DEVELOPMENT AND CHARACTERIZATION OF PARTICULATE SNAIL SHELL REINFORCED ALUMINUM COMPOSITES

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BEING A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF MATERIALS AND METALLURGICAL, FACULTY OF ENGINEERING, FEDERAL UNIVERSITY OYE-EKITI STATE, EKITI STATE, NIGERIA.

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APPROVAL PAGE

This project report has been approved as meeting the requirement for the Bachelor of Engineering (B.Eng) Degree in Materials and Metallurgical Engineering Federal University Oye- Ekiti, Ekiti State.

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CERTIFICATION

This is to certify that this project is an original work carried out by Awotiku, Olasunkanmi Michael with Registration No: MME/12/0869 in partial fulfilment of the requirements for the award of Bachelor of Engineering in Materials and Metallurgical Engineering

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DEDICATION

I dedicate this project work to God Almighty the owner of my soul for sparing my life throughout the duration of my course in Federal University Oye-Ekiti, Ekiti State.

I also dedicate this project work to my delightful parents Mr A.G Awotiku and Mrs Esther Awotiku for their full support to ensure that my academic ambition in life is realized.

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ABSTRACT

This study is about the development and characterization of particulate snail shell reinforced aluminium composites. Snail shells have low economic values and are mostly considered as environmental pollutants while aluminium used in this research is an ingot. However, re-melting them for further application in material processing can create significant economic value. Snail shell particles are known for their hardness, and thus useful as good alloying element for aluminium6063. In this paper, the potential of snail shell particles as reinforcement agent in PSS/Al composites is reported. Snail shell particles of weight fraction 5, 10 and 15 wt. % of the same seize size particles of 150 μm were added to 95, 90 and 85 wt. % aluminium6063 during casting and the aluminum6063 was also cast neat, which served as the control. The mechanical properties of the composites such as tensile properties (Elastic modulus, ultimate tensile strength, tensile strain, energy at maximum tensile stress), flexural and hardness were measured based on the experiments conducted using universal testing machine, flexural testing machine, brinell hardness test machine. The results showed that, the specimen with 90% aluminum and 10% snail shell particles are the hardest and strongest among the aluminum composites, which means that this composite has the overall best mechanical properties when considering the hardness and elastic modulus. It is concluded that both the elastic modulus and hardness are significantly enhanced, and snail shells can be used as a low-cost reinforcement for engineering applications.

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CHAPTER ONE

INTRODUCTION

I.1 GENERAL INTRODUCTION

A composite material 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 (McEvoy and Corell, 2015). Composite materials are classified, on the basis of matrix material, into three types; Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC), and Polymer Matrix Composites (PMC) (Callister, 2010). Polymeric materials are known for their low strengths and low Young's modulus while ceramic materials are strong, stiff and brittle. Metallic materials, on the other hand, have intermediate strength and moduli together with good ductility (Kumar and Theerthan, 2008).Metal matrix composites (MMCs) are a range of advanced materials that can be used for a wide range of applications within the aerospace, automotive, nuclear, biotechnology, electronic and sporting goods industries. Metal matrix composites (MMCs) possess significantly improved properties including high thermal conductivity, abrasion resistance, creep resistance, dimensional stability, exceptionally good stiffness-to-weight and strength-to-weight ratios, high specific strength, specific modulus, damping capacity and good wear resistance compared to unreinforced alloys (Bharath *et al.*, 2012 and Toptan *et al.*, 2009). The MMCs provide much better physical, mechanical, and tribological properties as an advanced material with respect to the conventional materials in their application field (Ashok *et al.*, 2012). Common reinforcement particles include ceramics such as Sic, Al_2O_3, Si_3N_4, AlN, TiC, TiB_2, TiO_2 and hard metals such metallic alloys like zinc (Zn), copper (Cu) and stainless steel have been used (Alaneme and Olubambi, 2013; Casati and Vedani, 2014).

Snail shells have low economic values, and are often considered as environmental pollutants. Consequently, effectively utilizing them can bring immense economic prosperity. Snail shell particles are known for their hardness, and thus considered as good alloying agent for aluminum based composites. In practice, limited mechanical properties of aluminum and its alloys, mostly strength and hardness, adversely affect the rage of their applications. Improving mechanical properties of alloys to suit different applications constitutes a major concern during fabrication. Hence, interests are growing in the use of aluminum based metal matrix with improved mechanical properties and wear resistance, especially in the transport industries where light weight and enhanced friction and wear performances are the key objectives.

The growing requirement of materials with high specific mechanical properties and weight savings characteristic has increased significant research activities in recent times focusing primarily on further development of aluminum based composites Alloys with distinctive properties such as high stiffness, high strength, significant toughness and low density have promoted an increasing number of applications in different areas. The demand for cost-effective and high performance structural materials is pushing researchers to develop novel processing techniques.

A significant improvement in the properties of aluminum based composite (especially strength and stiffness) was obtained with the introduction of fibre reinforcement but the properties of the resulting composites are anisotropic. Particle-reinforced metal matrix composites (MMCs) are attractive in that they exhibit near-isotropic properties when compared to the continuouslyreinforced matrices and have better wear resistance. In this study, aluminum matrix composite is produced from recycled Aluminum 6063 reinforced with snail shell particulates by stir cast process. The microstructure and the mechanical properties are obtained experimentally, studied and evaluated, and the results compared with those of as-cast aluminum 6063.

1.2 BACKGROUND

According to Rusal, (2015), aluminum is a silvery-white metal, the 13 element in the periodic table. One surprising fact about aluminum is that it's the most widespread metal on Earth, making up more than 8% of the Earth's core mass. It's also the third most common chemical element on our planet after oxygen and silicon. (Rusal, 2015). Asafa *et al*., (2015) used snail shell to reinforce discarded aluminum materials. Several other authors like Barekar *et al*., (2009), PE (2010), and Arjunraj *et al.,* (2015), have carried out varied studies on aluminum composite productions from aluminum scraps or ingots. Owoeye *et al*., (2012) studied a comparative analysis on aluminum plates in different concentrations of lime solution. Ibrahim *et al*., (2011) carried out their comparative analysis on aluminum welded joints, using SEM analysis.

In recent times, discarded aluminum parts have been used by industries and machinists for production and fabrication works. Making use of it has also been a way of recycling this waste into new parts, even though, it has been abandoned for sometimes and serves as both economic and industrial waste. In their discarded states, they are nuisance to the environment. Aluminum is the most widely used metal in the industries due to it light weight, malleability, and excellent corrosion resistance. It also exhibits a good strength-to-weight ratio for products manufactured using aluminum alloys, which have varying degree of hardness based on the alloy composition. Pure aluminum is used when corrosion resistance is more critical than strength in the end product. (All Metals and Forge Group, 2016). Aluminum is 100 percent recyclable. The metal can be melted down and reformed without losing any quality (Alupro, 2016). Accordingly, recycling 1 ton of aluminum saves 9 tons of CO_2 emissions. Making aluminum from raw materials is a complex process, however, once made the metal can be re-melted and reformed without losing any quality (IAI, 2009). The process can be repeated over and over again. Along with the energy savings, recycling aluminum saves around 95 percent of the greenhouse gas emissions compared to the "primary" production process (Alupro, 2016). Improving mechanical properties of alloys to suit different applications constitutes a major concern during fabrication. Hence, interests are growing in the use of aluminum based metal matrix with improved mechanical properties and wear resistance, especially in the transport industries where light weight and enhanced friction and wear performances are the key objectives. (kumar and Swamy, 2011).

The growing requirement of materials with high specific mechanical properties and weight savings characteristic has increased significant research activities in recent times focusing primarily on further development of aluminum based composites Alloys with distinctive properties such as high stiffness, high strength, significant toughness and low density have promoted an increasing number of applications in different areas (Asafa *et al.*, 2015).

Physical Properties of Aluminum

The major advantages of using aluminum are tied directly to its' remarkable properties. Some of these properties are outlined below:

1) Strength to weight ratio Aluminum has a density around one third that of steel and is used advantageously in applications where high strength and low weight are required. This includes vehicles where low mass results in greater load capacity and reduced fuel consumption (Aalco, 2016).

2) Corrosion resistance: A protective oxide coating is formed almost instantaneously when the surface of aluminum metal is exposed to air. This oxide layer is corrosion resistant and can be further enhanced with surface treatments such as anodizing (Aalco, 2016).
3) Electrical and thermal conductivity: Aluminum is an excellent conductor of both heat and electricity. The great advantage of aluminum is that by weight, the conductivity of aluminum is around twice that of copper. This means that aluminum is now the most commonly used material in large power transmission lines. The best alternatives to copper are aluminum alloys in the 1000 or 6000 series. These can be used for all electrical conduction applications including domestic wiring (Aalco, 2016).
4) Conductivity: Twice as good a conductor of heat and electricity as copper (based on weight), aluminum is now playing a major role in power transmission lines. (Constellium, 2016).
5) Reflectivity: As a reflector of heat and light, aluminum is suitable for such applications as solar technology and rescue blankets. (Constellium, 2016).
6) Recyclability: Aluminum is 100% and infinitely recyclable with no deterioration in quality (Constellium, 2016). Less energy is required for production of aluminum bars from recycled scraps than to produce the same volume of aluminum materials from raw materials.

Physical Metallurgy of Aluminum

Table 1.1 below illustrates some of the physical metallurgical properties of aluminium:

Table 1.1: Physical metallurgy of aluminum (Source: Tapany Udomphol, 2007)

Description	Specification
Density / specific gravity ($g.cm^{-3}$ at 20°C)	2.70
Melting point (° C)	660
Specific heat at 100° C, $cal.g^{-1}k^{-1}$ ($Jkg^{-1}k^{-1}$)	0.2241 (938)
Latent heat of fusion, $cal.g^{-1}$ ($kj.kg^{-1}$)	94.7 (397.0)
Electrical conductivity at 20°C (% of international annealed copper standard)	64.94
Thermal conductivity ($cal.sec^{-1}cm^{-1}k^{-1}$)	0.5
Thermal emissivity at 100° F (%)	3.0
Reflectivity for light, tungsten filament (%)	90.0

1.3 AIM

The aim of this research is to study the properties of PSS- Al composites and to show the behavior of the composites and cast neat aluminum6063.

1.4 OBJECTIVE

The specific objectives of this research work are to:

(a) produce particulate aluminum composite reinforced with different weight ratio of snail shell using stir casting;

(b) evaluate the mechanical properties (hardness, flexural and tensile strength) of the composites assessed in (a); and

(c) determine the best mix ratio that yields enhanced mechanical properties in the composites produced.

1.5 JUSTIFICATION

Aluminum matrix composites (AMCs) are potential materials for various applications due to their good physical and mechanical properties. The addition of reinforcements into the metallic matrix improves the stiffness, specific strength, wear, creep and fatigue properties compared to the conventional engineering materials. This paper present/give the overview of the effect of addition of snail shell particles reinforcement to aluminum alloy increased the tensile strength and the hardness value of the Al-snail shell particulate composites. This could potentially lead to the production of low cost aluminum composites with improved hardness and strength. These composites can find applications in automotive components like pistons, cylinder liners and connecting rods as well as applications where lightweight materials are required with good stiffness and strength.

1.6 CONTRIBUTION TO KNOWLEDGE

It is envisaged that at the completion of this research, it will;

(a) Extend the frontiers of knowledge in the science and technology of metal matrix composite development; and

(b) Proffer a scientific basis for the utilization of aluminum scraps (wastes) for low cost development of AL-PSS composite, and advance a viable alternative for recycling of aluminum scraps for productive use.

1.7 SCOPE OF THE RESEARCH

This research work would entail:

(a) Aluminum matrix composites with a single reinforcement (snail shell). Three weight ratios of the snail shell will be used.

(b) Hardness, flexural and Tensile strength of the produced composites will be evaluated.

CHAPTER TWO

LITERATURE REVIEW

2.1 COMPOSITE

Many of our advanced technologies require materials with uncommon combinations of properties that can't be met by the conventional metal alloys, ceramics, and polymeric materials. This is true for materials that are needed for aerospace, underwater, and transportation applications. For example, aircraft engineers are increasingly searching for structural materials that have low densities, strong, stiff, abrasion and impact resistant, and are not easily corroded. Frequently, strong materials are relatively dense; also, increasing the strength or stiffness generally results in reduction in impact strength. Generally speaking, a composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized (Callister, 2007).

Robert (1999) described composite as an indication that two or more materials are combined on a macroscopic scale to form the third material. Ekundayo (2012), articulated composite as engineering materials made of two or more constituent materials with significant different physical and chemical properties which remain separate and visible on a macroscopic level within the finished structure. Daniel *et al.*, (2002) opined that, composite materials are materials that are indifferent from common heterogeneous materials but the materials are made up of strong fibres-continuous or noncontinuous surrounded by weaker matrix materials. The matrix serves as distributor to the fibres and transfer load to the fibres.

Composite materials can be sourced from two major sources, that is, the natural fibers and the synthetic (man-made) fibers. The natural fibers are those from plants, animals and mineral sources while the synthetic fibers are those from the bye-Petrol chemical resources. Fibers generally are in filaments of different length and diameter. The synthetic fibers which form the raw materials can appear in different forms such as continuous, discontinuous or in particulate form and as a prepreg fibers (already impregnated with matrix) (Ekundayo, 2012). According to Pop and Bejinaru (2010) and UMESCO (2011), the advantages of using composite materials for engineering component production are high specific strength and stiffness, impact resistance, corrosion resistance, ductility and ability to carry loads (About.com, 2014).

Composites are one of the most advanced and adaptable engineering materials presently known (Shubham and Alok, 2013). Nowadays, it shows that composites are one of the options of materials for various engineering applications (Mazumdar, 2002). In composites, materials are combined in such a way that will enable us to make better use of their worth while minimizing to some extent the effects of their deficiencies (Rajeshkumar and Parshuram, 2013).

Composites are combinations of materials differing in composition, where the individual constituents retain their separate identities. Composite materials are composed of two or more distinct phases (matrix phase and dispersed phase). Matrix phase is the primary phase having a continuous character. Matrix is usually more ductile and less hard phase. It holds the dispersed phase and shares a load with it. Dispersed (reinforcing) phase is embedded in the matrix in a discontinuous form. This secondary phase is called the dispersed phase. Dispersed phase is usually stronger than the matrix, therefore, it is sometimes called reinforcing phase (Mayer *et al.*, 1998).

2.1.1 PROPERTIES OF COMPOSITE MATERIALS

Composite as an industrial material, are mostly used for their excellent resistance to chemicals. There are many other important and useful properties which are;

(i) Low cost,

(ii) Easy process ability,

(iii) Low strength,

(iv) Low specific gravity,

(v) Low modulus and low operating temperatures (Huang and Talreja, 2006).

2.1.2 CHARACTERISTICS OF COMPOSITE MATERIALS

The fundamental characteristics of composite materials are:

(i) High fatigue strength,

(ii) High specific strength and modulus,

(iii) Other unique functional properties - damping, low CTE (coefficient of thermal expansion).

2.1.3 ADVANTAGES OF COMPOSITE MATERIALS

There are many advantages of composites, together with lighter weight, improved fatigue life, the ability to adjust the layup for optimum strength and stiffness, and resistance to corrosion. The other advantages of composites are:

(i) High temperature,

(ii) High chemical stability,

(iii)High durability,

(iv) High selection of possible component size and shape (Campbell, 2010).

2.1.4 DISADVANTAGES OF COMPOSITE MATERIALS

Some disadvantages of composites are given below:

(i) Composite material structure has more complex mechanical characterization than a metal structure,

(ii) Repairing process of composites is complex as compared to that for metals,

(iii)Composites material does not have the property of high combination of strength and fracture toughness compared to metals,

(v) High cost of fabrication of composites (Campbell, 2010).

2.2 APPLICATION OF COMPOSITES

Composite materials are used for construction, marine goods, aerospace, transportation, sporting goods, and further newly infrastructure, with construction and transportation being the biggest.

(a) Aerospace Applications

Aircraft applications are the maximum significant uses of composites. Unlike other vehicles, commercial aircraft, essential to lay greater stress on safety and weight. They are realized by using materials through great specific properties. A modern civil aircraft designed as to encounter the several criteria of power and safety. As a result of forward-thinking technology that has gone beyond the design and application, the glass and carbon reinforced hybrid composites are the best preferred materials (Tetlow, 1973).

(b) Wind Power Generation

The applications of composite materials are used in wind power generation because the wind power engineering is a significance region of energy generation because of its resource saving and ecologically safe. The power monetary value mainly is determined substantially by simple power element blades. At present-day hybrid fibers (carbon, glass) are largely used for fabrication of the blades (Griffin and Aswill, 2003).

(c) Composite Material used in Marine Applications

In marine applications ships are under unbroken attack, both from the elements of nature and the enemy. The huge majority of ship hulls are created from common carbon steels, that are noticeably vulnerable to corrosion, but they also make different thermal and electromagnetic signatures simply noticeable from long distances (Boone, 2003).

(d) Hybrid Thermoplastic Application

Thermoplastic composites which used for mass producing lightweight structural parts because it has long held potential properties. On the other hand thermoset constructed composites, which undergo time consuming chemical cross linking throughout processing; thermoplastic based composites are typically treated using simply heat and pressure (Walsh *et al.*, 2005).

(e) Composite Material Application for Civil Construction

From the previous decade, largely in several countries, the research and development of totally hybrid FRP structures in civil engineering has developed (Keller, 2003). All the structural elements have been made with Hybrid Fiber Reinforcement Plastics (GFRP & CFRP). The all HFRP solution was chosen for this bridge due to its heavily corrosive atmosphere someplace the bridge is surrounded through the ocean. It is believed that the inventive materials can be competitive to other conventional materials in the close future when life cycle cost of the material is taken into account; there is a vital requirement for research and development of this revolutionary technology (Hiroshi *et al.*, 2009).

2.3 CONSTITUENT OF COMPOSITES

The principal components of composite material are matrix and reinforcement.

2.3.1 Matrix

Matrix material acts as an important part to obtain improved properties of composite construction.

The matrix material surrounds and helps the reinforcing materials by retaining their relative position (Cleveland, 2008). The main function of the matrix is to transmit the load to the reinforcement elements. Besides, it also gives protection to reinforcing elements against chemical attack and mechanical damage (Akovali, 2001). Matrix is the material that binds the filler and holds it. Matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous (Callister, 2007). A matrix material must be chemically compatibles with reinforcement and with any interface between it and the reinforcement. Matrices are generally metals, ceramics and polymers. In a composite, the major roles matrix performs are as follows:

(i) It holds the fibres together.

(ii) To protect the fibres from environment.

(iii) It distributes the loads evenly between fibres so that all fibres are subjected to the same amount of strain.

(iv) It helps to improves impact and fracture resistance of a component.

(v) It helps to avoid propagation of crack growth through the fibres by providing alternate failure path along the interface between the fibres and the matrix.

(vi) Carry inter laminar shear (Pandey, 2006).

(a) Factors Considered for Selection of Matrix Material

In selecting matrix material, following factors may be taken into consideration;

(i) The matrix and the reinforcement should be compatible.

(ii) The resultant composite should be cost effective. The matrix must stand up to the service conditions, via, temperature, humidity, exposure to ultra-violet environment, exposure to chemical atmosphere, abrasion by dust particles, to mention a few.

(iii) The matrix must be easy to use in the selected fabrication process.

(iv) Thermodynamically stable dispersions are essential for the use of metal matrix composites for high temperature applications (Chawla, 2008).

2.3.2 Reinforcements

Reinforcement plays a key role in both the mechanical and thermal ageing behaviour of the composite. Incorporation of the reinforcement in the matrices to produce MMCs has also been reported to be more profitable and economical due to its high specific strength and corrosion resistance properties. SiC, TiC, TaC, WC, B4C are the most commonly used particulates to reinforce in the metal or in the alloy matrix or in the matrices like Aluminum or magnesium (Rasit *et al.*, 2007).

Reinforcements are distinct incorporation used to improve the structural characteristics of a material.

The strength and stiffness is provided by the reinforcement components (Gibbons, 1988). In most cases, the reinforcement is harder, stronger and stiffer than the effectiveness of matrix to change failure mechanism to the beneficial of the composite. Reinforcement components are usually fiber, particulate, whiskers and flakes. Particulate reinforcements have nearly equaled in all directions of dimensions. They might be in form of spherical, platelets or any other regular or irregular geometry.

In contrast, the length of fiber reinforcement is much greater than its diameter. Length-to-diameter (lld) ratio is defined as Aspect ratio can be varying in different form of fibres. They can be grouped in continuous or discontinuous form. Continuous fibres have long aspect ratio with preferred orientation while discontinuous fibres have short aspect ratio with random orientation. Examples of continuous fiber reinforcement are unidirectional, woven cloth and helical winding while examples of discontinuous reinforcements are chopped fibres and random mat (Campbell, 2010).

(a) Fiber reinforcement

Fibers satisfy the desired conditions and transfer strength to the matrix, influencing their properties as desired (Ramakrishna *et al.,* 2011). The performance of a fiber composite is judged by its length, shape, orientation, and composition of the fibers and the mechanical properties of the matrix.

Organic and inorganic fibers are used to reinforce composite materials. Almost all organic fibers have low density, elasticity and flexibility. Inorganic fibers are of high modulus, high thermal stability and greater rigidity than organic fibers. The following different types of fibers are used; glass fibers, graphite fibers, alumina fibers, silicon carbide fibers, boron fibers and so on (Ramakrishna *et al*., 2011).

(b) Whiskers

They are usually discontinuous and short fibers of various sections made from materials like graphite, silicon carbide, iron, and copper. Whiskers where grown quite incidentally in laboratories for the first time, while nature has some geological structures that can be described as whiskers (Mishra *et al.,* 2002).

(c) Flakes

Flakes are often used in place of fibers as can be closely packed. Metal flakes that are in close contact with each other in polymer matrices can conduct electricity or heat, while mica flake and glass can resist both. Flakes are not expensive to produce and usually cost less than fibers. But they fall short of expectations in aspects like control of size, shape and show defects in the end product.

They are also resistant to be lined up parallel to each other in a matrix, causing uneven strength. They are usually set in matrices, or more simply, held together by a matrix with a glue type binder. Depending on the end use of the product, flakes are present in small quantities or occupy the whole composite (Pandey, 2006).

2.4 CLASSIFICATION OF COMPOSITES

Composite materials are classified based on matrix material or reinforcing material structure. There are three types of categories under matrix material systems which are known as Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC) and Polymer Matrix Composites (PMC) and Carbon-Carbon Composites. In reinforcing material structure, it is categorized as Particulate reinforced composites; Fibre reinforced composites and Structural composites (Pandey, 2004).

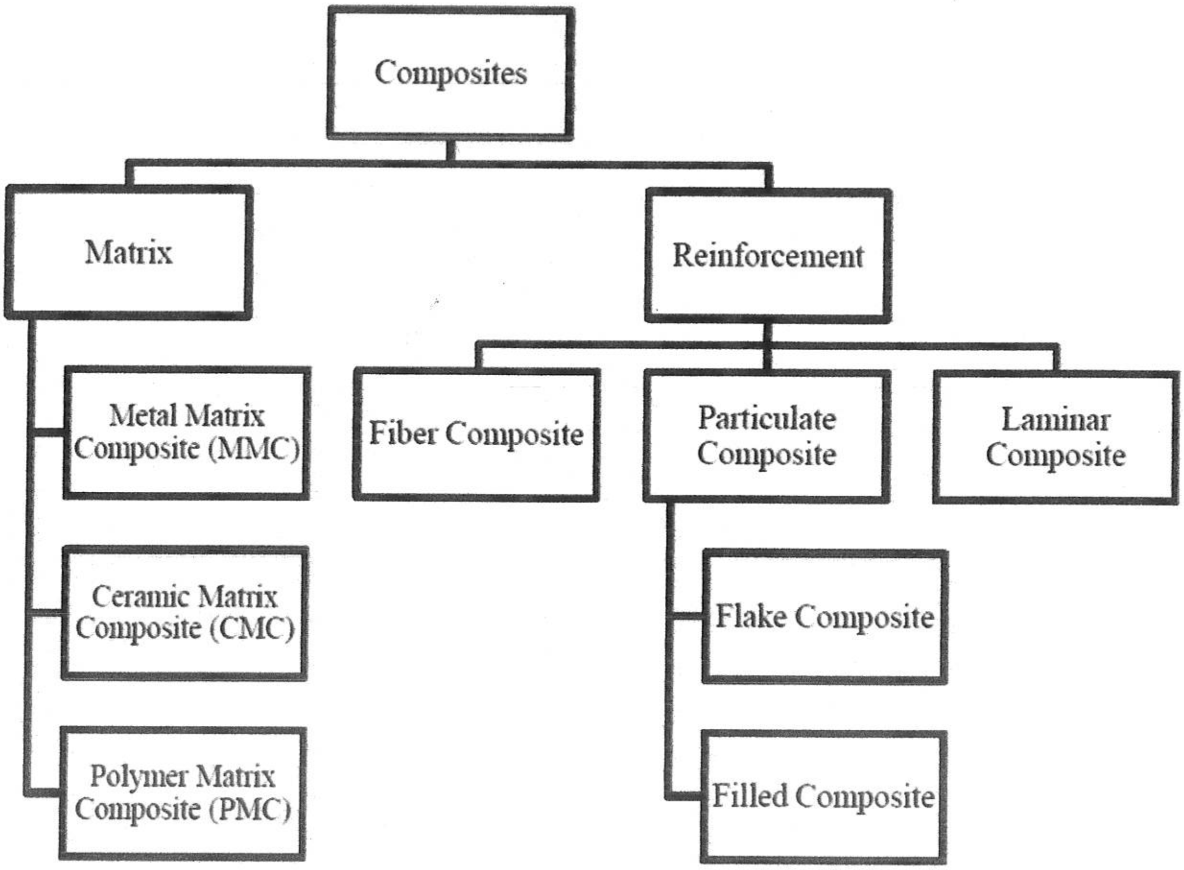


Figure2.1: Classification of composites system (Pandey, 2004).

2.4.1 BASED ON MATRIX MATERIAL

(a) Metal Matrix Composites (MMC)

MMCs comprises of a metallic matrix such as magnesium, titanium, copper, aluminum, dispersed ceramic (oxides, carbides) or metallic phase (Molybdenum, Tungsten, lead), and reinforcements with metals can either be beryllium, tungsten, among others (Sudipt and Ananda, 2008).

(b) Ceramic Matrix Composites (CMC)

Ceramic matrix composites (CMCs) have a ceramic matrix such as alumina, calcium silicate reinforced by fibers such as carbon or silicon carbide. Advantages of CMCs include high strength, hardness, high service temperature limits for ceramics, chemical inertness, and low density.

However, ceramics by themselves have low fracture toughness. Under tensile or impact loading, they fail catastrophically. Reinforcing ceramics with fibers, such as silicon carbide or carbon, increases their fracture toughness because it causes steady failure of the composite. This combination of a fiber and ceramic matrix makes CMCs more attractive for applications which high mechanical properties and extreme service temperatures are desired (Autar, 2006).

Ceramic matrix composites are finding increased application in high temperature areas in which metal and polymer matrix composites cannot be used. This is not to say that CMCs are not attractive otherwise, especially considering their high strength and modulus, and low density. Typical applications include cutting tool inserts in oxidizing and high-temperature environments (Autar, 2006).

(c) Polymer Matrix Composites (PMC)

The most common advanced composites are polymer matrix composites (PMCs) consisting of a polymer (e.g., epoxy, polyester, urethane) reinforced by thin diameter fibers (e.g., graphite, aramids, boron). For example, graphite/ epoxy composites are nearly five times stronger than steel on weight basis. The reasons why they are the most common composites include their low cost, high strength, and simple manufacturing principles. The main drawbacks of PMCs include low operating temperatures, high coefficients of thermal and moisture expansion, and low elastic properties in certain directions (Autar, 2006).

Two major classes of polymers based on their behavior are thermosetting and thermoplastic resin matrix reinforced by fibers that are stronger and stiffer than the matrix. Thermoset polymers are insoluble and infusible after cure because the chains are firmly joined with strong covalent bonds; thermoplastics are formable at high temperatures and pressure because the bonds are weak and plasticizers of the van der Waals type. Typical examples of thermoset include epoxies, polyesters, phenolics, and polyamide; typical examples of thermoplastics include polyethylene, polystyrene, polyether–ether–ketone (PEEK), and polyphenylene sulfide (PPS) (Autar, 2006).

Table2.1: Summarizes the key differences between thermosets and thermoplastics (Autar, 2006)

Thermoplastics	Thermoset
Soften on heating and pressure, and thus easy to repair	Decompose on heating
High strains to failure	Low strains to failure
Indefinite shelf life	Definite shelf life
Can be reprocessed	Cannot be reprocessed
Not tacky and easy to handle	Tacky
Short cure cycles	Long cure cycles
Higher fabrication temperature and viscosities have made it difficult to process	Lower fabrication temperature

(d) Carbon–Carbon Composite

Carbon–carbon composite are often known as carbon matrix composite; as the name implies, both reinforcement and matrix are carbon. These materials are relatively new and expensive and, therefore, are not currently being used extensively. Their desirable properties include high tensile moduli and tensile strengths. Furthermore, carbon–carbon composites have low coefficients of thermal expansion and relatively high thermal conductivities; these characteristics, together with high strengths, give birth to a relatively low susceptibility to thermal shock. Their major drawback is a propensity to high temperature oxidation. The carbon–carbon composites are employed in rocket motors, as friction materials in aircraft and high performance automobiles, for hot-pressing molds, in components for advanced turbine engines, and as ablative shields for re-entry vehicles (Callister, 2007).

2.4.2 BASED OF MATERIAL STRUCTURE

(a) Fiber Reinforced Composites

Most fiber-reinforced composites provide advanced strength and other mechanical properties and strength-to-weight ratio by incorporating strong, stiff but brittle fibers into a softer, more ductile matrix. The matrix material acts as a medium to transmit the load to the fibers, which carry most of the applied load. The matrix also provides defense to fibers from external loads and atmosphere.

These composites are classified as either continuous or discontinuous. Generally, the highest strength and stiffness are obtained with continuous reinforcement. Discontinuous fibers are used only when manufacturing economics demand the use of a process where the fibers must be in this form. The mechanical properties of fiber-reinforced composites depend not only on the properties of the fiber but also on the degree of which an applied load is transferred to the fibers by the matrix phase. Length of fibers, their orientation and volume fraction in addition to direction of external load application affects the mechanical properties of these composites (Mallick, 2008)

(b) Particulate Reinforced Composites

Particle reinforced composites consist of particles of one material distributed in the matrix of second material. The particles may be of any shape and size. Generally the particles are spherical, polyhedral, ellipsoidal, or irregular in shape. The particles which are combined into the matrix may be treated with chemicals or can be applied untreated. The particles are often used to enhance the strength of the materials, transform the electrical and thermal conductivity, reduce friction, increase wear and abrasion resistance, improve machinability and reduce shrinkage (Clyne, 2000).

A major problem of particle-reinforced composites is a non-uniform microstructure, often resulting from the manufacturing process, which can lead to the presence of clusters of particles, or regions without reinforcement. This intrinsic material in homogeneity can give a wide scatter in strength and ductility, wear resistance, fracture toughness and also in the fatigue behavior (Rasit *et al.,* 2007).

Large particle and dispersion-strengthened composites are the two sub classifications of particle reinforced composites. The distinction between these is based upon reinforcement or strengthening mechanism. The term “large” is used to show that particle–matrix interactions cannot be treated on the atomic or molecular level; rather, continuum mechanics is used. For most of these composites, the particulate phase is harder and stiffer than the matrix. These reinforcing particles tend to hinder movement of the matrix phase in the vicinity of each particle. In essence, the matrix transfers some of the applied stress to the particles, which bear a fraction of the load. The degree of reinforcement or improvement of mechanical behavior depends on strong bonding at the matrix–particle interface (Callister, 2007).

For dispersion-strengthened composites, particles are normally much smaller, with diameters between 0.01 and 0.1μm (10 and 100 nm). Particle–matrix interactions that lead to strengthening occur on the atomic or molecular level. The mechanism of strengthening is similar to that for precipitation hardening. Whereas the matrix carries the major portion of an applied load, the small dispersed particles hinder or impede the motion of dislocations. Thus, plastic deformation is limited such that yield and tensile strengths, as well as hardness improve (Callister, 2007).

(c) Structural composites

These are special class of composites, usually consists of both homogeneous and composite materials. Properties of these composites depend not only on the properties of the constituents but also on geometrical design of various structural elements. Two classes of these composites widely used are: laminar composites and sandwich structures (Callister, 2007).

(i) Laminar composites

There are composed of two-dimensional sheets/layers that have a preferred strength direction. These layers are stacked and bonded together according to the requirement. Laminations may also be constructed using fabric material such as cotton, paper, or woven glass fibers embedded in a plastic matrix. Thus a laminar composite has relatively high strength in a number of directions in the two dimensional plane; however, the strength in any given direction is, of course, lower than it would be if all the fibers were oriented in that direction (Callister, 2007).

Materials used in their fabrication include: metal sheets, cotton, paper, woven glass fibers embedded in plastic matrix, etc. Examples: thin coatings, thicker protective coatings, claddings, bimetallic, laminates. Many laminar composites are designed to increase corrosion resistance while retaining low cost, high strength or light weight

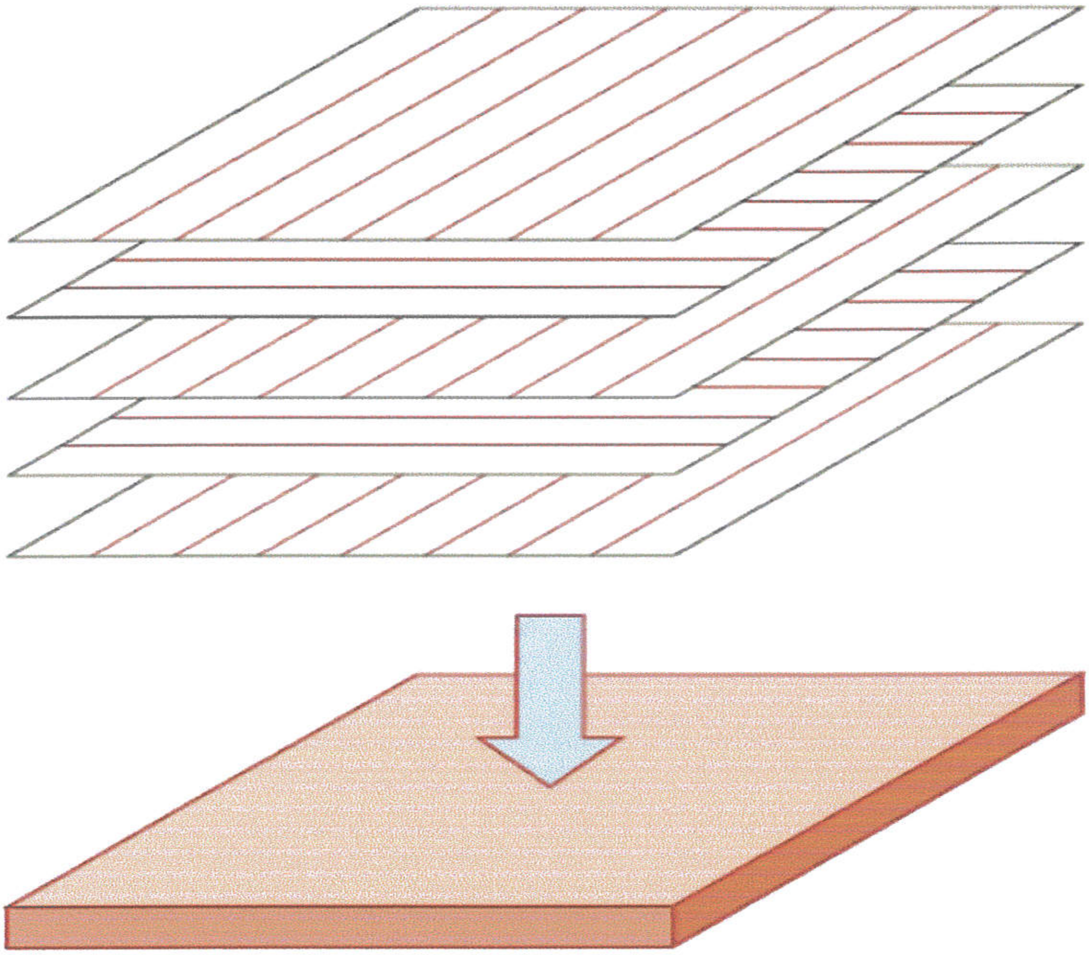


Figure 2.2: The stacking of successive oriented, fiber-reinforced layers for a laminar composite (Callister, 2007).

(ii) Sandwich structures

These consist of thin layers of a facing material joined to a light weight filler material. Neither the filler material nor the facing material is strong or rigid, but the composite possesses both properties.

Example: corrugated cardboard. The faces bear most of the in-plane loading and also any transverse bending stresses. Typical face materials include Al-alloys, fiber-reinforced plastics, titanium, steel and plywood. The core serves two functions – it separates the faces and resists deformations perpendicular to the face plane; provides a certain degree of shear rigidity along planes that are perpendicular to the faces. Typical materials for core are: foamed polymers, synthetic rubbers, inorganic cements, balsa wood. Sandwich structures are found in many applications like roofs, floors, walls of buildings, and in aircraft for wings, fuselage and tail plane skins

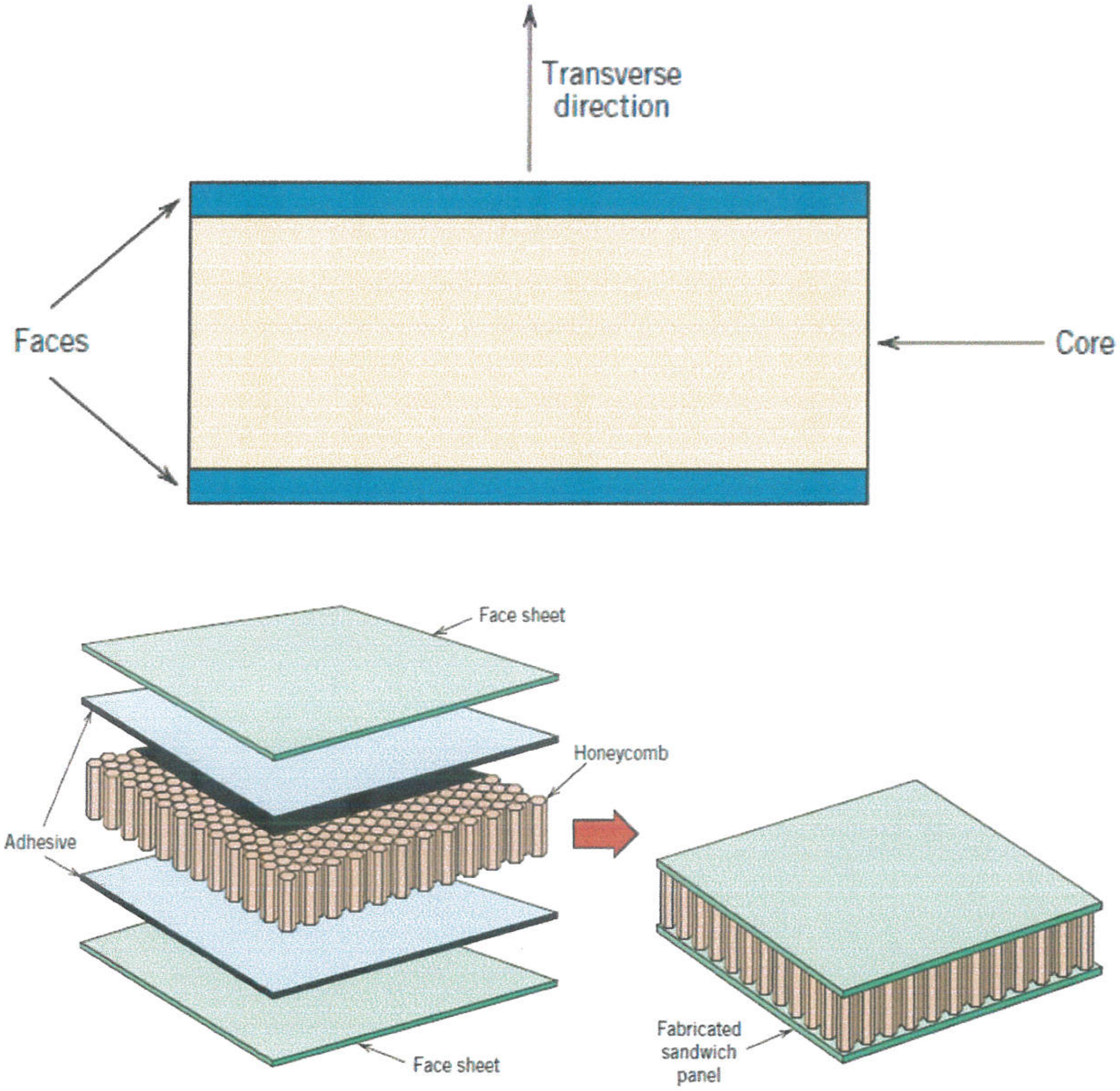


Figure2.3: Schematic diagram showing the construction of a honeycomb core sandwich panel (Callister, 2007)

2.5 METAL MATRIX COMPOSITES

MMCs are advanced engineering materials consisting of one or more reinforcements in a metal matrix to get a desired set of properties. Metal matrix composites (MMCs) possess valuable improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys (Bharath and Auradi, 2012).

MMCs, in general consist of at least two components: one is the metal matrix and second is the reinforcement. In all cases the matrix is defined as a metal, but pure metal is rarely used: it is generally an alloy. Some classes of MMCs, like Cermet, Diamond tools and Hard Metals, have dissimilar and extensive applications and, even if they can be considered as traditional materials, they are in continuous evolution (Rosso and Geminiani, 1997). Metal matrix composites have been extensively studied since many years, the main support has come from the aerospace industry for airframe and spacecraft components. Automotive, electronics and recreation industries have been working dispersed with composites (Mars, 2000).

MMC reinforcements can be generally divided into five major categories: continuous fibres, discontinuous fibres, whiskers, wires and particulate (including platelets). With exclusion of wires, which are metals, reinforcements are generally ceramics. Typically these ceramics are oxides, carbides and nitrides which are used because of their wonderful combinations of specific strength and stiffness at both ambient temperature and elevated temperature (Schwartz, 1997).

The two most commonly used metal matrices are based on aluminum and titanium. Both of these metals have comparatively low specific gravities and are available in a variety of alloy forms. Although magnesium is even lighter, its great connection for oxygen promotes atmospheric corrosion and makes it less suitable for many applications. Beryllium is the lightest of all structural metals and has a tensile modulus higher than that of steel. However, it suffers from severe brittleness, which is the reason of it not being used as potential matrix material. Nickel and cobalt- based super alloys have also been used as matrices, but the alloying elements in these materials tend to accentuate the oxidation of fibres at elevated temperatures (Schwartz, 1997).

Aluminum and its alloys are the most regard as matrix material for MMCs and the most common reinforcement is SiC. The titanium alloys are most useful in MMCs with higher tensile strength-to weight ratios as well as preferably strength retentions at 400-500°C than those of aluminum alloys. Titanium MMCs are used in applications where performance is required without regard to cost effectiveness. This is where one obtains high-temperature performance unattainable with conventional materials (Schwartz, 1997). However, their toughness is lower to monolithic metals and they are more expensive at present. In comparison with most polymer matrix composites, MMCs have certain superior mechanical properties, namely higher transverse strength and stiffness, greater shear and compressive strengths and better high temperature capabilities. There are also advantages in some of the physical attributes of MMCs such as no significant moisture absorption properties, non-inflammability, high electrical and thermal conductivities, and resistance to most radiations (Matthews and Rawlings, 1994).

Compared to monolithic metals, MMCs have:

(i) Better fatigue resistance

(ii) Better elevated temperature properties

(iii) Higher strength

(iv) Lower creep rate

(v) Better wear resistance

The Advantages of MMCs over polymer matrix composites are:

(i) Higher temperature capability

(ii) Fire resistance

(iii) Higher transverse stiffness and strength

(iv) Higher electrical and thermal conductivities

(v) Better radiation resistance

Some of the disadvantages of MMCs compared to monolithic metals and polymer matrix composites are:

(i) Higher cost of some material systems

(ii) Relatively immature technology

(iii) Complex fabrication methods for fiber-reinforced systems (except for casting).

2.6 FABRICATION OF THE METAL MATRIX COMPOSITE (MMC)

The manufacturing of metal matrix composites is done using liquid state or solid state process based on the property required and the type of the reinforcement used (Saravanan *et al.*, 2015).

2.6.1 LIQUID METHOD

Liquid state fabrication of MMC involves incorporation of dispersed reinforcing phase into a molten matrix metal, followed by its solidification. There are many liquid state fabrication methods such as stir casting, rheocasting, infiltration, gas pressure infiltration, squeeze casting infiltration, pressure die infiltration, and so on (Pei *et al.*, 2009).

Table 2.2: The common liquid methods of MMC fabrication are summarized below

S/No	MMC Fabrication Route	Inference	Applications	Cost aspects
1	Stir casting	Depends on material Properties and process parameters. Suitable for particulate reinforcement in AMC.	Available to large quantity Production. Commercial method of producing aluminium based composites.	Least expensive.
2	Squeeze Casting	Pertinent applicable to any type of reinforcement and suitable for mass	Used in automotive industry and aeronautical industry	

		Production.	for producing different components like pistons, connecting rods, cylinder heads, cylindrical Components and so on.	
3	Compo casting Or Rheo casting	For discontinuous fibres, especially for particulate Reinforcement. Lower porosity is Observed.	Used in aerospace industry, manufacturing industry, and Automotive.	Least Expensive
4	Spray casting	Particulate reinforcement used, and used to produce Full density materials.	Cutting and grinding tools, electrical brushes and Contacts.	Moderate
5	Liquid metal	Filament type	Production of	Moderate/Expensive

	infiltration	reinforcement Normally used.	tubes, rods, structural shapes and Structural beams.	
6	Insitu (reactive) processing	Good reinforcement/matrix compatibility, homogeneous distribution of the Reinforcing particles.	Automotive application.	Expensive
7	Ultrasonic assisted casting	Nearly uniform distribution and good Dispersion.	Mass production and net shape fabrication of complex structural Components.	Expensive

2.6.2 SOLID METHOD

Typical solid state fabrication method in which MMC is formed as a result of bonding matrix metal and dispersed phase due to mutual diffusion occurring between them. Raw powders of the matrix metal are mixed with the dispersed phase in form of particles or short fibers for subsequent compacting and sintering (Pei *et al.*, 2009). The common solid methods of MMC fabrication are summarized in Table 2.3

Table 2.3: Summarizes the solid method of fabricating MMC (Saravanan et al., 2015).

S/No	MMC Fabrication route	Inference	Applications	Cost aspects
1	Powder metallurgy	Both Matrix And Reinforcements used in powder form. Best for particulate Reinforcement.	Production of small objects (especially round), bolts, pistons, valves and high resistant Materials. Various application in automotive, aircraft, Defense and sports.	Moderate
2	Diffusion Bonding	Handles foils or sheets of matrix	Manufacture sheets, blades, vane, shaft,	Expensive

		and filaments of Reinforcing element.	Structural components.	
3	Vapour deposition technique	PVD coatings are sometimes harder and more corrosion resistant than	Aerospace/Automotive, surgical and moulds for all manner of material Processing.	Moderate
4	Friction stir process	Used as surface Modification process. Increase in micro hardness of the surface, significant improvement in wear Resistance.	In automotive and Aerospace application.	Moderate/ Expensive

2.6.3 FACTORS AFFECTING SUCCESSFUL FABRICATION OF MMCs

Sudipt and Ananda (2008) observed that there are some factors that need to be considered when preparing MMCs by the stir casting method which are:

(i) Its difficulty in achieving an equal distribution of the reinforcement material in the matrix phase.

(ii) Wettability between the matrix and reinforcing phase.

(iii) Pores in the cast metal matrix composites.

(iv) Chemical reactions may occur between the two phases.

2.7 STRENGTHENING MECHANISM OF COMPOSITES

The strengthening mechanisms of the composites are different with various kind of reinforcing agent such as fibres, particulate or dispersed type of reinforcing elements.

2.7.1 DISPERSION STRENGTHENING MECHANISM OF STRENGTHENED COMPOSITE

In the dispersion strengthened composite, the second phase reinforcing agents are well dispersed in the soft ductile matrix. The strong particles restrain the motion of dislocations and reinforce the matrix (Kurtoglu, 2004). Here the main reinforcing philosophy is by the strengthening of the matrix by the dislocation loop formation around the dispersed particles. Thus the further movement of dislocations around the particles is difficult. Degree of strengthening depend upon the several factors like volume % of dispersed phase, degree of dispersion, size and shape of the dispersed phase, inter particle spacing etc. In this kind of composite the load is mainly carried out by the matrix materials (Kurtoglu, 2004).

2.7.2 STRENGTHENING MECHANISM OF PARTICULATE COMPOSITE

In the particulate reinforced composite, the size of the particulate is more than 1μm, so it strengthens the composite in two ways. First one is the particulate convey the load along with the matrix materials and another way is by formation of incoherent interface between the particles and the matrix. So a larger number of dislocations are created at the interface, thus material gets strengthened. The degree of strengthening depends on the amount of particulate (volume fraction), distribution, size and shape of the particulate and so on (Prabu *et al.*, 2006).

2.7.3 PARTICLE SIZE AND SHAPE

The degree of strengthening in particulate reinforced metal matrix composites is nearly related to particle distribution and shape. Particle distribution can be specified by volume fraction of particle, average diameter of particle and mean inter-particle spacing (Dieter, 1988). These factors are interrelated so one of them cannot be changed without affecting the others. As an example, for a given volume fraction, reducing the particle size decreases the mean inter-particle spacing. For a given size, mean inter-particle spacing decreases with an increase in the volume fraction, there are several ways which fine particles act as a barrier to dislocations. One of them related to particulate reinforced metals is that, particles refuse to be cut by dislocations as they are hard and the dislocations are forced to bypass them. This situation increases the strength of the composite. When particle size is smaller at the same volume percent reinforcement, strength of the composite increases, experiment and theory justifies this effect (Dieter, 1988).

2.8 SNAIL (GASTROPOD)

Snails' ancestors are one of the earliest known types of animals in the world. There is fossil evidence of primitive gastropods dating back to the late Cambrian period (i.e. a period of the Paleozoic era, from 540 to 585 million years ago); this means that they lived nearly 500 million years ago.

There are many types of snails, but they fundamentally differ because they are aquatic or terrestrial. The former are adapted to live in the sea or bodies of fresh water, but the latter live exclusively on land, although in humid areas.

All land snails are gastropod mollusks, meaning that they belong to the same group of octopuses, which are part of the phylum Mollusca. At the same time, they are members of the class Gastropoda, which includes all snails and slugs. Being a mollusk means lacking an internal skeleton and bones, but snails are not unprotected

Gastropods can adapt to a variety of living conditions, and they don't require large amounts of food. They have been able to continually evolve to survive the conditions around them which many researchers find to be very fascinating.

2.8.1 GASTROPOD SHELL

The gastropod shell is part of the body of a gastropod or snail, a kind of mollusk or mollusc. The shell is an external skeleton or exoskeleton, which may serve for muscle attachment, but also for protection from predators, mechanical damage, dehydration, and calcium storage. Some gastropods appear shell-less (slugs) but may have a remnant within the mantle, or the shell is reduced such that the body cannot be retracted within (semi-slug). Some snails also possess an operculum that seals the opening of the shell, known as the aperture, which provides further protection. The study of mollusc shells is known as conchology. The biological study of gastropods and other molluscs in general, is malacology. Shell morphology terms vary by species group. An excellent source for terminology of the gastropod shell is "How to Know the Eastern Land Snails" by John B. Burch now freely available at the Hathi Trust Digital Library.

2.8.2 DESCRIPTION

In general, the shell of the giant African snail is a reddish-brown colour, with pale yellow vertical markings, although colouration can vary depending on the surrounding environmental conditions. When fully grown, the shell of the giant African snail has seven to nine whorls, and is most often narrow and conical in shape; however, some individuals appear much broader and shorter.

Size Length: up to 20 cm

Weight: up to 32 g

2.8.3 FORMATION OF THE SHELL

The gastropod shell has three major layers secreted by the mantle. The calcareous central layer, the ostracum, is typically made of calcium carbonate precipitated into an organic matrix known as conchiolin. The outermost layer is the periostracum which is resistant to abrasion and provides most shell coloration. The body of the snail contacts the innermost smooth layer that may be composed of mother-of-pearl or shell nacre, a dense horizontally packed form of conchiolin, which is layered upon the periostracum as the snail grows.

2.8.4 GROWTH OF THE SHELL

As the snail grows, so does its calcium carbonate shell. The shell grows additively, by the addition of new calcium carbonate, which is secreted by glands located in the snail's mantle. The new material is added to the edge of the shell aperture (the opening of the shell). Therefore, the Centre of the shell's spiral was made when the snail was younger, and the outer part when the snail was older. When the snail reaches full adult size, it may build a thickened lip around the shell aperture. At this point the snail stops growing, and begins reproducing.

A snail's shell forms a logarithmic spiral. Most snail shells are right-handed or dextral in coiling, meaning that if the shell is held with the apex (the tip, or the juvenile whorls) pointing towards the observer, the spiral proceeds in a clockwise direction from the apex to the opening.

Snail shells: primarily consist of calcium carbonate ($CaCO_3$) which happens to be conventional mineral filler for composites development.

The significant feature of snail shell-based activated carbon is that it is mostly made of calcium carbonate, crystals organized within a matrix of protein in two principal forms: aragonite and calcite. The crystal type in the shell of the land snail (Helix pomatia) is normally aragonite, but calcite has also been found in repaired areas of the shell.

Though the major composition of snail shell is calcium carbonate (97.5%), it is composed of other elements like calcium phosphate, calcium silicate, magnesium carbonate, magnesium oxide, iron oxide, manganese oxide and other organic substances. Snail shell is usually neglected and abundant agricultural waste. As a result of the chemical composition of the shell, it can be used as reinforcement agent in Al/snail shell particulate composites.

Table 2.4: The Chemical Analysis of Snail Shell Powder (Source: International Journal of Engineering Research & Technology (IJERT), 2014

Constituent	Description	% in Snail Shell Powder
LOI	Loss on Ignition	40.54
SiO_2	Silica	0.60
Al_2O_3	Alumina	0.51
FeO_3	Ferrous Oxide	0.56
CaO	Calcium Oxide	51.09
MgO	Magnesium Oxide	0.69
SO_3	Sulphur trioxide	0.19
NaO	Sodium Oxide	1.20
K_2O	Potassium Oxide	0.12
TiO_2	Titanium dioxide	0.03
P_2O_5	Phosphorus pentoxide	0.21
Mn_2O_3	Manganese Oxide	0.02
Cl	Chloride	0.034

Figure 2.4: Snail shells

2.9 ALUMINUM SMELTING AND REFINING

Aluminum is primarily used to produce pistons, engine and body parts for cars, beverage cans, doors, siding and aluminum foil. It may also be used as sheet metal, aluminum plate and foil, rods, bars and wire, aircraft components, windows and door frames. The leading users of aluminum include the container and packaging industry, the transportation industry, and the building and construction industry. Aluminum can either be produced from bauxite ore or from aluminum scrap. Refinement of aluminum ore is sufficiently expensive that the secondary production industry commands much of the market. About 40% of aluminum in the US is recovered for secondary refining (USEPA, 1995). Due to high energy requirements, the major primary aluminum producers tend to locate in areas with low energy costs, including the Northwest and Ohio River Valley. Secondary producers tend to locate near industrial centers, including southern California and the Great Lakes. Both primary and secondary aluminum producers refine and melt the aluminum and pour it into bars called ingots. The ingots are shipped to metal casting plants or other shaping plants for molding or rolling.

2.9.1 PRIMARY ALUMINUM REFINING

Aluminum production from bauxite ore is a three step process. First the alumina is extracted from bauxite ore usually using the Bayer Process. In the Bayer Process, finely crushed bauxite is mixed with sodium hydroxide and placed in a `digester.' High temperatures and pressures in the digester cause reactions in the ore / sodium hydroxide mixture. The result is dissolved aluminum oxide and ore residue. The residues, which include silicon, lead, titanium, and calcium oxides, form sludge in the bottom of the digester. The aluminum oxide is evaporated off and condensed. Starches and other ingredients are added to remove any remaining impurities from the oxide.

The solution is then moved to a precipitation tank where the aluminum oxide is crystallized. Aluminum hydroxide and sodium hydrizide are the products of the crystallization. The crystals are washed, vacuum dewatered and sent to a calcinator for further dewatering.

Aluminum oxide from the Bayer Process is then reduced to aluminum metal usually using the Hall-Heroult process. In this process the aluminum oxide is placed in a electrolytic cell with molten cryolite. A carbon rod in the cell is charged and the reaction results in carbon monoxide, carbon dioxide and aluminum. The aluminum sinks to the bottom where it is removed from the tank and sent to a melting or holding furnace.

The molten aluminum is then mixed with desired alloys to obtain specific characteristics and cast into ingots for transport to fabricating shops. In the fabrication shops, the molten aluminum or aluminum alloys are remelted and poured into casts and cooled. Molten aluminum may be further heated to remove oxides, impurities and other active metals such as sodium and magnesium, before casting. Chlorine may also be bubbled through the molten aluminum to further remove impurities.

WASTE SOURCES AND POLLUTION PREVENT OPPORTUNITIES

Air emissions come from a number of sources. The grinding of the bauxite, calcinating the aluminum oxide, and handling materials produce particulates. Air emissions equipment is used extensively to capture these particulates. The particulates may be metal rich. If the metallic content is sufficient, the emissions control dust can be remelted to capture any remaining metals or it may be otherwise reused or sold for its metallic content. If the dust is not sufficiently metal rich, it usually landfilled.

Another source of air emissions from primary aluminum production processes occurs during the reduction of aluminum oxide to aluminum metal. Hydrogen fluoride gases and particulates, fluorides, alumina, carbon monoxide, sulfur dioxide and volatile organics are produced. Electrolytic baths often use anode pastes in the cell. The paste must be continually fed into the cell through a steel sheet with an opening. This continual feed allows the gas to escape.

One method for reducing gas emissions is the use of pre-baked anodes. Pre-baked anodes must be manufactured in an on-site plant. The pre-baked anodes allow the electrolytic bath to be sealed, allowing gas to be captured. The anodes are then replaced every 14-20 days, containing the gasses for collection. Anode baking furnaces produce fluorides, vaporized organics and sulfur dioxide emissions. The emissions are often controlled using wet scrubbers.

Liquid waste is not a great concern in aluminum processing. Wastewater is produced during clarification and precipitation; however, much of the water is directly reused. Solid phase wastes include bauxite refining waste, called red mud, and reduction waste from spent pot liners. Red mud contains iron, aluminum, silica, calcium and sodium, depending on the ore used. Usually red mud is managed on site and is not hazardous. The refractory lining from the pots used to refine the aluminum are the other solid waste concern. The refractory breaks down with continuous use to produce RCRA K088 hazardous waste.

2.9.2SECONDARY ALUMINUM PRODUCTION

In the secondary aluminum production industry, scrap aluminum is melted in gas- or oil-fired reverberatory or hearth furnaces. Impurities are removed using chlorine or other fluxes until the aluminum reaches the desired purity. Other aluminum production plants use dross in addition to scrap. Dross is a by-product of primary aluminum melting. This process further reduces the pollution resulting from primary aluminum production. It contains fluxes and varying concentrations of aluminum. "Skim," "rich," or "white dross" refer to aluminum dross with high aluminum content. "Black dross" or "salt cakes" refer to aluminum dross from practices that use salt fluxes. The dross is crushed, screened and melted in a rotary furnace where the molten aluminum is collected in the bottom. The resulting salt slag is a waste product. To reduce this waste more of the remaining metallic may be leached into water and collected. To eliminate the need for salt fluxes, a new plasma torch treatment has been developed to heat the rotary furnace. High concentrations of aluminum are recovered from this procedure.

POLLUTION PREVENTION IN SECONDARY ALUMINUM PROCESSING

Air emissions and solid-phase wastes are the primary concerns in the aluminum processing industry. Air emissions depend largely on the quality of scrap used. Emissions can come from smelting, refining, and the furnace effluent gases. Gases can include combustion products, hydrogen chloride and metal chlorides, aluminum oxide metals and metal compounds. To reduce emissions regardless of the type of scrap used, aluminum fluoride can be substituted for chlorine to remove impurities from the molten metal. All systems are usually connected to emissions control equipment, typically a bag house for collecting fluorine and other gases.

Solid-phase waste from secondary aluminum production is slag formed during smelting. The slag contains chlorides, fluxes and magnesium. The metallic may be separated and reused or sold.

Liquid wastes include water that is added to the slag to help separate the different metals. The waste water may be contaminated with salt and fluxes, but can often be recovered and reused.

2.9.3RECYCLING

Recycling is an act of processing used materials (waste) into new, useful products and it is done to reduce the use of raw materials that would have been used. Recycling also aid the control of air, water and land pollution as it involves less energy use (Eschool, 2015). Using aluminum as the material to be recycled is more effective in order to control the environmental pollution because it is one of most discarded material in the environment and according to Alupro, (2016), it is 100 percent recyclable with no downgrading of its qualities: Re-melting of aluminum requires little energy: only about 5 percent of the energy required to produce the primary metal initially is needed in the recycling process.

ADVANTAGES

The recycling of aluminum generally produces significant cost savings over the production of new aluminum, even when the cost of collection, separation and recycling are taken into account. Over the long term, even larger national savings are made when the reduction in the capital costs associated with landfills, mines, and international shipping of raw aluminum are considered.

ENERGY SAVINGS

Recycling aluminum uses about 5% of the energy required to create aluminum from bauxite; the amount of energy required to convert aluminum oxide into aluminum can be vividly seen when the process is reversed during the combustion of thermite or ammonium perchlorate composite propellant.

ENVIRONMENTAL SAVINGS

Recycled aluminum uses 5% of the energy that would be needed to create a comparable amount from raw materials. The benefit with respect to emissions of carbon dioxide depends on the type of energy used. Electrolysis can be done using electricity from non-fossil-fuel sources, such as nuclear, geothermal, hydroelectric, or solar. Aluminum production is attracted to sources of cheap electricity.

2.10 STIR CASTING

Stir casting is one of the methods accepted for the production of large quantity commercially practiced (Dinesh *et al.*, 2013). It is attractive because of simplicity, flexibility and most economical for large sized components to be fabricated. In Stir casting method of composite materials fabrication, a dispersed phase is mixed with a molten metal matrix by using mechanical stirring. The composite material which is in liquid state is then cast by conventional casting methods and can be processed by conventional metal forming technologies. The stir casting method is relatively low cost and very simple (Saravanan *et al*., 2015). This can be prepared by conventional processing equipment and also can be carried out on a continuous and semi continuous basis by using stirring mechanism as shown in Figure 2.5.

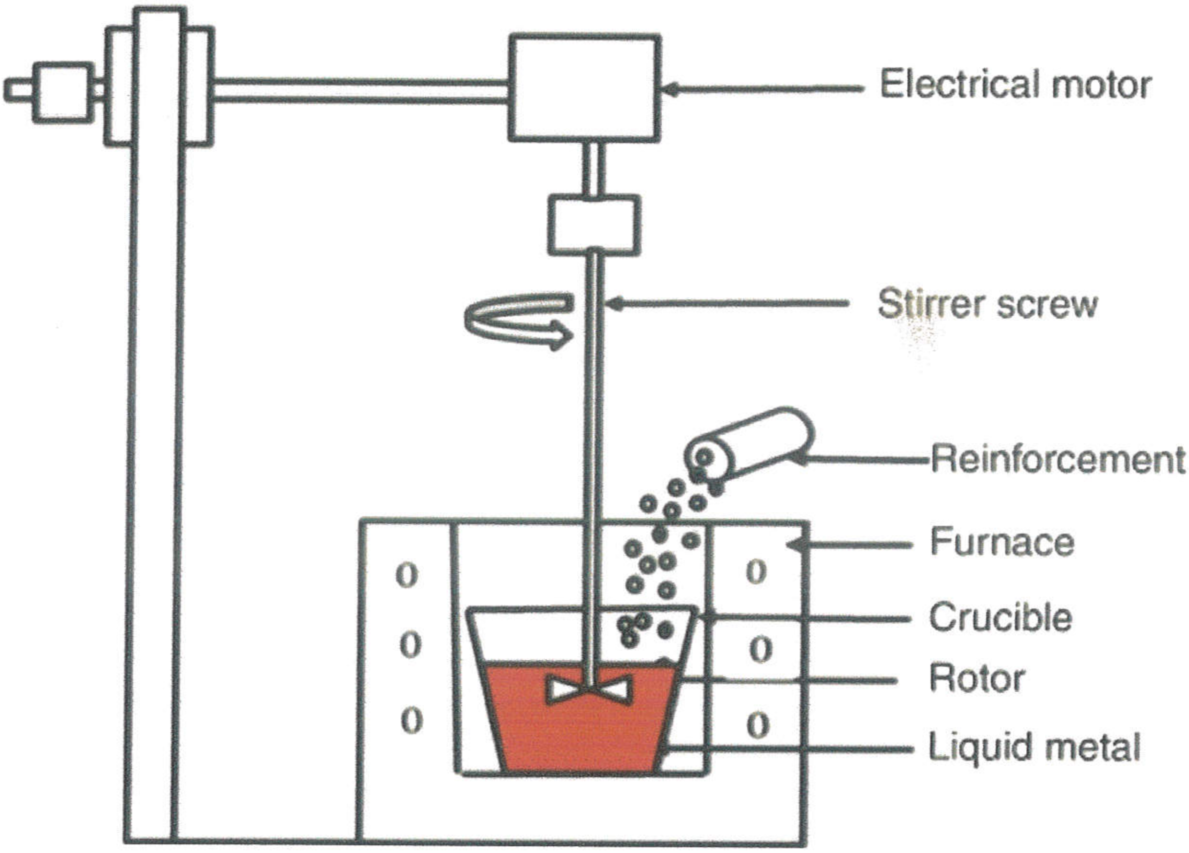


Figure 2.5: Stir Casting Experimental set up

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 attained. The simplest and the most cost effective method of liquid state fabrication is Stir Casting (Sudipt and Ananda, 2008).

Stir Casting is characterized by the following features:

(i) Content of dispersed phase is limited (usually not more than 30 vol. %).

(ii) Distribution of dispersed phase throughout the matrix is not perfectly uniform.

(iii)There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.

(iv)The technology is relatively simple and low cost.

Distribution of dispersed phase may be improved if the matrix is in semi-solid condition. The method using stirring metal composite materials in semi-solid state is called Recasting. High viscosity of the semi-solid matrix material enables better mixing of the dispersed phase.

A modified development in stir casting is a two-step mixing process. In two step mixing process, the matrix material first 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. More uniform microstructure obtained by this.

2.11 STIR CASTING PROCESS PARAMETERS

For manufacturing of composite material by stir casting knowledge of its operating parameter are very important. As there is various process parameters if they are properly controlled can lead to the improved characteristic in composite material.

(a) Stirring Speed:

Stirring speed is the important process parameter as stirring is necessary to help in promoting wettability i.e. bonding between matrix & reinforcement. Stirring speed will directly control the flow pattern of the molten metal. Parallel flow will not promote good reinforcement mixing with the matrix. Hence flow pattern should be controlled turbulence flow. Pattern of flow from inward to outward direction is best (Naher, 2003).

(b) Stirring Temperature:

It is an important process parameter. It is related to the melting temperature of matrix i.e. Aluminum.

Al generally melts at 660.3^0C. The processing temperature is mainly affected by the viscosity of Al matrix. The change of viscosity influences the particle distribution in the matrix. The viscosity of liquid is decreased when increasing processing temperature, with increasing holding time (Naher,2003).

(c) Stirring Time:

Stirring promotes uniform distribution of the particles in the liquid and create perfect interface bond between reinforcement and matrix. The stirring time between matrix and reinforcement is considered as an important factor in the processing of composite. For uniform distribution of reinforcement in matrix, metal flow pattern should from outward to inward (Naher, 2003).

CHAPTER THREE

MATERIALS AND METHODS

Sample materials used in this research include: Snail shells and Aluminum 6063.

3.1 Adopted procedures

The following procedures were adopted: collection, sorting, washing, drying, compacting, crushing, pyrolysis, mold making, melting and casting.

3.1.1 Collection and Sorting

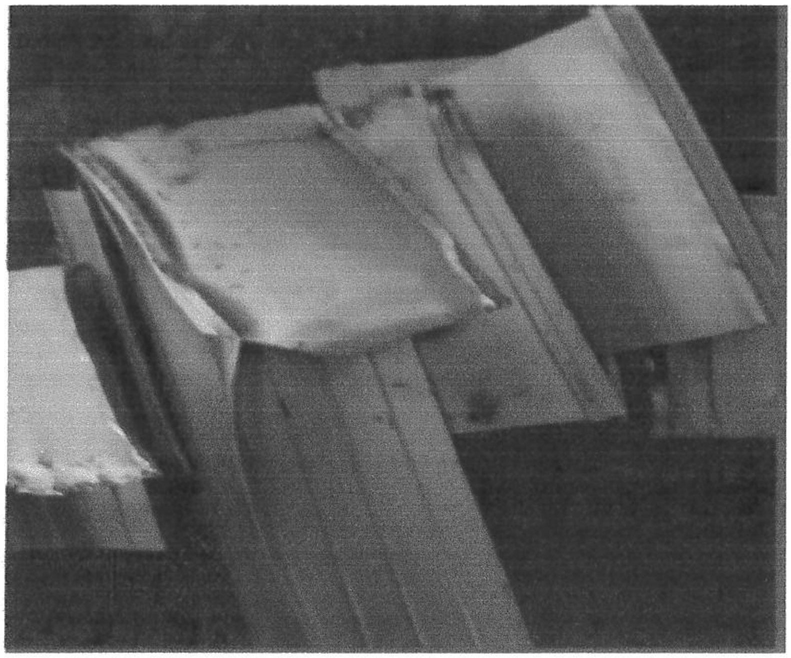
The snail shells were obtained from a disposal site around local markets in Ikole Ekiti, Ekiti State, Nigeria. Aluminum6063 was bought within the Federal University of technology Akure, Ondo State, Nigeria. Sorting was carried out to remove unwanted metallic materials and dirt clinging to the selected materials samples.

3.1.2 Washing, Drying, Compacting, Crushing and Pyrolysis

Washing with water and soap solution to remove sand, dirt and oil stains on the samples were done manually, after which they were sun-dried. The aluminum were cut into smaller sizes to ensure the lot fits into the crucible for melting, while the snail shells were then broken into smaller pieces (Figure 3.1a). These were then milled at 250 rpm to particles of different sizes (Figure 3.1b). The particle size analysis was carried out. The particles were placed onto a set of sieves arranged in descending order of fineness (600, 400 and 150 μm) and shaken for 15 min as recommended by Hassan and Aigbodion (2013) and Shuhadah, Supri, and Kamaruddin (2008).

Figure 3.1: (a) Snail Shells before grinding

Figure 3.1: (b) Snail Shells after grinding using ball mile



Fgure 3.2: Aluminum 6063

3.2 EQUIPMENT

The equipment used in the course of this research work are; measuring (volumetric) cylinder, crucible pot, diesel fired furnaces, electronic weighing balance, mechanical stirrer, universal testing machine, brinell hardness test machine(indenter), flexural test machine, grinding and polishing machine.

3.3 MOLD MAKING

The procedure followed in making the mold for the composites are;

The drag of the molding flask was placed on the molding board and the patterns were placed within the drag on the molding board. The pattern is a model of the desired casting. Dry facing sand was sprinkled over the board and pattern to aid the removal of the pattern, and then molding sand is riddled in to cover the pattern with the fingers until the drag is completely filled. The sand is then firmly packed in the drag by means of hand rammers. The ramming must be proper such that it is neither too hard (which could lead to blow holes due to trapping of gases within the mold cavity) nor too soft (as erosion by the molten metal when poured may occur).

After the ramming is over, the excess sand is leveled off with the strike-off bar vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during pouring and solidification. The finished drag flask is now turned over to the bottom board exposing the patterns. The cope half of the flask is then placed on the drag and aligned with the help of pins. Dry parting sand is sprinkled all over the drag and the patterns. Sprue pins for making sprue passages were located at a small distance from the pattern, the operation of filling; ramming and venting of the cope proceed in the same manner as performed in the drag. The sprue pins were removed first with care and a pouring basin was scoped out at the top to pour the liquid metal, then the pattern was removed from the drag and facing sand was applied all over the mold cavity and runners which gave the finished casting a good surface finish.

3.4 CHARGE CALCULATION

Charge calculation

Diameter of the rod=20 mm, length of the rod = 50 mm

Volume of pattern $= \pi r^2 h$

$$= \frac{22}{7} \times 1^2 \times 25$$

$$= 78.57 \text{ cm}^3$$

Density of Aluminum $(\rho_{Al}) = 2.70 \text{ gcm}^{-3}$

Density of snail shell $(\rho_{S.S}) = 1.614 \text{ gcm}^{-3}$

Composition for control sample

$\rho_2 = \rho_A . wt$

$= 2.70 \times 1$

$= 2.70\ gcm^{-3}$

Mass $= \rho \times v$

$M = 2.70 \times 78.57$

$M = 212.139\ g$

For 4 rods $= 212.139 \times 4$

$M = 848.556\ g$

For getting system $= 848.556 + 424.278$

$= 1272.834\ g$

5% of snail shell composition

$\rho_2 = \rho_{Al} .\ wt\% + \rho_{s.s} . wt\%$

$\rho_2 = 2.70 \times 0.95 + 1.614 \times 0.05$

$= 2.565 + 0.0807$

$= 2.6457 gcm^{-3}$

$M_2 = \rho_2 \times volume$

$= 2.6457 \times 78.57$

$= 207.8726$

For 4 rods $= 204.8726 \times 4$

$= 831.4905$ g

For getting system $= 831.4905 + 415.7452$

$= 1247.236\ g$

10% of snail shell composition

$\rho_3 = \rho_{Al} \cdot wt\% + \rho_{s.s} \cdot wt\%$

$= 2.70 \times 0.9 + 1.614 \times 0.1$

$= 2.43 + 0.1614$

$= 2.5914\ gcm^{-3}$

$M_3 = \rho_4 \times volume$

$= 2.5914 \times 78.57$

$= 203.6062\ g$

For 4 rods $= 203.6063 \times 4$

$= 610.8189g$

For getting system $= 814.4252 + 407.2126$

$= 1221.6378\ g$

15% of snail shell composition

$$\rho_4 = \rho_{Al} \cdot wt\% + \rho_{s.s} \cdot wt\%$$

$$= 2.70 \times 0.85 + 1.614 \times 0.15$$

$$= 2.295 + 0.2421$$

$$= 2.5371\ gcm^{-3}$$

$$M_4 = \rho_4 \times volume$$

$$= 2.5371 \times 78.57$$

$$= 199.3399\ g$$

For 4 rods $= 199.3399 \times 4$

$$= 797.3598\ g$$

For getting system $= 797.3598 + 398.0799$

$$= 1196.0397\ g$$

Finding the mass of aluminum and snail shell composition

Composition for control sample

$$M_{Al} = wt\% . Al \times M_1$$

$$= 1 \times 1272.834\ g$$

$$= 1272.834\ g$$

5% of snail shell composition

$M_{Al} = wt\% \, . Al \times M_2$

$= 0.95 \times 1247.236$

$= 1184.8742 \, g$

$M_{S.S} = wt\% \, . S.S \times M_2$

$= 0.05 \times 1247.236$

$= 62.8618 \, g$

10% of snail shell composition

$M_{Al} = wt\% \, . Al \times M_3$

$= 0.9 \times 1221.6378$

$= 1099.47402 \, g$

$M_{S.S} = wt\% \, . S.S \times M_3$

$= 0.1 \times 1221.6378$

$= 122.1638 \, g$

15% of snail shell composition

$M_{Al} = wt\% \, . Al \times M_4$

$= 0.85 \times 1196.0397$

$= 1016.6337g$

$M_{S.S} = wt\% . S.S \times M_4$

$= 0.15 \times 1196.0397$

$= 179.4060\ g$

Total mass of aluminum used $= 1272.834 + 1184.8742 + 1099.4740 + 1016.6337$

$= 4573.8159\ g$

Total mass of snail shell used $= 62.3618 + 122.1638 + 179.4060$

$= 363.9316\ g$

Table 3.1: Weight percentage (%) of the aluminum and snail shell

Sample	Aluminum	Snail shell
1	100	-
2	95	5
3	90	10
4	85	15

Table 3.2: Mass charged into the blast furnace

Sample	Aluminum in (g)	Snail shell in (g)
1	1272.834	-
2	1184.8742	62.3618
3	1099.47402	122.1638
4	1016.6337	179.4060

Therefore, the total mass of Aluminum used = 5 kg, while the total mass of Snail shell used = 400 g

3.5 COMPOSITE PRODUCTION

Stir casting process performed in accordance with Alaneme and Aluko 2012 was utilized to produce the composites. The process started with the determination of the quantities of aluminum and snail shell powder required to produce as shown in diagram------ below.

Figure3.3: Mass of the Snail Shell powder using electric weighing balance

Figure 3.4: Mass of the Aluminum using electric weighing balance

Aluminum were charged into the crucible and placed inside the gas blast furnace and heated at a temperature of $660.3^{0}C$ until aluminum melted completely.

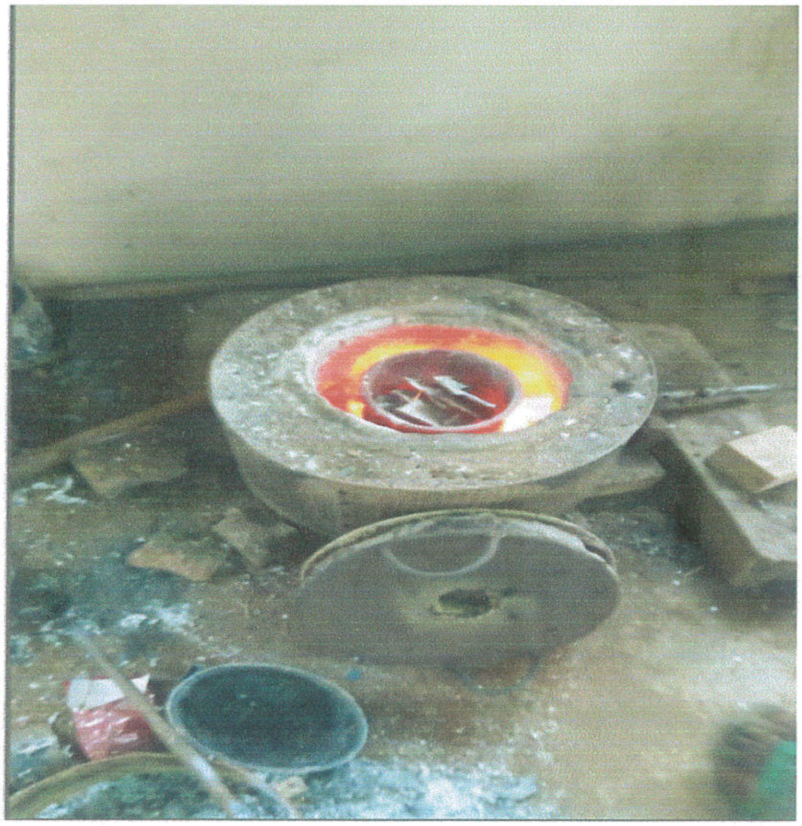


Figure 3.5: Charging of Aluminum into the blast furnace

The temperature was a bit lowered to add the reinforcement; it was stirred at 200rpm for 5 minutes to achieve homogenization of the mixture. The reinforcement was stirred manually and allow to heat.

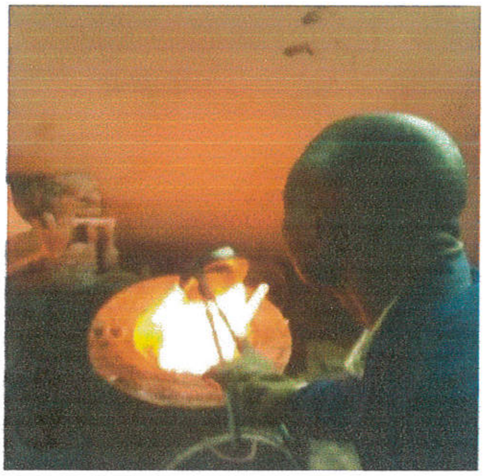
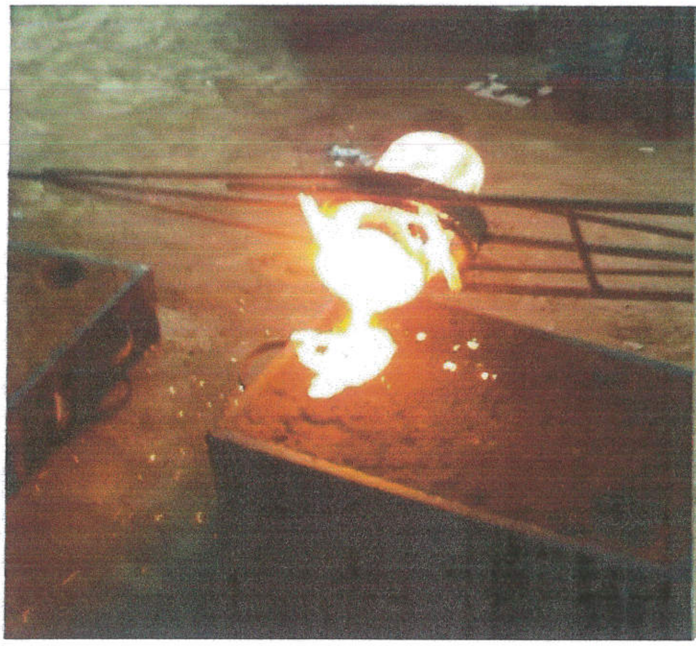


Figure 3.6: Adding the reinforcements into the molten metal

Figure 3.7: Mechanical stirring of the mixture

Thereafter the liquid composite was cast in sand mould. The cast was then removed in the mold after it has been solidified.



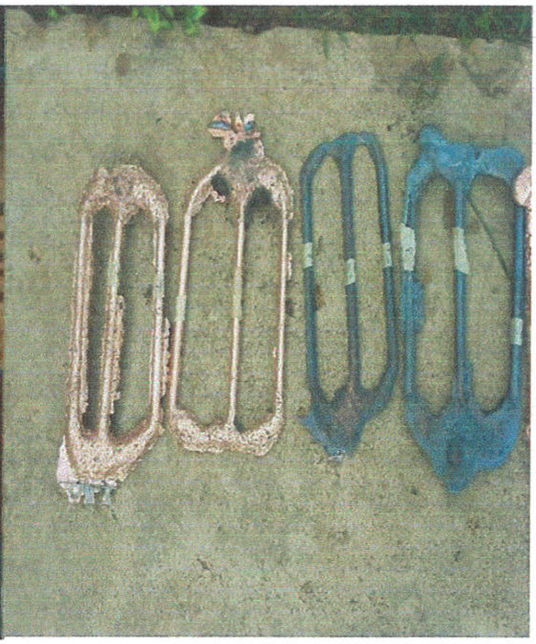


Figure 3.8: (a) pouring of the melt into the mould Figure 3.8: (b) cast material before fettling

3.6 CLEANING, FETTLING AND MACHINING

Stainless wire brush was used to remove sand that adhered to the castings and electrical abrasive wheel-cutting machine was used to clean off the dross and cut off the sprues and the risers from the cast rods. The rods were subsequently machined for tensile and impact specimens. Universal lathe machine was used to machine the cast samples into standard test samples for mechanical tests and microstructural analysis. The tensile samples were machined to a gauge length of 50 mm. of each of the test specimens.

3.7 EVALUATION OF SNAIL SHELL DENSITY

The experimental density was determined by dividing the measured weight of the snail shell sample by its volume.

3.8 EVALUATION OF THE MECHANICAL PROPERTIES

3.8.1 HARDNESS TEST

The hardness testing was carried out for all composite specimens. Before the test was carried out the mating surfaces of the indenter, plunger rod and test samples were cleaned by removing dirt, scratches and oil and the testing machine was calibrated using the standard block. Specimens for hardness test were cut to 10 by 10 mm diameter size and were properly grinded. A direct load of 120kgf was then applied on flat smoothly polished specimens of the composites for 10 seconds and the Brinell hardness test was carried out. The test was repeated three to five times and the average reading was taken.

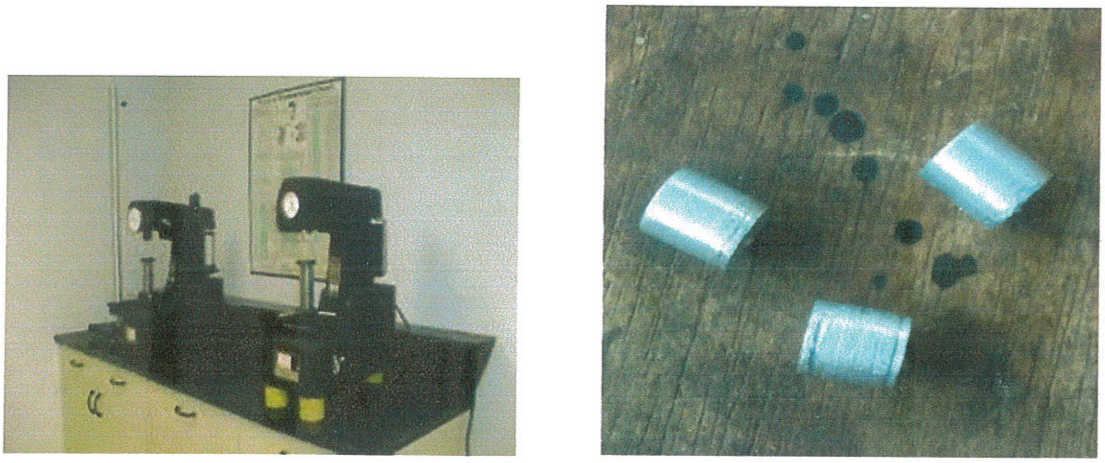


Figure 3.9: Hardness testing machine used and the samples

The Brinell hardness testing machine was used with load 98.07N

The average Brinell hardness values of each of the specimens were then determined

3.8.2 TENSILE TEST

The tensile properties of snail shell reinforced with aluminum 6063 were evaluated with the aid of tensile tests performed following ASTM standard D3039M-08. The test was carried out at room temperature using a universe testing machine and the average of three tests was taken.

Tensile Test Machines

Tensile test machines are universal testing machines specially configured to evaluate tensile strength of specimens. The tensile machine will measure characteristics such as ultimate tensile strength, yield strength, elongation and modulus etc. Each tensile test machine is configured with the correct controller, grips, and accessories. Due to modular machine design, the tensile tester can also be equipped to perform other applications such as compression, cyclic, shear, flexure, bend, peel, and tear just by adding fixtures.

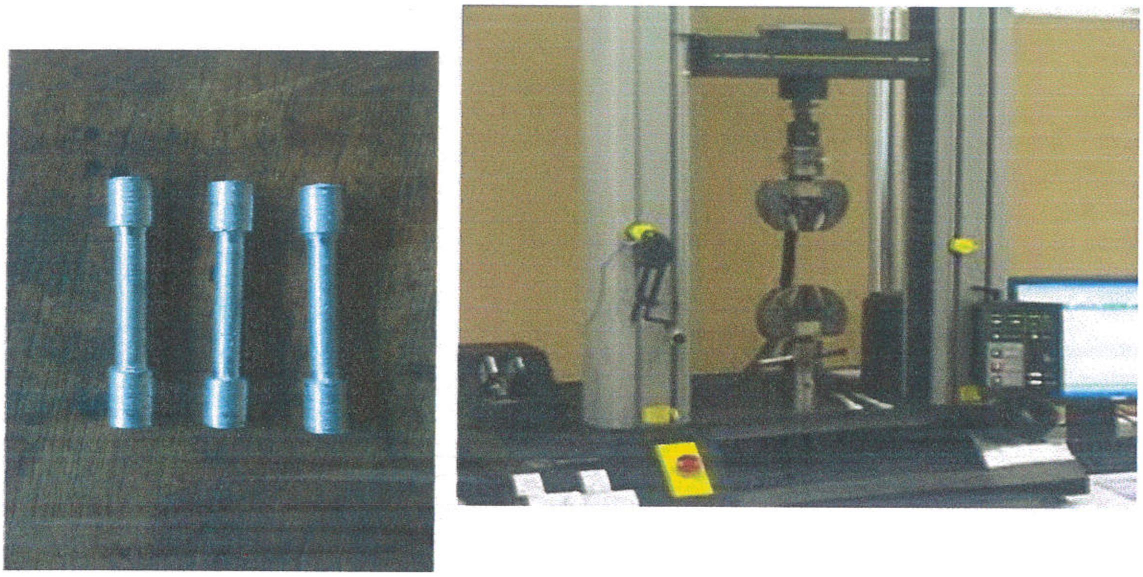


Figure 3.10: The samples and tensile testing machine used

3.8.3 Flexural test

Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. A flexure test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample.

Why perform a flexure test?

Unlike a compression test or tensile test, a flexure test does not measure fundamental material properties. When a specimen is placed under flexural loading all three fundamental stresses are present: tensile, compressive and shear and so the flexural properties of a specimen are the result of the combined effect of all three stresses as well as (though to a lesser extent) the geometry of the specimen and the rate the load is applied.

The most common purpose of a flexure test is to measure flexural strength and flexural modulus. Flexural strength is defined as the maximum stress at the outermost fiber on either the compression or tension side of the specimen. Flexural modulus is calculated from the slope of the stress vs. strain deflection curve. These two values can be used to evaluate the sample materials ability to withstand flexure or bending forces.

Flexure Test Types:

The two most common types of flexure test are three point and four point flexure bending tests. A three point bend test consists of the sample placed horizontally upon two points and the force applied to the top of the sample through a single point so that the sample is bent in the shape of a "V". A four point bend test is roughly the same except that instead of the force applied through a single point on top it is applied through two points so that the sample experiences contact at four different points and is bent more in the shape of a "U". The three point flexure test is ideal for the testing of a specific location of the sample, whereas, the four point flexure test is more suited towards the testing of a large section of the sample, which highlights the defects of the sample better than a 3-point bending test.

A bend test is similar to a flexure test in the type of hardware and test procedure involved. Bend tests are used with ductile materials whereas flexural tests are used with brittle materials.

Types of Materials:

Generally a flexure test is run until the sample experiences failure and is therefore ideal for the testing of brittle materials. The most common materials tested in flexure are plastic materials, composites, concrete, and ceramics. Because these materials have a very low ductility they will break before any permanent deformation of the sample occurs allowing for the accurate measurement of the flexural modulus and strength.

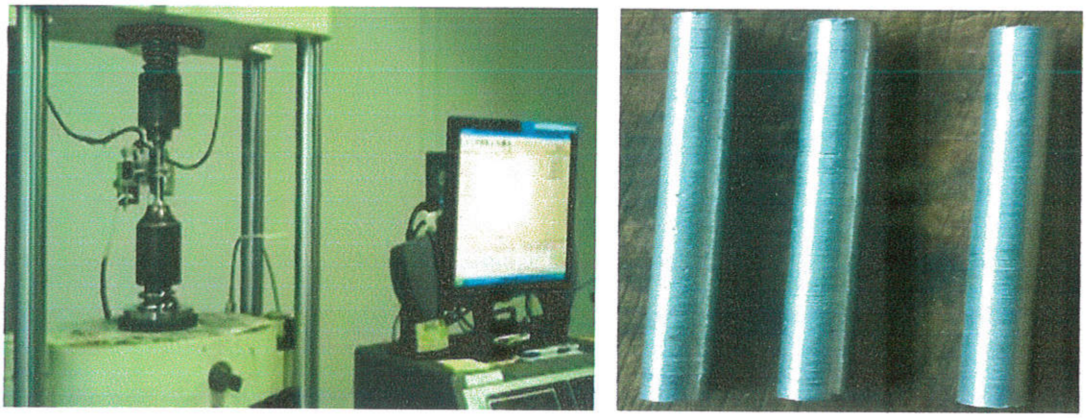


Figure 3.11: Flexural testing machine used and the samples

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Result

The results of the study are presented as follows, namely hardness test, flexural test and tensile test. Result of mechanical properties shows the behavior of the composites and cast neat aluminum 6063

4.1.1HARDNESS PROPERTY RESULTS

Table4.1 Hardness properties of neat and Snail Shell reinforced composites

Composition	BHN value
100% Aluminum 0% Snail Shell	20.88
95% Aluminum 5% Snail Shell	17.83
90% Aluminum 10% Snail Shell	22.07
85% Aluminum 15% Snail Shell	18.53

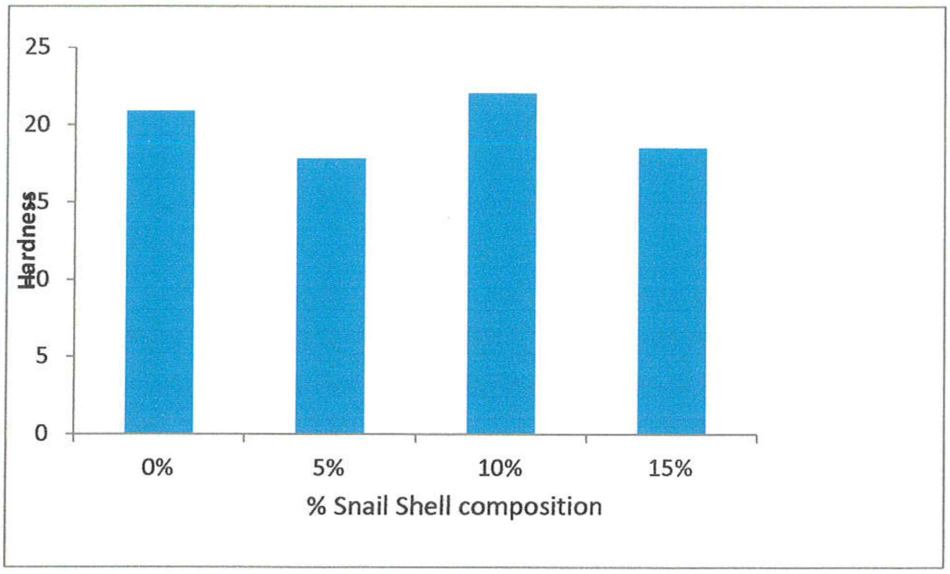


Figure 4.1: BHN variation of the aluminum composites containing varying weight ratio of Snail Shell

Figure 4.1 reveals the hardness variation of the composite containing varying weight ratio of Snail Shell. From Figure 4.1, the It was observed that the composite with 90 % aluminum and 10 % snail shell has the highest value of BHN of 22.067 which is the best among the other composition; followed by neat composite having 20.88, next is aluminum reinforced with 15% snail shell with hardness value of 18.53. Also the reinforced 95% aluminum with 5% of snail shell which is the second composition was observed to have the lowest hardness value of BHN of 17.833. It was generally observed that only 10% wt additive improved the hardness of the matrix, while others decreases the hardness. According to the Rockwell hardness test result, the hardness among the four specimens is shown. The hardness values of the composites produced are presented in Table 4.1. It was observed that the composite with 90 % aluminum and 10 % snail shell has the highest value of BHN of 22.067 which is the best among the other composition as compared to even the control specimen.

4.1.2FLEXURAL PROPERTY RESULTS

Table4.2: Flexural properties of neat and Snail Shell reinforced composites

Material	Flexural Strenght (MPa)
100% Aluminum 0% Snail Shell	113.63
95% Aluminum 5% Snail Shell	88.05
90% Aluminum 10% Snail Shell	101.46
85% Aluminum 15% Snail Shell	104.76

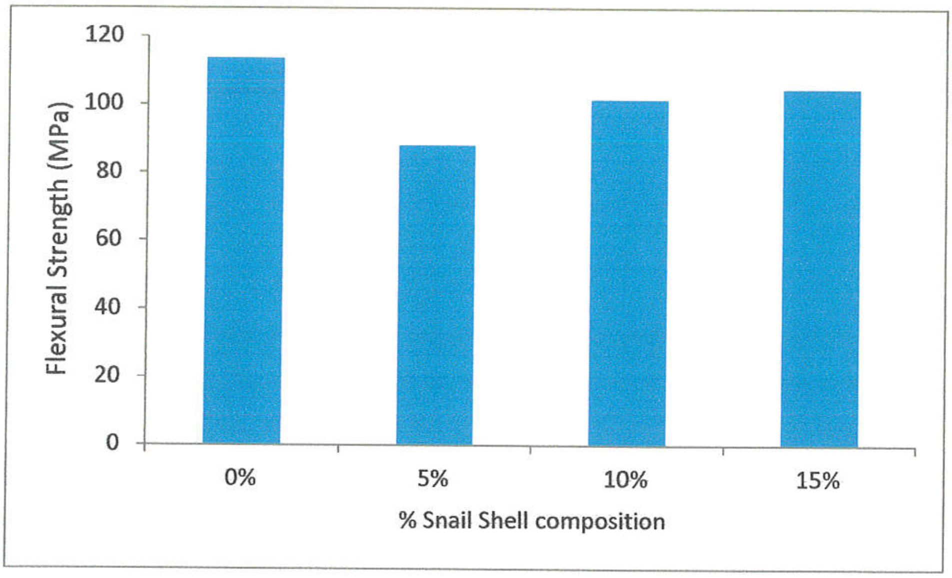


Figure 4.2: Flexural Strength variation of the aluminum composites containing varying weight ratio of Snail Shell

Figure 4.2 shows the flexural stress variation of the aluminum containing varying weight ratio of snail shell. It was observed that the neat has the highest maximum flexural stress (113.63 MPa); followed by composite reinforced with 15% snail shell particles with value of 104.76 (MPa), next is aluminum reinforced with 10% snail shell with flexural stress value of 101.46 (MPa). Finally the reinforced 90% aluminum with 5% of snail shell particles was observed to have the lowest value of 88.05 (MPa). The additives decrease the flexural strength of the composites.

4.1.3TENSILE PROPERTY RESULTS

Table4.3: Tensile properties of neat and Snail Shell reinforced composites

Material	Young modulus (MPa)	Ultimate tensile strength (MPa)	Strain stress (mm/mm)	Energy at maximum tensile stress (J)
100% Aluminum 0% Snail Shell	5709.39	1957.38	0.093	3.43
95% Aluminum 5% Snail Shell	6194.48	1516.16	0.062	1.84
90% Aluminum 10% Snail Shell	7391.37	1694.90	0.065	2.21
85% Aluminum 15% Snail Shell	6273.81	1522.43	0.0595	1.73

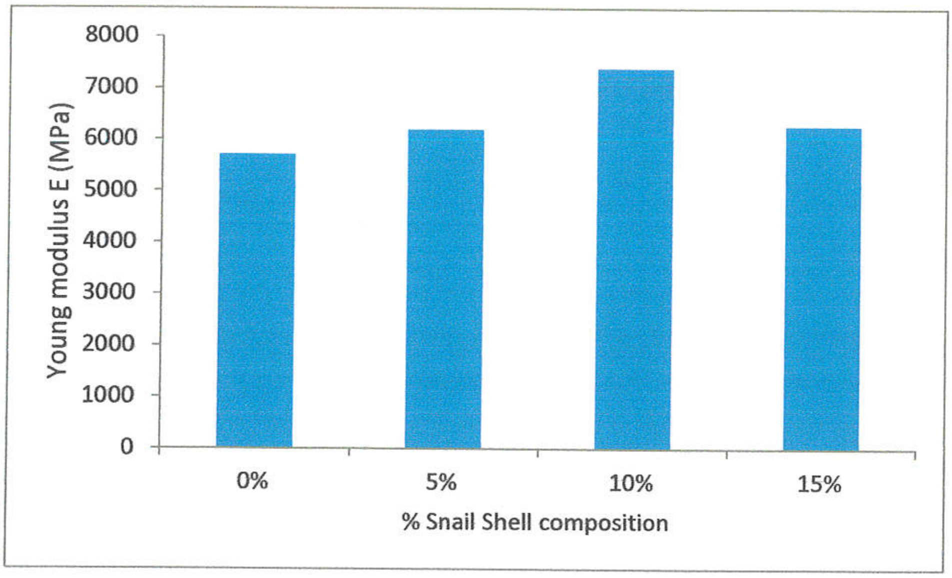


Figure 4.3: modulus variation of the composite containing varying weight ratio of Snail Shell

Figure 4.3 shows the young's moduli of neat and snail shell particles reinforce composites. It was observed that the composite reinforced with 10% snail shell particles has the highest modulus (7391.37 MPa); followed by composite reinforced with 15% snail shell particles with modulus value of 6273.81 MPa, next is composite with 5% snail shell composition with modulus value of 6194.37 MPa, while the least was exhibited to be the neat (i.e. unreinforced) composite. Generally, it was observed that the composites reinforced with snail shell have an increment in value of modulus, as shown in Table 4.3.

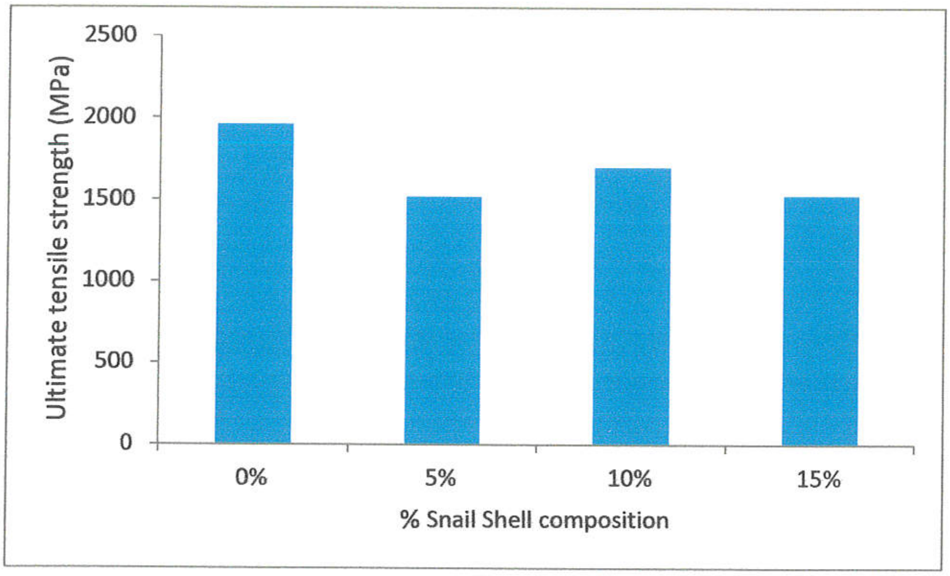


Figure 4.4: Ultimate Tensile Strength variation of the composites containing varying weight ratio of Snail Shell

Figure 4.4 reveals the ultimate tensile strength (i.e. Load at maximum tensile stress) variation of the composite containing varying weight ratio of Snail Shell. From Figure 4.4, the neat composite has the highest UTS (1957.38 N); followed by composite reinforced with 10% snail shell particles with UTS value of 1694.90 N, next is composite with 15% snail shell particles composition with UTS value of 1522.43 N, while the least was exhibited by composite reinforce with 5% snail shell powder, as shown in Table 4.3. It was generally observed that the additives reduce the UTS of the matrix material.

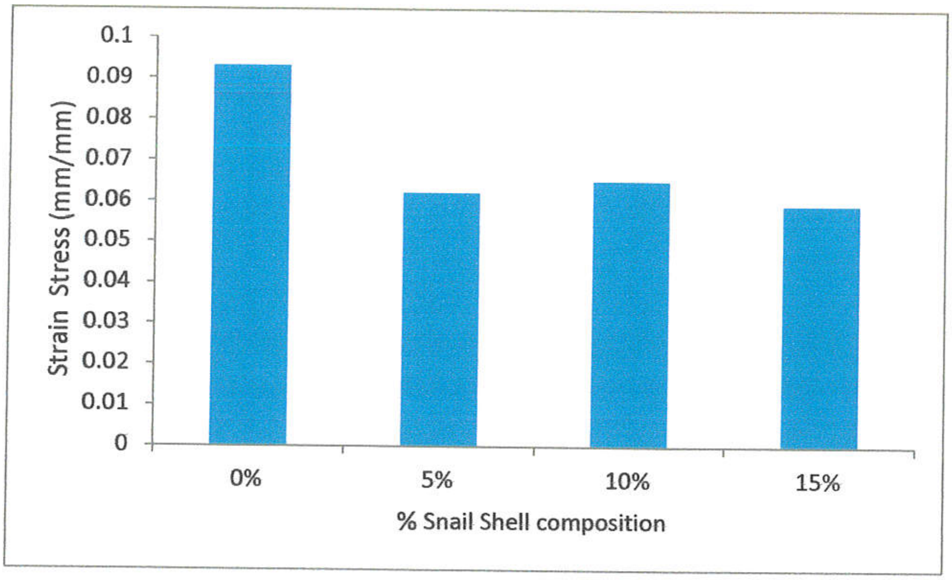


Figure 4.5: Tensile Strain at of the composites containing varying weight ratio of Snail Shell

Figure4.5 shows Strain variation of the composites containing different weight ratio of Snail Shell. It was observed that the unreinforced composite has the highest tensile strain at maximum tensile stress of 0.093 mm/mm, and then followed by composite reinforced with 10% snail shell powder with value of 0.065 mm/mm; next to it is the composite with the value of 0.062mm/mm, while the least was concluded be the composite reinforced with 15 engineering% snail shell particles (0.059 mm/mm), as shown in Table 4.3. It be deduced that additives lower the value of the matrix material.

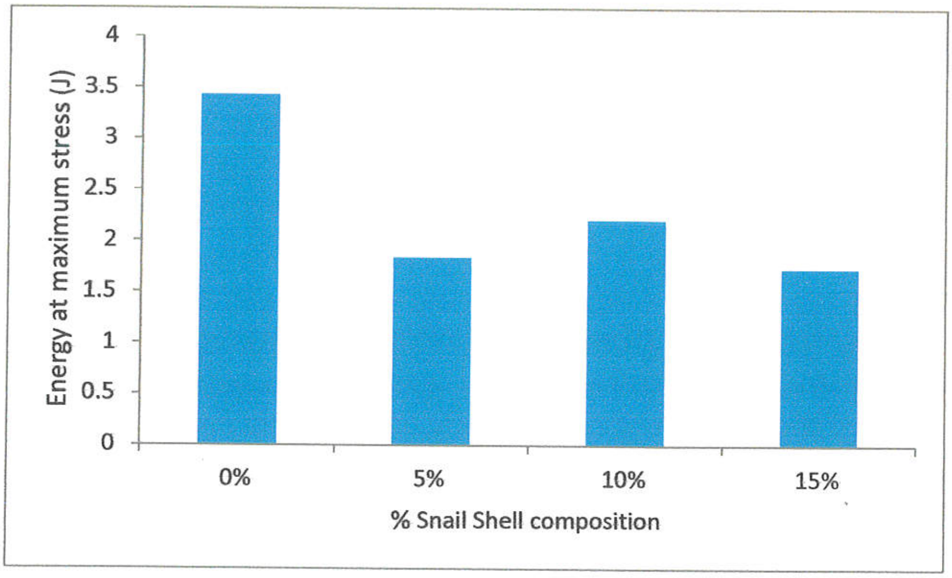


Figure 4.6: Energy maximum tensile stress variation of the composite containing varying weight ratio of Snail Shell

Figure 4.6: reveals energy maximum tensile stress variation of the composite containing varying weight ratio of Snail Shell. It was observed that the unreinforced composite has the highest energy maximum tensile stress 3.43 (J), and this follow the same trend of the tensile strain at maximum tensile stress; as shown in Table 4.3. The low values observed for the snail shell reinforced particles as compared with neat (i.e. unreinforced), may be attributed to various degree of immiscibility exhibited by the composites.

CHAPTER FIVE

CONCLUSION AND SUGGESTION FOR FURTHER RESEARCH

5.1 CONCLUSION

The results show that:

1. The composite with 90% aluminum and 10% (i.e. 9:1) snail shell powder value are the hardest and strongest the of aluminum composites.

2. The composite with same working length, dimension and shapes but different composition variables give different value of flexural strength, maximum flexural strain and flexural modulus. From the experiment, it is observed that the composite with 90 % aluminum and 10 % snail shell powder has the highest value of modulus (E-modulus) and load at break (standard).

3. The composite with 90% aluminum and 10% snail shell powder has the highest elastic modulus.

4. The 90% aluminum and 10% snail shell reinforced composites composition is observed to have the overall best combination of mechanical properties when considering the hardness and elastic modulus.

5. It is concluded that both the hardness and young modulus are significantly enhanced, and snail shells can be used as a low-cost reinforcement for engineering applications.

5.2 SUGGESTION FOR FURTHER RESEARCH

The 90% aluminum and 10% snail shell is recommended for consideration in the engineering applications design due to the improved mechanical properties, especially where hardness strength is needed.

Further research should be done to evaluate the corrosion behavior, wear resistance, fracture toughness and SEM analysis of the composites.

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