Scientific Journal of Impact Factor (SJIF): 4.72

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 10, October -2017

A Study of Improvement in Different Mechanical Properties for Aluminum Based Metal Matrix Composite

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Abstract — *Aluminium composites are a new generation of metal matrix composites who have the potentials of satisfying the latest demands of advanced engineering applications. These demands are met because of better mechanical properties, amenability for conventional processing technique and possibility of reducing cost of production for aluminium composites.*

Aluminium metal matrix composites are one of the most widely used materials for automobile, aerospace, electronics industries, agriculture machinery and many other industrial applications because of their improved properties such as high strength, low density, good wear resistance compared to any other metal. The addition of reinforcements into the matrix improves many important properties like stiffness, specific strength, wear, creep and fatigue compared to the other engineering materials. This paper shows the study of the different improvement in some of the important mechanical properties than conventional materials.

Keywords- Composite material, Metal Matrix composite(MMC), Tribological property.

1.INTRODUCTION

Two or more chemically different constituents combined macroscopically to yield a useful material which is called composite material. One constituent is called reinforcing phase and the one in which the reinforcing phase is embedded is called matrix.

Composite material offers to engineers many advantages that are especially appealing for engineering applications. They are made up of combining two or more materials in such a way that the resulting materials have improved properties . The Aluminium alloy composite materials consist of high specific strength, high specific stiffness, more thermal stability, more corrosion and wear resistance, high fatigue life. When designed properly, the new combined material exhibits better properties than would each individual material. The requirement of composite material has gaining momentum in these days due to these properties. Apart from defense and automotive industries, aircraft industries also using composites largely in the present days for reducing the weight of the aircraft and improved strength. The addition of high strength, high modulus refractory particles to a ductile metal matrix produce a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement.

Aluminium based composite materials are leading ones in this area, they are fabricated using many methods, including powder metallurgy processes, and then formed. The metal matrix composite can be reinforced with particles, dispersoids or fibres. However, the biggest interest in composite materials is observed for those reinforced with hard ceramic particles due to the possibility of controlling their tribological, heat or mechanical properties by selection of the volume fractions, size, and distribution of the reinforcing particles in the matrix. The ceramic preforms, being a framework, are the base of the composite materials manufactured by infiltration method. These preforms mainly determine the structure and the properties of the final product. The properly manufactured semi-finished product should be characterized by open porosity allowing the liquid metal to flow as easily as possible.

1.1 Matrix and Matrix materials

Composite material offers many advantages to engineers that are especially appealing for advance engineering applications. They are made up of combining two or more materials in such a way that the resulting materials have improved properties than parent material. The Aluminium alloy composite materials consist of high specific strength, high specific stiffness, more thermal stability, more corrosion and wear resistance, high fatigue life. When designed properly, the new combined material exhibits better properties than each individual material. The requirement of composite material has gaining momentum in these days due to improved properties. Apart from defense and automotive industries, aircraft industries also using composites largely in the present days for reducing the weight of aircraft and improved strength. The addition of high strength and high modulus refractory particles to a ductile metal matrix produce the material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement.

Aluminium based composite materials are leading ones in this area, they are fabricated using many methods, and then formed. The metal matrix composite can be reinforced with particles, dispersoids or fibres. However the biggest interest for composite materials is seen for those reinforced with hard ceramic particles due to the possibility of controlling tribological, heat or mechanical properties by selection of the volume fractions, size, and distribution of the reinforcing particles in the matrix. The ceramic preforms, being a framework, are the base of the composite materials manufactured

by infiltration method. These preforms mainly determine the structure and the properties of the final product. The properly manufactured semi-finished product should be characterized by open porosity allowing the liquid metal to flow as easily as possible.

1.2 Functions of the Matrix Material

•Provides the bulk form of the part or product made of the composite material.
•Holds the imbedded phase in place, usually enclosing and often concealing it.
•When a load is applied, the matrix shares the load with the secondary phase, in some cases deforming so that the stress is essentially born by the reinforcing agent.

1.3 Functions of the Reinforcement

Function is to reinforce the primary phase. Imbedded phase is most commonly one of the shapes Fibers ,Particles, Flakes. In addition, the secondary phase can take the form of an infiltrated phase in a skeletal or porous matrix Example: a powder metallurgy part infiltrated with polymer.

1.4 Important Manufacturing processes for Composites

- Open Process
  - Hand Lay-up
  - Spray Lay-up
  - Filament Winding
- Closed Process
  - Pressure Bagging Method
  - Compression moulding
  - Vacuum Bagging
  - Resin Transfer Moulding (RTM)
  - Centrifugal Casting
- Continuous process
  - Pultrusion
  - Braiding

2. Mechanical Properties

The aluminium metal matrix composites have shown important improvement in mechanical properties which are useful in many modern applications. The various mechanical properties that are considered in the present study are given below.

2.1 Impact strength

- The composite of aluminium alloy by silicon carbide as the reinforced material shows that as the amount of silicon carbide increased, the impact energy decreased and the reason behind this was the brittle nature of this material. It was inferred that impact strength is directly proportional to the addition of silicon carbide in terms of proportions but indirectly in terms of the particle size.
- In aluminium alloy the alumina is used as reinforcement for the fabrication of composite. The results of Charpy test shows that the weight percentage of aluminium and alumina in ratio of 98:2 shows the highest amount of energy absorbed.
- It is observed that when aluminium like pure Al, Al6061 or A356 are reinforced with various thgeiw egatnecrep of the reinforcement both the hardness and tensile strength improved as compared to that of base material with increase in the weight percentage of the reinforcement.
- When Aluminium 7075 reinforced with silicon carbide, flyash and red mud. The results of Charpy impact test shows that the impact strength increased with increase in percentage of silicon carbide but decreased with increase in percentage of flyash and red mud. When red mud and fly ash were compared, the former showed more impact strength.
- It was studied that the toughness (impact strength measured with the Izod impact test) for SiC-fly ash-reinforced hybrid Al 6061 matrix composites increases with increase in weight percent of SiC , which may be because of proper dispersion of reinforcements into matrix or strong interfacial bonding between the matrix and the reinforcement interfaces. The maximum value for toughness was obtained for the composite containing 10% of SiC and 5% of fly ash.
- It was determined that fracture toughness of SiC-reinforced Al 6063composites with circumferential notch tensile (CNT) method and seen that the fracture toughness improved either with ageing treatment or by increasing volume percent of SiC reinforcement.

2.2 Ductility

- It is studied that one piece Al6061 reinforced with silicon carbide and the other one with silicon carbide-graphite. In both types of composites, ductility reduces.
- The composite of aluminium matrix with silicon carbide composite and found the throughout the decrease in elongation as low as 2.4%.
- The increase in the weight percentage of flyash also results in the reduction of the ductility.
- It is seen that if composite is prepared of AlSi10Mg with rice husk and flyash as reinforcements, with the increase in fly ash and a decrease in rice husk the ductility is increased.
- It is studied that as percentage age of hybrid reinforcement increases the ductility for composite material decreases to 2.2%.
- Aluminium MMC's containing Titanium-boride are developed using liquid metallurgy technique. The composites were prepared with Al-10%Ti and Al-3%B master alloys as reinforcement Tensile strength increased in the MMC but the ductility of the MMC decreased in respect of the ductility of the matrix material.
- Elongation of aluminium decreased with addition the reinforcement particle when reinforced with mono particles like SiC or Al_2O_3 and hybrid composites like SiC+ Al_2O_3It may be reason of larger agglomeration for the reinforcement particles, brittleness and upper degree of micro porosity in this composite with higher SiC, Al_2O_3 and SiC+ Al_2O_3 reinforcement.
- The increased weight parentages of particles can reduce the effective slip distance for dislocations in tensile deformation which can lead to the reduce in the elongation. But in case of Al_2O_3 elongation decreased at 12 percentage by weight may be the result of greater agglomeration of particles.

2.3 Tensile strength

- It is studied during the evaluation of Al6061 with the flyash. Three sets of fly ash were reinforced with the weight fraction of 10 %,15% and 20%. It was found that the ultimate tensile strength was increased to 192.74 MPa .
- It is observed that Aluminium 7075 reinforced with flyash and titanium carbide, the reinforced aluminium alloy had 32% more tensile strength than the pure form of aluminium because of the hardening of the aluminium alloy by flyash ..
- A study shows that the 20% weight fraction of silicon carbide in the aluminium matrix has the maximum tensile strength. The reason for the increase in the tensile strength the tensile load transfer to strongly bonded silicon carbide reinforcement.
- It observed the increase in tensile strength of A-356SiC-Gr MMC. The increase in tensile strength was because the SiC acts as hurdles to the dislocation. The inter particulate distance between the reinforcement increases resistance to the dislocation as reinforcement increases.
- With Al7075 alloyed with the weight fraction of 3 to 6% silicon carbide, flyash and red mud which finds the higher tensile strength of Al 7075silicon carbide-red in comparison to Al 7075silicon carbide flyash.
- The aluminium hybrid composite of Al-6061silicon carbide-graphite and alumina shows that addition of 17% weight fraction of alumina increased the tensile strength but the graphite showed no significant change. The reason may be the thermal mismatch.
- It is observed that tensile strength increases with the increase in the weight percentage of fly ash and TiB2 in the case of Al7075 reinforced hybrid composites. The highest value obtained was 298 N/mm^2 at 10 weight percentage of reinforcement which was 25% greater than that of base alloy.
- Tensile strength for unreinforced Al was observed 77 MPa and increase in the tensile strength was observed to maximum of 113MPa when reinforced with 15% flyash,which is about 35% more than that of the unreinforced Aluminum matrix.
- When the flyash increased from 20 to 25%, tensile strength was decreased from 113 Mpa to 104 Mpa. There is the possibly because of clustering of the reinforcement particles this composites having more than 15% of fly ash particles and rate of increase of tensile strength decreased notably.
- It is studied that tensile strength of SiC coated unidirectional boron fibre reinforced Al2014 matrix composites is in the range of 312to 524MPa whereas that of the alloy was 172MPa.

2.4 Compressive strength

- Achievement of high compressive strength and corresponding strain was observed in A%3-356Albite MMC against unreinforced alloy with 17% and 37.5%.Compressive strength of aluminium alloy can be increased when reinforced with 3% albite. Compressive yield values, stress or strain were increased in both cast as well as cast stirred alloy over commercial alloy.
- Fly ash is the most compatible reinforcement for compressive strength and it is also economical . The addition of graphite with flyash in Aluminium alloy of LM25 as a base metal with varying part of silicon carbide 2, and 6% ,displayed the best combination that can withstand good compressive force.

- In the experiment on aluminium Alsi10Mg with rice husk ash as the reinforcing material. It was observed that compressive strength increases. However all the properties tend to decrease with increase in size of particles.
- At the time of investigating effect of matrix strength on compressive properties of SiC reinforced Al-Zn-Mg alloy matrix composites it is observed that yield strength increased in both the solution-annealed 485^0C/90min and over-aged 170^0C /36h conditions but reduced in the peak-aged 135^0C /16h conditions with the increase in volume percent of reinforcement.

2.5 Hardness

- The results of Vickers hardness results shows that when aluminum is reinforced with 3% albite a small increase in HV of A%3-356 Albite MMCs specified,4% more than unreinforced alloy where as hardness test showed on micro hardness scale. The increment might because of using of big particle size 150-90micro metre.
- Hardness of composites is reasonably large than A356 matrix when reinforced with nano Al_2O_3-10%ZrO.The reason for this is the existence of hard Al2O%10-3 ZrO_2 nano particles. As the proportion is increased to 1% Al2O3 and 10% ZrO_2 the property of hardness is increased contrary the hardness of the samples containing proportion of 1.5 and 2% of Al_2O_3-10%ZrO decreased. This happened because of heterogeneous allocation of nano-particles and high porosity.
- Trials of aluminium LM6 with increase in weight fraction of silicon carbide and alumina which finds that increase of weight fraction results in increase in the Rockwell hardness number. T ehreinforcement of flyash with Al6061 resulted in the increase of hardness throughout.
- It is observed that up to 25% of SiC, the hardness increases and then decreases which may be because of that at higher percentage the particles of SiC started settling down in the aluminium melt.
- While investigating the effect of thermal ageing temperature on hardness of SiCp reinforced6061 and 2014 Al matrix composites, it is observed that there is increase in hardness with ageing temperature and maximum hardness reaches at 150^0C to 200^0C and composites containing 2014 Al were much harder than those with 6061 Aluminum.
- osla saw tI reported that porosity was the major influencing factor for the hardness of AlO and SiC reinforced Al composites. The hardness of the composite was observed to be decreased with the increase in porosity.
- It is observed that Vickers hardness of both Al-Zn-Mg ,Al 7009 alloy and SiC-reinforced Al-Zn-Mg Al7009 composite improved by heat treatment and with the increase in percentage of SiC reinforcement in the matrix alloy.

2.6 Wear rate

Wear can be defined as the progressive loss of material at contacting surfaces in relative motion. Tribological property like wear rate was studied for silicon carbide reinforced aluminium matrix composite for various proportions.

- The loss of mass of aluminium-silicon carbide MMC is less in comparison to the pure form aluminium. This is because the exposed particles of silicon carbide protects the matrix from further wear. The maximum resistance to wear is observed at 20% weight fraction silicon carbide.
- The dry sliding wear behavior for B_4C particulates reinforced aluminium alloy composites were studied. Al6061 and 6 weight percentage of B_4C composites were fabricated with stir casting method. Pin on disc tribo meter was used to analyze wear behavior of Al6061- B_4C composites ,alloy by normal load by varying sliding velocities from 3.34 m/s to 10m/s at room temperature. Minimum wear rate observed for Al6061-6 weight % B_4C composites. Worn surface were studied by optical microscopy to understand wear mechanism exhibited by composites prepared.
- It is studied that the characteristics of LM alloy with silicon carbide-graphite and silicon carbide-flyash separately. Most prominent wear resistance is observed in 2%SiC-2%graphite and in the other case it was 4%SiC-2%flyash. So it is seen form these results that addition of silicon carbide in the alloy makes the material lose the wear characteristics at the higher percentage.
- Many studies have used unusual reinforced material such as boron carbide and/or titanium boride and they all show the tendency of increase of wear resistance up to a certain weight Percentage.
- It was investigated that Al 2024 alloy. Al2024-beryl composites were fabricated by liquid metallurgy route by varying the weight percentage of reinforcement from 0 to 10 weight percentage in steps of 2%. Dry sliding wear tests were conducted to test wear behavior of Al2024 alloy over its composites. Their results indicated that the wear rates of composite was lower than half of matrix alloy and friction coefficient was minimum when compared with monolithic alloy. Further beryl particles as reinforcement improves wear rate.
- Dry sliding behavior for electroless nickel-prosperous coating with thickness of ~35µm deposited on the 7075-T6 Al alloy was studied. The results shows that the wear behavior of EN mostly depended on pretreatment conditions. Heat treatment for temperature of 400^oC can enhance the wear resistance properties for all the types of pretreatment conditioned samples.

2.7 Fatigue Behaviour

- Fatigue results for potential MMC are studied some numerical values are obtained from fatigue curves. It is studied that generally fatigue limit for composites are higher that that of matrix materials. Fatigue limits of particular composite increases with fibre volume and fatigue ratio fatigue limit/ UTS are generally lower.
- The fatigue behavior for Aluminium alloy (LM4) and Alumina silicate ($Al_2O_3SiO_2$) particulate composite is studied in comparison with unreinforced LM4 aluminium alloy. Four different volume fractions 0.05, 0.15 and 0.20 of Alumina silicate particulates size 10 µm are introduced into this melt. The composite specimens have longer fatigue lives compare to matrix alloy in lower stress state and exhibited the reduced fatigue lives at the elevated stress state irrespective of their reinforcement volume fraction.
- Fatigue behavior of an artificial aged 6061 aluminium alloy and the composite made by this alloy with 15% volume fraction SiCp was investigated. The This alloy was subjected to T6 heat treatment, as was the composite material chosen which incorporated SiC particles of average size 30pm. An extensive experimental programme was carried out in which fatigue lives were determined by using load controlled axial loading for unnotched cylindrical samples at the stress ratios of 1 and 0.1.it has been found that while stiffness of this composite material was higher than that of the matrix tensile strength and fatigue life are lower in this composite as is ductility.
- Powder metallurgy based aluminium -A2014 alloy reinforced by micro and nano alumina particles were fabricated and then consolidated with hot extrusion process. The study of mechanical properties in this extruded composite was carried out. This composite was subjected to low cycle fatigue test with the constant strain rate. The failure cycle observed to be higher for the nano alumina reinforced composites when it is compared with micron sized alumina composites because of a lower order of induced plastic strain.
- Experiment was carried out for micro and nano particles of alumina. In order to understand the fatigue life of the both composite S–N curves with total strain amplitudes versus number of cycle to failure-N was drawn. Composite with nano particles exhibited a higher fatigue life when compared to the composite with micro particles due to nano sized alumina reinforcement which more effectively pinned down dislocations. A smaller percentage addition for nano sized alumina particles increased fatigue life to greater extent.

3.CONCLUSION:

For special application in advance engineering aluminium should contain better mechanical properties like high hardness, high stiffness, high tensile strength, high impact strength, better wear resistance, better compressive strength ,better fatigue properties etc. These properties can be altered by fabricating the aluminium composites by different fabrication methods. This study covers the effect of different reinforcement particles on mechanical properties of aluminium. From this study of different researchers we can conclude that mechanical properties improves appreciably with reinforcement particles than the parent metal.

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