EXPERIMENTAL INVESTIGATION OF MWCNT ON ALUMINIUM – SILICON CARBIDE COMPOSITES

V.Pradeep*, N.Mathiazhagan, S.Mathiyazhagan
Department of Mechanical Engineering, MeenakshiRamaswamy Engineering College, Thathanur, TamilNadu-621804, India.
*Corresponding author: mathiyazhagan4690@gmail.com

ABSTRACT

Silicon carbide particle reinforced aluminium matrix composites have been developed over past few decades, owing to their excellent properties like light weight, high elastic modulus and wear resistance. Thus, the silicon carbide particle reinforced aluminium matrix composites are expected to have many applications in aerospace, aircraft, automobile and electronic industries. In this study, aluminium powder and carbon nanotube containing several weight percentages of reinforcement particles were prepared by using powder metallurgy method. The main steps in Powder metallurgy are blending, compacting and sintering. The experiments were performed on different composition of silicon carbide and carbon nanotube in the composite. The study presents the results of experimental investigation on mechanical behavior of silicon carbide particle reinforced aluminum matrix. The influence of reinforced ratio of 10, 15, 20 and25 weight percentage of silicon carbide particles on mechanical behavior was examined. The effect of different weight percentage of silicon carbide and carbon nanotube in composite on hardness, compression test, impact test and microstructure, and Scanning Electron Microscope was analysed.

Key words: Metal matrix composites, Powder Metallurgy

INTRODUCTION

Composites: A combination of two or more materials differs in form or composition on a macro scale. The constituents retain their identities, that is, they do not dissolve or merge completely into one another although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another. Examples are cermets and metal-matrix composites.

Characteristics of the composites: Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the ‘reinforcement’ or ‘reinforcing material’, whereas the continuous phase is termed as the ‘matrix’.

Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties.

Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affects the properties the shape of the discontinuous phase (which may be spherical, cylindrical, or rectangular cross-sanctioned prisms or platelets), the size and size distribution (which controls the texture of the material) and volume fraction determine the interfacial area, which plays an important role in determining the extent of the interaction between the reinforcement and the matrix.

Types of composites
Polymer matrix composites
Metal matrix composites
Ceramic matrix composites

Components of a composite material: In its most basic form a composite material is one, which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. In practice, most composites consist of a bulk material (the ‘matrix’), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

Metal matrix composites:

Introduction of metal matrix composites: Metal matrix composites in general, consist of at least two components, one is the metal matrix and the second component is reinforcement. The matrix is defined as a metal in all cases, but a pure metal is rarely used as the matrix. It is generally an alloy. In the productivity of the composite the matrix and the reinforcement are mixed together. A material in which a continuous metallic phase (the matrix) is combined with another phase (the reinforcement) to strengthen the metal and increase high-temperature stability. The reinforcement is typically a ceramic in the form of particulates, platelets, whiskers, or fibers. The metals are typically alloys of aluminum, magnesium, or titanium. In recent years, the development of metal matrix composite (MMCs) has been receiving worldwide attention on account of their superior strength and stiffness in addition to high wear resistance and creep resistance comparison to their corresponding wrought alloys.
The ductile matrix permits the blunting of cracks and stress concentrations by plastic deformation and provides a material with improved fracture toughness.

**Role of matrix in composite:** Many materials when they are in a fibrous form exhibit very good strength property but to achieve these properties the fibres should be bonded by a suitable matrix. The matrix isolates the fibres from one another in order to prevent abrasion and formation of new surface flaws and acts as a bridge to hold the fibres in place. A good matrix should possess ability to deform easily under applied load, transfer the load onto the fibres and evenly distributive stress concentration. A study of the nature of bonding forces in laminates indicates that upon initial loading there is a tendency for the adhesive bond between the reinforcement and the matrix to be broken. The frictional forces between them account for the high strength properties of the laminates.

**Materials used as matrices in composites:** In its most basic form a composite material is one, which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. In practice, most composites consist of a bulk material (the matrix) and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

**Bulk phases metal matrices:** Metal matrix composites possess some attractive properties, when compared with organic matrices. These include (i) strength retention at higher temperatures, (ii) higher transverse strength, (iii) better electrical conductivity, (iv) superior thermal conductivity, (v) higher erosion resistance etc. However, the major disadvantage of metal matrix composites is their higher densities and consequently lower specific mechanical properties compared to polymer matrix composites. Another notable difficulty is the high-energy requirement for fabrication of such composites.

In the aerospace industry interest has been concentrated primarily on fibre reinforced Aluminium and titanium. Boron and to a lesser extent Titanium carbide have been investigated as the reinforcing fibres. Aluminium alloys reinforced with boron have been extensively produced by a variety of methods. Titanium reinforced with, boron coated with TiC and even with beryllium, used for compressor blades. Good elastic modulus properties can be achieved by the unidirectional incorporation of fibres or whiskers in the metal matrix even though the bonding between them may be poor. But, strong metallic matrices rather than weak metal or polymer matrices are essential for good transverse modulus and shear strength. Carbon/graphite fibres have been used with metal matrices on a laboratory/experimental scale only, because most basic fabrication techniques involve high temperatures which have detrimental effects on the fibre. However, research on these lines is continuing in view of the potential of the composites.

**Reinforcement:** Reinforcement increases the strength, stiffness and the temperature resistance capacity and lowers the density of MMC. In order to achieve these properties the selection depends on the type of reinforcement, its method of production and chemical compatibility with the matrix and the following aspects must be considered while selecting the reinforcement material.

- **Size – diameter and aspect ratio:**
- **Shape – Chopped fiber, whisker, spherical or irregular particulate, flake.**
- **Surface morphology – smooth or corrugated and rough:**
- **Poly – or single crystal:**
- **Structural defects – voids, occluded material, second phases:**
- **Surface chemistry – e.g. TiO2 or C on SiC or other residual films**
- **Impurities – Si, Na and Ca in sapphire reinforcement:**
- **Inherent properties – strength, modulus and density.**

Even when a specific type has been selected, reinforcement inconsistency will persist because many of the aspect cited above in addition to contamination from processing equipment and feedstock may vary greatly. Since most ceramics are available as particles, there is a wide range of potential reinforcements for particle-reinforced composites.

The use of graphite reinforcement in a metal matrix has a potential to create a material with a high thermal conductivity, excellent mechanical properties and attractive damping behavior at elevated temperatures. However, lack of wet ability between Aluminium and the reinforcement, and oxidation of the graphite lead to manufacturing difficulties and cavitations of the material at high temperatures.

Alumina and other oxide particles like TiC etc. have been used as the reinforcing particles in Al-matrix. Alumina has received attention as reinforcing phase as it is found to increase the hardness, tensile strength and wear resistance of Aluminium metal matrix composites. Rohatgi and co-workers have studied mica, alumina, silicon carbide, clay, zircon, and graphite as reinforcements in the production of composites. Numerous oxides, nitrides, borides and carbides were discontinuously reinforced Aluminum (HTDRA). It has been inferred from their studies that HTDRA containing TiC, TiB2, B4 C, Al3O7, SiC and Si3 N4 exhibit the highest values of specific stiffness.
It is proven that the ceramic particles are effective reinforcement materials in Aluminium alloy to enhance the mechanical and other properties. The reinforcement in MMCs are usually of ceramic materials, these reinforcements can be divided into two major groups, continuous and discontinuous.

The MMCs produced by them are called continuously (fibre) reinforced composites and discontinuously reinforced composites. However, they can be subdivided broadly into five major categories: continuous fibres, short fibres (chopped fibres, not necessarily the same length), whiskers, particulate and wire (only for metal). With the exception of wires, reinforcements are generally ceramics, typically these ceramics being oxides, carbides and nitrides. These are used because of their combinations of high strength and stiffness at both room and elevated temperatures. Common reinforcement elements are TiC, Al₂O₃, TiB₂, boron and graphite.

**ALUMINUM MATRIX MATERIAL**

Aluminium is the world’s most abundant metal and is the third most common element, comprising 8% of the earth’s crust. The versatility of Aluminium makes it the most widely used metal after steel.

Although aluminium compounds have been used for thousands of years, aluminum metal was first produced around 170 years ago.

In the 100 years since the first industrial quantities of aluminium were produced, worldwide demand for aluminium has grown to around 29 million tons per year. About 22 million tons is new aluminium and 7 million tons is recycled aluminium scrap. The use of recycled aluminium is economically and environmentally compelling. It takes 14,000 kWh to produce 1 ton of new aluminium.

**PROPERTIES OF ALUMINIUM**

- Light weight
- Corrosion resistance
- Electrical and thermal conductivity
- Reflectivity
- Ductility
- Impermeable and odorless
- Recyclability

**WHY ALUMINIUM MATRIX SELECTION?**

MMC materials have a combination of different, superior properties to an unreinforced matrix which are: increased strength, higher elastic modulus, higher service temperature, improved wear resistance, high electrical and thermal conductivity, low coefficient of thermal expansion and high vacuum environmental resistance. These properties can be attained with the proper choice of matrix and reinforcement.

Composite materials consist of matrix and reinforcement. Its main function is to transfer and distribute the load to the reinforcement or fibres. This transfer of load depends on the bonding which depends on the type of matrix and reinforcement and the fabrication technique.

The matrix can be selected on the basis of oxidation and corrosion resistance or other properties. Generally Al, Ti, Mg, Ni, Cu, Pb, Fe, Ag, Zn, Sn and Si are used as the matrix material, but Al, Ti, Mg are used widely.

Nowadays researchers all over the world are focusing mainly on Aluminium because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. The unique thermal properties of Aluminium composites such as metallic conductivity with coefficient of expansion that can be tailored down to zero, add to their prospects in aerospace and avionics. Titanium has been used in aero engines mainly for compressor blades and discs due to its higher elevated temperature resistance properly. Magnesium is the potential material to fabricate composite for making reciprocating components in motors and for pistons, gudgeon pins and spring caps. It is also used in aerospace due to its low coefficient of thermal expansion and high stiffness properties combined with low density. The choice of Silicon Carbide as the reinforcement in Aluminium composite is primarily meant to use the composite in missile guidance system replacing certain beryllium components because structural performance is better without special handling in fabrication demanded by latter’s toxicity. Recently Aluminium-lithium alloy has been attracting the attention of researches due to its good wettability characteristics.

In addition, literature also reveals that most of the published work has considered Aluminium-based composites with their attractions of low density, wide alloy range, heat treatment capability and processing flexibility. Many of these features are also exhibited by magnesium-based systems and with its lower elastic modulus. Magnesium often achieves a larger property improvement with reinforcement than does Aluminium also many of the composite fabrication processes are common to both Al and Mg based systems.

Magnesium and magnesium alloys are among the lightest candidate materials for practical use as the matrix phase in metal matrix composites. When compared to other currently available structural materials. Magnesium is very attractive because of its unique combination of low density and excellent machinability.
However, it has been reported by several authors that though their low density (35% lower than that of Al) makes them competitive in terms of strength/density values. Magnesium alloys do not compare favorably with Aluminium alloys in terms of absolute strength.

The reason for Aluminium being a success over magnesium is said to be mainly due to the design flexibility, good wettability and strong bonding at the interface.

**Procedure to be carried in powder metallurgy:** The steps involved in making Aluminum composites by powder metallurgy method are

- Blending
- Compaction
- Sintering

**Blending:** Powders are to be blended or mixed properly for obtaining the required properties after sintering. In this process the powder and blender are mixed together very finely. A lubricant is also employed some times to reduce the friction and hence obtaining a finer mixing. The lubricant should be removed of the die before submitting it for sintering as the presence of lubricant may change the properties of the final object. Many types of blenders are being used for the manufacturing of various parts by powder metallurgy technique.

The metal powder is mixed with lubricant and optional alloying elements to form a homogenous blend. 0.5 - 1.5% lubricant is normally added in the mix, and metallic sterate and waxes are commonly used lubricants. The main function of the lubricant is to reduce friction between the powder mass and the surfaces of the tool, die walls, core rods etc., along which the powder must slide during compaction.

** POWDER METALLURGY PROCESS**

**MIXING**

Compacting is done for shaping of the powder in to the required shape. In this the mixed mixture is subjected to pressure and due to the application of pressure the gap between the molecules gets reduced and the powder becomes compact and gains sufficient strength to with stand ejection and handling. Pressures applied on the powder should be strictly regulated as if low pressures are applied on then the part generated will be very fragile in nature. If the pressure applied is more then there may be a deformation of tool. In general a pressure of 1 to 150N/M².

Compacting is done by various processes like

- a. Isostatic pressing
- b. Explosive forming
- c. Powder rolling or roll compacting
- d. Powder extrusion
- e. Vibratory Compacting.

**Compaction process:**

**Sintering:**

**Definition:** The thermal treatment of a powder or compact at a temperature below the melting point of the main constituent, for the purpose of increasing its strength by bonding together of the particles. Sintering Atmospheres. The operation is almost invariably carried out under a protective atmosphere, because of the large surface areas involved, and at temperatures between 60 and 90% of the melting-point of the particular metal or alloys.

**Sintering Furnaces:**

**Hardness test:** Finally got the expected specimen. The specimen is checked for hardness using Rockwell harness machine. When the CNT is added with Aluminum composites specimen hardness gets increased. From the below chart we come to know that after adding CNT in Al – composites, the specimen hardness shows maximum deflection of Hardness

**RESULT**

The production MWNTs are made very simple and cost effective. More yield was attained by the simplified arc discharge technique. Economic analysis of the synthesis of MWNTs shows the technique used in the
present research is very cheap with better yield than the conventional technique. The results prove that MWNTs are good in quality and easily mixes with matrix powders with less agglomeration that lead to enhanced properties. The hardness are improved considerably with the addition of CNT 0.25%, 0.5%, but the relatively less when addition of silicon carbide concentration is beyond 25%.

CONCLUSION
MWNTs are made very simple and cost effective. The results prove that MWNTs are good in quality and easily mixes with matrix powders with less agglomeration that lead to enhanced properties. The hardness are improved considerably with the addition of CNT

REFERENCES