Synthesis of Newly Formulated Aluminium Composite through Powder Metallurgy using Waste Bone Material

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Abstract. The increasing concern for sustainable materials and waste management has led to innovative approaches in material science. This study explores the potential benefit of aggregate waste in the production of aluminum composites practicing powder metallurgy techniques. The aim is to investigate the feasibility of incorporating bone material into aluminium matrices to enhance the composite's mechanical properties. The research involves several key steps. Firstly, waste bone material is collected and processed to obtain a fine powder suitable for powder metallurgy. Various techniques such as grinding, milling, or pulverization are employed to achieve the desired particle size distribution. Next, the bone powder is mixed with aluminium powder in predetermined ratios to create composite blends. The composite blends are then subjected to compaction using powder metallurgy techniques, including cold pressing and sintering. The compaction process aims to consolidate the powders and facilitate the formation of a solid composite structure. The aluminum composites mechanical characteristics are then assessed. The effects of incorporating bone material are assessed using tests on tensile strength, ductility, hardness, and other relevant mechanical properties. Comparative analysis is performed between the composites with bone material and traditional aluminium composites to assess any improvements or changes in performance.

1. Introduction

Aluminum composite (AC) refers to a type of material that is commonly used in the construction industry for various applications such as building facades, interior decoration, signage, and cladding. It is made up of two thin aluminum sheets bonded to a non-aluminum core material, which can be polyethylene, fire-retardant mineral-filled core, or other materials

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depending on the desired properties. The main advantage of aluminium composite is its versatility and flexibility in design. It can be fabricated into various shapes and sizes, and can be customized to meet specific project requirements. It is also lightweight and easy to install, making it a popular choice for construction projects. AC is known for its durability, weather resistance, and low maintenance requirements. It is also fire-resistant and can be designed to meet fire safety standards. However, as with any building material, there are also some concerns about the safety of AC, especially when it comes to the use of combustible core materials. In some regions, regulations have been introduced to restrict or ban the use of certain types of AC to ensure safety standards are met. AC reinforcement refers to a type of material used to reinforce structures, typically in the construction industry. It is constructed of two thin aluminium sheets bonded to a non-aluminum core material such as polyethylene or a mineral-filled core. The combination of the aluminum sheets and core material creates a lightweight, yet strong and durable material that is commonly used in building facades, signage, cladding, and insulation. The aluminum sheets provide a protective outer layer, while the core material provides additional strength and insulation. One of the advantages of AC reinforcement is its versatility, as it can be shaped into various forms and can be customized to meet specific project requirements. Additionally, it is weather-resistant, fire-resistant, and easy to maintain. However, in recent years, there have been concerns about the safety of AC reinforcement, specifically related to the use of combustible core materials. This has led to increased regulation and scrutiny of the material in some regions. Animal bones become calcining at high temperatures to remove organic materials and leave a calcium phosphate residue, that is what bone ash is made. This residue is then ground into a fine powder and can be used in various applications, including as a reinforcement material in composite materials. Bone ash is known for its high compressive strength, bio compatibility, and ability to promote bone growth. As a result, it is often used as a reinforcement material in bone grafts, dental implants, and other medical applications. In composites, bone ash can be recycled as a filler or reinforcement to raise mechanical properties such as strength, stiffness and durability. It might be used to make composites with improved qualities by mixing it with such various matrix materials as polymers, ceramics, and metals. However, there are still several difficulties associated with using bone ash as a reinforcing ingredient in composite structures. Bone ash is a brittle material, and as a result, it may not be suitable for applications that require high toughness or impact resistance. Additionally, the use of animal bones as a raw material can addition ethical and environmental concerns. Overall, bone ash has unique properties that make it a promising reinforcement material for certain applications, particularly in the medical field. However, before employing bone ash as a reinforcing material, due attention should be given to the individual application needs as well as any ethical and environmental considerations. The use of waste materials as reinforcements in composite materials has gained popularity in subsequent years. This strategy has a number of potential merits, such as lowering waste, encouraging sustainability, and possibly enhancing the composite material's mechanical properties. Examples of waste materials that have been studied as potential reinforcements include recycled plastic, glass fibers from recycled bottles, agricultural waste such as rice husks and corn stover, and industrial waste such as fly ash and slag. Recycled plastic, for example, can be used as a filler or reinforcement in composite materials such as concrete or asphalt. Glass fibers from recycled bottles can be used as a reinforcement in polymer composites. Agricultural waste can be processed to extract fibers that can be used as a reinforcement in polymer composites, while fly ash and slag can be used as a filler or reinforcement in cement and concrete. The use of waste materials as reinforcements in composite materials has the potential to not only reduce waste and promote sustainability but also to improve the properties of the resulting composite. For example, waste materials can often be less expensive than traditional reinforcements, and they may also offer unique properties that can enhance the performance of the composite. However, the use of waste materials in composite reinforcement must be carefully evaluated because the properties of the final material might be highly reliant on the exact characteristics of the waste material and how it is treated. Additionally, environmental and safety concerns must be considered when using waste materials, particularly if the waste material contains hazardous substances. PradeepKumarKrishnan et al, said, A unique stir-squeeze casting method was utilised to successfully make aluminium metal matrix composites (AMMCs) in a recent study. It was investigated if it would be possible to employ spent alumina catalyst (SAC) from used oil refineries and vehicle scrap aluminium alloy wheels (SAAWs) as matrix materials. For comparison objective, a composite was also produced using aluminum alloy AlSi7Mg (quality LM25) as matrix and aluminum oxide as reinforcing particles in a stir draw casting process[AlSi7Mg + alumina, aluminium alloy scrap + alumina, AlSi7Mg + spent alumina catalyst, and aluminium alloy scrap + spent alumina catalyst] were all modified and characterised as composites.[1] Arunkumar et al, The hybrid composite material contains calcium oxide, which is tougher than carbide particles, is current in organic egg shell. Compared to synthetic materials, it's much less dense and has a higher natural strength. Compared to SiC and alumina particle reinforcement, egg shell density is reduced. [2] R. Akash et al, Aluminium matrix composites are commonly utilised in an array of industrial and automotive applications due to their availability, high strength-to-weight ratio, and exceptional wear and corrosion resistance. The composite is reinforced to increase tribological and mechanical qualities while remaining cost effective. Applying the components Al2O3 and Sic, aluminium can form internal connections between the matrix and reinforcement. In this study, a powder metallurgy process is employed to manufacture the new material, aluminium is used as the matrix material, and waste Al2O3 material from the oil refinery business serves as reinforcement [3]. Bhaskar Chandra Kandpa et al, These composite materials are in increasing demand from industry due to their enhanced properties. In this study, we have provided an overview of metal matrix composites proving various industrial/agricultural-based wastes available in industry and agriculture. The need for a variety of more troops, including fly ash, coconut shell ash, and bagasse is hazardous and ash, is now high in the industrial sector for many technological operation, particularly those in the building, automotive, and sporting goods industries [4]. Awss A. Abdulrazaq et al, Agricultural waste (date palm seeds) and dolomite rock at 2.5, 5, 7.5, and 10 wt% in addition to the aluminium matrix were used as reinforcing elements. We looked at the morphological and solid-phase characteristics of the AMC samples that had been made. The procedures involved consist of optical microscopy, scanned microscopy, and diffraction of X-rays. Because the PM approach was sufficient to embed the decay particles into the aluminium, the microscopic structure of the samples made for both reinforcements demonstrated a consistent particle size distribution among the waste reinforcements. The fabricated AMCs were subjected to various mechanical loads and the date palm seed reinforced composites were found to have high hardness properties. [5] Neelima Devi Chinta et al, Industrial waste called red mud (bauxite residue) is produced when alumina is processed using Bayer's method. Through the powder metallurgy procedure, efforts have been built to use industrial solid waste as reinforcement in aluminum metal matrix composites. Some high energy ball mill was used to mill red mud acquired from NALCO to a nano level of 42 NM after being sieved for micron levels of 100, 150, and 200 m. Samples are produced using a vacuum as the medium during conventional sintering with varying weight ratios of 2%, 4%, and 6% red mud. Pure Aluminium Powder and Micro and Nanostructured Red Mud Powder are blended in a V-Blender and compressed to a pressure of 40 bar [6]. V.S. Aigbodion et al, The development of aluminum-metal matrices depends greatly on biocomposites, which are the subject of intense global research and development. Environmentally benign, renewable, biodegradable, and economically advantageous are bio reinforced composites. Due to its low density, low cost, and widespread availability as an agricultural waste, bean pod ash (BPA) can be seen as a possible accelerator for the creation of bio composites. For use in automotive applications, this study examined the manufacturing, mechanical characteristics, wear behaviour, and fatigue properties of aluminium matrix composites (AMCs) with BPA nanoparticles [7]. Udaya Devadiga et al, the characteristics of fly ashes (FAs) in this study are made using the powder metallurgy technique and composites made of aluminium and reinforced with carbon nanotubes (CTS) were analyzed. Tests for the specimen's mechanical features were conducted when it comes to density, hardness, and compression. According to the experimental findings, adding FA can enhance hardness by 8 wt.% and then drops, while the composite's hardness drops as the CNT content rises [8]. Santosh Kumar Tripathy, and Ajit Kumar Senapati, the industrial waste that includes red mud, fly ash, and cenosphere ash-like material is regarded as reinforcement. Numerous studies have connected industrial waste to mechanical and tribological characterization of metal matrix composites consisting of aluminium alloys.However, very few researchers have studied industrial waste reinforced aluminium matrix composite machinability research [9]. M.G. Ananda Kumar et al, powder metallurgy is used to create cenospheric components for aluminium metal matrix composites (AMC), which are made of aluminium powder. Cenospheric composites with a volume percentage of 10–50% continue to be prepared and dry-pressed in a hydraulic press. Microwave sintering was used to compress the composite. The sintered composite's thermal and porosity percents were measured. Testing for thermal shock resistance (TSR) and coefficient of thermal expansion (CTE). Prior to and following thermal shock cycling, the composite's compressive yield strength (MPa) remained constant [10]. Anand Kumar Gummadi et al, Al6082 is a base material that is used to reinforce the boron carbide (B4C) particle. Al6082 and B4C metal matrix composites were created using the powder metallurgy (PM) method. These mixed powders of the chosen B4C fractions with weight ratios of 0, 3, 6, and 9% are first processed in a ball mill before being compressed for a cold process with sustaining conditions of 80 bar and 9.81 KN. These MMC specimens were then subjected to the sintering process to create the magnesium boron carbide composites [11]. Y. F. Fuziana et al, the findings indicated that Al 6061's green density was lower than its pure form. The green density rises as the ball mill speeds up for 100, 150, and 200 rev min-1. This samples were subsequently sintered at temperatures of 500, 550, and 600. As compared to samples with higher green densities and smaller, less apparent porosity, the microstructure of 100 rev min-1 shows larger and more frequent porosity [12]. Abhijit Pattnayak et al, this effort concentrated on using RHS for the powder metallurgical creation of Al-SiO2 composites. Clean rice husks were heated to temperatures of 6000 °C (RHS1) and 10000 °C (RHS2), and the resulting RHS was then characterised by XRD. RHS2 was crystalline in contrast to RHS1, which was amorphous [13]. S.T. Mavhungu et al, this research paper provides an overview of the progress and movement in aluminum matrix composites for industrial function. Composite have well-known in the industrial and automotive sectors as high-strength, lightweight parts. Ultimately, this results in the creation of parts made of sophisticated materials that function and operate more effectively [14]. R. Seetharam et al, for numerous deformation characteristics such axial strain, relative density, formability stress index, as well as various stress ratio parameters under the circumstances of tri axial stress state, experimental data are presumptive. During hot upsetting, the formability and compression behaviour were examined based on the axial strain (z) [15]. In this research work, the bone ash is prepared and added into the Aluminium alloy powder to produce composites using powder metallurgy process. The percentage of reinforcement is kept constant to find the best value [16-18]. After a successful manufacturing, mechanical characteristics like tension and rigidity are investigated and reported.

2. EXPERIMENTAL PROCEDURE

2.1 Fabrication of samples

Nanotubes are ground into amazingly fine powders using the ball milling grinding approach. Localized high pressure is developed during the ball milling process when the tiny rigid balls collide in a hidden container. Stainless steel, flint pebbles, and ceramic are usually used. To acquire a fine powder, it had to work at 300RPM for an hour.

Fig. 1. Ball milling process

Mixing of reinforcement as per the calculation, we have to mix the matrix (aluminium) and reinforcement (bone ash)

Fig. 2. Measurement of Aluminium and bone ash

Fig. 3. Aluminium and bone ash mixture

Due to the powder metallurgy the compaction had to be done for compressing the mixed. Powders into a solid 4000kg weight had to be applied for the compaction.

Fig. 4. Sintring

Sintering is the process of compressing and producing a solid mass of substance without melting it to a state of liquefaction. A muffle burner is typically a front-loading container or pipe design used for high-temperature applications like melting glass, generating enamel coatings, technical ceramics or soldering and brazing. It had to be warmed at 500 degrees Celsius for 2hours and 30 minutes. In numerous research centres, it is also used to identify the not flammable and non-volatile components of a sample, such as ash in it. The rapid temperature line of high temperature furnaces can now produce operating temperatures of up to 1,800°C (3,272°F) for more demanding applications like degreasing, sintering, etc. Thanks to advancements in heating element materials like molybdenum disilicide. Metallurgical applications are possible, end-to-end metal injection molding process.

2.2 WIRECUT ELECTRIC DISCHARGE MECHINE (EDM)

When working with metal, electrical discharge machining (EDM), also known as spark erosion, die-sinking, wire burning, or wire EDM, employs electrical discharges (sparks) to produce the desired forms. A series of quickly recurring electrical discharges between two electrodes separated by an electrically charged, dielectric liquid remove material from the workpiece. The tool electrode or electrode and the workpiece electrode, sometimes known as the workpiece and two electrodes. There is no actual contact between the tool and the workpiece in this procedure. Arcing is brought on by the dielectric breakdown of the liquid and an increase in the intensity of the electric field between the two electrodes as the voltage between them rises. By doing this, the electrode's substance is removed. Depending on the generator type, a fresh liquid dielectric is pumped between the electrodes when the current fails, clearing away any solid debris and restoring the dielectric's insulating qualities. Flushing is a term used to describe the addition of fresh liquid dielectric to the inter-electrode volume. The voltage across the electrodes restores to its pre-breakdown value after current flow, allowing the liquid dielectric to degrade once more and the cycle to continue.

Fig. 5. Wire-cut Electric Discharge Machine

Fig. 6. Final Wire-cut Electric Discharge Process

2.3 Compression Test

Compression tests include any testing in which a material is compressed, "squashed," shattered, or otherwise flattened while being subjected to opposing forces that push inward against the specimen from the opposite side. These tests were carried out by loading the test specimen of two plates and then implementing force by moving the crossheads together. As this is normally placed of two plates that evenly distribute the applied load throughout the full surface area of two opposite test faces, a universal test machine presses the plates together, flattening the test sample. Typically, a compressed sample develops perpendicular to the force and is shortened in the direction of the applied forces. The more popular tension test is essentially the opposite of a compression test.

2.4 Hardness

Hardness testing is used in mechanical engineering to measure the deformation hardness of materials. • For hardness testing, each specimen conned to be indented 3 times for 10 seconds and T. Force=200(gf). To ascertain whether a material or material treatment is appropriate for its intended use, hardness testing enables the evaluation of material attributes which includes strength, ductility, and wear resistance. "A test that determines the resistance of a material to permanent deformation by penetration of another harder material" is the precise meaning of a hardness test.

3 RESULTS AND DISCUSSIONS

3.1 COMPRESSION TEST

The compression test generates a load-deformation curve that represents the response of the AC under compressive forces. The curve typically shows an initial linear elastic region, followed by plastic deformation and eventual failure. Compressive Strength: The maximum stress reached during the compression test is the compressive strength about the composite. It hint the material's ability to resist compression before failure occurs. Higher compressive strength implies better resistance to deformation and higher load-bearing capacity. The yield strength corresponds to the stress at which plastic deformation begins. This marks the point at which the material changes from elastic to plastic behavior. Pressure testing provides data about the deformation behavior of materials by Strain Hardening or Strain softening. It helps understand how the composite responds to increasing compressive forces and whether it exhibits ductile or brittle behavior. The following Figure shows the compression test results of 4 composite samples.

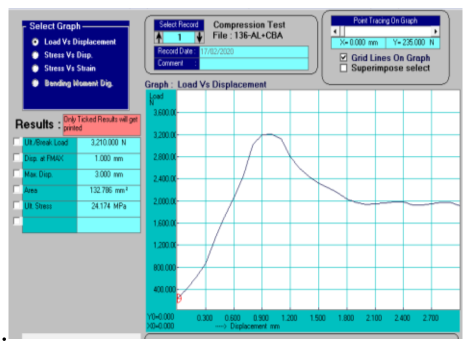

Fig. 7. Compression test for mutton Load Vs Displacement

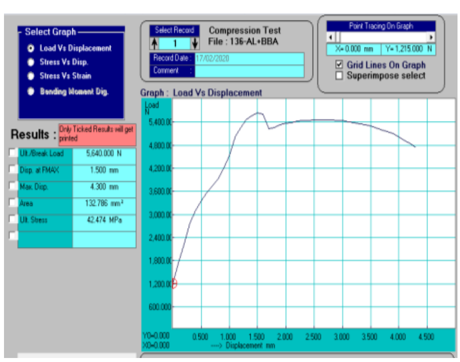

Fig. 8. Compression test for chicken Load Vs Displacement

 https://doi.org/10.1051/e3sconf/202339903016

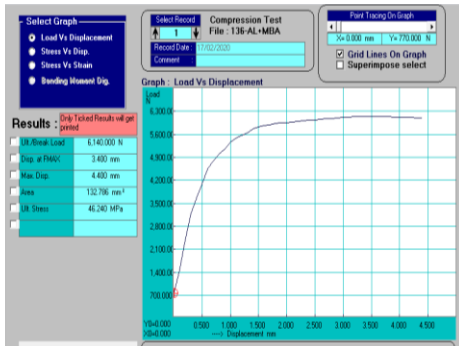

Fig. 9. Compression test for Beef Load Vs Displacement

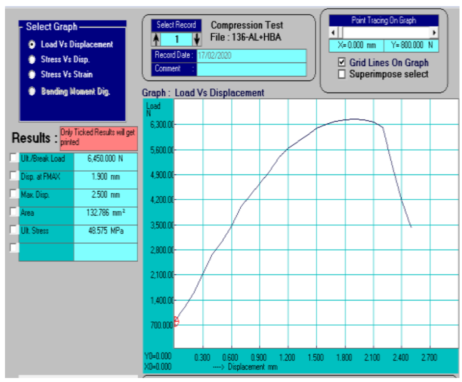

Fig. 10. Compression test for Hybrid Load Vs Displacement

The results can be compared with the properties of the base aluminum material to assess the effectiveness of incorporating the waste bone material. Any improvements or deviations in compressive strength, yield strength, or deformation behavior can be discussed. If different compositions of bone material were used, the influence of varying bone content on the mechanical properties can be analyzed. It helps determine the optimum bone material ratio that provides the desired enhancement without compromising the overall performance. If the composite samples exhibit failure during compression testing, a fracture analysis can be conducted to understand the failure mechanism. The discussion may cover features like crack propagation, fracture surfaces, and the role of bone material in influencing the failure mode. The compression data are compared with existing studies on similar composites or other materials produced using powder metallurgy comparatively elevated properties are achieved.

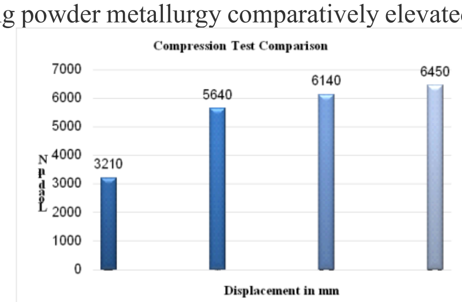

Fig. 11. Compression Test Comparison

The hardness test, commonly conducted using techniques such as the Vickers or Rockwell hardness test, provides a numerical value that represents the material's hardness. This value indicates the resistance of the aluminum composite to indentation or penetration by an indenter. Multiple hardness measurements can be taken across the aluminum composite to create a hardness profile. This profile helps identify any variations in hardness within the composite and provides insights into the homogeneity of the material. To determine the effect of including the spare bone material, the hardness value of the aluminum composite may be compared on the base aluminum material. The significant changes or improvements in hardness are discussed. The different compositions of bone material were used, the influence of varying bone content on the hardness of the aluminum composite are analyzed. The discussion may focus on the relationship between bone material content and hardness, aiming to identify the optimum content for desired hardness improvements. To comprehend the total material performance, the hardness values are compared to other mechanical properties like yield strength or tensile strength. Higher hardness values may show increased mechanical strength and durability in addition to improved resistance to indentation and compressive forces. The elevated properties may be attribute with the help of uniform distribution and reinforcement of the bone ash powder within the aluminum matrix. The maximum hardness number is achieved for the hybrid composite.

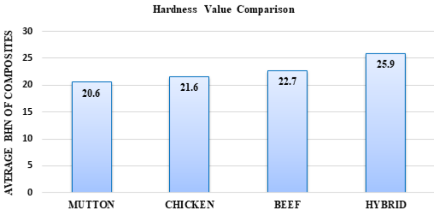

Fig. 12. Hardness Value Comparison

4 CONCLUSIONS

Because of their excellent mechanical properties, aluminum metal matrix composites are becoming more popular across a variety of industries. In the aerospace, military, automotive, marine, and other domestic applications, aluminum metal matrix composites are preferred. The numerous reinforcements used in powder metallurgy to generate aluminum metal matrix composites have enhanced mechanical properties, including ultimate tensile strength, compressive force, hardness, and wear rate. Because it can produce close to net shapes and generates small material waste, powder metallurgy is its best fabrication technique for MMCs. A several aspects of the mechanical features of aluminum MMCs manufactured using the powder metallurgy technique have been attempted to be combined in this survey. Among various samples prepared the hybrid aluminium composite showed better results for hardness. The hardness value of hybrid composite is 25.9. The maximum compression strength Aptian in hybrid composite of 6450N

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