IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Impact Factor: 7.301

Volume 3, Issue 1, February 2023

A Review of the Effects of Reinforcement on Aluminum Metal Matrix Composites

Kishor Dagale[1] , Mohd Mukhtar Alam[2], Mahesh Harne[3]

Research Scholar, Department of Mechanical Engineering[1]

Professor, Department of Mechanical Engineering[2,3]

Vivekananda Global University, Jaipur, Rajasthan, India[1,2]

Amrutvahini College of Engineering, Sangamner, Maharashtra, India

Abstract: *Aluminum-based composites are becoming more popular in all manufacturing sectors due to their unique properties such as high strength-to-weight ratio, good mechanical properties, and longer durability. As a result, much research has been conducted in aluminum composite materials with the addition of carbide-based particulate reinforcement. However, in the present In a competitive market, manufacturing sectors seek better properties, such as easy nature and eco-friendly based materials. It has been discovered that there is a significant research gap for excellent property improvement and eco-friendly materials. Continuous research in this area has improved fabrication methods, which has led to the use of these composite materials in structural and marine applications rather than the majority of monolithic materials. The current studies are based on a review of the literature on the density, hardness, and wear behavior of composites made of aluminum and metal.*

Keywords: Composites Material, AL, Sic, Hardness, Density

I. INTRODUCTION

Composite materials are made up of two components: reinforcement and a matrix. When compared to bulk materials, the main advantages of composite materials are their high strength and stiffness combined with low density, allowing for weight reduction in the finished part.

Composites are commercialized in three major categories: polymer-matrix composites (PMCs), metal-matrix composites (MMCs), and ceramic-matrix composites (CMCs). Other classification schemes based on matrix/fiber notation, for example, The nature of the matrix material is used to distinguish the three basic types of composites. For property enhancement, each of these types may employ particle or discontinuous (short fibre) or continuous fiber reinforcement. It is important to understand that systems reinforced with particulate, discontinuous, and continuous fibers have different physical and mechanical properties and must be used accordingly. According to previous works, a number of research papers on the corrosion behaviour of MMCs have been published. However, only a few studies have been conducted on the weight fraction of SiC. AISI-C metal matrix composite is also used to determine mechanical properties such as impact strength, microstructure, micro hardness, and tensile strength. However, no work has been completed in the area of acoustic emission testing to date. To cast the AISiC composite, various weight fractions of silicon carbide particulates are mixed with an aluminium matrix in this study. Various samples were cast by hand stir casting, and their microstructure, impact strength, microstructure, micro hardness, and tensile strength interface with AE were reported. In this paper, the weight fraction of various SiC particles (5%, 10%, 15%, and 20%) is used to calculate mechanical properties such as yield strength and tensile strength. The ultimate tensile strength is further tested using a growing NDT technique. Microhardness, impact strength, and acoustic emission/AE microstructure are all being investigated

II. LITERATURE REVIEW

Neelimadevi, Mahesh[1] Metal Matrix Composite (MMC) is a tailored combination of metal (Matrix) and hard particles (Reinforcement) that is essential for automotive applications. Lightweight monolithic titanium, magnesium, and aluminium alloys cannot achieve these properties. When compared to long fibre reinforced composites, particle metal matrix composites have nearly isotropic properties. The mechanical behaviour of the composite is determined by the matrix composition and the manufacturing method used. According to Mark Occhionero, AlSiC is an excellent packaging material for today's microelectronic components and devices that require thermal management. Because of its low density, AlSiC is an excellent choice for weight-sensitive applications such as portable devices. Because of significant process and material advancements in Al SiC in recent years, AlSiC heat sinks , packages and substractes in both military and commercial appli cations have gained acceptance.Al SiC in recent years Dunia abdulsaheb[2]According to reports, aluminium silicon carbide alloy composite materials are widely used for a variety of applications such as engineering structures, aerospace and marine applications, automotive bumpers, sporting goods, and so on. Based on their findings, the weight-to-strength ratio of aluminium silicon carbide is approximately three times that of mild steel during tensile testing. The weight of aluminium silicon carbide alloy composite material is twice that of aluminium of the same dimensions. The maximum tensile strength was obtained at a SiC ratio of 15%. This indicates that the aluminum-silicon carbide composite material is lighter and stronger. This data is extremely useful for practical aerospace applications.

K.L.Meena,et al [3]It has been reported that increasing the composition of SiC increases the material's hardness. He has also explained the material's hardness. The best results were obtained with a SiC particle weight fraction of 25%. By using a stirring process, homogeneous dispersion of SiC particles in the Al matrix is achieved, improving material properties. The distribution of particles and composite properties are significantly improved by using graphite reinforcement particles in the matrix, which improves the strong interfacial bond between them, resulting in the best result possible. In his experiment, he used a 4% weight fraction of graphite particles

S. Satya, et al,[4]The optical micrographs of SiC particles revealed a reasonably uniform distribution of SiC particles, which is consistent with previous work. The samples show an increasing trend in the homogeneous dispersion of SiC particles in the Al matrix. Tensile properties improve as the weight fraction (5%, 10%, 15%, 20%) of SiC particles increases. Hardness increases as reinforced particulate size and weight fraction increase. Impact strength decreases as the weight fraction of SiC particles increases (5%, 1%, 5%, 20%)

S.Basavarajappa, et al,[3]It was reported that SiC/NWs/Al composites were made using a hot pressing technique. SiC NWs were used as reinforcing fibres to improve the composite's wear resistance. The results showed that SiC NWs were evenly distributed in the Al matrix. The addition of SiCNWs significantly improves the wear resistance of metal-based materials. The composite containing 15% vol. SiC NWs has the best wear resistance

Michael Oluwatosin Bodunrina [5]Aluminium matrix hybrid composites with particulate reinforcement and their philosophies; mechanical, corrosion, and tribological properties were studied. The presented on the new generation of hybrid composites, which involve the use of agro and industrial waste derivatives, have established improved performance in comparison to the unreinforced alloy. However, the degree of improvement of hybrid AMCs containing fly ash over single, reinforced AMCs containing synthetic reinforcement needs to be investigated further. The hybrid AMCs reinforced with agro waste derivatives demonstrated that high performance levels in AMCs can be maintained at lower production costs, even when synthetic reinforcement is replaced with agro waste derivatives to the tune of 50%.

Ashok Kr. Mishra, Rakesh Sheokand, R.K.Srivastava[6]It is being investigated whether the addition of SiC reinforcement will improve wear properties. SiC, due to its high hardness and thermal conductivity, improves the wear resistance of the Al - SiC metal matrix composite after being accommodated in a soft ductile aluminium base matrix. Swamy et al. [2] discovered that increasing the graphite content within the aluminium matrix increases ductility, UTS, compressive strength, and Young's modulus while decreasing hardness. By varying the amount of WC, the properties of cast Al6061-WC composites are significantly improved. It was discovered that increasing the WC content of the matrix material resulted in significant improvements in mechanical properties such as hardness, tensile strength, and compressive strength at the expense of decreased ductility.

M.Mahendra Boopathi, et al [7]It was discovered that increasing the area fraction of reinforcement in the matrix improved tensile strength, yield strength, and hardness. With the addition of SiC and fly ash to Al2024 alloy, the percentage rate of elongation of hybrid MMCs is significantly reduced.

P.B.Pawar[8] has created a Spur Gear Aluminum Silicon Carbide Particulate Metal Matrix Composite. Stir-casting was used to create silicon carbide reinforced aluminium matrix composites (AMCs) with varying particle weight fractions (2.5%, 5%, 7.5%, and 10%). the subsequent findings have been reached:

a) Al-SiC has substantially better hardness than aluminium metal. The hardest and toughest material is produced when silicon carbide content is raised, and the highest value is at a silicon carbide content of 10%.

b) Powder metallurgy, which is more expensive than stir casting, can produce composites with SiC particles that are distributed more uniformly

c) These composites can be utilised to create gears and other power-transmitting components that must withstand constant loading.

d) The stress distribution found by FEA analysis reveals that the tips of the teeth are under the most stress.

From an application perspective, the composites' mechanical qualities are of utmost significance.

Michael Oluwatosin Bodunrina[5][8][9]Researchers suggested that the top and lower bounds of the composites' modulus can be accurately predicted using the modified principles of mixture. If Al-MMCs are processed with a controlled gradient of reinforcing particles and by using a better manufacturing technique, it may be possible to produce an optimal mix of surface and bulk mechanical properties.

Devaraju Aruria, Kumar Adepua, Kumaraswamy Adepub, Kotiveerachari Bazavada[10]has looked at "Wear and mechanical properties of friction stir processed 6061-T6 aluminium alloy surface hybrid composites [(SiC + Gr and (SiC + Al2O3)]. The results show that the presence and pinning impact of hard SiC and Al2O3 particles causes micro-hardness to grow. Due to the mechanically mixed layer created between the composite pin and steel disc surfaces, which contained fractured SiC and Gr, the Al-SiC/Gr surface hybrid composite showed low wear rate. Gr particles served as a solid lubricant, and SiC particles served as load-bearing components. Due to the presence of reinforcing particles that make the matrix brittle, tensile characteristics are reduced in comparison to the base material.

G. B. Veeresh Kumar, et al[11] Particulate Reinforced Aluminum Metal Matrix Composites' Mechanical and Tribological Behavior was examined. The results include a review of the wear performance of hard ceramic reinforced aluminium matrix composites with a focus on mechanical and physical parameters, as well as material considerations and the effects of lubrication, work hardening, mechanical mixed layer, heat treatment, etc. The tribological performance of Al-MMC and counter-face metal couples is significantly impacted by each factor. Al-MMCs with ceramic reinforcement will have greater wear resistance than alloys without reinforcement. Finally, there is tremendous promise, scope, and opportunity for researchers in the realm of soft computing methodologies for mechanical and tribological property prediction of particle reinforced metal matrix composites.

S.V.Prasada, et al [12]Al MMCs reinforced with SiC and Al2O3 particulates have been developed. Finally, it was concluded that particulates will reduce weight and increase engine efficiency, lowering fuel consumption and vehicle emissions. To replace cast iron engine components with light-weight Al alloys, SiC, Al2O3, or graphite particles must be dispersed in Al to overcome the poor adhesion and seizure resistance of Al. The use of these particulates results in a significant reduction in wear and friction. Furthermore, higher cylinder pressures (and thus higher engine performance) are possible because Al MMCs can withstand high mechanical and thermal loads, as well as reduce heat losses by allowing for a closer fit due to the lower thermal expansion coefficient of Al MMCs.

Jufu Jiang [13]Research was done on the Compression Mechanical Behavior of Semisolid 7075 Aluminum Matrix Composite Reinforced with Nano-sized SiC Particles. The following are the conclusions: a) Before semisolid compression, the 7075 AMCs reinforced with nano-sized SiC particles have a microstructure made up of fine and spheroidal solid grains surrounded by liquid phase. Solid grains underwent a non-uniform plastic deformation as a result of semisolid compression. Due to the reliance of deformation on the liquid flow (LF) mechanism and the flow of liquid incorporating solid grains (FLS) mechanism, solid grains somewhat distorted in the areas close to the free surface. Due of the plastic deformation of solid grains' (PDS) contribution to deformation, there was obvious plastic deformation at the centre site and location contacting the die. Fig. 2 shows the microstructure of the 7075 AMCs before and after semisolid compression when they were reinforced with nanoscale SiC particles. Locations 1 before semisolid compression, 1 after semisolid compression, 2 before semisolid compression, 2 after semisolid compression, 3 before semisolid compression, and 3 after semisolid compression are shown in (a), (b), (c), (d), and (e), respectively. deformation.

Subhranshu Chatterjee [14] Al2O3 and SiC-reinforced 6061-Al metal matrix composites' nano-tribological and tensile properties were investigated for their effects on microstructure and residual stresses. The wear and tensile characteristics of 6061-Al/Al2O3 and 6061-Al/SiC composite sample wear and tensile properties are significantly influenced by microstructure and residual stresses. Due to the different coefficients of thermal expansion between the reinforcement and matrix, as well as the kind and size of the reinforcement, residual stresses are produced. The diverse forming procedures employed for fabrication are to blame for differences in their values. The wear property of the composites is also impacted by residual stresses. The wear tracks of 6061-Al/SiC showed more debris than those of 6061-Al/Al2O3 composite due to the higher residual stress, which is also supported by the higher wear rate of the former.

P.K.Jayashree[9]conducted a literature review and came to the conclusion that more research was needed to compare the properties of welded joints in heat-treated and unheated conditions in order to improve the quality of welded joints. Particular emphasis was placed on how SiC particles behaved in metal matrix composites during welding by microstructural examination, as well as how these properties improved following the precipitation hardening process.

Dunia abdul saheb[2] Metal Matrix Composites (MMCs) have been used in several applications in aerospace and automotive industries. Although several technical challenges exist with casting technology. Achieving a uniform distribution of reinforcement within the matrix is one such challenge, which affects directly on the properties and quality of composite. Experiments have been conducted by varying weight fraction of SiC, graphite and alumina (5%, 10%, 15%, 20%, 25%, and 30%), while graphite weight fraction 2%, 4%, 6%, 8% and 10% keep all other parameters constant. The results indicated that the „developed method" is quite successful to obtain uniform dispersion of reinforcement in the matrix. An increasing of hardness and with increase in weight percentage of ceramic materials has been observed. The best results (maximum hardness) have been obtained at 25 % weight fraction of SiC and at 4% weight fraction of graphite.

Vijaya Ramnath.c[15]Aluminum matrix composites (AMCs) are potential materials for various applications due to their good physical and mechanical properties. The addition of reinforcements into the metallic matrix improves the stiffness, specific strength, wear, creep and fatigue properties compared to the conventional engineering materials. This paper presents the overview of the effect of addition on different reinforcements in aluminium alloy highlighting their merits and demerits. Effect of different reinforcement on AMCs on the mechanical properties like tensile strength, strain, hardness, wear and fatigue is also discussed in details.

III. CLASSIFICATION COMPOSITE MATERIAL

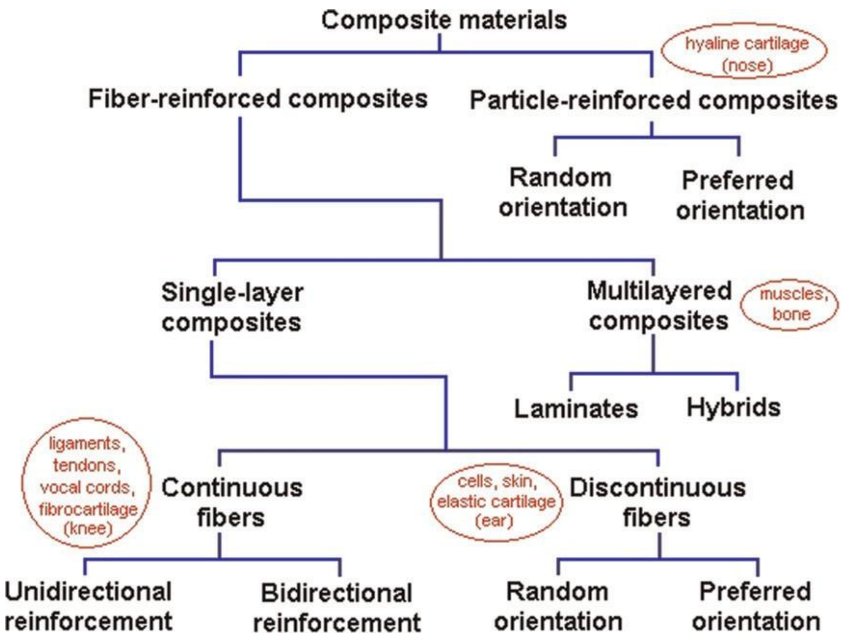

Figure 1 Classification of composites based on reinforcement phases, Singh et al. (2014).

3.1 Hybrid Metal

Hybrid composites contain more than one type of reinforcements in a single matrix material. In principle, several different reinforcements may be incorporated into a hybrid, but it is more likely that a combination of only two types of fibers would be most beneficial. Hybrid composites have unique features that can be used to meet various design requirements in a more economical way than conventional composites. Some of the specific advantages of hybrid composites over conventional composites include balanced strength and stiffness, balanced bending and membrane mechanical properties, balanced thermal distortion stability, reduced weight and/or cost, improved fatigue resistance, reduced notch sensitivity, improved fracture toughness and/or crack arresting properties, and improved impact resistance. The last century has seen the creation of products fabricated from the most enduring and, consequently, the most un-Machinable materials in history .In an effort to meet the technological challenges in manufacturing, created by properties of these materials, tools have now been developed from materials such as alloy steels, carbide, diamond and ceramics. Researchers have done a lot of work to examine the performance of different cutting and abrasive tool .They have used cemented carbide, coated carbide, and diamond in turning, milling, drilling, and reaming of MMC materials. Tools and power sources developed and utilized to tackle manufacturing challenges greatly enhanced the capabilities of manufacturers. However as old problems are solved, new problems and challenges arise.

3.2 Metal Matrix Composite (MMC)

Science and technology advances have placed unexpected needs in the manufacturing industry One of the aspects of these demands is that 2 engineering materials such as metal matrix composites with high strength-to-weight ratios have been developed to serve specific purposes Although, they have been successfully introduced in few commercial applications, their potential for widespread application is still impeded due to the challenges in machining these materials. They are difficult to machine due to the presence of hard and abrasive ceramic reinforcements. The issues like rapid tool wear, surface and sub-surface damage, along with high cost are associated. Therefore, these materials have attracted researcher worldwide in last decade (Sikder n.d.). Lack in machinability study of these hard to cut materials has reduced the applications of these advanced materials. Although some research on traditional and nontraditional machining of hard MMCs have been carried out. Still a lot of applied research on traditional and non-traditional machining process are required as to explore the efficient application of the process parameters for effective machining of aluminum hybrid metal matrix composites Metals and alloys are generally produced and shaped in bulk form but can also be intimately combined with another material that serves to improve their performance: The resulting material is a metal matrix composite (MMC). The first is that the composite approach to materials design makes it possible to go beyond boundaries drawn in property space by basic attributes of the main materials classes. A classical example is the specific modulus of metals, defined as elastic modulus E divided by density ρ: (E/ρ).

3.3 Mechanical Properties of Al 6063

The Al series 6000 alloys is one of the most important groups of alloys for the extrusion of plates, rods, tubes, bars, and other shapes. These alloys have good formability and corrosion resistance with medium strength and very good surface finish. They contain silicon and magnesium in the appropriate proportions to form magnesium silicate, thus making the heat treatable by applying T5 temper and reach full properties with an additional T6 artificial aging. The most widely used A extrusion alloys for structural applications is AA 6063 with the range of composition shown in Table 1 The major alloying elements are silicon and magnesium, while the elements like Cu, Mn, Cr, Ti and Zn may be present in the alloy below the specified maximum limits. The maximum permissible limit of Fe, one of the most common impurities in Al alloys, is also shown in Table 1. Although the impurity elements are restricted to small amounts (~0.1 wt %), such impurities could have substantial effects on the mechanical properties of these alloys. The precipitation behavior of Al–Mg–Si alloys has been extensively studied.

The Tensile Strength of the MMCs produced are higher than that of the non-reinforced Al 6063 alloy. The addition of Silicon Carbide particles improved the Tensile Strength of the composites. The increase in the volume fraction of silicon carbide particle increases the tensile strength of the composites. The tensile strength of Al 6063 alloy in non-reinforced condition is 180 N/mm2, and this value increases at 252 N/mm2 for the composite A4, which is about the 40 % improvement of the non-reinforced material. The thermal conductivity of the composites A1, A2, A3 and A4 are varies due to the combination of the reinforced particles. The Scanning Electron Microscope represent the microphotographs of casted Al 6063, SiC and Graphite composites. it is observed that, the distributions of the reinforced composite particle are fairly uniform. There are the cracks are also seen in the microstructure.

Table 1. Chemical Composition of Al 60603

Si	Fe	Cu	Mn	Mg
0.43	0.102	0.0037	0.0029	0.50
Cr	Zn	Ti	Ni	Al
0.0026	0.0049	0.013	0.0036	Balance

3.4 Mechanical properties of SiC

The aluminum-alloy-based metal matrix composites reinforced with SiC particles are widely used in aerospace, military, and civil manufacturing industries, because of their high strength, modulus, wear resistance and fatigue resistance. Usually, the introduction of the SiC particles increases the elastic modulus and yield stress but decreases the ductility and toughness of the composites. Optimizing the mechanical properties of the SiC reinforced aluminum alloy composites attracted continuous interest during the last several decades. The work includes both experimental studies and mechanical modeling. The Shelby-type model, the shear lag model and the modified shear lag model. It was shown by the models that the mechanical properties (including both the strength and plasticity) of the composites depend a lot on the volume fraction and granularity of the SiC particles. Recent studies have indicated that glass and glass ceramic matrix-silicon carbide (SIC) fiber composites possess excellent potential for achieving significant increases in both the fracture toughness and forgiveness towards catastrophic fracture of brittle load-bearing systems.

Fig.2 SiC reinforced

3.5 Mechanical Properties of Graphite

The mechanical properties of graphite in the forms of single graphene layer and graphite flakes (containing several graphene layers) were investigated using molecular dynamics (MD) simulation. The in-plane properties, Young's modulus, Poisson's ratio, and shear modulus, were measured, respectively, by applying axial tensile stress and in-plane shear stress on the simulation box through the modified NPT ensemble. In order to validate the results, the conventional NVT ensemble with the applied uniform strain filed in the simulation box was adopted in the MD simulation. Results indicated that the modified NPT ensemble is capable of characterizing the material properties of atomistic structures with accuracy. With the characteristics of high strength and stiffness, the graphite has been used as reinforcements in composite materials The natural graphite is constructed by numbers of graphene layers with interlayer spacing of around 3.4 Å. Through chemical oxidation in the environment of sulfuric and nitric acid, the acid intercalate can be intercalated into the graphite galleries to form an intercalated graphite compound. Subsequently, by applying rapid heating because of the vaporization of the acid intercalate in the graphite galleries, the interacted graphite was significantly expanded along the thickness direction and converted into the expanded graphite (EG). After a mechanical mixer together with sanitation process, the expanded graphite was dispersed and exfoliated into the polymer matrix to form graphite-reinforced nano composites.

Fig.3 Graphite reinforced

3.6 Stir casting

Casting is likely one of the oldest methods of producing metallic components. The stir casting method is used to750oC.reate the metal matrix composite used in this study. Aluminum silicon carbide composites are prepared using stir casting mass basis ratios of 100:2.5, 100:5, 100:7.5, and 100:10. The raw materials and sample aluminum silicon Carbide material are depicted in Aluminum alloy is used in the form of ingots. In graphite crucibles, the metal ingots are cleaned and melted to the superheating temperature of 750oC. Figure 2 depicts a schematic setup for the stir casting technique. For melting, a three-phase electrical resistance furnace with a temperature control device is used. Each melt requires 300–400 g of alloy. At a temperature of 7800C, the superheated molten metal is degassed. SiC particulates, preheated to around 500oC, are then added to the molten metal and continuously stirred at 720°C by a mechanical stirrer.

a) The stirring time ranges from 5 to 8 minutes. Borax powder was added in small amounts during stirring to increase the wetability of SiC particles.

b) The melt is poured into the dried, coated, cylindrical permanent sand mould with the reinforced particulates.

c) The pouring temperature is kept constant at 680 degrees Celsius. The strip was filled with the same molten metal and SiC particle mixture. In the moulds, the melt was allowed to solidify.

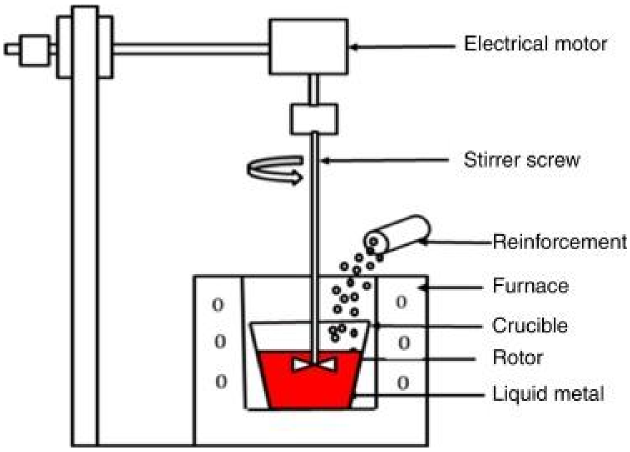

Fig.4 process of stir casting

IV. MECHANICAL TESTING OF MATERIALS

In many of the properties of materials the mechanical ones are of great significance, since they deal with the principal phenomena regarding stability under force. Deformation under applied forces and the fracture of materials depend on their structure. The macroscopic responses of materials to the acting forces may result in their changing shape or even dissent Engrafting, if these forces are sufficiently large. Inter atomic forces must be overcome by external forces in order to cause shape changes in a material, which may eventually lead to its separation into two or more parts, depending on the atomic forces which resist any structural change, either in shape or dimension. The overall macroscopic behavior and the changes occurring in materials are inspected, tested experimentally and described in terms of the acting force per unit area, namely stress and the displacement per unit distance or strain. In a perfectly ideal material, free of lattice defects (which, in reality, does not exist, except in the form of whiskers), tremendous forces are required to cause the above changes. Real crystals contain various defects; lattice defects, such as dislocations, are responsible for the ease of deformation, which may often be observed in functioning machine elements. Mechanical engineers are expected to prevent this from occurring

4.1 Dislocations

A dislocation, due to its extent, is considered to be a line defect and is one of the various types of defects found in materials which determine each and every property of a crystal. Briefly, materials are not perfect and contain a variety of defects. These defects, that determine the properties of a material, are: (a) point defects – various vacancy and interstitial configurations and foreign atoms; (b) line defects – the various configurations of dislocations; (c) planar defects – grain boundaries and surfaces (internal and external surfaces), stacking faults, etc.; and (d) volume defects – voids and precipitates.

By expanding this concept, a point defect might also be considered to be a volume defect, but of atomic dimensions. Thus, the volume of a single vacancy or interstitial defect has the dimensions of one atom. In general, defects disrupt the periodicity of a lattice. The defects considered in this chapter are the dislocations that determine the mechanical properties of materials. When Taylor, Orowan and Polanyi published their ideas on deformation and strengthening mechanisms, no actual observations of dislocations per se were as yet available; their abstract theory was based on observations of the behavior of materials in response to acting forces. It is commonly said that: "Seeing is believing." A giant step forward, toward eliminating any doubt as to the existence (and necessity) of dislocations, was taken with the development of modern technology for their visual observation by means of TEM. Field ion microscopy and atom probe techniques (magnification: typically three million times and above) permit the observation of dislocations at much higher magnifications, on an atomic scale.

Plastic deformation can be realized by the motion of dislocations. During the process, bonds break and re-bond. The energy required to break a single bond is far less than that required to break all the bonds of the atoms on an entire plane at once; this is what causes entire planes to slip. With an increase in the density of the dislocations, overlapping between the strains fields of adjacent dislocations gradually increases the resistance to further dislocation motion. This causes hardening of the material as deformation progresses. The effect is known as 'strain hardening'. Dislocation pile-ups at various obstacles having large strain fields coalesce and resemble small micro-cracks, which propagate under the effect of more applied stress. These cracks grow as a result of the action of normal stresses. At high stresses, creep is controlled by the movement of dislocations. The non-conservative motion of dislocations is also known as 'dislocation climb'. Fatigue is one reason for the failure of many structures and a prerequisite of fatigue is the initiation of a crack. Experimental studies have revealed that fatigue first starts with the accumulation of high-density dislocations.

4.2 Plastic Deformation

'Plastic deformation' refers to effects involving time and temperature, such as creep or fatigue (which will be treated later in separate chapters). Fracture can be a consequence of deformation, resulting from either creep or fatigue, and static loading in the plastic region may also eventually lead to fracture. Brittle materials may fracture without any deformation in the elastic region. However, this section focuses on plastic deformation actually occurring during a short time while loading is in process. Plastic deformation predominantly occurs by slip, but 'twinning' is also a way to induce deformation in a material given the appropriate conditions for this to occur

4.3 Critical Resolved Shear Stress (CRSS)

When stress exceeds a critical value, materials irreversibly change their dimensions by the process of plastic deformation. The stress applied may be tensile or compressive. Thus, a critical stress is necessary in order for plastic deformation to occur. Shear stress, acting in a specific plane, is responsible for plastic deformation. Basically, shear stress causes a change in the dimensions of a material, measured after the load has been removed from it. Plastic deformation is usually associated with a slip mechanism, but that is not the sole mechanism which may be involved. Clearly, twinning may occur simultaneously if no time element, temperature or cyclic stresses are involved. But before considering slip and the systems in which it occurs, it is worth exploring the details regarding the applied stress which initiates slip deformation. Slip is aided by dislocation movement.

4.4 Fatigue

The most common failure that occurs in materials, such as metals, is caused by fatigue. The simplest way of looking at fatigue is by considering a specimen which is being repeatedly stressed under tension and compression. Not only tensile stresses that are repeatedly applied can cause fatigue failure, but any force which is acting in a reverse direction may ultimately result in such a failure. Loading a test specimen repeatedly by applying a force acting axially, torsion ally or flexural can induce fatigue failure. The danger in fatigue failure is that it may occur without any warning at stress levels considerably below the yield stress. Over the years, much experience has been accumulated by exploring the possible reasons for fatigue failure and tests have been suggested to evaluate the propensity for the failure of machine elements, exposed to pulsating or vibrational stresses.

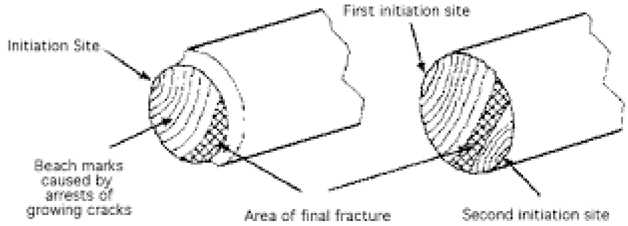

Fig. 5: Fatigue in metals

4.6 Mechanical Behavior of Materials

Strength properties increase with decreasing dimensions, while ductility decreases. Decreasing the dimensions of a material may decrease the size of the grains in polycrystalline materials. The size of single crystals depends on their growth conditions, but, also in this case, decreased size has the same influence on the mechanical properties. The expectation of improved mechanical characteristics, especially in the submicron/nanometer range, however, must be supported by experimental evidence. Experimental evidence has, indeed, indicated the outstanding mechanical properties of monocrystalline (NC) materials that often show: super strength, super hardness, improved specific strength and tribological performance.

4.7 Metallographic Analysis

Metallographic analysis offers a powerful quality control as well as an important investigative tool for micro structural study. The more important use of optical microscope in microstructure examination was in the analysis of reinforced particles in aluminium matrix. Examination of the composites microstructures was carried out using optical microscopy and SEM to determine the primary characteristics of the specimens. For optical microscopy, the samples were observed using a Nikon 200 inverted optical microscope shown in Figure 3.8. The detailed features of the microstructure were also characterized at high magnification using a JSM-5800LV (Tokyo, Japan) scanning electron microscope (SEM) with a maximum resolution of 100 nm in a backscattered model and maximum useful magnification of 30,000. Figure 3.9 show the scanning electron microscope (HITACHI Model S-3000). In order to maximize the composition reading of the energy dispersive spectroscopy data an etchant was applied to the polished specimens for microscopic examination. Worn out s surfaces of specimens and wear debris were analyzed with the SEM to ascertain the nature of wear mechanisms.

V. METHODOLOGY

The current work will be completed in the following stages: • Alumina will be used as a reinforcement material in metal matrix composites, and aluminium alloy will be used as the matrix material. • The composite will be manufactured using a liquid metallurgy route, specifically the stir casting technique. • The mechanical properties of the composites will be determined, including ultimate tensile strength, percentage elongation, hardness test, and microstructure examination for varying percentages of reinforcements. • Wear studies will be detailed by varying the various test parameters.

VI. DISCUSSION

Various experiments were carried out on fabricated MMCs samples with varying weight fractions of SiC (5%, 0%, 15%, and 20%) to evaluate casting performance. Various tests are used to evaluate material properties. Various experimental studies suggested increasing the mass fraction of SiC to increase hardness. This work will extract various mechanical properties and estimate failure before it occurs. The addition of SiC significantly increases impact strength. The AlSiC microstructure is made up of a continuous AI-metal phase and a discrete SiC phase. The AISiC microstructure is completely dense and void-free. The micro hardness increases as the SiC content increases.

VII. CONCLUSION

The microstructure studies revealed that the matrix has a uniform distribution of reinforcing particulates. SEM analysis revealed that the samples had a uniform distribution of the hybrid reinforcement particles (SiC and graphite) in the matrix, with no tunnelling or voiding effects. Based on the results of the experiments, SiC/Gr hybrid composites could be used as a lightweight engineering material. According to the review, the resistance to indentation of the composite increases with the addition of reinforcement by weight or volume when compared to a monolithic metal that acts as a matrix material in a composite. It is also observed that the presence of stiffer and stronger hybrid reinforcements in the Al matrix effectively impedes dislocation movement, thereby increasing hardness. It is also observed that the hardness increases up to a certain percentage of reinforcement and then decreases as more reinforcement is added because cluster formation occurs, resulting in porosity. It can also be deduced that the inherent property of hardness is transferred to the composites, thereby improving their mechanical properties.

REFERENCES

[1]. H. Kala, K. K. S. Mer, and S. Kumar, "A Review on Mechanical and Tribological Behaviors of Stir Cast Aluminum Matrix Composites.," *Procedia Mater. Sci.*, vol. 6, no. 2008, pp. 1951–1960, 2014, doi: 10.1016/j.mspro.2014.07.229.

[2]. D. A. Saheb, "Aluminum silicon carbide and aluminum graphite particulate composites," *J. Eng. Appl. Sci.*, vol. 6, no. 10, pp. 41–46, 2011.

[3]. A. Thirumoorthy, T. V. Arjunan, and K. L. Senthil Kumar, "Latest Research Development in Aluminum Matrix with Particulate Reinforcement Composites - A Review," *Mater. Today Proc.*, vol. 5, no. 1, pp. 1657–1665, 2018, doi: 10.1016/j.matpr.2017.11.260.

[4]. S. Satya, S. Balaji, and P. Murari, "Nature of Aluminium-6063 Metal Matrix Composite with Reinforcement of Silicon Carbide by Using Stir Casting : A Review," pp. 11107–11112, 2018, doi: 10.15680/IJIRSET.2018.0711048.

[5]. K. K. Alaneme, M. O. Bodunrin, and E. A. Okotete, "On the nanomechanical properties and local strain rate sensitivity of selected Aluminium based composites reinforced with metallic and ceramic particles," *J. King Saud Univ. - Eng. Sci.*, no. xxxx, 2021, doi: 10.1016/j.jksues.2021.02.011.

[6]. A. K. Mishra, R. Sheokand, and R. K. Srivastava, "Tribological Behaviour of Al-6061 / SiC Metal Matrix Composite by Taguchi ' s Techniques," *Int. J. Sci. Res. Publ.*, vol. 2, no. 10, pp. 1–8, 2012.

[7]. M. Mahendra Boopathi, K. P. Arulshri, and N. Iyandurai, "Evaluation of mechanical properties of Aluminium alloy 2024 reinforced with silicon carbide and fly ash hybrid metal matrix composites," *Am. J. Appl. Sci.*, vol. 10, no. 3, pp. 219–229, 2013, doi: 10.3844/ajassp.2013.219.229.

[8]. P. B. Pawar, R. M. Wabale, and A. A. Utpat, "A Comprehensive Study of Aluminum Based Metal Matrix Composites: Challenges and Opportunities," *Mater. Today Proc.*, vol. 5, no. 11, pp. 23937–23944, 2018, doi: 10.1016/j.matpr.2018.10.186.

[9]. P. K. Jayashree, S. Sharma, and N. Shetty, "TIG welding parameters optimization of Al–Si–Mg ternary alloy–SiC powder reinforced composites using Taguchi and RSM techniques," *Cogent Eng.*, vol. 9, no. 1, 2022, doi: 10.1080/23311916.2022.2083473.

[10]. D. Aruri, K. Adepu, K. Adepu, and K. Bazavada, "Wear and mechanical properties of 6061-T6 aluminum alloy surface hybrid composites [(SiC + Gr) and (SiC + Al2O3)] fabricated by friction stir processing," *J. Mater. Res. Technol.*, vol. 2, no. 4, pp. 362–369, 2013, doi: 10.1016/j.jmrt.2013.10.004.

[11]. P. Madhukar, N. Selvaraj, C. S. P. Rao, and G. B. Veeresh Kumar, "Enhanced performance of AA7150-SiC nanocomposites synthesized by novel fabrication process," *Ceram. Int.*, vol. 46, no. 10, pp. 17103–17111, 2020, doi: 10.1016/j.ceramint.2020.04.007.

[12]. V. Aswinprasad, V. S. Sriharish, C. Venkatesh, A. Husen Meda, and N. Kamalakannan, "Experimental investigation of wear characteristics of Aluminium 6063 hybrid composite reinforced with Graphite and Molybdenum di sulfide (MoS2)," *Mater. Today Proc.*, vol. 22, pp. 3190–3196, 2019, doi: 10.1016/j.matpr.2020.03.456.

[13]. J. fu JIANG, Y. WANG, Y. ze LIU, G. fei XIAO, and H. LI, "Microstructure and mechanical properties of

7005 aluminum alloy processed by one-pass equal channel reciprocating extrusion," *Trans. Nonferrous Met. Soc. China (English Ed.*, vol. 31, no. 3, pp. 609–625, 2021, doi: 10.1016/S1003-6326(21)65523-1.

[14]. S. K. Pradhan, S. Chatterjee, A. B. Mallick, and D. Das, "A simple stir casting technique for the preparation of in situ Fe-aluminides reinforced Al-matrix composites," *Perspect. Sci.*, vol. 8, pp. 529–532, 2016, doi: 10.1016/j.pisc.2016.06.011.

[15]. G. Ramakrishnan *et al.*, "A Review on Aluminium Metal Matrix Composites," *Adv. Sci. Eng. Med.*, vol. 10, no. 3, pp. 263–267, 2018, doi: 10.1166/asem.2018.2163.

[16]. S. Mahdavi and F. Akhlaghi, "Effect of SiC content on the processing, compaction behavior, and properties of Al6061/SiC/Gr hybrid composites," *J. Mater. Sci.*, vol. 46, no. 5, pp. 1502–1511, 2011, doi: 10.1007/s10853-010-4954-x.

[17]. A. Sridhar and K. P. Lakshmi, "Investigation of graphite effect on the mechanical and tribological properties of Al 7075-SiC-graphite hybrid metal matrix composites," *Tribologia*, vol. 37, no. 1, pp. 26–32, 2020, doi: 10.30678/FJT.82667.

[18]. P. Ravindran, K. Manisekar, P. Narayanasamy, N. Selvakumar, and R. Narayanasamy, "Application of factorial techniques to study the wear of Al hybrid composites with graphite addition," *Mater. Des.*, vol. 39, pp. 42–54, 2012, doi: 10.1016/j.matdes.2012.02.013.

[19]. K. Adiga, M. A. Herbert, S. S. Rao, and A. Shettigar, "Applications of reinforcement particles in the fabrication of Aluminium Metal Matrix Composites by Friction Stir Processing - A Review," *Manuf. Rev.*, vol. 9, 2022, doi: 10.1051/mfreview/2022025.

[20]. A. S. K. D.S.Chandra Mouli, R. Uma Maheswara Rao, "A Review on Aluminium Based Metal Matrix Composites by Friction Stir Processing," *Int. J. Eng. Manuf. Sci. http//www.ripublication.com*, vol. 07, no. 2, pp. 203–224, 2017.

[21]. S. C. Okumus, S. Aslan, R. Karslioglu, D. Gultekin, and H. Akbulut, "Thermal expansion and thermal conductivity behaviors of Al-Si/SiC/graphite hybrid metal matrix composites (MMCs)," *Medziagotyra*, vol. 18, no. 4, pp. 341–346, 2012, doi: 10.5755/j01.ms.18.4.3093.

[22]. M. V. Krishna and A. M. Xavior, "An investigation on the mechanical properties of hybrid metal matrix composites," *Procedia Eng.*, vol. 97, pp. 918–924, 2014, doi: 10.1016/j.proeng.2014.12.367.

[23]. J. Singh, "Fabrication characteristics and tribological behavior of Al/SiC/Gr hybrid aluminum matrix composites: A review," *Friction*, vol. 4, no. 3, pp. 191–207, 2016, doi: 10.1007/s40544-016-0116-8.

[24]. R. Rana, R. Purohit, and S. Das, "Review of recent Studies in Al matrix composites," *Int. J. Sci. Eng. Res.*, vol. 3, no. 6, pp. 1–16, 2012, [Online]. Available: http://www.ijser.org/researchpaper%5CReview-of-recent-Studies-in-Al-matrix-composites.pdf

[25]. P. Yadav, A. Ranjan, H. Kumar, A. Mishra, and J. Yoon, "A contemporary review of aluminium mmc developed through stir-casting route," *Materials (Basel).*, vol. 14, no. 21, pp. 1–30, 2021, doi: 10.3390/ma14216386.

[26]. S. R. Chauhan and K. Dass, "Optimization of machining parameters in turning of titanium (Grade-5) alloy using response surface methodology," *Mater. Manuf. Process.*, vol. 27, no. 5, pp. 531–537, 2012, doi: 10.1080/10426914.2011.593236.

[27]. S. K. Dewangan and A. Arora, "Mechanical Properties of Aluminum 6063 Alloy based Graphite Particles Reinforced Metal Matrix Composite," *IJSRD-International J. Sci. Res. Dev.*, vol. 3, no. January 2015, pp. 2321–0613, 2015, [Online]. Available: www.ijsrd.com

[28]. S. Kumae and D. Arun, "Mechanical Properties of Aluminum 6063 Alloy based Graphite Particles Mechanical Properties of Aluminum 6063 Alloy based Graphite Particles Reinforced Metal Matrix Composite," vol. 3, no. January 2015, pp. 1–6, 2017.

[29]. A. Baradeswaran and A. Elaya Perumal, "Study on mechanical and wear properties of Al 7075/Al2O 3/graphite hybrid composites," *Compos. Part B Eng.*, vol. 56, pp. 464–471, 2014, doi: 10.1016/j.compositesb.2013.08.013.

[30]. S. V. Prasat and R. Subramanian, "Tribological properties of AlSi10Mg/fly ash/graphite hybrid metal matrix composites," *Ind. Lubr. Tribol.*, vol. 65, no. 6, pp. 399–408, 2013, doi: 10.1108/ILT-05-2011-0031.

[31]. N. Radhika, R. Subramanian, S. V. Prasat, and B. Anandavel, "Dry sliding wear behaviour of aluminium/alumina/graphite hybrid metal matrix composites," *Ind. Lubr. Tribol.*, vol. 64, no. 6, pp. 359–366, 2012, doi: 10.1108/00368791211262499.

[32]. a A. Moorthy, N. Natarajan, R. Sivakumar, M. Manojkumar, and M. Suresh, "Dry Sliding Wear and Mechanical Behavior of Aluminium / Fly ash / Graphite Hybrid Metal Matrix Composite Using Taguchi Method," *Int. J. Mod. Eng. Res.*, vol. 2, no. 3, pp. 1224–1230, 2012.

[33]. P. Ravindran, K. Manisekar, R. Narayanasamy, and P. Narayanasamy, "Tribological behaviour of powder metallurgy-processed aluminium hybrid composites with the addition of graphite solid lubricant," *Ceram. Int.*, vol. 39, no. 2, pp. 1169–1182, 2013, doi: 10.1016/j.ceramint.2012.07.041.

[34]. A. Md Ali, M. Z. Omar, H. Hashim, M. S. Salleh, and I. F. Mohamed, "Recent development in graphene-reinforced aluminium matrix composite: A review," *Rev. Adv. Mater. Sci.*, vol. 60, no. 1, pp. 801–817, 2021, doi: 10.1515/rams-2021-0062.