iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** X **Month of publication:** October 2017

DOI: http://doi.org/10.22214/ijraset.2017.10178

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

Aluminium Based Metal Matrix Composites: A Review of Reinforcement; Mechanical, Wear Properties

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Abstract*: Aluminium metal matrix composites (AMMCs) have received extensive attention for practical as well as fundamental reasons. Aluminium alloys and aluminum-based metal matrix composites have found applications in the manufacture of various automotive, agriculture, Space shuttles and marine applications. Aluminium Metal Matrix Composites are finding increased applications in aerospace, automobile, space, underwater, and transportation applications. This is mainly due to improved mechanical and tribological properties like strong, stiff, abrasion and impact resistant, and is not easily corroded. This paper presents to review the different combination of reinforcing materials used in the processing of aluminum matrix composites and how it affects mechanical, corrosion wear performance of the materials.
Keywords: Aluminium alloy, Metal matrix, reinforcement, properties

I. INTRODUCTION

From the last few years in much industrial application the important parameter in material selection is specific strength, weight and cost. Here we discussed the review paper relevant to this. Before going the review section we must know the difference between the composite and MMC. The composite defined as the made of several part or element but only combined different material not a non-metal whereas the non-metal is mixed with material this called MMC. Aluminum alloys are preferably material for aerospace, mineral, and automobile processing industries for various high performing components that are being used for variety of applications owning to their lower weight, excellent thermal conductivity properties. MMC are fast replacing conventional metallic alloys in so many applications as their use have been extended from predominantly aerospace and automotive, to defense marine, sports and recreation industries. MMCs are basically metal- lic alloys reinforced with mostly ceramic materials. The common metallic alloys utilized are alloys of light metals (Al, Mg and Ti) however, other metallic alloys like zinc (Zn), cop- per (Cu) and stainless steel have been used. In Metal Matrix Composites (MMCs), aluminum and its alloys have attracted most attention as base metal in metal matrix composites because of its low density, low weight, high strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity, etc. In AMMCs one of the constituent is aluminium, which forms percolating network and is termed as matrix phase. Aluminium alloys, such as the 2000, 5000, 6000 and 7000 alloy series are the most commonly utilized materials in composite fabrication the other constituent is embedded in this aluminium and serves as reinforcement. Mono filaments, whiskers, fibers or particulate types are widely used as reinforcement phases. In recent years, Al based composite materials have gained significance in aerospace, automotive and structural applications due to their enhanced mechanical properties and good stability at high temperature.

II. REINFORCING MATERIALS IN AMCS

The different reinforcing materials used in the development of AMCs can be classified into three broad groups, which are syn- thetic ceramic particulates, industrial wastes and agro waste derivatives. The final properties of the hybrid reinforcement depend on individual properties of the reinforcement selected and the matrix alloy.Based on the published articles studied, the discussion on the combinations of reinforcement used in the synthesis of hybrid MCs is divided into three broad groups. These are hybrid AMCs with two synthetic ceramic materials; an agro- waste derivative combined with synthetic ceramic materials; and industrial waste combined with synthetic reinforcement.

III. AMCS WITH SYNTHETIC CERAMIC MATERIALS

Conventional AMCs reinforced with SiC or Al_2O_3 have shown improved strength and specific stiffness over the monolithic alloys but this occurs at the expense of ductility and fracture toughness.Ductility and frac- ture toughness are important material properties

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that are necessary for preventing failures under in-service stress or shock load applications. As mentioned earlier, corrosion performance of these AMCs are also not consistent judging from reports published in the past. Deravaju et al.[1] studied the influence of SiC/Gr and SiC/Al2O3 on the wear properties of friction stir processed Al 6061-T6 hybrid composites. The authors reported uniform distribution of the reinforcing materials in the nugget zone of the hybrid. . Ravindran et al.[2] investigated the microstructure and mechanical properties of aluminium hybrid nano-composites with the addition of graphite as a solid lubricant. The com- posites had 5 wt% SiC with varied graphite content up to 10 wt%. It was reported that tensile strength, wear resistance and hardness increased with increasing reinforcement. The hybrid composites had superior mechanical properties than the single reinforced Al/5 wt% SiC composite with Al/5 wt% SiC/10 wt% Gr. having the highest strength and wear resistance.

IV. ALUMINIUM OXIDE REINFORCED

Park et al.[3] Investigated the effect of $Al2O_3$ in Aluminium for volume fractions varying from5-30% and found that the increase in volume fraction of $Al2O_3$ decreased the fracture toughness of the MMC. This is due to decrease in inter-particle spacing between nucleated micro voids.

A. Boron Carbide Reinforced AMC:

BoYao et al.[4] investigated the trimodal aluminium metal matrix composites and the factors affecting its strength. The test result shows that the attributes like nano-scale dispersoids ofAl2O3, crystalline and amorphous AlN and Al4C3, high dislocation densities in both NC-Al and CG-Al domains, interfaces between different constituents, and nitrogen concentration and distribution leads to increase in strength. Mahesh Babu et al. [5] Investgated the Characteristics of surface quality on machining hybrid aluminium-B4C-SiC metal matrix composites using taguchi method. It was found that feed rate was the most important parameter followed by the cutting speed. Moreover it was concluded that the feed rate does not have a significant effect on surface quality.

B. Fiber Reinforced AMC:

Sayman et al. [6] studied the elasto plastic stress analysis of aluminium and stainless steel fiber and found that under 30 MPa pressure and at a temperature of 600 ^{o}C, good bonding between matrix and fiber was observed, moreover increase in the load carrying capacity of the laminated plate was also visualised. OnurSayman [7] analysed the elastic-plastic thermal stress on steel fiber reinforced Aluminium metal-matrix composite beams and found that the intensity of the residual stress and the equivalent plastic strain are greatest at 0^{o}orientation angle and concluded that the higher the orientation angle the lower the temperature that causes plastic yielding.

V. MECHANICAL PROPERTIES

V.RamakoteswaraRao et.al. [8] produced AA7075/TiC metal matrix composite with stir casting process. They observed that hardness shows increasing trend with increasing weight percentage of TiC particulates in both cast and heat treated condition (fig.1). The author also revealed that the ultimate tensile strength of the composite increased linearly with increase in weight percentage of TiC.ManojSingla et.al. [9] studied that with increase in composition of SiC, an increase in hardness, impact strength and normalized displacement. Mahendraboopathi.M et.al. [10] studied evaluation of mechanical properties of aluminum alloy 2024 reinforced with silicon carbide and fly ash hybrid metal matrix composites. Al-SiC, Al-fly ash, Al-SiC-fly ash composites were successfully prepared by two-step stir casting process. The author observed that optical micrographs both the SiC and fly ash particles were distributed uniformly in aluminium matrix. They reported that tensile strength, yield strength and hardness of the hybrid composite increased with Increase in area fraction of reinforcement in matrix.They also concluded that the addition of SiC and fly ash with higher percentage the rate of elongtion of the hybrid MMCs is decreased significantly.

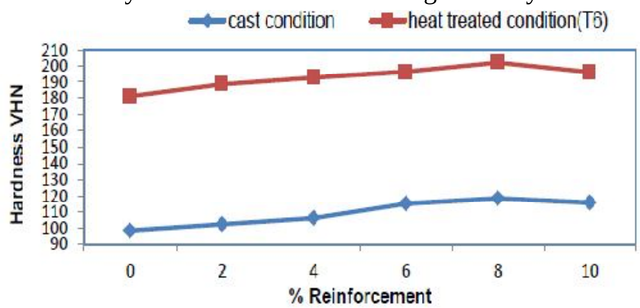

Figure 1 :Hardnessbehavior of Al 7075 alloy and Al7075/TiC Composites

Anilkumar et.al. [12] produced three sets of Al (Al6061) metal matrix composites reinforced with fly ash of particle sizes 75-100, 45-50 and 4-25 µm with the weight fractions of 10, 15 and 20%.The author observed that tensile Strength, compression Strength and hardness increased with the increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash and ductility of the composite decreased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. Dora Siva prasad et.al. [11] investigated on mechanical properties of aluminum hybrid composites. They produced aluminum hybrid composites reinforced with different volume percentages of (2, 4, 6, and 8wt%) Rice hush ash(RHA) and SiC particulates in equal proportions by double stir casting process. They found that up to 8% rice hush ash and SiC particles could be easily fabricated. The authors observed that density of hybrid composites decreases, whereas the porosity and hardness increases with the increase in percentage of the reinforcement and yield strength and ultimate tensile strength increase with the increase in RHA and SiC content.

VI. WEAR PROPERTIES

Aluminium alloys have been widely used as a matrix material and reinforced with various materials like SiC, Al2O3, TiC, alumina and Tib2 etc., in the form of particles or fibers for the fabrication of metal matrix composites. Along with this the addition of the metals like Cu, Zn and Nickel will further improve the properties because they have developed strong bonding between matrix material and reinforced material. These AMMCs are operated under severe friction conditions because of their good tribological properties. Various factors will influence the tribological properties of AMMCs, such as normal load, sliding distance, interfacial bond strength, environment conditions, surface finish, shape and size of the reinforced particles and weight percentage of the reinforcement etc.The below (Fig. 2) shows that wear rate is constant with increase in sliding distance. Suresha et.al. [13] investigated statically the dry sliding friction behavior of the hybrid aluminum matrix composite reinforced with SiC and graphite particles. The investigation shows that load is prominent factor in affecting the friction coefficient of the hybrid composite followed by sliding speed and with increase in load and sliding distance the coefficient friction also increases. Further, when compared with pure alloy the average coefficient of friction is low.

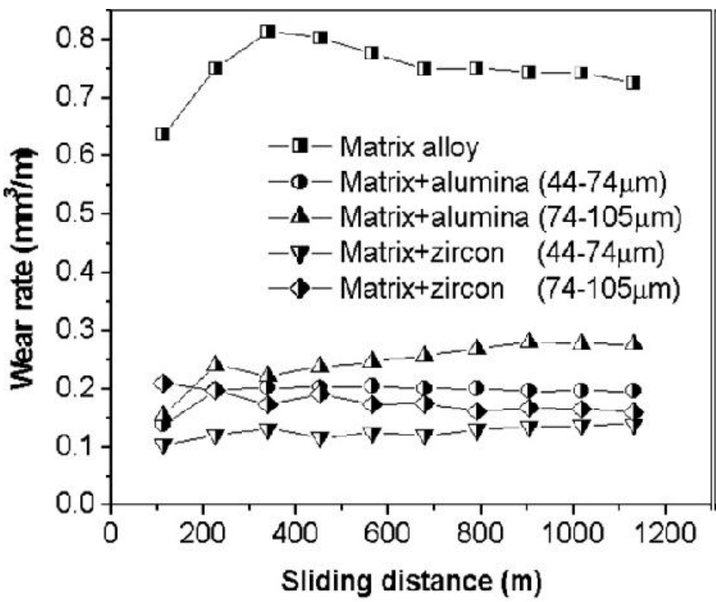

Figure 2: The wear behaviour aluminium matrix alloy with sliding distance

VII. CONCLUSIONS

Several confronts must be surmounted in order to strengthen the engineering usage of AMCs such as processing methodology, influence of reinforcement, effect of reinforcement on the mechanical properties and its corresponding applications.By increasing the wt % and decreasing the particle size of reinforced material in the aluminium composites the hardness, tensile strength and yield strength increases.From the above investigations, we observed that the wear rate mostly depends on applied load, sliding distance and sliding speed and the most influence parameter is sliding distance. It has been found that the increase in volume fraction of $Al2O_3$ decreases the fracture toughness of the Al MMC.

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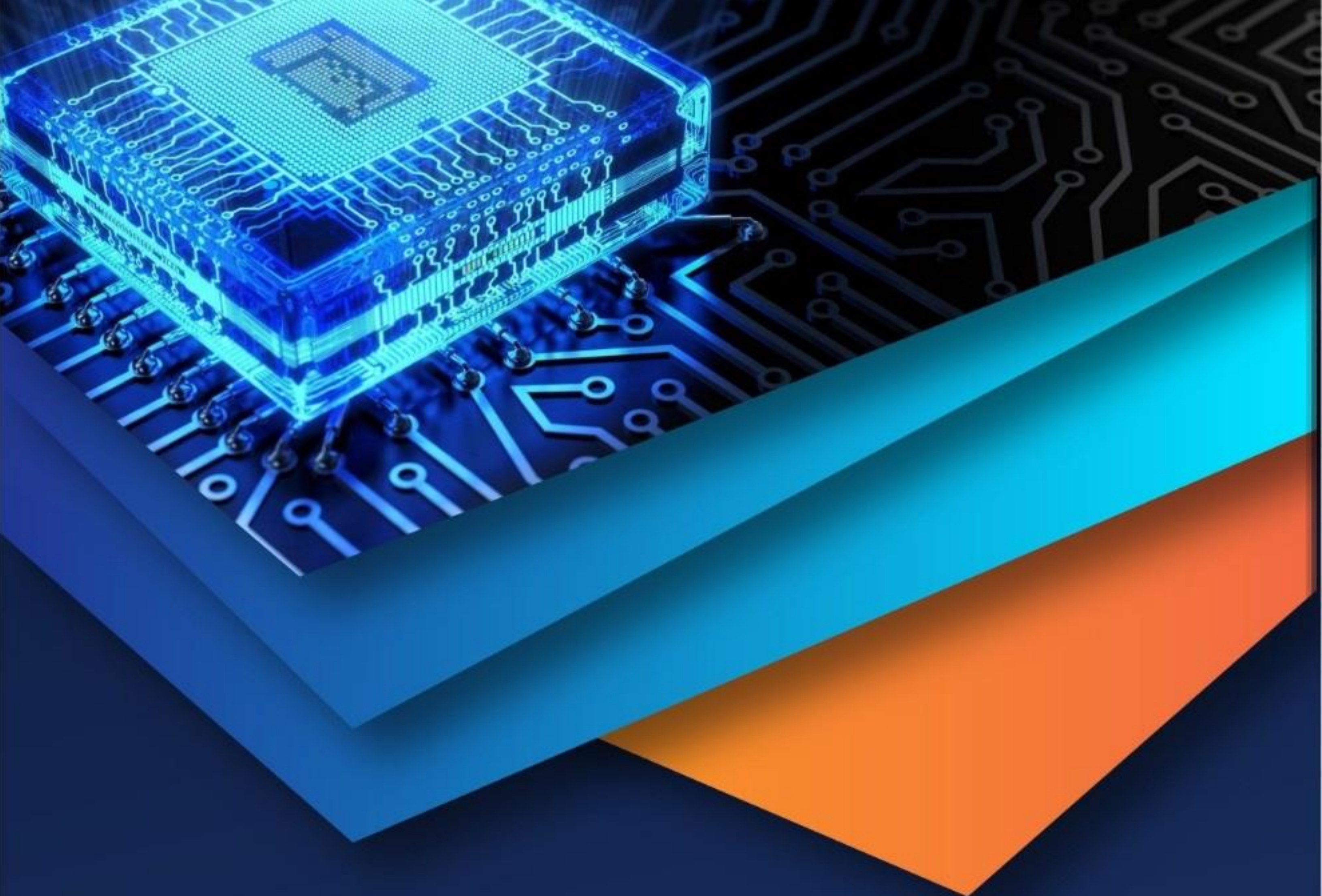

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