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A Review on Mechanical Properties on Aluminium LM6 Based Metal Matrix Composites with Sodium Feldspar as Reinforcement

Harsha G B¹, Dr.Lakshmi Narasimhan², Dr.D.Ramesh³, Dr.Batluri Tilak Chandra⁴

PG Student, Department of IEM Engineering, SSIT Tumkuru Sri Siddhartha Academy of Higher Education, Karnataka, India¹

Professor, Department of IEM Engineering, SSIT Tumkuru Sri Siddhartha Academy of Higher Education, Karnataka, India²

Professor, Department of IEM Engineering, SSIT Tumkuru Sri Siddhartha Academy of Higher Education, Karnataka, India³

Assistant Professor, Department of IEM Engineering, SSIT Tumkuru Sri Siddhartha Academy of Higher Education, Karnataka, India⁴

ABSTRACT : Aluminium amalgams are generally utilized in aviation and car ventures because of their low thickness and great mechanical properties, better consumption obstruction and wear, low warm coefficient of extension when contrasted with regular metals and compounds. The great mechanical properties of these materials and generally low creation cost make them an exceptionally alluring contender for an assortment of use both from logical and innovative view point. The point included is that the Aluminum LM6/Sodium Feldspar composite was effectively set up by mix projecting defeat and assessed for various properties from the examination. The Aluminum LM6 combination network composites have been effectively evolved with genuinely uniform scattering of Sodium Feldspar.

KEYWORDS: Aluminium, Sodium Feldspar

I. INTRODUCTION

The engineering fraternity has always been on the lookout for wonder-materials which would fit the bills for all types of service conditions. It stem from the need to make progressive discoveries made by scientists, affordable. This affordability quotient has persuaded many researchers to develop such materials which would satisfy various hitherto unexplored conditions. In today's world almost all generic materials have been tried for various uses and their limitations have been met. But the never ending quest of civilization requires that materials qualify for harsher environments. This unavoidable situation demands that new materials be created from various combinations of other compatible materials. It is to be noted here that this method is not new; it has been with mankind since ages. In every part of the world, various materials have been combined to achieve some intended properties, albeit each case differs from the others, i.e. one can create new materials with unique properties, which can be tailor-made and are different from their base ingredients. This concept holds true for a genre of materials called Composite materials where in, various types of matrices may be combined with reinforcements which contribute to the enhancement of the properties. Neither the matrices nor the reinforcements taken alone can stand up to the requirement, but the composite may be able to do so. This alteration in properties can be controlled by many ways, viz. controlling the matrix and reinforcement quality, their proportion or the fabrication route. This flexibility in manufacturing allows one to develop composites with varying properties in a precisely controlled fashion.

It is the superiority of properties that has triggered the penetration of composite materials into all fields of manufacturing. Metal Matrix Composites (MMCs) have emerged as a class of materials suitable for structural, aerospace, automotive, electronic, and thermal and wear applications owing to their advantages over the conventional monoliths. They score over in terms of specific modulus, specific strength, high temperature stability, controlled coefficient of thermal expansion, wear resistance, chemical inertness, etc. But the down side is populated by inferior

toughness and high cost of fabrication in comparison with Polymer Matrix Composites (PMCs). But MMCs supersede in terms of higher transverse strength and stiffness, shear strength and high temperature capabilities.

Compositionally, MMCs have at least two components, viz. the matrix and the reinforcement. The matrix is essentially a metal, but seldom a pure one. Except sparing cases, it is generally an alloy. The most common metal alloys in use are based on Aluminium and Titanium. Both of them are low density materials and are commercially available in a wide range of alloy compositions. Other alloys are also used for specific cases, because of their own advantages and disadvantages. Beryllium is the lightest of all structural materials and has a tensile modulus greater than that of steel, but it is extremely brittle, rendering it unsuitable for general purpose use. Magnesium is light, but is highly reactive to Oxygen. Nickel and Cobalt based super alloys have also found some use, but some of the alloying elements present in the matrices have been found to have undesirable effect (promoting oxidation) on the reinforcing fibers at high temperatures.

The reinforcements for MMCs can be broadly divided into five major categories, viz. Continuous fibers, discontinuous fibers, whiskers, wires and particulates. Except the wires being metals, the reinforcements are generally ceramic; which can be oxides, carbides and nitrides which are used because of their excellent combination of specific strengths and stiffness at both ambient and elevated temperatures.

Aluminium alloys have found greater adoption as potential matrix materials in comparison with other alloys. And the 6xxx series of Aluminium alloys are coming into the picture very fast. The aerospace, automotive and utensil industries were the first reporting their use. On the reinforcement side, the most common reinforcement in use is Silicon. In the present work, commercial grade Aluminium alloy LM6 and Sodium Feldspar fiber have been used for the composite preparation.

Metal Matrix Composites, as alternatives to traditional materials, provide the mechanical properties necessary for elevated as well as ambient temperature applications. The performance advantages of these materials include their tailor able mechanical, physical and thermal properties supplemented with light weight, high specific modulus, high strength and thermal conductivity, good fatigue response, control of thermal expansion, and high abrasion and wear resistance. Hence they find use in fabrication of satellite parts, missile, helicopter structures, structural support girders, piston, sleeves and rims, high temperature structures, drive shafts, brake rotors, connecting rods, engine block liners, bike frames, etc.

However, it is to be clearly understood and acknowledged that the addition of certain volume fraction of a stiff ceramic reinforcement to a ductile matrix (Al 6061 in this case) results in a phenomena specific to reinforced materials. Hence, these issues need to be taken care of i.e. interfacial bonding between the reinforcement and the matrix, residual stresses, matrix dislocations generated by the thermal mismatch between the phases and reinforcement, and alterations in matrix precipitation kinetics.

Aluminium LM6, Sodium Feldspar alloy composites having 0wt%, 2wt%, 4wt%, 6wt% of Sodium Feldspar fiber were fabricated by liquid metallurgy (stir cast) method. The casted ingots were subjected to T6 heat treatment to optimize the properties. The composite specimens were machined as per test standards. The specimens were tested to know the common casting defects using ultra-sonic flaw detector testing system. Some of the mechanical properties have been evaluated and compared with Aluminium LM6. Significant improvement in tensile properties, compressive strength and hardness are noticeable as the wt % of the Sodium Feldspar Fiber increases. The microstructures of the composites were studied to know the dispersion of the Sodium Feldspar fiber in matrix. It has been observed that addition of Sodium Feldspar fiber significantly improves ultimate tensile strength along with compressive strength and hardness properties as compared with that of unreinforced matrix.

II. LITERATURE SURVEY

Literally the term composite means a solid material that results when two or more different substances, each with its own characteristics, are combined to create a new substance whose properties are superior to those of the original components for any specific application. The term composite more specifically refers to a structural material within which a reinforcement material (such as Sodium Feldspar) is embedded. And the engineering definition would also go alongside. A material system composed of a mixture or combination of two or more constituents that differ in form or material composition and are essentially insoluble in each other. In principle, composites can be fabricated out of any combination of two or more materials metallic, organic, or inorganic; but the constituent forms are more restricted. The matrix is the body constituent, serving to enclose the composite and give it a bulk form. Major structural constituents are fibers, particulates, laminates or layers, flakes and fillers. They determine the internal structure of the composite. Usually, they are the additive phase.

When two or more materials are interspersed, there is always a contiguous region. Simply this may be the common boundary of the two phases concerned, in which case it is called an interface. A composite having a single interface is feasibly fabricated when the matrix and the reinforcement are perfectly compatible. On the other end, there may an altogether separate phase present between the matrix phase and the reinforcement phase. This intermediate

phase is called an inter-phase. In case there is an inter-phase present, there are two interfaces, one defining the boundary between the matrix and the inter-phase, and the other between the inter-phase and the reinforcement. The strength of the composite in such a case is dependent upon the strength of the weaker of the two interfaces. There are certain advantages of having a preferred inter-phase. Such a composite with an inter-phase is fabricated if the matrix and reinforcement are not chemically compatible or if the wettability of the pair is very poor. Such a composite is materialized, by introducing a third material that has good bonding properties, individually with the matrix and the reinforcement, which would not be possible otherwise.

More or less, the strength of a composite is a function of the strength of its interface between the matrix and the reinforcement. The failure of a functional composite is essentially a result of the failure of the interface. Hence the strengthening mechanism is the most dominant parameter in successful fabrication of a high strength composite.

Composites differ by their matrix type, reinforcement type, size and form, composition, temper state, etc. With such a big window available for fabricating a composite from different constituent materials, it is not uncommon to experiment with materials with vividly different properties. There are three broadly classified groups of composites: Polymer Matrix Composite, Metal Matrix Composite and Ceramic Matrix Composite.

- **Metal Matrix Composite**

The sustained interest to develop engineering materials which could cope with the raised performance standards, resulted in emergence of a newer class of materials, called Metal Matrix Composites (MMCs). They constitute a family of customizable materials with customizable critical property relationships. Such materials are known for their exceptional high modulus, stiffness, wear resistance, fatigue life, strength-to-weight ratios, tailor able coefficient of thermal expansion, etc. With these enhancements in properties, they pose for strong candidature for replacing conventional structural materials. But what makes them stand apart is the ability to customize their properties to suit the service requirement. Such advantages have made this group of materials a nice pick for use in weight-sensitive and stiffness-critical components in transportation systems.

MMCs can be described as a group of materials in which a continuous metallic phase (matrix) is combined with one or more reinforcement phases. The aim of such a composite material is to enhance the suitability of the end product by selectively enhancing the complimentary properties, and masking the detrimental properties of the matrix and the reinforcement. While fabricating the MMC, a solid material results when two or more substances are physically (not chemically) combined to create a new material whose properties are superior to those of the original substances for a specific application.

The matrix may be a pure metal or any alloy suitable for the intended application. The reinforcement may be any other material in the form of particulates, whiskers, fibers, platelets, etc. The most common reinforcements are ceramics and metals having nominal size in the range of 0.1 to 100 micrometers. But in fact, just about anything suitable for the application may be utilized as a potential reinforcement. Even though at times, the matrix and the reinforcement both can be metallic in nature, MMCs are not fabricated by conventional alloying methods suitable for metals; since, such a process would mar the essence of a composite. In alloys the phases are not chemically and physically distinct. But in a composite, such phases are intentionally kept distinct, to exploit the properties of the constituents to the fullest. The reinforcing phase is the nominal constituent of a composite. It is the principal load bearing component in the system. Hence the reinforcements with better mechanical properties than the matrix materials are chosen while designing a composite. The matrix is responsible for holding the load-carrying reinforcement together and retaining the bulk shape of the composite. It also shares some portion of the total load which is transferred to the reinforcement via the interface or vice versa. It is the effectiveness of the interface that decides how much load is transferred to and from the matrix.

In MMCs a high degree of interaction between the matrix and the reinforcement is inherent. The resulting strength is a direct function of effectiveness of the interface between the matrix and the reinforcement. The character of the interface depends upon the chemical and mechanical compatibility of the two phases involved. The chemical incompatibility constraint can be overcome either by opting for a low-temperature processing route or by selecting stable constituents. The thermal-mechanical incompatibility problem is sorted out by employing a ductile matrix that accommodates the strain generated by the thermal alterations. Also it helps to select a pair of matrix and reinforcement having matching coefficient of thermal expansion. However when it is chemically or thermo-mechanically not feasible to fabricate a composite from a pair of constituents, an intermediate phase which is compatible with the matrix and the reinforcement may be introduced in between the two that masks the incompatibility of the original pair. This interphase prevents the chemical reaction between the matrix and the reinforcement and/or aids the matrix in accommodating the strain generated due to any incongruous strain build-up. A soft precipitate-free layer around the reinforcing particulates limit the propagation of the crack generated at their surface by effectively reducing the stress value gradually, thereby increasing the ultimate strength.

Metal matrix composites have been under constant development since the days of the World War-II. They were intended to be used in the aircrafts as structural materials. After the war ceased, no longer the purpose was the war, rather MMCs found interest in civilian uses. Today the composites are extensively used in all aspects of life, be it food packaging, medical implants, military armours, automotive applications, space applications or just about anything else. This deep penetration of MMCs in a wide spectrum of application can be attributed to the previously mentioned advantages associated with them. However, MMCs are not without some drawbacks either. Their inadequate fracture toughness and damage tolerance, poor ductility, size limitations, in homogeneity of properties, isotropy of properties stand as hindrance to their usability front. Continuous research works are underway to overcome these limitations and explore new possibilities. S.C. Sharma et al. [5] suggests that Aging characteristics of short glass fiber reinforced ZA-27 alloy composite materials by use of liquid metallurgy technique, in which preheated short glass fibers were introduced into the ZA-27 alloy melt above its liquids temperature. The aging temperature was 125 °C for 6, 12, 18, and 24 h. The aged alloy (no fibers) reached the peak hardness after 18 h, while the composites (regardless of filler content) reached the same hardness in 12 h. It is hypothesized that the aging treatment of a composite improves the strength of the interface between the short fibers and the matrix. This shows that the tensile fracto graph analysis, which indicates that at a given aging temperature, the composites aged for 18 h exhibit short fibers that remain attached to the metal matrix, while those aged for 6 h undergo debonding. S.C. Sharma et al. [6] studied the effects of artificial aging on the hardness of cast ZA-27 zinc–aluminium alloy composites containing short glass fibres of diameter 4–6 μm, length 0.4–0.6 mm and contents of 1, 3 and 5% by weight. The age-hardening characteristics of the unreinforced ZA-27 alloy as well as of the glass fibre-reinforced composite materials were determined using hardness measurements. The aging temperatures were 75, 100 and 125°C, respectively and the aging durations were 6, 12 and 18 h, respectively. This suggests that for any particular glass fibres content and aging temperature, hardness seems to increase monotonically with aging time, although it probably tends towards an asymptotic value. For the unaged composites, glass fibre content plays a significant role in determining their hardness values, whereas for all the aged composites, their hardness values are not so dependent on glass fibre content. S.C. Sharma et al. [7] have studies The micro structural and tensile behaviour of aluminium alloy 7075 reinforced with E-glass short fiber in the as-cast and heat-treated (T6) conditions, in order to elucidate the influence of heat treatment and microstructure of the composites on tensile properties. The reinforcement noticeably enhances the dislocation density in the matrix upon cooling from the solution temperature. In composites the dislocation density serves as heterogeneous nucleation sites for strengthening precipitates during subsequent ageing. Due to higher dislocation density more intermediate precipitates were observed. There was a marginal improvement of ultimate tensile strength and hardness with ageing. Llorea and Gonzalez [8] did a detailed analysis of failure and in the results they proposed that at the initial stages of plastic deformation the increase in load carried by the particles is mainly due to the progressive strain hardening of the surrounding matrix, which is relatively ductile. As the matrix strain hardening capacity is saturated, relaxation of stresses from fractured particles result in the stress transfer to nearby particles causing greater particle fracture. They further inferred that the final fracture of the composites takes place by a ductile mechanism involving the nucleation and growth of voids in the matrix, which ultimately coalesce around the broken particle. Weng et al. [9] suggested that saturation in strain hardening of narrow channels of matrix passing in between closely packed reinforcements raise the stress concentration around the reinforcements. Kopp et al [10]. Have suggested that the understanding of inter diffusion between MMC components and their consequences is an indispensable tool in material selection for long term high temperature applications. But Rajeev Kapoor, et al. suggests that at fixed strain, the hardening behaviour is independent of the volume fraction and shape of the reinforcements, rather depends on the matrix properties [12]. Failure modes of MMCs are generally predominantly brittle in nature. Fracture in discontinuously reinforced composites can result from (a) debonding of particles from the matrix, (b) particle cracking leading to a matrix crack, (c) matrix cracking leading to composite failure. At room temperature under uniaxial loading, the predominant mode of failure observed in PRMMC is particulate cracking followed by subsequent linkage in matrix [12] [13] [14]. Prashant Sharma et al. [15] in this study the corrosion is equally important as it is a subject extremely complex and difficult to analyze because of the large number of variables involved. Hence it is an almost necessary that engineer familiarizes the principles of corrosion. An engineer whose design must not only attain the strength required by a structure, but also should give a serious thought and prevent the deterioration of the metal or alloy or composites as a result of the material being exposed to the so causing environment. K. Annamalai et al. [16] in this study the characterize and quantify the properties of hybridized aluminium reinforced composites. Different configurations of aluminium E-glass and graphite particles are manufactured using vortex method and subjected to heat treatment where the residual stresses are relieved. Specimens of composite with 1.25% & 2.5% of both E-glass fibers and graphite particles by weight are prepared for macrostructure and microstructure study to understand the distribution of reinforcements. Further these specimens are subjected to experiments to identify the mechanical behaviour. The plots of properties bring out a composition in which, a composite of 1.25% & 2.5% of both E-glass fibers and graphite particles by weight show satisfactory results when compared to Al-356 alloy.

Summary of the literature survey

New materials with tailored properties can be made from pre-existing materials. As there is freedom to choose the ingredients, there is indirect freedom to choose the required properties and derive intended results.

The effect of addition of fly ash and E-Glass to commercially pure alloys in a pure academic interest. The results have little practical relevance, as the matrix in question is seldom used industrially. Thus, the present work aims to address the shortcomings by using commercially used materials. Discontinuously reinforced Aluminium alloy composites find their use in weight-sensitive and stiffness critical component. The discontinuous reinforcement in Aluminium alloy metal matrix develops properties not attainable by other means. Non-uniform size and dispersion of the reinforcing phase caused the particles to crack at low values of applied stress. Increasing the SiCp volume fraction resulted in higher fatigue strength for a given volume fraction of the SiCp, fracture morphology was observed to be essentially similar at different cyclic stress amplitude. With an increase in SiCp contents in the metal matrix, fractures of the composite were dominated by particulate cracking and decohesion at the interface. Effect of a soft interface between the particle and the matrix shows that the stress concentration towards the surface of the reinforcement diminishes substantially. The precipitate free zone around the reinforcement appears to limit the surface cracking of the SiC and, consequently, to increase the ultimate strength of the composite. Aging characteristics of short glass fiber reinforced ZA-27 alloy composite materials by use of liquid metallurgy technique, in which preheated short glass fibers were introduced into the ZA-27 alloy melt above its liquidus temperature. The aging temperature was 125 °C for 6, 12, 18, and 24 h. The aged alloy (no fibers) reached the peak hardness after 18 h, while the composites (regardless of filler content) reached the same hardness in 12 h. It is hypothesized that the aging treatment of a composite improves the strength of the interface between the short fibers and the matrix. This shows that the tensile fractograph analysis, which indicates that at a given aging temperature, the composites aged for 18 h exhibit short fibers that remain attached to the metal matrix, while those aged for 6 h undergo debonding. The effects of artificial aging on the hardness of cast ZA-27 zinc-aluminium alloy composites containing short glass fibres of diameter 4–6 µm, length 0.4–0.6 mm and contents of 1, 3 and 5% by weight. The age-hardening characteristics of the unreinforced ZA-27 alloy as well as of the glass fibre-reinforced composite materials were determined using hardness measurements. The aging temperatures were 75, 100 and 125°C, respectively and the aging durations were 6, 12 and 18 h, respectively. This suggests that for any particular glass fibres content and aging temperature, hardness seems to increase monotonically with aging time, although it probably tends towards an asymptotic value. For the unaged composites, glass fibre content plays a significant role in determining their hardness values, whereas for all the aged composites, their hardness values are not so dependent on glass fibre content. S.C. Sharma et al. [7] have studied the microstructural and tensile behaviour of aluminium alloy 7075 reinforced with e-glass short fiber in the as-cast and heat-treated (T6) conditions, in order to elucidate the influence of heat treatment and microstructure of the composites on tensile properties. The reinforcement noticeably enhances the dislocation density in the matrix upon cooling from the solution temperature. In composites the dislocation density serves as heterogeneous nucleation sites for strengthening precipitates during subsequent ageing. Due to higher dislocation density more intermediate precipitates were observed. There was a marginal improvement of ultimate tensile strength and hardness with ageing. Final fracture of the composite takes place by a ductile mechanism involving growth of voids in the matrix. Finally these voids tend to coalesce and form larger voids that originate around larger particles. Weng et al. [9] suggested that saturation in strain hardening of narrow channels of matrix passing in between closely packed reinforcements raise the stress concentration around the reinforcements. Interdiffusion of the components of MMCs helps in selecting the components for composite processing for long-term high temperature applications.

Addition of large ceramic particles to Aluminium alloys does not change the basic hardening mechanism of the matrix, rather the formation of precipitates in the matrix significantly influences the work-hardening behaviour. Particle morphology and volume fraction have little or no influence on the work-hardening behaviour which appears to be matrix microstructure dominated. In compression, the stresses experienced by particles are much lower than their failure strengths; hence the particles merely act as obstacles to the flow of the matrix. Larger particles show greater propensity to crack than smaller particles owing to the higher probability of larger particles having a critical sized defect. The corrosion is equally important as it is a subject extremely complex and difficult to analyze because of the large number of variables involved. Hence it is almost necessary that engineer familiarizes the principles of corrosion. An engineer whose design must not only attain the strength required by a structure, but also should give a serious thought and prevent the deterioration of the metal or alloy or composites as a result of the material being exposed to the so causing environment.

III. CONCLUSION

The characterize and quantify the properties of hybridized aluminium reinforced composites. Different configurations of aluminium E-glass and graphite particles are manufactured using vortex method and subjected to heat treatment

where the residual stresses are relieved. Specimens of composite with 1.25% & 2.5% of both E-glass fibers and graphite particles by weight are prepared for macrostructure and microstructure study to understand the distribution of reinforcements. Further these specimens are subjected to experiments to identify the mechanical behaviour. The plots of properties bring out a composition in which, a composite of 1.25% & 2.5% of both E-glass fibers and graphite particles by weight show satisfactory results when compared to Al-356 alloy.

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