkage cavities and particle cracking. Also it has been observed that there is a loss of Mg content during stirring of MMC fabrication and hence decrease in mechanical properties.

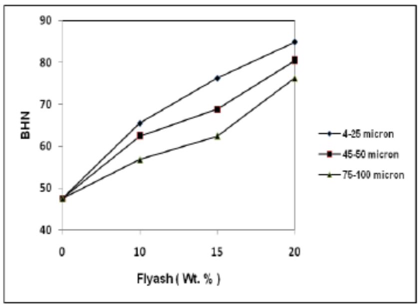
R. Hariharan et.al.[7] in his studies shows that the addition of the TiB2particles into Al-6061 is a good route to improve the mechanical properties of materials. Aluminium alloy reinforced with TiB 2MMCs materials are prepared by using stir casting technique have cost advantages over the composites made by other. The resulting composite showed the increase in tensile strength when compared to the unreinforced alloy. SEM and XRD analysis of the composite confirms the presence of TiB2 particle and its volume fraction. The increased volume fraction of the TiB2 particles contributed to increase the strength of composites.

Sachin Malhotra A et.al.[8] presented a paper on Synthesis and Characterization of Aluminium 6061 Alloy-Flyash & Zirconia Metal Matrix Composite. The results of an experimental investigation of effect of reinforcement (Zirconia+ Fly Ash) on mechanical properties of aluminium alloy (Al 6061) composites samples, processed by stir casting method are reported in this paper. From the experiment it was observed that the best properties were obtained from the sample containing (Fly ash (10%) + Zirconia (10%)) as compared to the base metal. The characterization of the best obtained sample was done by Scanning electron microscopic machine & image analysis.

H.C. Anilkumar et.al.[9] developed Al6061 reinforced with fly ash with three different particle sizes processed by stir casting. Three sets of composites with fly ash particle sizes of 4-25, 45-50 and 75-100 μm were used. It was found that the tensile strength, compressive strength and hardness of the aluminium alloy (Al 6061) composites decreased with the increase in particle size of reinforced fly ash as shown n figure 1, 2, and 3. Increase in the weight fractions of the fly ash particles increases the ultimate tensile strength, compressive strength, hardness and decreases the ductility of the composite. The scanning electron micrographs of the samples indicated uniform distribution of the fly ash particles in the matrix without any voids.

G. B. Veeresh Kumar et.al.[10] in his studies shows that the addition of SiC and Al2O3 resulted in improving the hardness and density of their respective composites. Further, the increased %'age of these reinforcements contributed in increased hardness and density of the composites. Liquid metallurgy techniques were successfully adopted in the preparation of Al6061-SiC and Al7075-Al2O3 composites containing the filler contents upto 6 wt %'age. The densities of the composites are found improved than their base matrix. The tensile strength properties of the composites are found higher than that of base matrix and Al6061-SiC composites superior tensile strength properties then that of Al7075-Al2O3 composites. The wear resistance of the composites are higher, further the SiC contributed significantly in improving the wear resistance of Al6061-SiC composites. From the studies in overall it can be concluded that Al6061-SiC exhibits superior
mechanical and tribological properties.





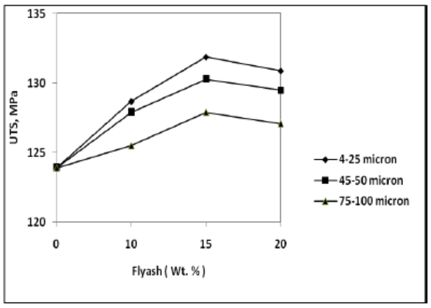


Figure1.1: Variation of compressive strength Figure1.2: Variation of hardness with. Figure1.3: Variation of tensile strength with the weight fraction of fly ash the weight fraction of fly ash the weight fraction of fly ash.

Dr. JameelHabeeb Ghazi [11] presented a paper on Production and Properties of Silicon Carbide Particles Reinforced Aluminium Alloy Composites. Al–Si / SiC composites containing three different volume fractions 7, 14 and 21 weight percentage of SiC have been fabricated by stir casting technique. The hardness, ultimate tensile strength and yield strength of composite found increasing with increased reinforcements in the composites. Increasing the amount of SiC particles in composites caused the impact energy to decrease. The microstructural studies revealed the uniform distribution of the particles in the matrix system.

T. P. Bharathesh et.al.[12] conducted a experiment on Influence of Heat Treatment on Tribological Properties of Hot Forged Al6061-TiO2 Composites. Al6061 matrix composite reinforced with Ni–P coated TiO2 particles were fabricated by liquid metallurgy route. Percentage of TiO2 particles in Al6061 matrix alloy was varied from 2-8wt% in steps of 2wt%. The microhardness of hot forged Al6061-TiO2 composites increases with increase in weight percent of TiO2 in the matrix alloy. On heat treatment, for a given content of TiO2 after quenching in ice, results in maximum hardness of the composites. Co-efficient of friction of hot forged composites reduces with increase in content of TiO2 in both as forged and heat treatment conditions.

N R Prabhu Swamy et.al.[13] made a studies on Effect of heat treatment on strength and abrasive wear behaviour of Al6061–SiCp composites. In his study Al6061–SiCp composites was fabricated by liquid metallurgy route with percentages of SiCp varying from 4 wt% to 10 wt% in steps of 2 wt%. Results shows that addition of SiCp as reinforcement in Al6061 alloy system improves its hardness, tensile strength and wear resistance. Tensile strength of composites increased significantlywith increased content of SiCp. Adhesive wear loss of composites decreases, with the increase in content of SiCp in matrix alloy under identical test condition.

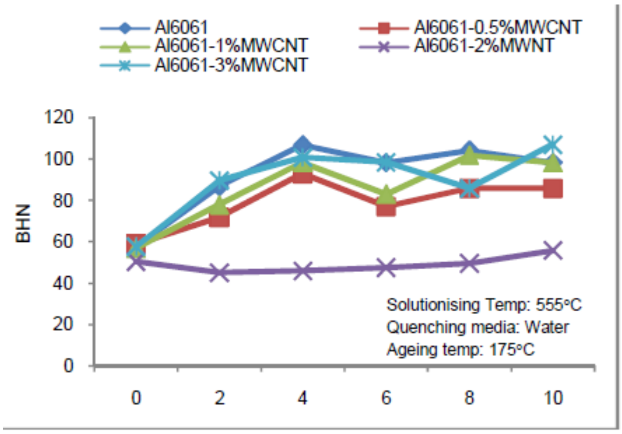


Figure1.4: Variation of hardness with increase in ageing time under

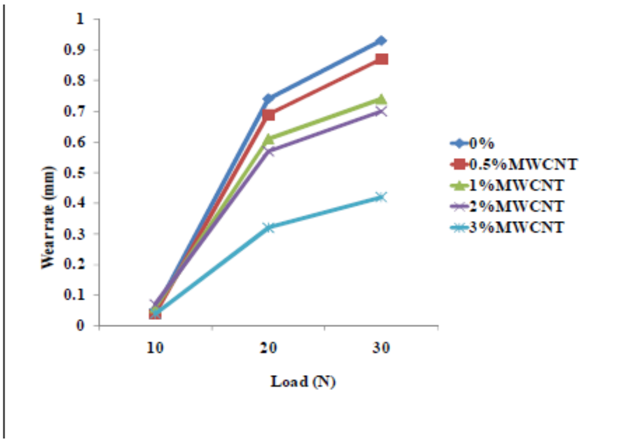


Figure 1.5: Wear rate v/s load (6 h water quench).heat treatment condition quenched in water.

L.H. Manjunatha and P. Dinesh [14] conducted a studies on effect of heat treatment and water quench age hardening on microstructure strength, abrasive wear behaviour of Al6061-MWCNT metal matrix composites. Composites were prepared by using stir casting technique. It has been observed that macro-hardness of composites increased significantly with increased content of MWCNT. Heat treatment has a significant effect on micro-hardness of Al6061 matrix alloy and its composites. Heat treatment has a significant effect onAl6061 metal matrix alloy and its composites. Adhesive wear loss of composites decreases, with the increase in content of MWCNT in the matrix alloy under identical testcondition as shown in figure 4 and 5. Heat treatment has a profound effect on adhesive wear behavior of matrix alloy and its composites.

J.K. Chen , I.S. Huang [15] succesfully developed aluminum–graphite composites by powder metallurgy to test the thermal properties of composites. 10–90 vol.% of flake graphite is combined with aluminum powders to form aluminum–graphite composites via vacuum hot pressing process. Results shows that thermal conductivity of aluminum–graphite composites increases with increasing amount of graphite. For composites containing 10–80 vol.% of graphite, the measured thermal conductivity increases from 324 to 783 W/m K. Coefficients of thermal expansion for aluminum–graphite composites decrease with increasing flake graphite. This study demonstrates that the thermal conductivity and thermal expansion of aluminum–graphite composites can be controlled easily by the percentage of graphite and orientation via hot pressing.

S. Cem OKUMUS et.al.[16] conducted a studies on Aluminum-silicon based hybrid composites reinforced with silicon carbide and graphite particles which are processed by liquid phase particle mixing (melt stirring) and squeeze casting. The thermal expansion and thermal conductivity behaviors of hybrid composites with various graphite contents (5.0; 7.5; 10 wt.%) and different silicon carbide particle sizes (45 µm and 53 µm) were investigated. Results indicated that increasing the graphite content improved the dimensional stability, and there was no obvious variation between the thermal expansion behaviors of the 45 µm and the 53 µm silicon carbide reinforced composites. The thermal conductivity of hybrid composites was reduced due to the enrichment of the graphite component

D. Ramesh et.al.[17] carried out an experimental ivestigation on Role of Heat Treatment on Al6061- Frit Particulate Composites. Al6061-Frit particulate composites were succesfully produced by 'VORTEX' method with varying weight percentages of Frit particulate from 0 wt% to 10 wt% in steps of 2. Results reveal that as the weight percentage of reinforcement increases the density of the composites decreases. Hardness increases with ageing duration, reaches a peak value at 6 h, and with further increase in ageing duration, there is a decrease in hardness.

Hossein Bisadi, Asghar Abasi [18] presented a paper on Fabrication of Al7075/TiB2 Surface Composite Via Friction Stir Processing. In this work friction stir processing was utilized to successfully disperse and embed TiB2 particles with global size of 2.62 µm in Al 7075. The effects of rotational and traverse speeds with two FSP passes on particle distribution and microstructures were studied. The results showed that increasing the rotational speed caused a more uniform distribution of TiB2 Particles. Furthermore by increasing the traverse speed to 60 mm/min improve the hardness of surface layer composite. Also by tensile test result identified that yield strength of the composites is almost 2 times of the base metal.

Deepak Singla1, S.R. Mediratta [19] successfully fabricated the Al 7075-Fly Ash Composites by using Stir Casting arrangement withproper distribution of ash particles all over the specimen. Results shows that by increasing the amount of ash the toughness value gradually increased up to some level but after this it diminishes. Hardness and tensile strength of the composites also showed the same results as like of toughness. The density of the composites decreased with increasing ash content. Hence these light weight composites can be used where weight of an object maters as like in the aero and space industries.

M.Murali et.al.[20] made a study on Micro Structural and Mechanical Properties of AA 7075/Tio2 In Situ Composites. AA7075/TiO2 in situ composites with different mass fractions of reinforcement were fabricated by stir casting method. It was found that the variation of the tensile strength of the composite increased by 51% from 10%wf to 15%wf and tensile strength increased by 20%. When the mass fraction is varied from 5% to 20%, the compressive strength increases by 60% and hardness increases 27% due to the metal-matrix behaviour in the interphase and influenced greatly by the shear and normal stresses induced by the insitu composite

Mina Bastwros, Gap-Yong Kim [21] succesfully synthesised 1.0 wt.% graphene reinforced aluminum 6061 (Al6061) composite to investigate the effects of graphene dispersion by ball milling technique. The ball milling time varied from 10 min to 90 min. Results shows that the strength increase for the Al6061- 1.0 wt.% graphene composite was 47% and 34% for the 60-min and 90-min times, compared with the reference Al6061 sample. It was concluded that the strengthening was significantly affected by the dispersion of the graphene in the matrix phase.

S.Dhinakaran, T.V.Moorthy [22] adopted a stir cassting technique to fabricate AL6061 reinforced with B4C particles of size 220µm with different weight percentage (3, 6 and 9). Results reveals that the increase of the wt. % of reinforcement of the B4C in the stir casting method has led to the increase of the micro and macro hardness of the AMCs. The tensile strength of Aluminum metal matrix composite was found to be on the increase with increasing wt% percentage of reinforcement.

Bhaskar H. B. and Abdul Sharief [23] conducted a experimental investigation of Effect of Solutionising And Ageing OnHardness Of Al2024-Beryl Particulate Composite. Composites werefabricated by liquid metallurgy route by varying the weight percentage of beryl particulates from 0 wt% to 10 wt% in steps of 2 wt%. The cast matrix alloy and its composites have been subjected to solutionizing treatment at a temperature of 495°C for 2 hrs followed by quenching in different media such as air, water and ice. Investigation shows that the density of the composite material decreases as the reinforcement content increases in the matrix material and confirms the stability of the liquid metallurgy technique for successful development of the composite material. Also the Brinell hardness of the composites increased significantly with increased content of Beryl particles.

3.METHODOLOGY

Various Researchers has used different methods to fabricate composites each having merits and demerits like [14] in their studies uses stir casting technique and finds better homogenity and microhardness at surface. [21] investigate the effects of graphene dispersion by ball milling technique to give proper distribution and to increase the strength. [18] uses friction stir casting in their studies to disperse and embed TiB2 particles throughly.[16] employed squeese casting method to fabricate hybrid composites. [15] used powder metallurgy technique to fabricate composites. [7] conducted experiments in which materials are prepared by using stir casting technique have cost advantages over the composites made by other.

Summary

- It could be seen that MMCs fabricated by stir casting is simple and shows high surface hardness and homogeneity. Thus most of the researchers have used this method. But leads to inferior wear resistance.
- The use of Ceramic materials as hybrid reinforcement generally increase hardness, tensile strength, toughness, wear resistance and corrosion resistance of the composites over the base aluminum alloy.
- Heat treatment of hybrid composites promotes uniform grain structure which reduces porosities thereby enhancing the hardness.
- Different methods of production of hybrid composites have been identified with the vortex principle (stir – cast procedure) being the most widely used. Good quality composites can be produced by this method through proper selection of the process parameters such as pouring

temperature, stirring speed, preheating temperature of reinforcement etc.

- Use of graphite as a reinforcement reduces friction and increses the machinability of the composites.

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