Synthesis and Characterization of Aluminum MMC's

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Abstract- In the last decade, as demand for high quality materials are increased, the development of lightweight aluminum (Al) also increased especially in aerospace and automotive industries. It has been well known that Al based metal matrix composites (MMCs) offers a very low thermal expansion coefficient, high specific strengths, wear and heat resistance as compared to conventional Al alloys. In order to combine all these properties, MMCs have become a very attractive method for various industrial applications. The interest in Silicon Nitride (Si_3N_4) and Graphane as reinforcements for aluminum (Al7175) has been growing considerably. Efforts have been largely focused on investigating their contribution to the enhancement of the mechanical performance of the composites. In this present research paper emphasis, the effect of Silicon Nitride (Si_3N_4) and Graphane content on the Physical properties of the composites like Wear Test, Hardness Test & Microstructure Testing was investigated. The improvement of physical properties for composites of Al/Si_3N_4+Graphane has been compared with pure aluminum.

Key Points:- Material Matrix Composites, Composite Materials, Aluminium 7175, Graphane ,Silicon Nitride, Stir Casting, Microstructure, Wear Test, Hardness Test

1 INTRODUCTION

1.1COMPOSITE MATERIALS

A composite material (also called a composition material or shortened to composite, which is the common name) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure, differentiating composites from mixtures and solid solutions.

The new material may be preferred for many reasons. Common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials.

Wattle and daub is one of the oldest synthetic composite materials, at over 6000 years old. Concrete is also a composite material, and is used more than any other synthetic material in the world. As of 2006, about 7.5 billion cubic metres of concrete are made each year—more than one cubic metre for every person on Earth

A composite material is formed when one or more material is distributed in a continuous second phase. The two constituents of composite materials are:

1. The Matrix

2. The Reinforcement.

The matrix phase surrounds the other phase which is called the reinforcement or dispersoid. The reinforcement material can be of different shapes and sizes. Reinforced cement concrete is good example for composite materials where steel bars are used as reinforcement in a matrix of cement, sand and crushed stones.

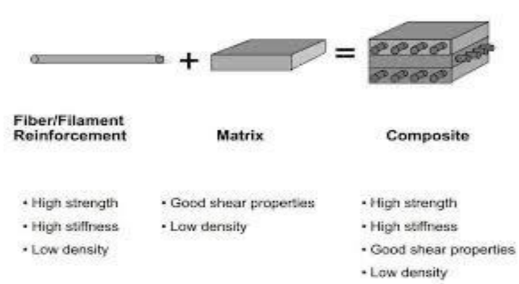


Figure: 1.1 Constituents of a Composite material

2. Background studies

Recently there has been a remarkable growth in the large-scale production of fiber and/or filler reinforced epoxy matrix composites owing to their high strength-to-weight and stiffness-to-weight ratios. Composites are extensively used for a wide variety of structural applications as well as in aerospace, automotive and chemical industries. The use of fillers in polymeric composites helps to improve mechanical, tribological characteristics and thermal stability and other properties. In addition to the higher mechanical strength can also be obtained by the addition of fillers in polymeric composites, there is cost reduction in terms of consumption of resin material. The critical and final selection of filler is primarily depends upon the requirements of the end products.

A composite material is a type of material composed with a combination of two or more constituent material work together to form a composite. These constituent materials have significantly different physical, chemical and mechanical properties and remain separate at microscopic or macroscopic scale within finished product. Metal matrix composites are one of the important types in composites material due to their modified properties by the addition of reinforcement and their application in automobile and aerospace industries.

In recent years particulate reinforced MMCs are widely used as reinforced material because of their specific strength and specific stiffness at elevated or room temperatures .In metal matrix composites the properties depends on microstructural parameters of the reinforcement material like shape, size, orientation, distribution and volume fraction within the matrix material proposed by Gallaspy the bicycle can be balanced by controlling the torque exerted on the steering handlebar. Based on the amount of roll, a controller controls the amount of torque applied to the handlebar to balance the bicycle. Advantages of such a system include low mass and low energy consumption. Disadvantagesinclude the ground reaction force it requires andits lack of robustness against large roll disturbance.

3. Classification of Composites

There are two classification systems of composite materials. One of them is based on the trix material and the second is based on the material structure.

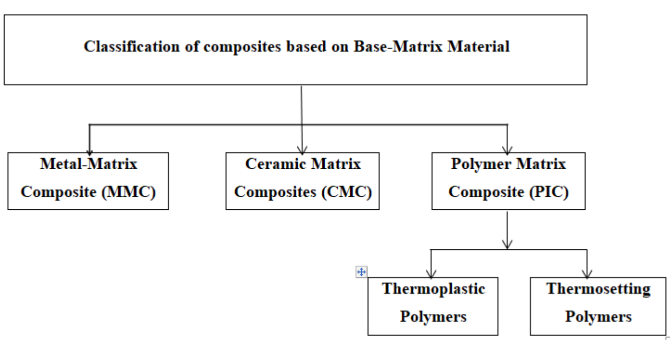


Figure: 3.1 Classification of composites based on Base-Matrix Material.

3.2 METAL MATRIX COMPOSITE (MMC)

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. An MMC is complementary to a cermet. MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix.

4 MATERIAL SELECTION

The aim of designing metal matrix composite materials is to combine the desirable attributes of metal and ceramics The addition of high strength high modulus re factory particles to a ductile metal matrix will produce a material Whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement metal have a useful combination of Properties such as high strength, ductility, and high temperature resistance, but sometimes some of them have a low stiffness value, where as ceramics as normally stiff And string but brittle

There are a number criteria that need to be considered before a right selection of the material can be made some of these criteria are inter related several criteria

The selection of matrix and reinforcement materials is as follows

1) Compatibility
2) Thermal Properties
3) Fabrication Method
4) Application
5) Cost

4.1 Selected Materials

1. ALUMINIUM 7175
2. SILICON NITRIDE
3. GRAPHANE

4.2 ALUMINIUM 7175

Aluminium /aluminum alloys are good low-temperature alloys with strong corrosion resistance characteristics and high electrical conductivity. Both aluminium /aluminum and its alloys are in great demand as they are easy to acquire, fabricate and maintain Aluminium is the third most abundant material in earth, having low density, relatively soft, durable, lightweight, ductile malleable, better strength and cost effective, still it's properties are comparably lower than Titanium and its Alloys . Aluminium alloys are used extensively in aerospace industries for having the properties such as Corrosion resistance, Low density, High strength to weight ratio, Low modulus of Elasticity, Non-Magnetic, low Thermal Expansion Microstructure of alloys can be varied significantly in the processes of plastic working and heat treatment allowing for fitting their mechanical properties including fatigue behavior to the specific requirements. Function of Alloying elements is to increase the alloy

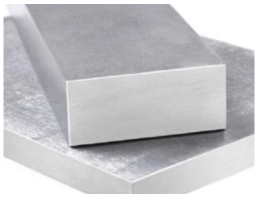


Figure: 4.2 Aluminium 7175

strength (Pure Aluminium has low strength of < 60 MPa) Alloying elements when added to Aluminum alloys produces effects of precipitation hardening (age hardening), solid solution hardening, dispersion strengthening, grain refining, modifying metallic and intermetallic phases, suppression of grain growth at elevated temperatures (e.g. during annealing),wear resistance and other tribological properties. Alloy Al-7175 is typically utilized in applications where improved formability and toughness are desired.

4.3 SILICON NITRIDE

Silicon nitride is a chemical compound of the elements silicon and nitrogen. Si_3N_4 is the most thermodynamically stable of the silicon nitrides. Hence, Si_3N_4 is the most commercially important of the silicon nitrides and is generally understood as what is being referred to where the term "silicon nitride" is used. It is a white, high-melting-point solid that is relatively chemically inert, being attacked by dilute HF and hot H_2SO_4. It is very hard (8.5 on the mohs scale). It has a high thermal stability. Silicon nitride is difficult to produce as a bulk material—it cannot be heated over 1850 °C, which is well below its melting point, due to dissociation to silicon and nitrogen. Therefore, application of conventional hot press sintering techniques is problematic. Bonding of silicon nitride powders can be achieved at lower temperatures through adding additional materials (sintering aids or "binders") which commonly induce a degree of liquid phase sintering. A cleaner alternative is to use spark plasma sintering where heating is conducted very rapidly (seconds) by passing pulses of electric current through the compacted powder. Dense silicon nitride compacts have been obtained by these techniques at temperatures 1500–1700 °C

Figure: 4.3 SILICON NITRIDE

4.4 GRAPHENE

Graphene is the thinnest material known to man at one atom thick, and also incredibly strong about 200 times stronger than steel. On top of that, graphene is an excellent conductor of heat and electricity and has interesting light absorption abilities. It is truly a material that could change the world, with unlimited potential for integration in almost any industry

Figure: 4.4 Graphene

5 DESIGN CALCULATIONS FOR TESTING

CALCUATION

Table: 5 Calculation

SL NO	ALUMINIUM Alloy IN %	GRAPHANE IN %	SILICON NITRIDE IN %	TOTAL WEIGHT IN GRAMS
1	100 (500 gms)	0	0	500
2	96 (480 gms)	4 (20 gms)	0	500

3	94 (470 gms)	4 (20 gms)	2 (10 gms)	500
4	92 (460 gms)	4 (20 gms)	4 (20 gms)	500
5	90 (450 gms)	4 (20 gms)	6 (30 gms)	500
6	88 (440 gms)	4 (20 gms)	8 (40 gms)	500

6 STIR CASTING FABRICATION METHOD

Among the variety of manufacturing process available process available for discontinuous metal matrix composites, stir casting is generally accepted ,and currently practiced commercially its advantages lie in its simplicity ,applicability to large scale production and because in principle it allows a conventional metal processing route to be used and its low cost this liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production , the cost of preparing composites material using a casting method is about one-third to one-half that of a competitive methods, and for high volume production , it is projected that costs will fall to one-tenth

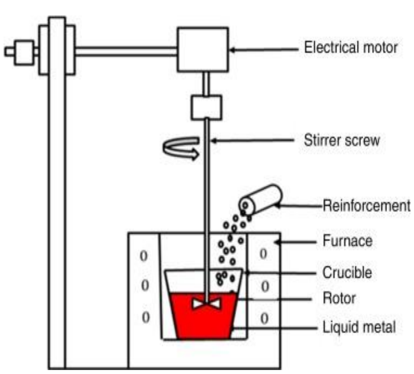


Figure: 6 Stir Casting Process

A improvement in conventional stir casting is a double stir casting method or two step process. In the first stage, the matrix material is heated to above its liquidus temperature and then cooled down to a temperature to keep in a semi solid state .at this stage, the preheated reinforcement material are added and mixed with a mechanical stirrer. Again the slurry is heated to liquid state and mixed thoroughly. Now days this two step mixing process as used in the fabrication of aluminium because of more uniform micro structure as compared of conventional stirring

6.1 Stir Casting Procedure

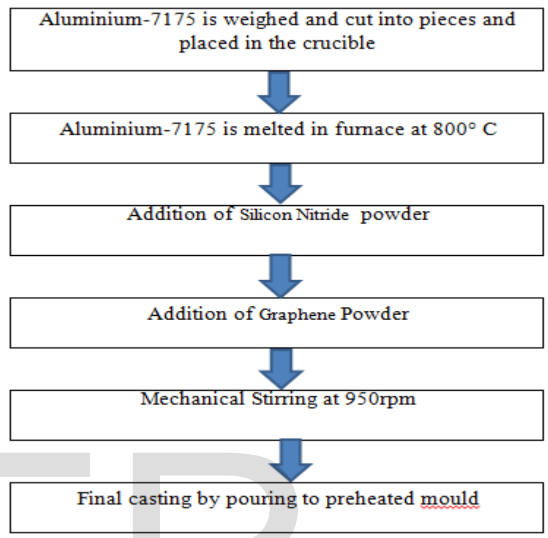


Figure: 4.5 Stir Casting Procedure

7 Machining

Casting generally does not yield good surface finish. If casting process is carried out then, it should be followed by machining. Machining is the process of removing excess material from the work piece to get the required size and shape of the work piece. Machining is done to obtain the desired surface finish and dimensional accuracy in the specimen

In this work Microstructure, Ware Test and Hardness Test on all the samples of the composite have been done. Hence tensile and hardness test specimens are machined. The specimens for both the tests were machined as per the ASTM standards. The machining was carried out on a conventional Lathe machine as shown in the above figure.

8 TESTING

8.1 WEAR TESTING

Wear test is carried out to predict the wear performance and to investigate the wear mechanism. Two specific reasons are as follows: – From a material point of view, the test is performed to evaluate the wear property of a material so as to determine whether the material is adequate for a specific wear application.

8.1.1 PIN-ON-DISC WEAR TESTER

Pin on disk testing provides a method of characterizing the wear between two materials. Our Engaged Experts use this method to evaluate the performance of a "wear couple" or to characterize the performance of different materials against a standard surface In a pin-on-disc wear tester, a pin is loaded against a flat rotating disc specimen such that a Circular wear path is described by the machine. The machine can be used to evaluate wear and Friction properties of materials under pure sliding conditions. Either disc or pin can serve as Specimen, while the other as counterface. Pin with various geometry can be used. A convenient way is to use ball of commercially available materials such as bearing steel, tungsten carbide or alumina (Al2O3) as counterface, so that the name of ball-on-disc is used

Figure: 8.1.1 Wear Test Machine

8.2 MICROSTRUCTURE TESTING

8.2.1 MICROSTRUCTURE

Microstructure is the very small scale structure of a material, defined as the structure of a prepared surface of material as revealed by an optical microscope above 25× magnification. The microstructure of a material (such as metals, polymers, ceramics or composites) can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior or wear resistance. These properties in turn govern the application of these materials in industrial practice. Microstructure at scales smaller than can be viewed with optical microscopes is often called nanostructure, while the structure in which individual atoms are arranged is known as crystal structure. The nanostructure of biological specimens is referred to as ultrastructure. A microstructure's influence on the mechanical and physical properties of a material is primarily governed by the different defects present or absent of the structure. These defects can take many forms but the primary ones are the pores. Even if those pores play a very important role in the definition of the characteristics of a material, so does its composition. In fact, for many materials, different phases can exist at the same time. These phases have different properties and if managed correctly, can prevent the fracture of the material.

Figure: 8.2.1 Microstructure Testing Machine

8.3 HARDNESS TESTING

DEFINITION OF HARDNESS TESTING

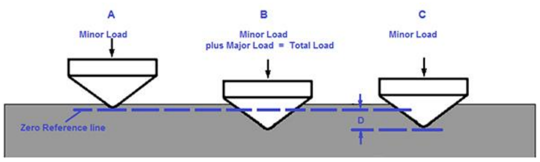
The definition of hardness testing is 'a test to determine the resistance a material exhibits to permanent deformation by penetration of another harder material.' However, hardness is not a fundamental property of a material. Therefore, when drawing conclusions of a hardness test, you should always evaluate the quantitative value in relation to

- The given load on the indenter
- A specific loading time profile and a specific load duration
- A specific indenter geometry

Figure: 8.3 Rockwell Hardness Testing Machine

Test Method Illustration

A = Depth reached by indenter after application of preload (minor load)
B = Position of indenter during Total load, Minor plus Major loads
C = Final position reached by indenter after elastic recovery of sample material
D = Distance measurement taken representing difference between preload and major load position. This distance is used to calculate the Rockwell Hardness Number.



- **Figure: 8.3.1 Illustration**

9 EXPECTED OUTCOMES

- To form light weight composites.
- To improve stiffness.
- To improve hardness number.
- To reduce the ductility value.
- To improve the wear rate.
- To improve the thermal resistance.

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