FABRICATION OF ALUMINUM/METAL MATRIX COMPOSITE REINFORCED BY SIC NANO PARTICLES

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Abstract

Presently Al-5000 arrangement is broadly utilized within car sector, marine and aviation sector because of their unrivalled erosion resistance, phenomenal formability, beneficial welding aspects and light weight. Al5083, An non-heat treatable secondary Mg-Al created alloy, is extensively utilized within the car segment. Nano sic particles support over aluminum compound upgrade its mechanical properties such as hardness, ductile strength, compressive quality without affecting the ductility of the material. In this fill in micron Furthermore Nano sic /Al 5083 composites were created toward stir casting process Furthermore investigated it mechanical properties. Effect demonstrated that Hardness, rigidity and compressive quality at 2% sic nano composites might have been higher in comparison of all other compositions. Creation and testing of car gears might have been also conveyed out and found suitable to displace existing materials steel in vehicles. The composites refer to the material consisting of two or more individual constituents, in that the reinforcing particulates are embedded to the base matrix to form composite materials by improving the mechanical and tribological properties. Different types of composite materials are available and these are increasing because of their good enhanced properties, among these Metal Matrix Composites (MMCs) finds its applications in various aspects like aerospace, automotive, defense, and marine etc. These improved properties are obtained from different form of particulates which are different in their aspect ratio are mixed with base material to provide good bonding and strength between them. To obtain these enhanced properties different manufacturing techniques are followed to prepare the composites. This paper presents an overview of types of composites, different fabrication techniques available to prepare the composites and also wear behavior of particulates reinforced MMC's by studying different types of wear mechanism. The usage of AMCs in ranges from claiming aviation Furthermore auto businesses incorporates performance, monetary What's more natural profits. The key profits of AMCs to transportation division need aid easier fuel consumption, less noise Furthermore bring down contamination and airborne outflows.

Key words: Aluminum, SiC, nanomaterial, Al alloy, mechanical properties.

1. INTRODUCTION

A. Composite

A composite is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. The composite generally has superior characteristics than those of each of the individual components. Generally a composite material is composed of reinforcement (fibers, particles/ particulates, flakes, and/or fillers) embedded in a matrix (metals, polymers). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the mechanical properties of matrix. When designed properly, the new combined material exhibits better than would each individual material.

I. Classification of composite: Composite materials are commonly classified at following two distinct levels:

The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.

The second level of classification refers to the reinforcement form - fibre reinforced composites, laminar composites and particulate composites. Fibre Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibres. Fibre Reinforced Composites are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced. Fibres are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling. Laminar Composites are composed of layers of materials held together by matrix. Sandwich structures fall under this category. Particulate Composites are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category.

II. Properties of composites: The following are the various properties of Composites:

[1] Lower density (20 to 40%)

[2] Higher directional mechanical properties (specific tensile strength (ratio of material strength to density) 4 times greater than that of steel and aluminium.

[3] Higher Fatigue endurance.

[4] Higher toughness than ceramics and glasses.

[5] Versatility and tailoring by design.

[6] Easy to machine.

[7] Can combine other properties (damping, corrosion).

[8] Cost

B. Introduction of metal matrix composites

Metal Matrix Composites (MMCs), like all composites; consist of at least two chemically & physically distinct phases, suitably distributed to provide not obtainable with either of the individual phases. Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to-weight ratios of resulting composites can be higher than most alloys.

The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials. For many researchers the term metal matrix composites is often equated the term light metal matrix composites (MMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications.

Objectives of metal matrix composites

[1] Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness,
[2] Increase in creep resistance at higher temperatures compared to that of conventional alloys,
[3] Increase in fatigue strength, especially at higher temperatures,
[4] Improvement of thermal shock resistance,
[5] Improvement of corrosion resistance,
[6] Increase in Young's modulus,
[7] Reduction of thermal elongation.

To summarize, an improvement in the weight specific properties can result, offering the possibilities of extending the application area, substitution of common materials and optimisation of component properties.

C. Stir casting

This involves incorporation of ceramic particulate into liquid aluminium melt and allowing the mixture to solidify. Here, the crucial thing is to create good wetting between the particulate reinforcement and the liquid aluminium alloy melt. The simplest and most commercially used technique is known as vortex technique or stir- casting technique. The vortex technique involves the introduction of pre-treated ceramic particles into the vortex of molten alloy created by the rotating impeller. Microstructural inhomogeneities can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. Inhomogeneity in reinforcement distribution in these cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification. Generally it is possible to incorporate up to 30% ceramic particles in the size range 5 to 100 μ m in a variety of molten aluminium alloys. The melt–ceramic particle slurry 11 may be transferred directly to a shaped mould prior to complete solidification or it may be allowed to solidify in billet or rod shape so that it can be reheated to the slurry form for further processing by technique such as die casting, and investment casting. Another variant of stir casting process is compo- casting. Here, ceramic particles are incorporated into the alloy in the semi-solid state. Some of the generally used metallic alloys are Aluminum, Magnesium, Titanium, Zinc, Cobalt, and Cobalt –Nickel alloy. On the other hand the structure and the properties of these composite materials are controlled by different size (macro, micro, and nano) and different types of reinforcements which are reinforced into base matrix. The research drive from macro to nano size particles and has been enhanced extraordinarily nowadays.

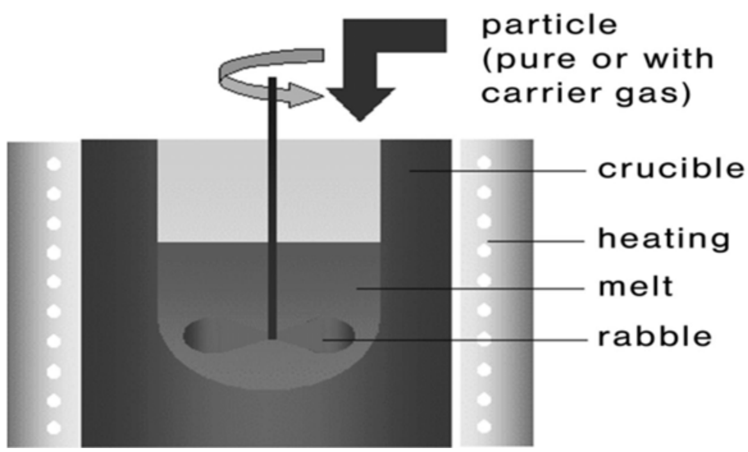

Fig. 1 Schematic operational sequence during melt stirring

Owing to nano particles it increases the surface area and surface energy and supports to lead better tribological performance as compared to macro size reinforcements. This reinforcement impart there special mechanical and physical characteristics to enhance the properties of the matrix. The reinforcement surface can be coated to avoid the chemical reaction with matrix. The MMCs uses three types of reinforcements they are particulate, fibrous, and continuous. Particulates reinforcement consists of powders such as Boron Carbide, Silicon Carbide and

Aluminum Oxide etc. Fibrous reinforcements include silicon carbide fiber; jute fiber etc. and finally continuous reinforcement include carbon fibers, woven carbon fiber, filament wounded etc. Generally it is believed that fibers and hard particles increase the strength and wear resistance of composites, but reductions in the ductility. Soft particles acts as lubricant but decrease the coefficient of friction, the ductility and the strength of filled matrix.

The wear rate alters through the repeated contact procedure under constant load and constant speed. It is usually great in initial unstable state and moderately lower in the later steady. Initial wear and study wear are the relations used to define wear variations causing from wear due to repeated constant. For example in case of SiC to SiC contact in water the wear rate altersfrom a high value of 10^{-6} mm^3 N/m to 10^{-8} mm^3 N/m, this is caused by continuous wear of surface aspertion and better conventionality of smooth worn surface. Wear is caused by brittle nano particles in the surface grains and in later stage by tribochemical reaction. Friction is also one of the terms in tribology, friction is the mechanical force which resists moments (dynamic or kinetic friction) or hinders moment (static friction) between sliding and rolling surface.There are several types of friction like dry friction, fluid friction, lubricated friction and internal friction.The cause of external friction is beyond all the microscopic interaction point between the sliding surfaces this causes adhesion, material distortion, and grooving.The energy which is lost as friction can be measured as heat and mechanical vibration. Lubricants should reduce or avoid the micro interaction which causes the extreme part of external friction.The friction method is also related with the failure and rebonding of setting junctions and moreover it is believed that the nature of static friction is similar for both metal and polymers.Usually friction force is a function of pressure, sliding velocity, contact time, and other external friction parameters. In practice the minimal friction force is often used which is determined by the ratio of friction force to minimal contact area.

2. FABRICATION OF METAL MATRIX COMPOSITE

Following steps are involved in manufacturing of gear using stir casting process:

[1] Cut the aluminum alloy-5083 ingot weight it and put it in the ceramic crucible in the electric resistance furnace.

[2] Start the electric furnace and set the casting temperature 800ºC.

[3] Three castings were done. One for AA5083/10% micron SiC one for AA5083/1% nano SiC and one for AA5083/2% nano SiC. When aluminum alloy-5083 fully melt than added SiC particles 10% micron by weight,1% nano and 2% nano SiC by weight .

[4] After addition of SiC particles it mixed by Mechanical stirring.

[5] After the fully mixing of SiC particles, then crucible take out from the furnace.

[6] Melt was poured in the pre heated mild steel disc die for circular disk and hollow cylindrical die for tensile, compression & hardness specimen.

[7] After solidification of melt casted circular disc were removed from die.

[8] Machining on circular disc was done on lathe machine to get the gear of required dimensions.

[9] After being machined cut the teeth over circular disc by milling machine.

3. MATERIAL SELECTION

A. Composition analysis of al-alloy 5083

We take Al-5083 for this project because Al5083, a non-heat treatable, high Mg-Al wrought alloy, and light weight. It is extensively used for the marine and automobiles applications .

TABLE I. Percentage of composition in Al-alloy 5083

Element	Zn	Fe	Ti	Cu	Si	Pb	Mn	Mg	Cr	Al
%Present	0.03	0.173	0.04	0.0181	0.16	0.0140	0.526	5.13	0.097	Balance

B. Particle size analysis

This analysis has done to find out the size of the particle. Under this analysis two type of test has conducted to find out Micron and Nano size particle.

1) Scanning electron microscope (s.e.m.) analysis of sic particle: SEM analysis of SiC particles were carried out to find out the size micron particles present in SiC powder.

In the below fig. 2 we see the average size (500nm) of particle which is more than 100 nm i.e it is micron particle.

2) Transmission electron microscope of sic particle: This analysis has done to find out the size of the Nano size particle. The images come from this test which shows the size of the particle.

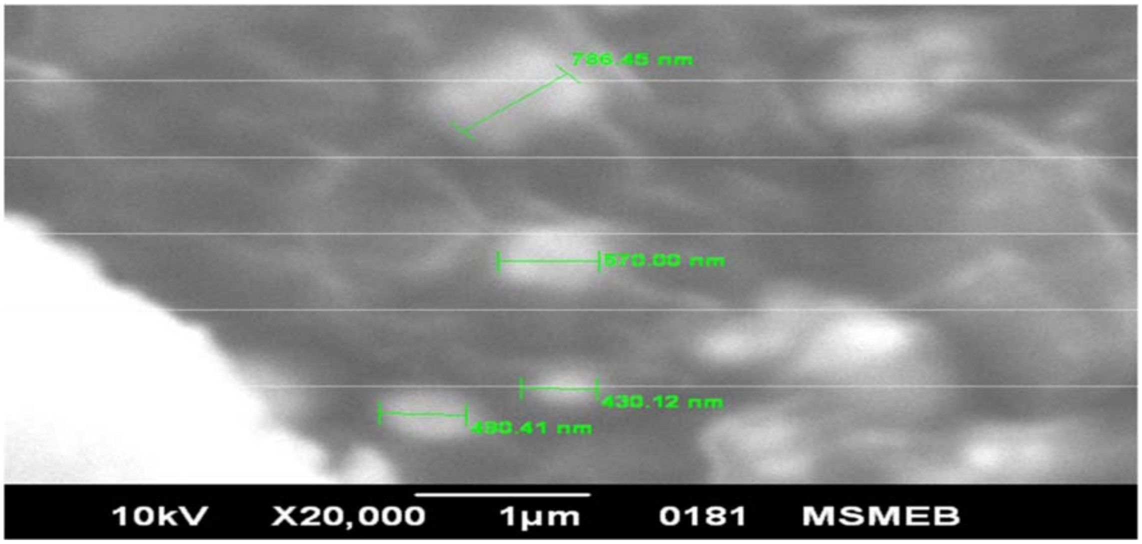

Fig. 2 SEM analysis of SiC particle

4. Types Of Composites

Based on the type of matrix used to prepare the composites, have been classified into the following types.

4.1 Polymer Matrix Composites

Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. Polymer matrix composites are also known as FRP - Fiber Reinforced Polymers (or Plastics). These materials use a polymer-based resin as the matrix, and a variety of fibers such as glass, carbon and aramid as the reinforcement.Two main kinds of polymers are thermosetand thermoplastics. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the chopped fiber composites form particularly when a premixed or moulding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins.

Thermoplastics have one- or two-dimensional molecular structure and they tend to at an elevated temperature and show exaggerated melting point. Another advantage is that the process of softening at elevated temperatures can reversed to regain its properties during cooling, facilitating applications of conventional compress techniquesto mould the compounds.

4.2 Metal Matrix Composites

Metal matrix composites, at present though generating a wide interest in research fraternity are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the after mentioned reasons are characterized by high modulus.

4.3 Ceramic Matrix Composites

Ceramics can be described as solid materials which exhibit very strong ionic bonding in general and in few cases covalent bonding. High melting points, good corrosion resistance, stability at elevated temperatures and high compressive strength, render ceramic-based matrix materials a favorite for applications requiring a structural material that doesn't give way at temperatures above 1500ºC. Naturally, ceramic matrices are the obvious choice for high temperature applications. High modulus of elasticity and low tensile strain, which most ceramics posses, have combined to cause the failure of attempts to add reinforcements to obtain strength improvement. This is because at the stress levels at which ceramics rupture, there is insufficient elongation of the matrix which keeps composite from transferring an effective quantum of load to the reinforcement and the composite may fail unless the percentage of fiber volume is high enough. A material is reinforcement to utilize the higher tensile strength of the fiber, to produce an increase in load bearing capacity of the matrix. Addition of high-strength fiber to a weaker ceramic has not always been successful and often the resultant composite has proved to be weaker. The use of reinforcement with high modulus of elasticity may take care of the problem to some extent and presents pre-stressing of the fiber in the ceramic matrix is being increasingly resorted to as an option.When ceramics have a higher thermal expansion coefficient than reinforcement materials, the resultant composite is unlikely to have a superior level of strength. In that case, the composite will develop strength within ceramic at the time of cooling resulting in micro-cracks extending from fiber to fiber within the matrix. Micro-cracking can result in a composite with tensile strength lower than that of the matrix.

5. RESULT AND DISCUSSION

A. Hardness result

The average Rockwell hardness values of cast Al-alloy, Al-alloy with 10% SiC composites, Al-alloy with 1% nano composites, and Al-alloy with 2% nano composites measured on the polished surfaces of the samples using B scale on Rockwell hardness tester are shown in table II and Fig.4. Total 100 Kg load applied and 1/16inch indenter used.

TABLE II. Hardness of composite

Composition	Hardness (HRB)
Al alloy	29.1
Al alloy with 10% SiC composite	44.5
Al alloy with 1% SiC nano composite	40.1
Al alloy with 2% SiC nano composite	48.1

B. Tensile strength result

The average tensile strength values of cast Al-alloy, Al-alloy with 10% SiC composites, Al-alloy with 1% nano composites, and Al-alloy with 2% nano composites measured on the polished surfaces of the samples using U.T.M tester.

The above table is showing the effect of SiC particle on alloy of Al-5083. From the above table the following result has found out from tensile test- The Tensile strength Young modules of specimen produced by micron particle and nano particle are having strength as compare to pure alloy. Nano particle specimen having higher tensile strength and Young modules as compare to micron particle. As the amount of nano particle increases the Tensile strength and Young modules value increases. Hence the tensile strength and young modules of Al alloy with 2% SiC nano composite is more among all tested composition.

C. Compression strength result

The average compression strength values of cast Al-alloy, Al-alloy with 10% SiC composites, Al-alloy with 1% nano composites, and Al-alloy with 2% nano composites measured on the polished surfaces of the samples.

6. Conclusions

Now a day's micro particulate reinforced metal matrix composites are widely used in military and aerospace applications. Several matrix materials are available as a matrix.

Among all the matrix materials aluminium, magnesium and zinc are the most popular materials. Micro particulates like Al_2O_3, graphite; B_4C, TiC, TiO_2 and WC can be used as the reinforcements. In processing of metal matrix composites, several techniques like solid and liquid state methods are used. Among all the fabrication techniques liquid stir casting process is the more simpler and economical one. For most of industrial applications wear plays important role. The materials should possess good wear resistance for durability of assemblies.

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