# Analysis And Material Characterization of Aluminium-Carbon Fiber Composite.

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**ABSTRACT**-This thesis presents the construction and mechanical evaluation of aluminum-carbon fiber composites. The aim is to produce a composite materialthatcombinesthedesirablepropertiesofaluminiu m,suchasitslowdensityandhighthermal conductivity, with the excellent strength-to-weight ratio

Firstly, to determine the purity of the procured materials, we use X-ray diffraction test. We perform the homogeneous mixing of our samples using a planetary ball mill. The mixed sample is collected and then undergoes compaction on a hydraulic press, followed by sintering in a Muffle furnace. After the samples of different configurations are prepared, sample testing is carried out to evaluate their performance in real-life.

In a nutshell, the development of the aluminum-carbon fiber composite presented in this paper offers a viable solution as needed of lightweight and materials of high strength in a variety of industries. A comprehensive mechanical characterization and analysis of the composite's microstructure are used to justify the same. Future studies ought to be directed at optimizing the fabrication process and investigating the composite's long-term durability and environmental sustainability.

**KEY WORD** – composites, Classification, Carbon fiber, literature review, Aluminium, experimental setup and procedures

## 1. INTRODUCTION

Carbon fiber/aluminum powder composites are advanced materials that combine the strength and stiffness of carbon fiber with the lightweight and high thermal conductivity of aluminum. These Aerospace, automotive, and other industries employ composites extensively, high-performance applications where strength, stiffness, and thermal management are critical.

The fabrication of these composites involves the combination of carbon fiber reinforcement and aluminum powder matrix which is then processed through a series of steps to yield a high-strength, lightweight material. The resulting composites exhibit exceptional mechanical properties and are highly resistant to fatigue, making them ideal for use in high-stress applications.

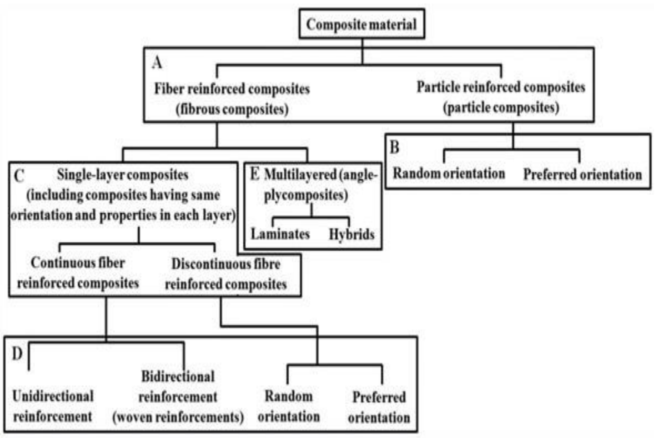
In this article, we will discuss the fabrication process for carbon fiber/aluminum powder composites, including the materials and equipment required, as well as the steps involved in creating these advanced materials

To ensure the homogeneity of the prepared samples, we performed ball milling process. Ball milling is a mechanical process that involves the use of a rotating cylindrical chamber or container filled with balls made of various materials, such as steel or ceramic. The materials to be milled are placed inside the container along with the balls, and the container is rotated at a certain speed to create a grinding and mixing effect. As the container rotates, the balls inside it collide with each other and with the materials being milled, causing them to break down into smaller particles and become uniformly distributed. Ball milling is widely used in various fields, including materials science,metallurgy and chemical engineering.

## 2. COMPOSITES

Composites are substances made of two or more distinct and distinctive materials combined in a specific way. Composites are designed to give new materials the advantages of both components' strengths while concealing the shortcomings of the original materials. Typically, a composite is classified according to the kind of reinforcements that were employed to make it.. This matrix, which contains the reinforcements, keeps it together. [1].

**Fig. 1 Classification of composite materials**



Knowing these elements is essential since composites have two (or more) chemically distinct phases that are separated by a clear interface on a microscopic level.. The term "matrix" refers to the continuous component that is frequently, but not always, present in the higher quantity in composites. The conventional notion is that the qualities of the matrix are enhanced when another ingredient is added to generate composites

### 2.1 ALUMINIUM

Chemically speaking, aluminium is a 13-atomic-number chemical element with the symbol Al. Its colour is silvery-white that is both soft and lightweight, with a density only about three-quarters that of steel . Aluminum is also nonmagnetic, non-sparking, and has excellent thermal and electrical conductivity. It is a popular material for use in construction, transportation, packaging, and electrical applications due to its combination of low cost, light weight, and durability.

After silicon and oxygen, aluminium is the third most prevalent element in the Earth's crust., and is found in a variety of minerals, including bauxite. It is extracted from bauxite through the Bayer process, which involves refining the ore and then reducing it to aluminum oxide through smelting. The aluminum oxide is then electrolytic ally reduced to produce aluminum metal.

Aluminum has many unique properties that make it an ideal material for a wide range of applications. For example, it is highly reflective, making it a popular choice for use in reflectors for lighting and for solar panels. It is also resistant to corrosion, meaning that it does not rust and does not need to be painted or coated to maintain its appearance and structural integrity. This makes aluminum a popular choice for use in outdoor applications such as bridges, buildings, and power lines.

Aluminum has many applications due to its unique combination of properties, including:

- Construction: aluminum is commonly used in building construction for windows, doors, siding, roofing, and framing. It is also used in the construction of bridges, high-rise buildings, and other structures.
- Transportation: The strength and light weight of aluminium make it a popular material in the automotive and aerospace industries. It is used to create structural elements, engine blocks, and body panels for automobiles and aircraft.
- Packaging: aluminum is used in a variety of packaging applications, including aluminum cans for beverages and food, aluminum foil for wrapping food, and aluminum containers for personal care and household products.
- Electrical: aluminum is a good conductor of electricity and is used in electrical wiring and in the manufacture of various electrical components, such as transformers and capacitors.

### 2.2 CARBON FIBER

Carbon fiber is a high-strength, lightweight, and flexible material made from thin fibers of carbon. Precursor materials like rayon or polyacrylonitrile are heated and spun into a high-temperature carbon matrix to create the fibres. The resulting material is lightweight yet strong, making it ideal for a wide range of applications, from aerospace and sporting goods to construction and medical devices.

The exceptional tensile strength of carbon fibre, which enables it to bear significant strain and stress without breaking, is well recognised. It is also very stiff, meaning it does not deform easily, making it ideal for applications where stability and precision are important. Additionally, carbon fiber has a high resistance to corrosion and does not conduct electricity, making it suitable for use in electrical and electronic applications.

Carbon Fiber has following properties:

- high tensile strength and stiffness
- reduced weight to strength
- increased chemical resistance
- temperature that can withstand extreme heat

@ low thermal expansion

Carbon fiber has a wide range of uses Because of its great strength, stiffness, low weight, anda lack of corrosion , including:

- Aerospace: Carbon fiber is used in the aerospace industry to make lightweight and strong aircraft components, such as fuselage and wing structures, as well as in the manufacture of satellites and rockets.
- High-performance sporting goods including tennis rackets, golf clubs, bicycles, and hockey sticks are made from carbon fibre.
- Automotive: Carbon fiber is used in the automotive industry to make lightweight body panels and other structural components, such as suspension arms and drive shafts, which can improve fuel efficiency and performance.

- Construction: Carbon fiber is used in construction to reinforce concrete structures, such as bridges and buildings, and to make lightweight and strong support beams and columns.

## 3. LITERATURE REVIEW

Composite materials are a combination of two or more materials with distinct physical and chemical properties that are combined to form a new material with improved properties. One such composite material is an Aluminium-Carbon Fiber composite. This composite material is made by mixing Aluminium powder and Carbon fiber. The Aluminium powder used in this composite is atomized Aluminium powder with a size of 149 microns (100 mesh) and a purity of 99.27%. The Carbon fiber used is a kind of Polymer and is sometimes known as graphite fiber. It has a high weight to strength ratio compared to metallic materials.

The application of Aluminium-Carbon Fiber composite substances has been studied in a variety of industries like aerospace, automotive, and industrial applications. These composites have high strength to weight ratio and good thermal and electrical conductivity, which makes them suitable for high-performance applications. Aluminium-Carbon Fibre Composites' mechanical characteristics rely on the type and amount of reinforcement used, the manufacturing process, and the microstructure of the material.

A numerous studies and research have been carried out in composite materials due to high demands in industrial sector as In contrast to metallic materials, it has a great mass/rigidity/resistance ratio. [12].

Excellent malleability, high strength, low weight, excellent corrosion resistance, ease of machining, and strong thermal [23].

A study examined the microstructure and its evolution of the mixture powders and the fabricated composites and the mechanical properties of the composites. After 6 hours of ball-milling, CNTs had uniformly scattered throughout the Al matrixthanks to the steady dispersion that occurred as ball-milling time increased. The CNTs suffered severe degradation when the ball-milling period was increased to 8–12 hours.demonstrated that the tensile and yield strengths of the composites increased as the ball-milling time increased, but the elongation increased initially and then dropped. [1]

Another study by [2] examined how the length of time that carbon fiber/aluminum powder compositeswere ball milled affected their microstructure and mechanical characteristics. It was discovered that lengthening the milling time helped reduce particle clustering, homogeneously disperse reinforcement particles, and shorten the distances between composite particle pairs. Due to the intense plastic deformation of the particle during milling, an increase in milling time also causes grain refinement.

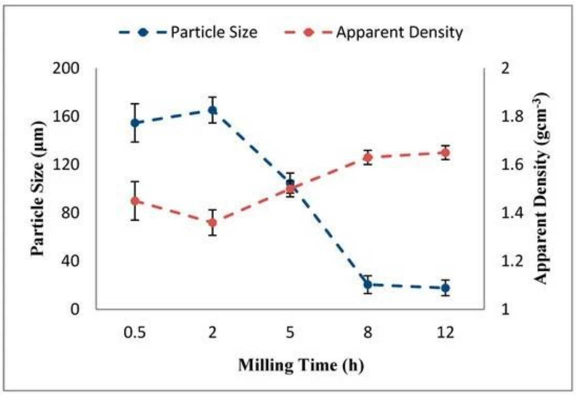



Fig. 3 The fluctuation in Al-5Al2O3 nanocomposite powders' apparent density and particle size as a function of milling time.

Overall, it has been demonstrated that using ball milling to create carbon fiber/aluminum powder composites . The parameters that have been investigated in these studies include carbon fiber content, aluminium powder content, the addition of epoxy resin which can be optimized to achieve the desired mechanical properties for specific applications.

The modulus of the fibre is significantly greater than that of the matrix fiber-reinforced polymer matrix composites with good performance. When the composite is subjected to a certain strain, the fibre will therefore be able to support more weight than the interface, which regulates damage growth, is especially important in applications that need damage tolerance and endurance in hostile situations [35]. The surrounding fibres experience a stress concentration when a fibre breaks

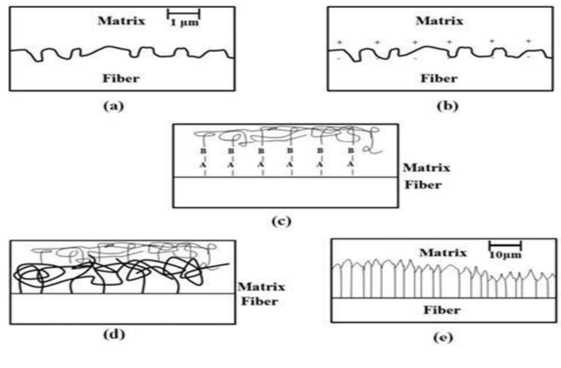



Fig. 4 Graphs showing several interactions at the fiber-matrix interface Examples include chain entanglement, chemical bonding, induced or permanent dipole connections, micromechanical interlocking, and more.

Prior research has shown that regulating the interface is crucial for both protecting the fibres and influencing characteristics. This makes some interface development regions crucial for enhancing composite performance. There are several specific requirements for optimal carbon fibre sizing.

An inert gas will be injected into the boundary layer at the carbon composite surface to offer some defence. Researchers have examined the oxidation of carbon fibre reinforced carbon matrix composites in the presence or absence of inert nitrogen injected into the boundary layer of the wall surface by certain authors [41]. They have demonstrated that the nitrogen gas protective boundary layer flow reduces the carbon mass loss at the tube surface by a factor of roughly 3.3 at 1500 K and by a factor of 3 at 2000 K. Other flow parameters, temperatures, and pressures must be considered in order to optimise this intriguing new protection approach.

To develop is what this project's goal is an aluminum-carbon fiber composite material and to study its mechanical characterization. This involved testing of both aluminum powder and carbon fiber, and its verification. Sample preparation will involve mixing aluminum powder and carbon fiber using a planetary ball mill. The density of the samples will also be calculated using Archimedes principle.The samples' mechanical characteristics will be investigated using a range of techniques, including.

X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy- dispersive X-ray spectroscopy (EDX).This project's objective is to comprehend the properties of the composite material and how it can be used in various applications

## 4. OBJECTIVE:

The objectives of this study re as under:

- To compare of analytical density of the composites manufactured with the density obtained by Archimedes' principle.
- To investigate the change in strength of the al composite with varying the% of carbon fiber.
- To determine the bonding among the matrix and reinforcement in the mmc.

## 5. EXPERIMENTAL SETUP AND PROCEDURES

### 5.1 Materials required

- o Aluminium Powder
- o Carbon Fiber

Particles' size distribution of aluminum powder was determined using the sieve analysis method. The weight of aluminium powder on each filter was measured and the percentage of all the constituents should be calculated separately. This step is very imperative considering the ratio of particle size on composites' properties [42- 43].

**5.2 Mixing procedure:** The mixing procedure for ball milling is commonly used forsample preparation in composite material development.

Ball Milling:

5.1.1 Weighed the required quantity of aluminum powder and carbon fiber.

5.1.2 Transferred the weighed powders to the bowl of a planetary ball mill.

5.1.3 Placed the bowl on the plate of the planetary ball mill and secure it in place.

5.1.4 Started the planetary ball mill and ball size used of 10 mm and 5 mm dia and let it run at 445 r.p.m for 2 hours, with 5 min break in 15 min cycle

5.1.5 Once the milling is completed, removed the bowl and the mixed powder collected for further testing.

- ○ comparing with JCPDS [44] data, Al powder was found to be pure.

**5.3 Compression molding**:

The development of green composites of Aluminium-Carbon Fiber was done via Uniaxial Compaction Method under a load of 10 Tones.

Finally, the specimen obtained was sintered at 550 degrees Celsius for 2h in inert atmosphere of Argon

Further the testing of specimens will be done:

- o Metallography: FESEM, Optical Microscopy
- o Spectroscopy: XRD and EDX Analysis
- o Mechanical Testing: Micro Hardness and Density Test

The effects of die design, compaction pressure, lubrication, sintering procedure, and part orientation in the oven on the Powder Metallurgy part quality will be investigated thoroughly by repeating the above procedure no. of time.

## 6.1 RESULTS AND DISCUSSIONS

In an XRD (X-ray Diffraction) graph of aluminum, the peaks represent the diffraction patterns of the crystal lattice of the aluminum. Each peak corresponds to a specific distance between planes of atoms in the crystal lattice, known as the interplanar spacing. The positions and intensities of these peaks can be used to identify the specific crystal structure and phase of the aluminum. Additionally, these peaks can also be utilised to establish the purity, crystallinity, and grain size of the aluminum sample.

Peaks on an XRD (X-ray diffraction) graph of carbon fiber represent the different crystalline planes present in the carbon fiber sample. These peaks correspond to the specific distances between the atoms in the crystal lattice of the carbon fiber, and the intensity of each peak is related to the amount of that specific crystalline plane present in the sample. The positions of the peaks can also give information about thea level of order and alignment of the carbon fibers in the sample. The XRD pattern of Carbon fiber is typically characteristic of graphite, with sharp and intense peaks at around 2θ = 26.5°, 43.5°, and 62.7°, which correspond to the (002), (100), and (004) planes of graphite respectively.

Aluminum have **FCC** Crystal structure

**Crystallographic data**: Crystal system is **cubic** and Cell parameters is (a= **4.04958 Å**)

### 6.1TEST RESULTS:

### 6.1.1 XRD-PLOT OF AL POWDER

- For verifying Al powder, we have done XRD analysis of Al between 20 to 80 degrees. After plotting it and comparing with JCPDS [44] data, Al powder was found to be pure

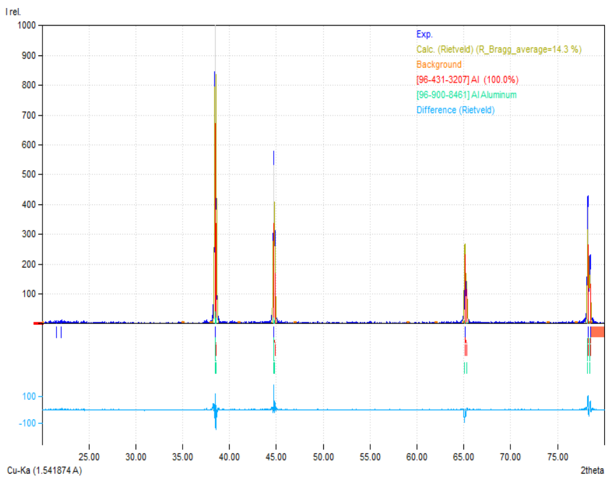



Fig.5 AL Powder XRD-Plot in Match! 3

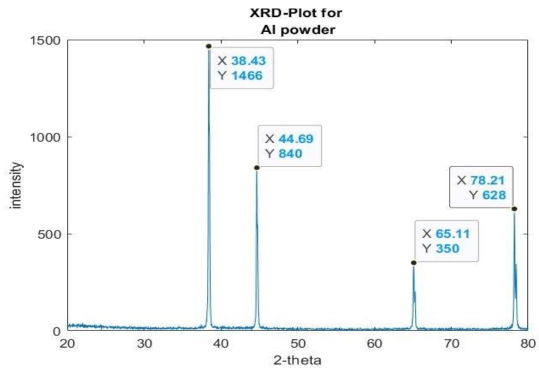



Fig.6 XRD-Plot of Al Powder in MATLAB

## 7. DENSITY TEST RESULT

To determine the density using Archimedes' Principle, the following steps are involved

1.Weight in Air: The first step is to measure the weight of the composite pellet in air using a balance or scale. This measurement represents the weight of the pellet in the presence of atmospheric conditions, without any buoyant force acting on it.

2 Weight in Water: Next, a container or beaker is filled with water, and the pellet is carefully submerged into the water using a thread or fine wire. It is essential to ensure that the pellet is fully immersed and there are no air bubbles clinging to its surface. The weight of the pellet is then measured while it is suspended in the water. This measurement accounts for the buoyant force acting on the pellet due to the water, which reduces its apparent weight. Calculating Density: The density of the composite pellet may be determined using the following calculation using the, Density of composite = Weight in air / (Weight in air - Weight in water)

1.Units of Density: The resulting density value is typically expressed in units such as grams per cubic centimetre ($g/cm^3$) or kilograms per cubic meter ($kg/m^3$), representing the mass of the composite pellet per unit volume

Using the methods described above, the composite's density was computed. The graph below shows the test results.

Analytically Density was calculated using the formula:Density of Composite = (Mass of Carbon

Powder / To Fiber / Total Volume) + (Mass of Aluminiumtal Volume

The graph below shows the density comparison between theoretical density calculation and density test results obtained from Archimedes principle density calculation

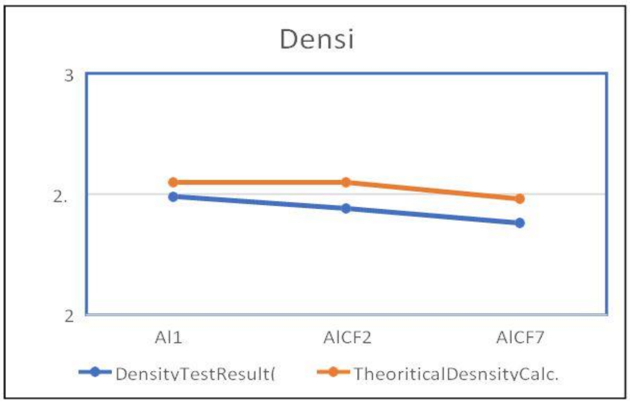



Fig.8 Density Results graphical representation

### 7.1 VICKER'S HARDNESS TEST

The Vickers hardness test is a widely used method for evaluating the hardness of materials. This test involves applying a controlled load to the surface of the material using a diamond indenter in the shape of a square-based pyramid. The material's hardness is determined by measuring the size of the indentation left on its surface. To conduct the test, the material sample is carefully prepared to ensure a clean and flat surface. It is then placed on a stable platform within a testing machine or microscope equipped with a Vickers hardness tester. A predetermined load is applied, and the resulting indentation is examined using a microscope or optical system with a measuring scale. By measuring the diagonals of the indentation precisely, the Vickers hardness value can be calculated using the formula:

Vickers Hardness = 1.854 * (Load / (Indentation Diagonal) ^2).The material's resistance to plastic deformation brought on by the indenter can be better understood thanks to this. The Vickers hardness test is commonly utilized across various industries and disciplines to assess the hardness of metals, ceramics, and certain polymers

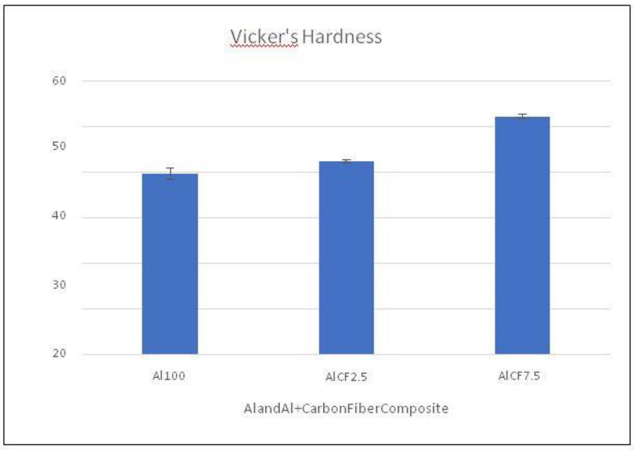
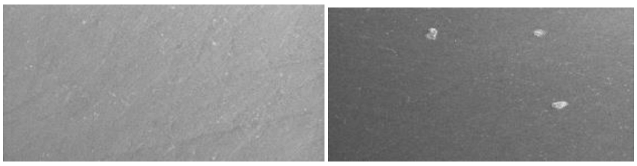



Fig.7 Vicker's Hardness Test Result

## 8. FESEM AND EDX RESULTS

FESEM and EDX tests are powerful analytical techniques used to investigate the surface morphology and elemental composition of materials. FESEM is a type of scanning electron microscopy that utilizes a focused beam of electrons to obtain high-resolution images of a material's surface. It offers detailed information about surface topography, grain structure, and particle distribution. The sample is prepared by mounting it on a sample holder and coating it with a conductive material to enhance imaging quality and minimize charging effects. The FESEM instrument



A1100 AlCF2.5

Figure 9. EDX Images of the samples

## 9. CONCLUSION-

1 The project aimed to develop aluminium-carbon fiber composites with exceptional properties, including light weightness and excellent hardness.

1 An extensive literature survey identified various challenges and limitations in existing approaches

2 A comprehensive methodology was formulated, involving the use of powder metallurgy techniques

3 The raw materials, aluminium, and carbon fiber, were uniformly mixed using a ball milling process to create a new composite material

4 Mechanical characterization tests confirmed that the composite displayed the desired characteristics and was well-suited for use in industries like Aerospace and Automotive

5 Density and hardness tests were conducted, and the results were plotted on a graph for better visualization and comparison

6 SEM and EDX tests provided detailed two-dimensional images of the sample's microstructure

7 The project demonstrated significant progress in achieving the objectives, with the density decreasing as the reinforcement percentage increased, while the overall hardness increased with an increasing percentage of carbon fiber

8 The outcomes of the project contribute to the advancement of knowledge and have the potential to impact various fields where high strength-to-weight ratio and weight effectiveness are crucial

9 In conclusion, the project successfully developed aluminium-carbon fiber composites with exceptional properties, providing valuable insights and potential applications in industries such as Aerospace and Automotive

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