



PREPARATION, CHARACTERIZATION AND MECHANICAL PROPERTIES OF ALUMINIUM ALLOY (LM 24) MATRIX COMPOSITES REINFORCED WITH MGO PARTICLES

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ABSTRACT

In this research Aluminum alloy (LM 24) matrix composite reinforced with Magnesium Oxide particle in the weight % of 0.5, 1.0, 1.5, and 2.0 %. Reinforcement process is carried out by stir casting method. And the mechanical Test will be conducted out in order to identify the properties of the composites reinforcements of MgO in Al (LM 24) and the Tensile, wear properties and hardness strength has been tested. The conventional and new processes for the fabrication of magnesium matrix composites will be summarized and the composite



microstructure is subsequently discussed with respect to grain refinement, reinforcement distribution, and interfacial characteristics have been identified by the composites of aluminium alloy matrix composites.

Key Words; *Aluminium alloy, Reinforcement process, mechanical Test, magnesium matrix*

CHAPTER-1

1. INTRODUCTION

Nowadays, demands for developing metal matrix composites for use in high performance applications, have been significantly increased. Among these composites, aluminium alloy matrix composites attract much attention due to their lightness, high thermal conductivity, moderate casting temperature, etc. Various kinds of ceramic materials, e.g. SiC, Al₂O₃, MgO and B₄C, are extensively used to reinforce aluminium alloy matrices. Superior properties of these materials such as refractoriness, high hardness, high compressive strength, wear resistance, etc. makes them suitable for use as reinforcement in matrix of composites. Nevertheless, low wet ability with molten metal's and density differences increases their tendency toward agglomeration, which deteriorates mechanical properties. Numerous attempts have been made to overcome the mentioned weakness. As aerospace technology continues to advance, there is a rapidly increasing demand for advanced materials with high mechanical and thermal capabilities for such ultra high applications. Its application also stretched to automobile, electronic and computer industries to replace the existing materials including plastics.

The early 1990s are considered to be the renaissance for Al as structural material due to environmental concerns, increasing safety and comfort levels. A significant improvement in the



properties of Al alloys, reduced fuel consumption because of Lightweight has made huge demand from automobile industry. This growing requirements of materials with high specific mechanical properties with weight savings has fuelled significant research activities in recent times targeted primarily for further development of Al based composites.

A recent industrial review revealed that there are hundreds of components from structural to engine in which aluminium alloy is being developed for variety of applications. It is also predicted that for Al alloys demand increased globally at an average rate of 20% every year. It is noticed that the limited mechanical properties (strength and hardness) of Al and its alloys adversely affect its applications in automobile and aerospace industries. This remains one of the major concerns in its fabrication to suit its application in recent days.

1.1 AIM AND OBJECTIVES

With Al-based PMMCs, the main objective of this thesis is to overcome problems that exist in the current processing technologies and produce composites with high quality microstructures, a uniform distribution of the reinforcement and good mechanical properties of the final product.

The key idea is to apply sufficient shear stress (τ) on particle clusters embedded in the liquid metal to overcome the average cohesive force or the tensile strength of the cluster.

Two commercially available casting Al-alloys, LM24 (USA designation A380) and LM25 (USA designation A356) were used as the matrix materials.

The grain refining potential of intensive shearing has been studied on the AZ91D, AM60B and AJ62 magnesium alloys. AZ91D alloy, as the most commonly used cast Mg-alloy, has been studied in further detail and its mechanical properties have been evaluated after the



implementation of intensive shearing.

1.2 DEFINITION OF COMPOSITES

Composites are made by combining two or more natural or artificial materials to maximize their useful properties and minimize their weaknesses. One of the oldest and best-known composites, glass-fibers reinforced plastic (GRP), combines glass fibers (which are strong but brittle) with plastic (which is flexible) to make a composite material that is tough but not brittle. Composites are typically used in place of metals because they are equally strong but much lighter. Most composites consist of fibers of one material tightly bound into another material called a matrix. The matrix binds the fibers together somewhat like an adhesive and makes them more resistant to external damage, whereas the fibers make the matrix stronger and stiffer and help it resist cracks and fractures. Fibers and matrix are usually (but not always) made from different types of materials. The fibers are typically glass, carbon, silicon carbide, or asbestos, while the matrix is usually plastic, metal, or a ceramic material (though materials such as concrete may also be used).

1.3 TYPES OF COMPOSITES

Broadly, composite materials can be classified into three groups on the basis of matrix material.

They are:

- Metal Matrix Composites (MMCs)
- Ceramic Matrix Composites (CMCs)
- Polymer Matrix Composites (PMCs)

Metal Matrix Composites (MMCs)



Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as aluminium, calcium, aluminosilicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture.

Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

1.4 WHY USE COMPOSITES

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The greatest advantage of composite materials is strength and stiffness combined with lightness. By choosing an appropriate combination of reinforcement and matrix material, manufacturers can produce properties that exactly fit the requirements for a particular structure for a particular purpose. Modern aviation, both military and civil, is a prime example. It would be much less efficient without composites. In fact, the demands made by that industry for materials that are both light and strong has been the main force driving the development of composites. It is common now to find wing and tail sections, propellers and rotor blades made from advanced composites, along with much of the internal structure and fittings. The airframes of some smaller aircraft are made entirely from composites, as are the wing, tail and body panels of large commercial aircraft.

In thinking about planes, it is worth remembering that composites are less likely than metals (such as aluminium) to break up completely under stress. A small crack in a piece of metal can spread very rapidly with very serious consequences (especially in the case of aircraft). The fibers in a composites act to block the widening of any small crack and to share the stress around.

The right composites also stand up well to heat and corrosion. This makes them ideal for use in products that are exposed to extreme environments such as boats, chemical-handling equipment and spacecraft. In general, composite materials are very durable.

Another advantage of composite materials is that they provide design flexibility. Composites can be moulded into complex shapes – a great asset when producing something like a surfboard or a boat hull.

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The downside of composites is usually the cost. Although manufacturing processes are often more efficient when composites are used, the raw materials are expensive. Composites will never totally replace traditional materials like steel, but in many cases they are just what we need. And no doubt new uses will be found as the technology evolves. We haven't yet seen all that composites can do.

Metal Matrix Composite (MMC):

Metal matrix composite materials can be produced by many different techniques. The focus of the selection of suitable process engineering is the desired kind, quantity and distribution of the reinforcement components (particles and fibers), the matrix alloy and the application. By altering the manufacturing method, the processing and the finishing, as well as by the form of the reinforcement components It is possible to obtain different characteristic profiles, although the same composition and amounts of the components are involved.

PRODUCTION OF MMC

Metal matrix composite materials can be produced by many different techniques. The focus of the selection of suitable process engineering is the desired kind, quantity and distribution of the reinforcement components (particles and fibers), the matrix alloy and the application. By altering the manufacturing method, the processing and the finishing, as well as by the form of the reinforcement components it is possible to obtain different characteristic profiles, although the same composition and amounts of the components are involved. The production of a suitable precursor material, the processing to a construction unit or a semi-finished material (profile) and the finishing treatment must be separated.



1.5 PROCESSING OF MMC

PROCESSING STEPS

1. Pre-processing: All steps which precede primary processing (e.g., surface treatment of ingredient materials, or preform fabrication for infiltration processing).

Preform: a shaped porous assembly of ingredient material elements such as fibers, whiskers or particles. Typically, preforms are produced for subsequent infiltration with liquid metal, or foil-fiber-foil stacks prior to diffusion bonding. The mechanical stability of the shape may be provided by the adjunction of a binder, potentially but not always fugitive, and amounting to only a few mass % of the preform.

Hybrid preform: a preform containing at least two types of ingredient material elements which form at least two distinct “reinforcing” constituents in the composite (e.g. particulate-fiber mixtures, hollow micro-spheres).

2. Primary processing of composites: production of composite material by combining ingredient materials (e.g., powdered metal and loose ceramic particles, or molten metal and fiber preforms), but not necessarily to final shape or final microstructure.

3. Continuous MMC primary process: a process for the production of MMC material that is essentially continuous (e.g., foil-fiber-foil diffusion bonding using a rolling mill, or continuous infiltration).



4. Secondary processing: processing steps which follow primary processing, and aim to alter the shape or microstructure of the material (e.g., shape casting, forging, extrusion, heat-treatment, machining). Secondary processing may change the constituents (phases, shape) of the composite.

5. Consolidation of MMC: a secondary composite manufacturing process during which composite elements are consolidated (e.g., the consolidation of composite elements consisting of the reinforcement coated with the matrix metal)

6. MMC insertion casting: a secondary process for production of partially reinforced components, in which a pre-fabricated MMC is placed within a mould, and incorporated into a metal or alloy, by a casting process.

7. Partially reinforced metal component: semi-products or components which contain MMC material metallurgical bonded to a conventional metal or alloy (e.g. by diffusion bonding, insertion casting, co-extrusion).

8. In-situ MMC: a MMC in which the ingredient reinforcement material changes its phase or shape during primary composite processing (e.g. TiB₂ reacts to form TiC in some metals by adding carbon). To be an MMC, the constituents must, however, retain its local identity, although they change in shape and/or composition (otherwise, it is an alloy).

1.6 LIQUID STATE PROCESING

Liquid state fabrication of Metal Matrix Composites involves incorporation of dispersed



phase into a molten matrix metal, followed by its Solidification. In order to provide high level of mechanical properties of the composite, good inter facial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained. Wetting improvement may be achieved by coating the dispersed phase particles (fibers). Proper coating not only reduces inter facial energy, but also prevents chemical interaction between the dispersed phase and the matrix. The simplest and the most cost effective method of liquid state fabrication is Stir Casting.

The methods of liquid state fabrication of Metal Matrix Composites are

- Infiltration
- Gas Pressure Infiltration
- Squeeze Casting Infiltration
- Pressure Die Infiltration
- Spray Deposition Processes
- Stir Casting

CHAPTER-2

2. LITERATURE REVIEW

HAI ZHI YE, XING YANG LIU

In this paper, recent progress in magnesium matrix composite technologies is reviewed. The conventional and new processes for the fabrication of magnesium matrix composites are summarized. The composite microstructure is subsequently discussed with respect to grain refinement, reinforcement distribution, and interfacial characteristics.

GIRISHA K.B1, DR.H.C.CHITTAPPA

In this research Aluminum alloy (Al 356.1) matrix composite reinforced with Magnesium



Oxide Nano particle in the weight % of 0.5, 1.0, 1.5, and 2.0 %. Reinforcement process is carried out by stir casting method Microstructure and mechanical properties of Nano composites. The nanocomposites were characterized by scanning electron microscope (SEM) and X-ray diffraction (XRD). mechanical Test were carried out in order to identify the properties The results reveal that the composites containing 1.5 wt % reinforcement particle fabricated at 850o C have homogenous reinforcements of MgO in Al356.1 Tensile, wear properties and hardness strength also improved .

RICCARDO CASATI AND MAURIZIO VEDANI *

Metal matrix composites reinforced by nano-particles are very promising materials, suitable for a large number of applications. These composites consist of a metal matrix filled with nano-particles featuring physical and mechanical properties very different from those of the matrix. The nano-particles can improve the base material in terms of wear resistance, damping properties and mechanical strength. Different kinds of metals, predominantly Al, Mg and Cu, have been employed for the production of composites reinforced by nano-ceramic particles such as carbides, nitrides, oxides as well as carbon nanotubes.

M. MARIMUTHU1, L. JOHN BERCHMANS2

This paper describes the fabrication and mechanical testing of Al-Mg-boron carbide particulate composites using stir casting technique. The size of the boron carbide particulates is ranging between 30 to 100 μm . The boron carbide contents are varied from 3 and 7% by weight and are dispersed in the alloy matrix. The mechanical properties of the castings, particularly their tensile properties and hardness are measured.

S. BALASIVANANDHAPRABU,L. KARUNAMOORTHY, S. KATHIRESAN, B. MOHAN

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In the present study, high silicon content aluminium alloy–silicon carbide metal matrix composite material, with 10% SiC were successfully synthesized, using different stirring speeds and stirring times. The microstructure of the produced composites was examined by optical microscope and scanning electron microscope. The Brinell hardness test was performed. Increase in stirring speed and stirring time resulted in better distribution of particles. The hardness test results also revealed that stirring speed and stirring time have their effect on the hardness of the composite. The uniform hardness values were achieved at 600 rpm with 10 min stirring. But beyond certain stirring speed the properties degraded again.

M. KOK

In this author examined AA 2024 aluminium alloy metal matrix composites (MMCs) reinforced with three different sizes and weight fractions of Al_2O_3 particles up to 30 wt. % were fabricated by a vortex method and subsequently applied pressure. The effects of Al_2O_3 particle content and size on the dispersion of the coarser sizes of particles was more uniform while finer particles led to agglomeration of the particles and porosity. The results show that the hardness and the tensile strength of the composites increased.

G. B. VEERESH KUMAR¹, C. S. P. RAO, N. SELVARAJ, M. S. BHAGYASHEKAR

Author examined the base matrix and the reinforcing phase for the present studies selected were AA 6061, AA 7075 and particles of Al_2O_3 and SiC of size 20 μm . It can be observed that the densities of composites are higher than that of their base matrix, further the density increases with increased percentage of filler content in the composites. It can be observed that the tensile strength of the composites is higher than that of their base matrix also it can be observed that the increase in the filler content contributes in increasing the tensile strength of the composite. In microstructure studies it can be observed that, the distributions



ofreinforcements in the respective matrix are fairly uniform.

DANIEL B. MIRACLE (2000),

In Air Force Research Laboratory author studied 6092/SiC/17.5p & 2009/SiC/15p-T4 forF16 aircraft Door and body purposes. It can be observed that the densities of composites arehigher than that of their base matrix, further the density increases with increased percentageof filler content in the composites.

CHAPTER 3

3 SELECTION OF MATERIAL

3.1 SELECTION OF MATERIALS FOR FABRICATION

- Aluminium LM 24 is the base metal for our metal matrix composite.
- Magnesium oxide is the selected ceramics for reinforcement in the metal matrix composite.

Aluminium in General:

- Aluminium is the most abundant metal available in earth's crust, the most abundant element after Oxygen and silicon.
- Aluminium is mostly used for its high strength to low weight ratio.
- Aluminium has high electrical and thermal conductivity along with good corrosion property.
- Aluminium can also be anodized as it is corrosion resistant.
 - Aircraft and aerospace components
 - Marine fittings
 - Transport
 - Bicycle frames



- Camera lenses
- Drive shafts & Valves
- Electrical fittings and connectors
- Brake components & Couplings

3.2.4 OTHER PROPERTIES

• MACHINABILITY

- Machining practice is similar to that for other Aluminium castings alloys containing Silicon. Whilst there is not the tendency to drag associated with high silicon alloys such as LM6, tool wear is more rapid than in the case of alloys containing relatively small amounts of Silicon. The use of carbide-tipped tools is recommended but a good finish can be obtained with high speed tools.

• CORROSION RESISTANCE

- Resistance to attack under normal atmospheric conditions is similar to that of alloy LM4, i.e fairly good. In marine atmospheres, or under other severe conditions, castings should be protected by painting.

3.2.5 USES OF LM 24

LM24 is essentially a pressure die casting alloy, for which it has excellent casting characteristics and is generally a little simpler to die cast than the high Silicon containing alloys. Die castings in LM24 are suitable for most engineering applications and have an advantage over an alloy such as LM6 when maximum mechanical properties are required. In practice LM6 is preferred to LM24 only for die castings in which a high resistance to corrosion is the primary requirement. LM24 has poor weldability and brazeability. For the vast majority of die castings, the alloys LM2 and LM24 are equally suitable. Castings in LM24 are not usually heat treated



3.3 THE PROCESSING OF MAGNESIUM MATRIX COMPOSITES

A key challenge in the processing of composites is to homogeneously distribute the reinforcement phases to achieve a defect-free microstructure. Based on the shape, the reinforcing phases in the composite can be either particles or fibers. The relatively low material cost and suitability for automatic processing has made the particulate-reinforced composite preferable to the fiber-reinforced composite for automotive applications.

3.4 CONVENTIONAL PROCESSING

Due to the similar melting temperatures of magnesium and aluminum alloys, the processing of a magnesium matrix composite is very similar to that of an aluminum matrix composite. For example, the reinforcing phases (powders/fibers/whiskers) in magnesium matrix composites are incorporated into a magnesium alloy mostly by conventional methods such as stir casting, squeeze casting, and powder metallurgy.

3.4.1 STIR CASTING

In a stir casting process, the reinforcing phases (usually in powder form) are distributed into molten magnesium by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced aluminium particles into an aluminum melt by stirring molten aluminum alloys containing the ceramic powders. A typical stir casting process of magnesium matrix composite is illustrated. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting. Stir casting is suitable for manufacturing composites



with up to 30% volume fractions of reinforcement. The cast composites are sometimes further extruded to reduce porosity,

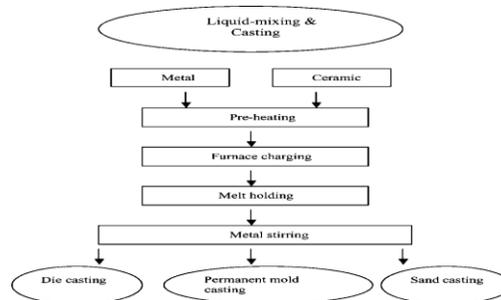


Fig 3.1 stir casting method

3.4.2 THE PROCESS OF STIR CASTING

A homogeneous distribution of secondary particles in the composite matrix is critical for achieving a high strengthening effect because an uneven distribution can lead to premature failures in both reinforcement-free and reinforcement-rich areas. The reinforcement-free areas tend to be weaker than the other areas. Under an applied stress, slip of dislocations and initiation of microcracks can occur in these areas relatively easily, eventually resulting in failure of the material. In the areas of significant segregation or agglomeration of normally highly brittle hard particles, weak bonds are formed in the material which can lead to the reduced mechanical properties.

A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on

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material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification. The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added.

An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquidus temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquidus and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminum A356 and 6061 matrix composites reinforced with SiC particles. The resulting microstructure has been found to be more uniform than that processed with conventional stirring.

The effectiveness of this two-step processing method is mainly attributed to its ability to break the gas layer around the particle surface. Particles usually have a thin layer of gas absorbed on their surface, which impedes wetting between the particles and molten metals.

Compared with conventional stirring, the mixing of the particles in the semi-solid state can more effectively break the gas layer because the high melt viscosity produces a more abrasive action on the particle surface. Hence, the breaking of the gas layer improves the effectiveness of the subsequent mixing in a fully liquid state.



Another concern with the stir casting process is the entrapment of gases and unwanted inclusions. Magnesium alloy is sensitive to oxidation. Once gases and inclusions are entrapped, the increased viscosity of the vigorously stirred melt prevents easy removal of these detriments. Thus, the stirring process needs to be more judiciously controlled for a magnesium alloy than for an aluminum alloy in order to prevent the entrapment of gases and inclusions.

In principle, stir casting allows for the use of conventional metal processing methods with the addition of an appropriate stirring system such as mechanical stirring; ultrasonic or electromagnetic stirring; or centrifugal force stirring. The major merit of stir casting is its applicability to large quantity production. Among all the well-established metal matrix composite fabrication methods, stir casting is the most economical. For that reason, stir casting is currently the most popular commercial method of producing aluminum-based composites. However, no commercial use of stir casting has been reported on magnesium matrix composites.

3.4.3 OTHER PROCESSING TECHNIQUES

In addition to the three well-established synthesis methods described above, a number of other techniques have been explored for the fabrication of magnesium matrix composites, including in-situ synthesis, mechanical alloying, pressureless infiltration, gas injection, and spray forming.

In-situ synthesis

Unlike other fabrication methods of the composite material, in-situ synthesis is a process wherein the reinforcements are formed in the matrix by controlled metallurgical reactions. During fabrication, one of the reacting elements is usually a constituent of the molten matrix



alloy. The other reacting elements may be either externally-added fine powders or gaseous phases. One of the final reaction products is the reinforcement homogeneously dispersed in matrix alloy. This kind of internally-produced reinforcement has many desirable attributes. For example, it is more coherent with the matrix and has both a finer particle size and a more homogenous distribution. However, the process requires that the reaction system be carefully screened. Favourable thermodynamics of the anticipated reaction is the pre-requisite for the process to be applicable.

Mechanical alloying

Mechanical alloying, which was developed in the late is a process in which raw powders are mixed with high energy milling balls, with or without additives, in an inert atmosphere. (Strictly speaking, the mechanical alloying is also a powder metallurgy process.) During the mixing process, the powders go through repeated cold welding and fracturing until the final composition of the very fine powders corresponds to that of the initial charge. Along with the refining of powders, some solid state chemical reactions may also occur, driven by the high mixing energy. Thus, materials of unique microstructures and properties can be produced during the mechanical alloying process.

Pressureless infiltration

Fabricating magnesium matrix composites through spontaneous or pressureless infiltration is relatively new as compared with pressure infiltration (squeeze casting). During the infiltration process, molten alloys flow through the channels of the reinforcement bed or perform



under the capillary action. Certain criteria have to be met for the spontaneous infiltration to occur. A SiC/Mg composite has been attained using this Method.

Gas injection

Particulate reinforced metal matrix composites were incepted in the 1960s, when Ni-coated graphite powders were injected into an Al alloy melt with N₂ gas to form a reasonably uniform distribution in the final castings which solidified at moderately rapid rates. More recently, this method has been employed to synthesize a magnesium matrix composite where SiC and Al₂O₃ particles of various sizes were transported pneumatically through a tube or lance below the bath surface of a molten AZ91 alloy at 720–730°C with a carrier gas of either Ar or N₂. The ceramic powders were transported by the injection gas under a flow rate of 3.0–3.5 l/min from a screw powder feeder at a rate of 30–40 g/min. The reinforcing particles were found to have a reasonably uniform distribution in the AZ91 matrix after being injected with N₂. The maximum volume fraction of the injected SiC particles was about 17%, The microstructure of gas injected 17 vol% SiC/Mg composite and the SiC particles were, for the most part, evenly distributed in the cast alloys, in spite of a number of clusters and agglomerates of the particulates.

Spray forming

Spray forming or spray deposition is a process during which an atomized stream of molten material droplets is directed onto a substrate to build up bulk metallic materials. For a metal matrix composite, reinforcing particles are injected into the stream of the atomized matrix



materials. The droplet velocities typically average about 20–40 m·s⁻¹, and inhomogeneous distributions of ceramic particles are often present in the spray formed metal matrix composite.

A number of studies [94–97] on the fabrication of magnesium matrix composites using the spray forming method have examined the relationships between the spray processing parameters, the microstructure, and the mechanical properties of the composites.

3.5 MAGNESIUM OXIDE

MATRIX COMPOSITES

The key features in the microstructure of a composite material resulting from the interaction between the matrix and the reinforcement usually include the type, size, and distribution of secondary reinforcing phases, matrix grain size, matrix and secondary phase interfacial characteristics, and microstructural defects. The mechanical properties of the composite materials are strongly influenced by these factors.

3.5.1. TYPES OF REINFORCEMENT

Two types of reinforcing materials have been investigated for magnesium matrix composites. The first and most widely used is ceramic. The other is metallic/ intermetallic. Ceramic particles are the most widely studied reinforcement for magnesium matrix composites. Some common properties of ceramic materials make them desirable for reinforcements. These properties include low density and high levels of hardness, strength, elastic modulus, and thermal stability. However, they also have some common limitations such as low wettability, low ductility, and low compatibility with a magnesium matrix. Among the various ceramic

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reinforcements, SiC is the most popular because of its relatively high wettability and its stability in a magnesium melt, as compared to other ceramics.

The shape of reinforcement is another factor affecting the reinforcing effect. In a magnesium matrix composite, the most commonly used reinforcements assume a shape of short fiber/whisker, or particle, or a mixture of these two configurations. Short fiber/whisker reinforced magnesium alloys usually show better mechanical properties than the particle reinforced magnesium alloy with some degree of anisotropic behaviors. The strengthening effect depends on the characteristics of the strengthening mechanism. To overcome the barriers of relatively high cost and the anisotropic properties associated with fiber reinforcement, some recent efforts have been made to reduce the fiber cost by developing a new fibrous material and using hybrid reinforcements that incorporate particles into fibers. For instance, because the cost of aluminum borate whiskers is about only 10% of that of SiC whiskers, this material has been used recently and shows promise for commercial applications of the magnesium matrix composite. The size of the reinforcement used has ranged from nanometers to micrometers.

Because metallic solids will generally have a much better wettability with liquid metals than ceramic powders, the reinforcing of a magnesium matrix with metallic/intermetallic particulates has recently been examined.

Elemental metal powders, such as Cu, Ni, and Ti particulates with a diameter of a few micrometers, have been used as reinforcement agents in magnesium matrix composites because of their high melting points and very low solubility in magnesium.

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The advantages of the metallic reinforcements lie in their high ductility, high wettability and high compatibility with the matrix as compared with ceramics, and their great strength and elastic modulus as compared to the magnesium matrix. A major concern in the use of the elemental metallic powders is that their relatively high density could compromise the lightweight of the magnesium-based composites. The higher specific strengths that the metallic powder reinforced composites have shown as compared to the ceramic reinforced ones indicated that the density increase was compensated for by the increased reinforcing effect of the metallic powders.

Since the high density of the metal powders can also cause mixing difficulties, the process has to be carefully designed and controlled to minimize the segregation of the reinforcements. Recently, the in-situ formation of aluminum based intermetallic particles such as Al₃Ni, Al₃Fe, and other transitional metal aluminides as a reinforcement for lightweight metal composites, has been proposed. These intermetallics have similar benefits as the metallic reinforcement with a much lower density. The methods of in-situ formation of these particles are yet to be developed.

It is worthwhile to mention an interesting recent discovery associated with the formation of hard amorphous or quasi-crystalline phases at grain boundaries of some magnesium alloys. Depending on the alloy composition, the amorphous or quasi-crystalline phases are reported to form under both rapid cooling and standard casting conditions. Furthermore, the amorphous or quasi-crystalline phases cannot be removed by annealing. The high thermal stability of the amorphous or quasi-crystalline phases has led to increased strength of magnesium alloys at elevated temperatures. However, the formation mechanism and the thermal stability of the



amorphous and quasi-crystalline phases have to be further confirmed and better understood before any real application should be attempted.

3.5.2. MATRIX

Various magnesium alloy systems have been used as the matrix for composites. In addition to the normal crystalline alloys predominantly used as the matrix, the recent developments in magnesium alloys, with high glass formation ability, has also triggered the investigation of magnesium composites to fully explore the unique mechanical properties of amorphous metals.

3.5.3. AMORPHOUS MATRIX

The strength of magnesium metallic glasses is two to four times greater than that of commercial magnesium alloys. Normally, amorphous metals are formed at a very high cooling rate, which has prevented the industrial production of amorphous metals. Some magnesium alloys developed recently exhibited a high glass formation ability and high thermal ability. These glass alloys can be cast with conventional techniques while maintaining their amorphous state at relatively high temperature. Studies have also revealed that the presence of nanoscale precipitates or homogeneously distributed fibers or particles can further improve the mechanical properties of the glass metals. Based on these findings, a magnesium composite with an amorphous matrix has been produced by mechanical alloying of powder mixture of Mg55Cu30Y15 with MgO, CeO₂, Cr₂O₃, or Y₂O₃ oxide particles. The addition of these oxide particles does not significantly affect the formation tendency of an amorphous matrix. However, they do affect the thermal stability of the amorphous matrix. The mechanical properties of this

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amorphous magnesium matrix composite are excellent. The composite containing 5 vol% Y₂O₃ possessed a room temperature strength of 709 MPa, 1.5–2.5 times greater than that of the conventional crystalline magnesium alloys. The addition of oxide particles increased the fracture strength by 100–150 MPa and Young's modulus by 28 GPa. The improvement in mechanical properties of the amorphous matrix magnesium composite was more pronounced at elevated temperatures where the amorphous matrix was stable. The yield strength of the composite containing 5 vol% oxide at 150°C was almost the same as at room temperature while the yield strength corresponding to 20 vol% oxide addition exceeded that at room temperature. While the strengthening mechanism in the amorphous matrix composite is not well understood, in general it has been attributed to the change in the deformation mechanism of the matrix caused by the presence of oxide particles. At room temperature, the deformation of an amorphous material is governed by a localized shear band in a depth of several tens of nanometers. At high temperatures, the deformation becomes more homogenous because each volume element contributes to the deformation. Thus, the addition of oxide particles changes the homogenized deformation by the interaction with the matrix. Consequently, the homogeneity of the particle distribution is believed to be more important in an amorphous alloy matrix composite. Further studies are needed to gain a better understanding of the exact microscopic interaction mechanisms between the particles and the matrix.

3.5.4 CRYSTALLINE MATRIX

Mg-Al alloys such as AM60 and AZ91 are presently the most prevalent magnesium alloys utilized in the automotive industry. They are also the most widely studied matrix for magnesium-based composites. Other magnesium materials, such as pure magnesium, Mg-Li alloy, and Mg-

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Ag-Re (QE22) alloys, have also been employed as a matrix material, although less frequently. Grain refinement is a key principle in the strengthening of engineering alloys. The yield strength of a material normally varies proportionally with the reciprocal square root of its grain size, as depicted by the wellknown Hall-Petch equation: $\sigma = \sigma_0 + Kd^{-1/2}$, where σ is the yield stress, σ_0 the yield stress of a single crystal, K a constant, and d the grain size.

In a metal matrix composite, the secondary reinforcing phase can significantly influence the grain size of the matrix. Some studies reported significant grain refinement in the matrix in the SiC particle reinforced AZ91 magnesium alloys, The yield strength and grain size of AZ91 and 5083 alloys. The grain size of AZ91 and SiC/AZ91 composite. SiC particle size and magnesium composite matrix grain size.

The grain refinement effect has been attributed to heterogeneous nucleation of the primary magnesium phase on SiC particles and the restricted growth of magnesium crystals caused by the presence of rigid SiC particles. The heterogeneous nucleation mechanism is supported by the fact that the smaller the SiC particles, the finer the grains of the composite matrix. This is because more nucleation sites are provided.

On the other hand, it has also been reported that the primary magnesium phase could not heterogeneously nucleate on the surface of SiC particles, and thus the SiC particles would not refine the matrix grains.

Another study on the microstructures of a metal matrix composite further suggests that the matrix grains may coarsen if no heterogeneous nucleation exists. That particular study reports that, whereas the liquid flow is an important condition to form fine grain microstructures in



castings, the reinforcement hinders the convection of the liquid metal. The conditions and mechanisms for heterogeneous nucleation of magnesium on the SiC particles were investigated in a recent research paper.

The solidification microstructure of a 15 vol% SiC/Mg-Al-Zn composite that was investigated in the study showed that a majority of the SiC particles were pushed by the primary magnesium phases and segregated at the grain boundaries. At the same time, about 3% SiC particles were entrapped in the magnesium grain. The formation of the microstructure was discussed from the perspective of cooling, geometrical similarity, and surface defects of the SiC particles and the magnesium matrix. Firstly, SiC particles have a lower thermal conductivity and heat diffusivity than the magnesium melt.

During the cooling process the temperature of SiC particles is somewhat higher than that of the surrounding magnesium melt. The SiC particles with the higher temperature would heat up the surrounding magnesium melt, and thus retard its solidification. In such a situation, primary magnesium could not nucleate at the SiC particle surfaces, and the latter would be pushed by the solidifying primary magnesium. Secondly, both magnesium and SiC have a hexagonal lattice and exhibit a close match in lattice parameters in certain orientations.

3.6. INTERFACIAL CHARACTERISTICS

The interface between the matrix and the secondary reinforcing phase plays a crucial role in the performance of composite materials. The key features of the interface are the chemical reactions and the strength of bonding.

3.6.1. INTERFACIAL CHEMISTRY



Interfacial reactions in the magnesium matrix composite are predominantly determined by the composition of the matrix and the reinforcement materials. A comparison study of the interfacial reactions in pure magnesium and AZ91 alloy based composites reinforced with SiC particles has evinced the effect of a matrix alloy composition on the particle/matrix interfacial phenomena. In the pure Mg based composite, SiC particles were stable and no reaction products were found at the interface. On the other hand, in AZ91 based composites the particle/matrix interfacial reactions were confirmed by the presence of a Mg₂Si phase.

3.7. POROSITY AND INCLUSIONS

Porosity and inclusions are detrimental to the mechanical properties of magnesium matrix composites. The existence of porosity in magnesium matrix composite can remarkably reduce the creep resistance of the materials. At low porosity levels, the degree of damage to the mechanical properties caused by the porosity is the sum of that from each pore, in which case the tensile strength is found to be a linear function of the porosity density. This occurs because the distribution of the stress fields around each pore does not overlap. When the porosity volume fraction reaches a certain level, the stress fields of the pores overlap with each other, and the tensile strength of the material is no longer linearly affected by the porosity. The porosity in a composite may arise from a number of sources. These include: the entrapment of gases during mixing, hydrogen evolution, and the shrinkage of the alloy during its solidification. The entrapment of gases depends mainly on the processing method, such as mixing and pouring. Holding time and stirring speed as well as the size and position of the impeller can also significantly affect the porosity formation.



The hydrogen production is mainly the result of the reactions between the absorbed H₂O and Mg melt. Usually some water vapour is absorbed on the surface of the added fibers or particles. Once entering the melt, the water vapour can react strongly with Mg, forming MgO and releasing H₂. Although gas porosity in casting is much more sensitive to the volume fraction of the inclusions than to the amount of dissolved H₂, the recommended practice is to thoroughly dry the raw materials before adding them to the magnesium melt for the purposes of both safety and quality control. In the magnesium matrix composite, the presence of relatively large amounts of fibers/particles may impose a serious porosity problem if the reinforcement is not properly degassed prior to its addition to the melt. This is especially true for finer particles due to the larger number of specific surface areas involved. Inclusion is another major microstructural defect that is deleterious to material properties. The inclusions normally encountered in magnesium alloys include magnesium oxide and nitride, Na, Ca, Mg, K-based chlorides, magnesium-based sulfide, fluoride, and sulfate.

The processing of some metal matrix composites requires melt stirring. Some of the conventional methods for removing inclusions, such as flux refining and gas sparging and settling, may no longer be suitable for processing the metal matrix composites. Due to the high oxidation potential of the magnesium and the limitations of the oxidation protection, the inclusion content in cast magnesium alloys is usually 10–20 times higher than that in aluminum alloys. In addition to the inclusion density, the inclusion size is also important in determining the mechanical properties of the composite materials. It was observed.

CHAPTER 4

4. EXPERIMENTAL WORK



4.1 FABRICATION OF STIR CASTING

Liquid state fabrication of Metal Matrix Composites involves incorporation of dispersed phase into a molten matrix metal, followed by its Solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained. Wetting improvement may be achieved by coating the dispersed phase particles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix. The simplest and the most cost effective method of liquid state fabrication is Stir Casting.

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

4.2 FEATURES OF STIR CASTING

- Content of dispersed phase is limited (usually not more than 30 volume %).
- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous:
- There are local clouds (clusters) of the dispersed particles (fibers);
- There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.
- The technology is relatively simple and low cost.
- The method using stirring metal composite materials in semi-solid state is called Rheocasting.

4.3 METAL MATRIX COMPOSITE SYSTEMS

- ALUMINIUM MATRIX



- Continuous fibers: boron, silicon carbide, alumina, graphite
- Discontinuous fibers: alumina, alumina-silica
- Whiskers: silicon carbide

4.4 FURNACE

A furnace is a device used for heating. The name derives from Latin fornax, oven. The term furnace can also refer to a direct fired heater, used in boiler applications in chemical industries or for providing heat to chemical reactions for processes like cracking, and are part of the Standard English names for many metallurgical furnaces worldwide. In American English and Canadian English usage, the term furnace on its own refers to the household heating systems based on a central furnace and sometimes as a synonym for kiln, a device used in the production of ceramics. In British English, a furnace is an industrial furnace used for many things, such as the extraction of metal from ore (smelting) or in oil refineries and other chemical plants, for example as the heat source for fractional distillation columns.

The heat energy to fuel a furnace may be supplied directly by fuel combustion, by electricity such as the electric arc furnace, or through induction heating in induction furnaces.

4.4.1 MUFFLE FURNACE

Principle of Operation

- The chamber section is heated by six (in type F46100 furnaces) or eight (in type F46200 furnaces) Super Kanthal 33 heating elements suspended in a chamber made of alumina and silica high temperature refractory fiber.
- This high temperature refractory fiber is in the form of blocks which line the inside of the chamber. Because of the stresses caused by extremely high
- Temperature operation, these blocks will show some surface cracking. This cracking is

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not detrimental to the operation of the furnace.

- A precious metal type B thermocouple senses the temperature in the chamber and transmits this information to the temperature control in millivolts.
- The control section consists of a temperature controller, a current controller, a transformer, a contactor (relay), a circuit breaker, and a pilot light. The temperature controller senses the furnace temperature (by means of the thermocouple) and adjusts electricity to the heating elements by means of the current controller.
- The current controller controls electricity to the heating elements by adjusting the magnitude of the electrical current (rather than turning the electricity completely on or off). This is the preferred method of controlling electricity to molybdenum disilicide heating elements.
- The transformer supplies the proper electrical voltage to the heating elements. The contactor removes electricity from the heating elements if the furnace temperature equals or exceeds the high limit set point of the controller The circuit breaker is used to turn the furnace on and off and also protects the electrical supply in the event that the furnace draws too much electrical current.
- The pilot light indicates that the circuit breaker is ON and that the controller is being supplied with electricity. A fan is provided in each section of the furnace to provide forced air cooling.



Figure 4.1 Muffle furnace

4.4.2 ELECTRIC FURNACE

Electric furnaces contain an electric resistance heating coil that simply converts electricity directly into heat. The coil is mounted in a cabinet with a circulation blower. Except for a small amount of heat loss through the cabinet, nearly all the heat from the coil is transferred to the circulating house air. The efficiency of an electric furnace is close to 100%.

Electric furnace is used for heating purpose in various industrial production processes. Electric furnaces are used where more accurate temperature control is required.

Induction heating furnaces and arc furnaces are beyond the scope of this project profile. The scope of this project profile is confined to the resistance heating furnace only. In resistance heating furnaces, the resistance heating elements are used to generate the heat in a heating chamber. The heating elements used are Nichrome wire, Kanthal wire or Graphite rods depending upon the temperature requirements. The unit proposed in this project profile envisages



manufacturing furnaces to a maximum temperature of 1000⁰C and only up to 50 kW power rating. In this case, Kanthal wire is used.

4.5 STIR CASTING

In a stir casting process, the reinforcing phases (usually in powder form) are distributed into molten Aluminium by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into aluminium melt by stirring molten aluminium alloys containing the ceramic powders. A typical stir casting setup used for Aluminium alloy matrix composite is illustrated in Figure below. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mould casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement

This two-step mixing process has been used in the fabrication of aluminium LM 24 matrix composites reinforced of graphite and alumina (Al₂O₃) particles. The resulting microstructure has been found to be more uniform than that processed with conventional stirring. Compared with conventional stirring, the mixing of the particles in the semi-solid state can more effectively break the gas layer because the high melt viscosity produces a more abrasive action on the particle surface.

Stir casting allows for the use of conventional metal processing methods with the addition of an appropriate stirring system such as mechanical stirring; ultrasonic or electromagnetic stirring; or centrifugal force stirring. The major merit of stir casting is its applicability to large quantity production. Among all the well-established metal matrix



composite fabrication methods, stir casting is the most economical(Compared to other methods, stir casting costs as little as one third to one tenth for mass production. For that reason, stir casting is currently the most popular commercial method of producing aluminium based composites.

4.5.1 STIR SETUP

- Specification of Stir Setup:
- Motor: 3-Phase induction motor
- Motor speed: 1440 rpm
- Stir speed: 750 rpm
- Stirring Time : 10 min.
- Speed Reduction: Using gears
- Stir Blades : Mild Steel

4.6 STIRRING MECHANISM

These both degrade the final property of the composition and raises viscosity of the slurry, making subsequent casting difficult. The rate of reaction reduced, and can become zero, if the melt is Si-rich, either by prior alloying or as a result of the reaction. The reaction Kinetics and Si levels required to eliminate it are such that it has accomplished that casting of Al-SiC involving prolonged melt holding Operations suited to conventional (high Si) casting alloys, but not to most wrought alloys.

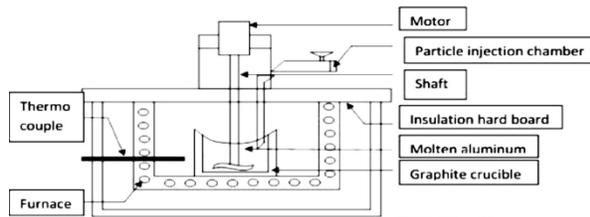


Figure 4.2 Schematic view of stirring mechanism for the fabrication of composites

4.6.1 STIRRING SPEED

Stirring speed is the important process parameter because of the following reason

- Stirring in a fully liquid condition does not help to incorporate particles into the matrix.
- Stirring while the slurry (melt of matrix and reinforcement) is solidifying improves incorporation of the particles into the matrix alloy. However the slurry must then be re-melted to a fully liquid condition in order to enable pouring into a mould. A decrease in solidifying time during stirring increases the percentage wetting.
- The particles tend to float to the top of the molten alloy, regardless of the speed of stirring.

4.6.2 STIRRING TEMPERATURE

It is another important process parameter (it is related to the melting temperature of matrix). The processing temperature is mainly influencing the change in viscosity of Al matrix and it also accelerates the chemical reaction b/w matrix and reinforcement. The change of viscosity influences the particle distribution in the matrix. The viscosity of liquid decreased when increasing processing temperature with increasing holding time (stirring time)

4.6.3 STIRRING TIME



Effect of holding time helps in Al-Sic composite mainly 2 ways: to distribute the particles in the liquid and to create perfect interface bond b/w reinforcement and matrix. The holding time b/w matrix and reinforcement is considered as important factor in the processing of composite. When the holding time is less the particles are distributed uniformly in the matrix the liquid matrix has sufficient viscosity in the temperature range and velocity of particle flow is small. as the result the particles were attached with air bubbles to form the particles clusters in the matrix.

CHAPTER-5

CONCLUSION

The excellent mechanical properties of these materials and relatively low production cost make them a very attractive candidate for a variety of applications both from scientific and technological viewpoints. In the present study involved in designing metal matrix composite materials is to combine the desirable attributes of metals and Ceramics. Present work is focused on the study of behaviour of Aluminium Cast Alloy (LM 24) with MgO composite produced by the stir casting technique. Ongoing process the Different percentage will be reinforcement with Aluminium alloy with MgO particle and the Tensile test, Hardness Test and Impact test performed on the samples obtained by the stir casting process. Microstructure was taken to know the presence of the phases of reinforced material. Hardness tester is employed to evaluate the interfacial bonding between the particles and the matrix by indenting the hardness with the constant load and constant time. Metallurgical microscopy was used to know the distribution of MgO/Alumina particles in Aluminium alloy.

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