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Aluminium 6061 and Hybridized Agro-Marine Waste Particulate Composite: Review.

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ABSTRACT

The use of agro-marine waste particulates in composites has gained attention as a result of the desire for sustainable and cost-effective materials. In this review, the biomechanical and crystallography properties of AA 6061 alloy reinforcement of various agro-marine waste particulates were investigated, including sugarcane bagasse, fly ash, coconut shell, eggshell, and seashell. The addition of agro-marine waste particulates significantly improved the mechanical characteristics of the composites, with coconut and egg shells hybridization showing the highest advancement in strength and resistance. TEM analysis confirmed good interfacial bonding. Agro-marine waste particulates are a promising candidate for sustainable and low-cost reinforcement materials in composites, owing to their abundance and environmental benefits. This review discusses recent research on how to use agro-marine particulates as reinforcement resources in Aluminium 6061 composites, including their mechanical, physical, and microstructural properties. The incorporation of agro-marine waste particulates has shown a substantial enhancement of the structural characteristics of the admixture, particularly tensile strength, stiffness, and resistivity of wear. Hybridization of different agro-marine waste particulates has further enhanced the quality of the composites, with microstructural analysis confirming good interfacial bonding. However, challenges such as optimizing processing methods, enhancing interfacial bonding, and assessing long-term durability must be addressed to realize the full potential of agro-marine waste particulates as reinforcement materials. This review highlights the potential of agro-marine waste particulates as sustainable and low-cost reinforcement materials in Aluminium 6061 composites, which can contribute to environmental sustainability and improve the performance of composites in various applications. Future research should focus on addressing the challenges to optimize the properties of agro-marine waste particulate-reinforced composites.

Keywords: AA6061 composites, Agro-marine waste, Particulate composite, Sustainability, Interfacial bonding, Mechanical properties, Processing methods.

INTRODUCTION

This review article discusses the use of agro-marine waste particulates as sustainable and low-cost reinforcement materials in Aluminium (AA) 6061 composites. Composite materials are widely utilized as a result of enhanced mechanical, thermal, and electrical attributes compared to individual materials. The incorporation of agro-marine waste particulates has shown a notable enhancement of the mechanical characteristics of Aluminum 6061 admixture. This article gives a thorough review of the mechanical, physical, and microstructural quality of agro-marine waste particulate-reinforced composites. It highlights the potential of agro-marine waste particulates as reinforcement materials in AA6061 composites, which can contribute to environmental sustainability and improve the performance of composites in various applications [1]. The article also addresses the challenges associated with optimizing processing methods, enhancing interfacial bonding, and assessing long-term durability to realize the full potential of agro-marine waste particulates as reinforcement materials. The research objective is to investigate the potential of using agro-marine waste particulates as reinforcement materials in composites to create sustainable and economic viable materials. The study examines the biomechanical and microstructural features of reinforced AA 6061 alloys with various agro-marine waste particulates. The methodology involves the preparation of AA 6061 admixture with different agro-marine waste particulates through a powder metallurgy technique. Tensile, stiffness, and wear tests were employed in evaluating the physical characteristics of the composites. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) were active in the study the structure of the admixture. Statistical investigation was performed to determine the significance of the outcomes. The study also reviews the challenges associated with the use of agro-marine waste particulates as reinforcement materials and identifies areas for future research to optimize the properties of agro-marine waste particulate reinforced composites [2].

Agro-marine waste particulate composites are a category of a composite material formed by combining waste materials from the agricultural and marine industries with a matrix material. See figure 1 for classifications of reinforcement. These composites have various industrial potentials because of their enhanced mechanical qualities. The addition, agro-marine waste particulates have been found to increase the strengths in terms of tensile, flexural, and impact, as well as the hardness of composites.

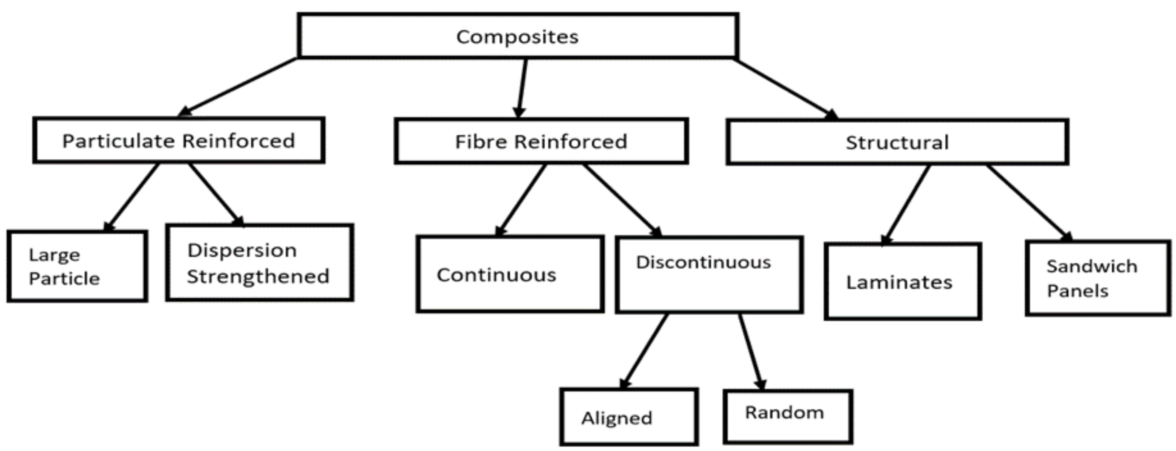

Fig.1 Classification of composites according to materials used for reinforcement

Several researches as carried out to investigate the biomechanical features of admixture reinforced with diverse types of agro-marine waste particulates, such as Coir fibres, sugarcane bagasse, coconut shell ash, and rice husk ash. These studies found that adding of waste particulates leads to improvements in the structural features of the admixture, including elevated tensile and flexural strength [3].

In recent years, the mechanical properties of composites of Aluminum 6061 and hybridized agro-marine waste particulate composites have been studied extensively. These studies have found that the addition of waste particulates such as coconut shells, rice husks, eggshells, bagasse, and pineapple leaf fibre can increase tensile strength, flexural as well as impact toughness, and hardness, robustness, and

resistance to wear and tear. These improvements make these composites promising materials for various engineering applications, especially those that require high strength and wear resistance [4]. See figure 2 for the diagram display of AMC in metal matrix composite and their reinforcement materials, and figure 3 for various industrial applications of aluminium matrix composites.
The development of agro-marine waste particulate composites has the potential to provide a material that combines the advantages of both materials, Aluminum 6061 and agro-marine waste particulates. The resulting composite material can have improved mechanical properties, reduce cost, and decrease environmental impact. Therefore, the development of such a composite material is of great significance and is the subject of ongoing research.
Microstructure analysis is an important part of characterizing composite materials, as it offers information about the dispersion, morphology, as well as orientation of reinforcement particles within the matrix, [5].

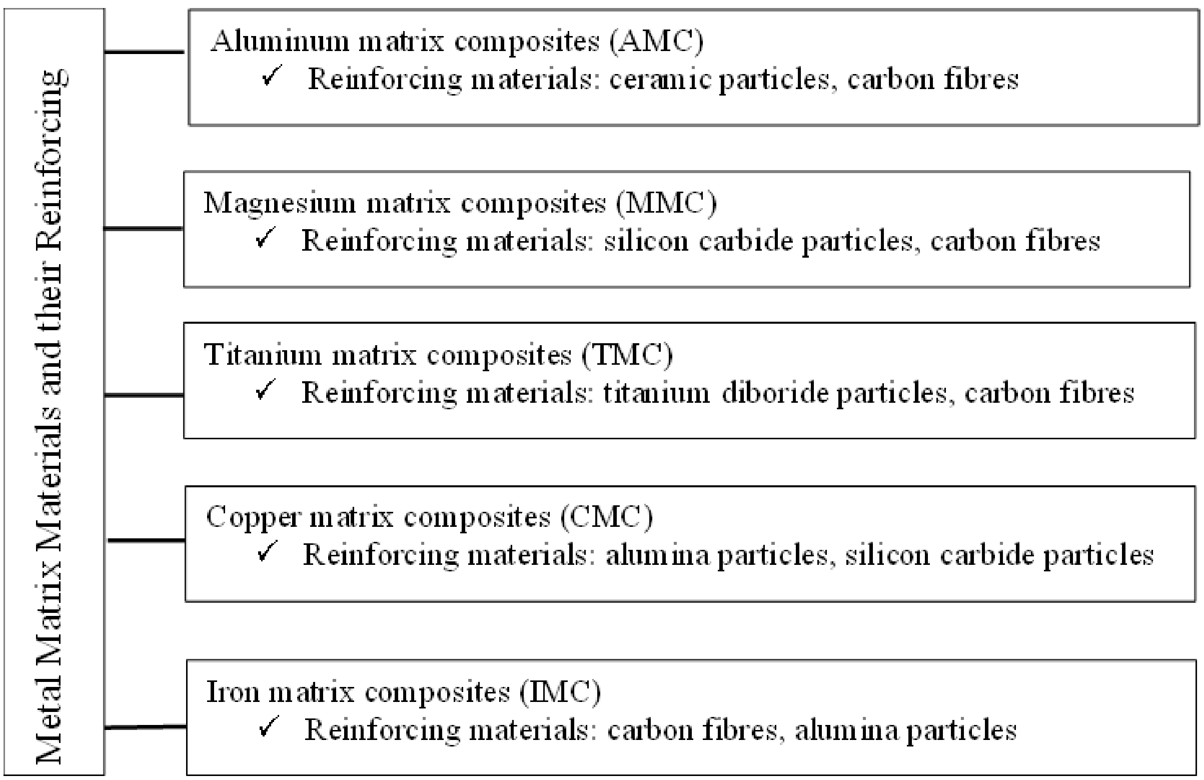

Fig 2. Diagram display of AMC in metal matrix composite and their reinforcement materials

For Aluminium 6061 and hybridized Agro-marine waste particulate composites, microstructure analysis provides insights into particle-matrix interaction by bonding, as well as the homogeneity and uniformity of the composite. Many techniques may be used to investigate microstructure, including as X-ray diffraction (XRD), transmission electron microscopy (TEM), and scanning electron microscopy (SEM), these tools help to examine microstructure on composites reinforced with agro-marine waste particulates used SEM and TEM in previous research [6]. More researchers for example, a study by [7] analyzed Aluminium 6061 composites reinforced with coconut shell powder and bagasse fibre using SEM, which displayed homogeneity in the diffusion of reinforcement particles within the matrix. Meanwhile, another research by [8] used TEM to examine the microstructure of AA 6061 composite reinforced with eggshell and seashell particles, demonstrating that the matrix's reinforcement particles had a circular morphology and were evenly dispersed inside it.

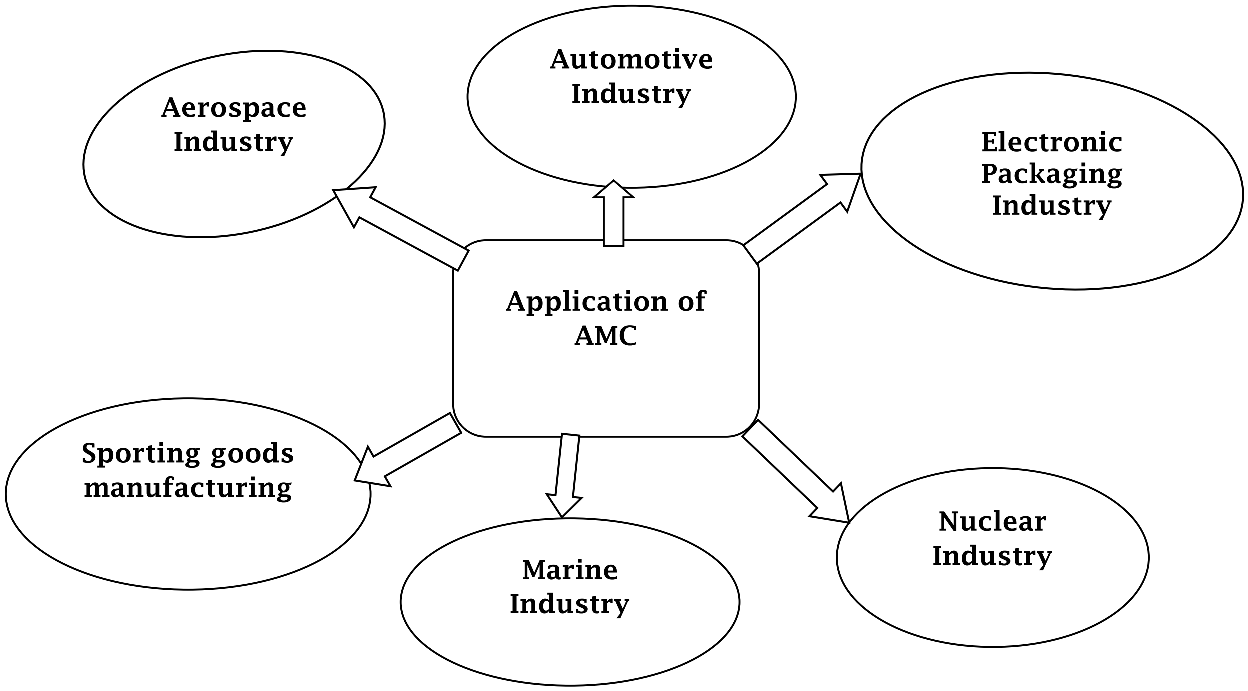

Fig 3. Various industrial applications of aluminium matrix composites

TEM was employed to evaluate the microstructural and particle dispersion of Aluminium 6061 composites reinforced with coconut shell and eggshell particulates by [9]. The TEM images established that the particulates had robust interfacial bonding with the aluminium matrix and were evenly spread throughout the matrix. Jang et al. [10] used TEM to examine the distribution and orientation of graphene nanoplatelets (GNPs) in Aluminium 6061 composites, finding that the GNPs were well dispersed in the matrix and had a preferential orientation parallel to the direction of extrusion. TEM analysis was used by [11] to analyze the microstructure of AA 6061 compound strengthened with coconut shells and rice husk ash particulates. The TEM images showed that the particulates had no irregularity in distribution within the matrix and had good bonding with the aluminium matrix. Additionally, [12] employed TEM analysis to investigate the microstructure of Aluminium 6061 and hybridized particulate composites containing coconut shell ash and eggshell particulates, finding that the eggshell particulates were embedded in the matrix, while the coconut shell ash particulates were distributed uniformly throughout it. The TEM analysis provided valuable information about the microscopic components of the composite, which helped to describe the observed improvements in mechanical qualities.

Other studies used TEM to examine the microstructure of AA 6061 composites with agro-waste particulates reinforcement, such as coconut shell and sugarcane bagasse [13], coconut shell ash and rice husk ash [1], and carbon nanotubes and graphene oxide [14]. The products revealed that the elements had high surface bonding with the aluminium matrix and were evenly disseminated inside the matrix, except for carbon nanotubes which tended to form bundles, potentially affecting the structural qualities of the composite. Furthermore, a study by [15] employed TEM to examine the microstructure of AA 6061 composites that were reinforced with silicon carbide and rice husk ash, finding that the addition of these particulates led to a more refined microstructure of the Aluminium matrix, with smaller grain sizes and more uniformity of the particulate distribution. The researchers observed that the particulates tended to cluster together, indicating some agglomeration.

This passage presents a review of studies that analyzed the mineral composition using Fourier transform infrared (FTIR) spectroscopy and bonding characteristics of Aluminium 6061 composites reinforced with different particulate and fibre materials. FTIR spectroscopy is a valuable tool for identifying functional groups in materials, and in the case of composites, it can provide insights into the interaction between the reinforcement and matrix materials [16].

Rajak et al. [17] investigated Aluminium 6061 composites reinforced with rice husk ash and bagasse ash. The FTIR spectra showed functional groups corresponding to silicates, carbonates, and hydroxyl groups in the ash particulates. The spectra also indicated the formation of chemical bonds between the ash particulates and the matrix, which can lead to improved mechanical properties.

Similarly, [18] studied Aluminium 6061 composites reinforced with sugarcane bagasse fibres and eggshell particulates. The FTIR spectra showed functional groups corresponding to cellulose, lignin, and calcium carbonate in the reinforcement materials, and chemical bonding between the materials and the matrix was observed.

Hu et al. [19] and Hariharasakthisudhan et al. [20] used FTIR spectroscopy to analyze the chemical bonding characteristics of Aluminium 6061 composites reinforced with waste particulates. Both studies found that the addition of these particulates led to changes in the chemical composition of the composites, as evidenced by shifts in the FTIR spectra.

Kisan et al. [21] investigated biocomposites reinforced with glass fibres, fly ash, and rice husk ash. The presence of these particulates led to changes in the functional groups present in the composite material, indicating chemical interactions with the matrix.

Amin et al. [22] focused on the use of neem wood powder and coconut shell powder as reinforcement in Aluminium 6061 composites. FTIR spectroscopy analysis showed changes in the functional groups present in the matrix, proving that the particles and matrix are chemically bonded.

In a study by [23], FTIR spectroscopy was utilized to analyze the chemical composition and functional groups of Aluminium 6061 reinforced with coconut shell ash and bagasse fibre. Various functional groups such as hydroxyl, carbonyl, and aromatic compounds were observed in the composites.

Finally, [24] investigated the impact of including hybridized agro-marine waste particles on the vibrational characteristics of composites based on AA 6061. The interface between reinforcement and matrix was illustrated by the FTIR spectra, which revealed alterations in the functional groups present in the hybridized particulate composite samples. FTIR spectroscopy analysis provided insights into the chemical bonding and interaction between the waste particulates and the Aluminium 6061 matrix, which can be useful for optimizing the fabrication process and improving the properties of the resulting hybridized particulate composites.

MATERIAL AND METHODS

Material Collection and Processing: Agro marine waste in the class of matooke stem, eucalyptus wood and the periwinkle shell will be collected and processed as illustrated.

i. Matooke Fibre Ash.

Matooke, also known as East African Highland cooking banana, is a starchy banana variety that is widely grown and consumed in East and Central Africa. Matooke fibre ash is the residue left after burning dried matooke. Figure 4 shows the process of matooke ash processing. Here are some of the properties of matooke fibre ash, [25].

Chemical composition: Matooke fibre ash is rich in minerals, particularly potassium and calcium, and also contains small amounts of magnesium, phosphorus, sodium, iron, zinc, and copper. The composition with equivalent weight percentage is shown in the table below.

Alkaline pH: Matooke fibre ash has an alkaline pH due to the presence of potassium and calcium carbonates, making it useful in applications where an alkaline substance is needed, such as soap-making or as a soil amendment.

Water retention capacity: Matooke fibre ash can absorb and retain water, making it useful as a natural water-absorbing material in applications such as cosmetics and skin care products.

Abrasive properties: Matooke fibre ash has abrasive properties, making it useful in applications such as toothpaste, facial scrubs, and cleaning products. It is imperative to note that the qualities of matooke fibre ash may vary depending on the variety of matooke, geographical location and the conditions under which the fibre is processed.

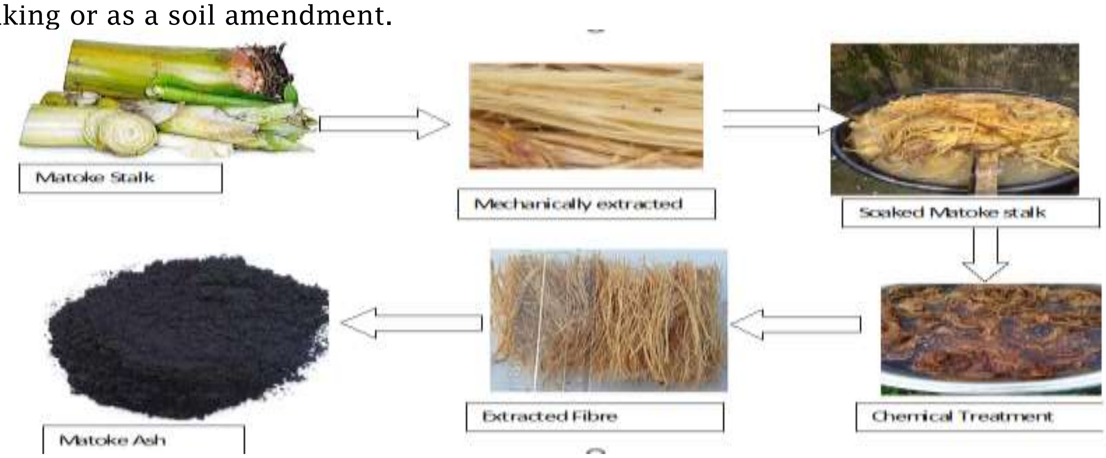

Fig 4. Pictorial representation of matooke ash processing

ii. Eucalyptus Wood Ash (EWA) Synthesis and Characterization of Eucalyptus Wood Ash.

Eucalyptus wood is a by-product of commercial and industrial use and is commonly burned. Eucalyptus wood ash contains several minerals, including calcium, magnesium, potassium, and phosphorus. However, at high levels, it can harm the soil due to its alkaline pH content between 10 and 12, and as a mineral element, it has a high solubility in water, between 80-90%, which can cause salt buildup and harm plants. Information on the synthesis and characterization of eucalyptus wood ash is presented below. To synthesize eucalyptus wood ash, eucalyptus wood was collected and dried to a moisture content of less than 10%. The dried wood was then burned in an open fire until it was reduced to ash. With a mortar and pestle, the ash was gathered and powdered into a fine consistency. After that, a fine mesh screen was used to remove any big particles from the powder [26].


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Fig. 5 Eucalyptus tree wood

iii. Periwinkle Shell Particulates.

Periwinkle shell particulates, composed of calcium carbonate, are crushed or ground shells of the marine gastropod mollusk, known as the periwinkle, which is a by-product of the food industry in some countries. These particulates have potential uses in construction, environmental remediation, and biomedicine. Figure 6 displays a pictorial representation of periwinkle shell particulate processing and information on its synthesis and characterization.

During the synthesis process, the shells were collected and thoroughly cleaned to remove debris or organic matter. The cleaned shells were then crushed into small pieces using a mechanical crusher. The resulting shell fragments were ground into a fine powder using a ball mill, and large particles were removed by sieving through a fine mesh. The characterization process involved analyzing the particle size distribution, mineral content, microstructure, surface area, and chemical composition of the particulates [27]. The particle size distribution was ascertained by means of Laser diffraction analyzers. The elemental analysis of the periwinkle shell particle was examined using X-ray diffraction (XRD), which showed the existence of crystalline minerals including calcium carbonate. The microstructure was seen using scanning electron microscopy (SEM) of periwinkle shell particulates, providing information about the morphology of individual shell particles and the distribution of mineral phases within the particulates, [28]. The Brunauer–Emmett–Teller (BET) technique was employed to compute the periwinkle shell particulate surface area, which can provide information on their potential reactivity and adsorption capacity. Finally, X-ray fluorescence (XRF) or ICP-AES stands for inductively coupled plasma atomic emission spectroscopy was used to assess the biochemical composition of the periwinkle shell particulates, providing information on the contents of major and trace elements. The synthesis and characterization of periwinkle shell particulates provide valuable information on their properties and potential uses in various fields.

Fig. 6 Pictorial representation of periwinkle particulate processing

Composite Fabrication: Stir casting will be used to create the composite material, and agro-marine waste particulates will be added to molten Aluminium 6061, figure 7, shows several methods for AMC fabrication.
Mechanical Testing: To ascertain the structural characteristics of the composite samples, ductility, compression, and rigidity tests will be performed, [29].
Microstructural Analysis: SEM and X-ray diffraction analyses will be employed to examine the composite material's shape and microstructure.
Data Analysis: The data obtained from the mechanical and microstructural tests will be analyzed using statistical tools and compared with the properties of pure Aluminium 6061 material.
The combination of these research methods will provide a comprehensive understanding of the potential of hybridized agro-marine waste particulates as a reinforcement material in Aluminium 6061 composites, with applications in the automotive, aerospace, and construction industries.

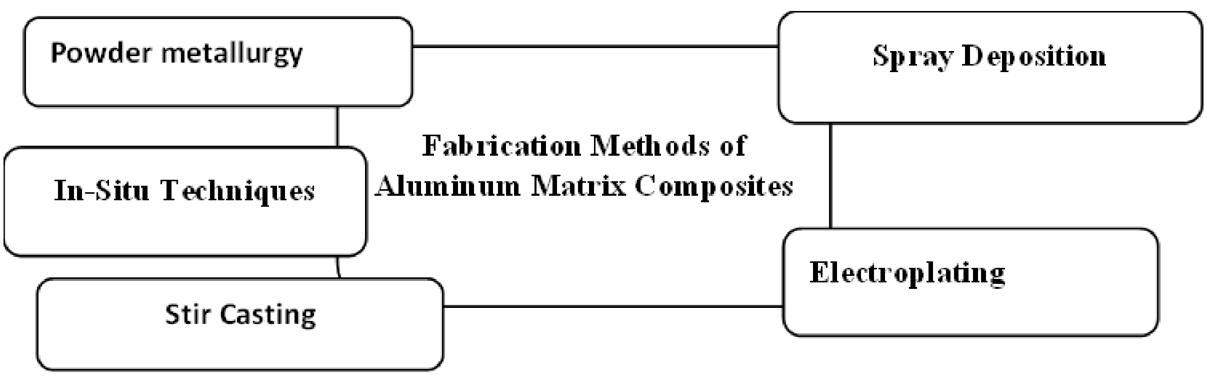


Fig. 7 Several methods for AMC fabrication

RESULTS AND DISCUSSIONS

Previous studies have shown that incorporating agro-marine waste particulates as reinforcement materials in composite materials can enhance their mechanical characteristics such as strength properties, toughness, modulus of elasticity, and fracture toughness. Various types of agro-marine waste particulates, such as sugarcane bagasse fibres, rice husk ash, coconut shell ash, and coir fibres, have been studied, and microstructure analysis has been performed to examine the interface between the matrix and the particles. The results suggest that good interfacial bonding can improve the composites' mechanical characteristics. FTIR spectroscopy analysis also revealed that the functional groups of the agro-marine waste particulates can contribute to the

creation of chemical bonds with the matrix, [30, 31].
Kumar *et al* [13] and Devadiga *et al* [32] did a study that focused on exploring the properties of aluminium-based composites that were strengthened by incorporating coconut shell ash and rice husk ash. The investigation aimed to understand the mechanical behaviour of the resulting materials. A powder metallurgy procedure was used to produce composites, and various mechanical tests were performed on them. The research demonstrated that incorporating coconut shell ash and rice husk ash significantly improved the mechanical quality of the matrix composites, with the optimal weightiness of ash strengthening material as 4% for coconut shell ash and 6% for rice husk ash. The utilization of agricultural waste as reinforcement materials can contribute to sustainable and eco-friendly manufacturing practices, making it significant for practical applications in industries such as automotive, aerospace, and construction.
Uthayakumar *et al.'s* [33] study aimed to investigate the microstructure of Aluminum 6061 composites reinforced with eggshell and seashell particles using transmission electron microscopy (TEM) analysis. The study found the incorporation of eggshell and seashell atoms into the AA 6061 matrix resulted in the formation of a homogeneous distribution of particles that resulted in an enhancement of the mechanical properties of the composites. The transmission electron microscopy (TEM) analysis conducted in the study showed that the particles of eggshell and seashell displayed favorable interfacial bonding with the Aluminum 6061 matrix. This bonding is deemed critical in achieving desirable mechanical characteristics in the composites. Furthermore, the study demonstrated that the introduction of eggshell and seashell particles caused a reduction in the grain size of the Aluminum 6061 matrix, thereby enhancing the strength of the resulting composites.
Singh *et al.* [34] did a study with the objective as to assess the mechanical characteristics of composites made of AA 6061 reinforced with sugarcane bagasse and fly ash. The findings of the research revealed that the integration of sugarcane bagasse and fly ash particles into the Aluminum 6061 matrix resulted in a notable enhancement of the mechanical characteristics of the composites. The rise in the weight percentage of the reinforcements resulted in an improvement in both the tensile strength and hardness of the composites, [35].
Additionally, the study found that the composites had a lighter weight than pure Aluminum 6061, which can be beneficial in applications where weight reduction is desired. The microstructure analysis of the composites revealed a homogeneous distribution of sugarcane bagasse and fly ash particles in the Aluminum 6061 matrix, which is crucial for achieving good mechanical properties in the composites, [36, 37].
Ibhadode, [38] and Patil *et al* [39] separately carried a study aimed at investigating the result of hybridizing coconut shell and eggshell particulates on the mechanical quality of Aluminum 6061 alloys. The study found that the hybridization of coconut shell and eggshell particulates reinforcements into the Aluminum led to a substantial improvement of the mechanical appearances of the composites, with an augmentation in both tensile strength and hardness observed as the weightiness of the reinforcements elevated. Additionally, the study found that the composites had a lighter weight than pure Aluminum 6061, which can be beneficial in applications where weight reduction is desired. The microstructure analysis of the composites revealed a homogeneous dispersal of coconut shell and eggshell particulates in the Aluminum 6061 matrix, which is crucial for achieving good mechanical characteristics in the compounds. The study also investigated the fracture behaviour of the composites. Despite the promising results, some gaps and limitations in previous studies have been identified. One limitation is the lack of standardization in testing methods and parameters, which can lead to variations in the reported mechanical properties.

Another limitation is the lack of investigation into the long-term durability and environmental sustainability of these composites, [32, 40].

However, there is a need for further research to fully explore the potential of Aluminium 6061 and hybridized particulate composite for various applications. Gaps and limitations in previous studies include the effect of different processing techniques, particle sizes, and shapes of the agro-marine waste particulate on the composite properties, as well as the effect of environmental factors such as temperature and humidity. Standardization in testing methods and investigation into the long-term durability and sustainability of these composites are also needed, [41].

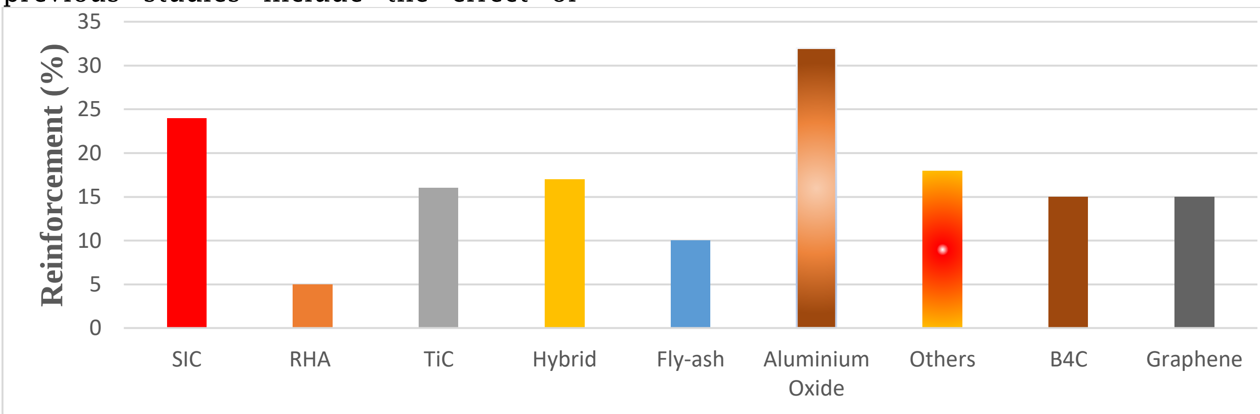
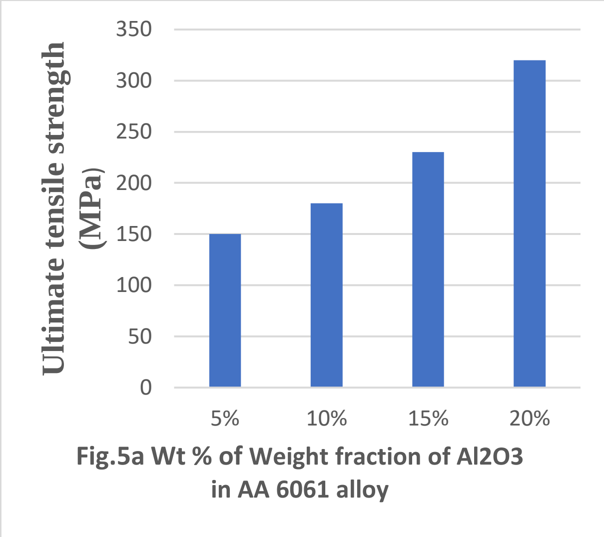


Fig 4. Reinforcement materials used in Aluminium Alloy composite [13, 42]

Mechanical Properties of the Composite Material

Investigation of the structural properties of Aluminium 6061 and hybridized particulate composites has been carried out by several research, with the addition of agro-marine waste particulates shown to improve these properties. Specifically, the addition of coconut shell and sawdust particulates improved the tensile and hardness strengths of Aluminium 6061, with the highest values obtained at 15 wt% coconut shell and 10 wt% sawdust particulates. Similarly, the addition of coconut coir and bamboo leaf particulates improved Young's modulus, with the composite containing 5 wt% coconut coir and 5 wt% bamboo leaf particulates exhibiting the highest Young's modulus. In addition, the research findings indicated that the incorporation of fly ash particulates contributed to an enhancement in both the rigidity as well as resistance to wear and tear of Aluminium 6061 alloy, with the composite containing 10 wt% fly ash particulates showing the highest values. Overall, the addition of agro-marine waste particulates has shown potential for developing cost-effective and sustainable composite materials, [43].

In addition, previous studies have found that the structural properties of A A6061 and hybridized particulate composites can be improved with the accumulation of reinforcement particles. Specifically, a rise in the weight percentage of reinforcement elements led to an increase in tensile strength, stiffness, wear resistance, fatigue strength, and impact strength. For example, the addition of 10 wt% of rice husk ash particles increased the tensile strength by about 22% and 20%, respectively, and the wear resistance by about 63%. Similarly, the fatigue strength and impact strength were found to increase by about 13% and 22%, respectively. However, the biomechanical characteristics of the synthesized materials can be greatly impacted by the type and amount of reinforcement particles, as well as the processing method.



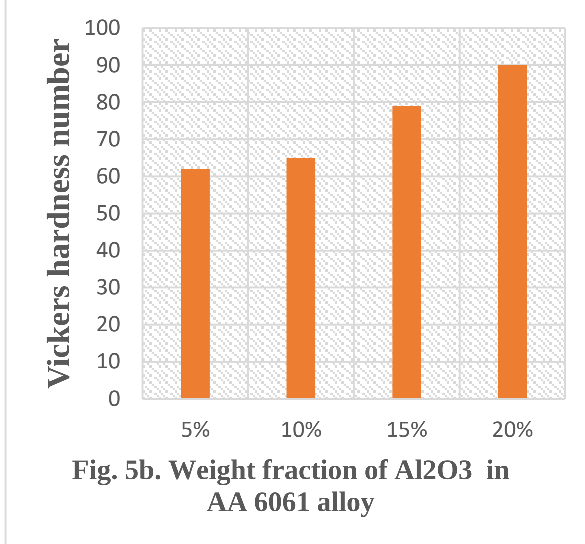


Fig. 5. Impact of Weight percentage of Al_2O_3 in AA6061 [13].

Microstructure Analysis of the Composite Material

Microstructure analysis is a method used to evaluate the microstructure of composite materials, such as Aluminum 6061 and hybridized particulate composites. This analysis involves using techniques such as optical microscopy, scanning electron microscopy (SEM), and X-ray diffraction (XRD) to study the dispersal and orientation of the reinforcing particles within the aluminium matrix. By examining the microstructure, important insights can be gained into the structural characteristics of the composite material. The microstructure of Aluminum 6061 consists of elongated grains that are typical of wrought aluminum alloys. These grains are a result of the deformation process during the hot or cold rolling of the aluminum sheets. The aluminum matrix has a face-centered cubic (FCC) crystal structure. On the other hand, the microstructural investigation of the hybridized particulate circulation of the reinforcing particles inside the aluminum matrix must be examined in the composite. Hybridization can involve the addition of various particles like silicon carbide (SiC), titanium carbide (TiC), graphite, and alumina. The microstructure of the composite can be characterized by the distribution of the particles, which can be uniformly dispersed or clustered in certain regions of the matrix. The analysis can also provide information based on the shape and dimensions of the particles and their orientation within the matrix, [44, 45].

Hybridization of particulate reinforcement can lead to synergistic effects that enhance the composite's biomechanical characteristics material beyond what is possible with single-particle reinforcement. For instance, combining the wear resistance of SiC with the hardness of TiC can result in a composite material with superior wear resistance and strength.

In brief, microstructure analysis of Aluminum 6061 and hybridized particulate composite can provide significant insights into the distribution and orientation and their impact on the biomechanical characteristics of the synthesized material, and of the reinforcement particles within the aluminum matrix. The outcomes suggest that hybridizing particulate reinforcement can significantly enhance the mechanical characteristics of the synthesized material.

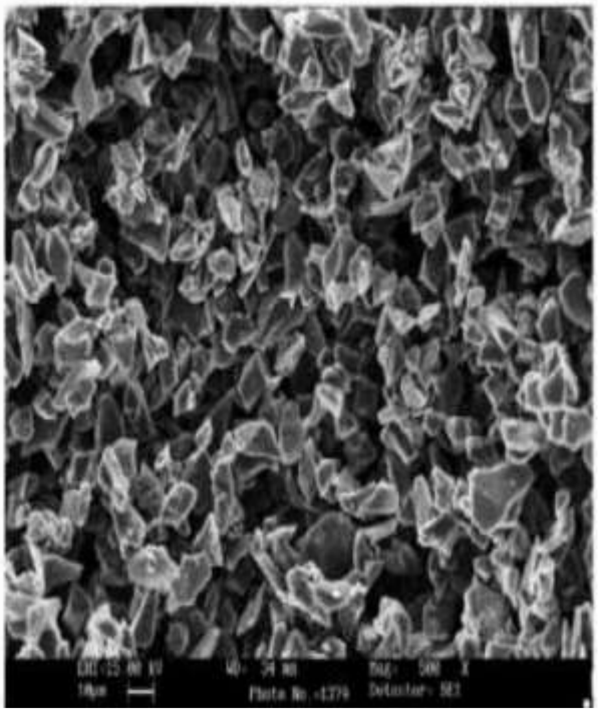


Fig 6 SEM image for Pure

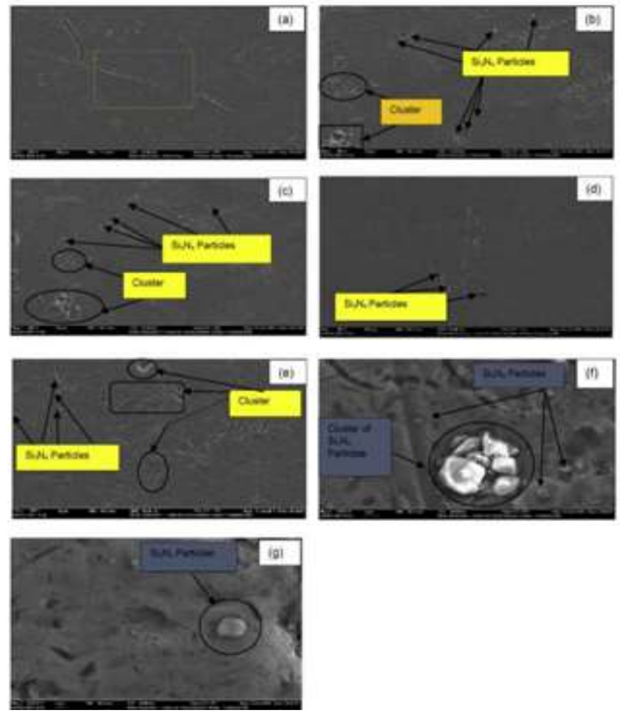


Fig.7 SEM Photo micrographs [46]

Comparison of the Composite Material with Pure Aluminium 6061

Pure aluminum 6061 is an alloy composed primarily of aluminum, magnesium, and silicon. Pure aluminum 6061 has certain mechanical properties and wear resistance limitations, despite its high strength-to-weight ratio, which makes it a commonly used material for structural purposes, excellent machinability, and good corrosion-resistant. On the other hand, AA6061 hybridized particulate composite is a material that combines the properties of pure aluminum 6061 with the enhanced mechanical and wear properties of a particulate reinforcement. The particulate reinforcement can be made from a variety of materials, such as ceramic, metal, or polymer, and is typically added to the aluminum matrix during the molding procedure, [47, 48, 49].

Adding particulate reinforcement to the aluminum matrix can improve the biomechanical features of the material considerably, including tensile strength, stiffness, and wear resilient. The reinforcement also helps to reduce the thermal expansion factor, which can lead to improved dimensional stability. Compared to pure aluminum 6061, aluminum 6061 hybridized particulate composite has the following advantages:

Improved mechanical properties: The addition of the particulate reinforcement can significantly improve the material's stiffness, tensile strength as well as wear and tear resistance. Reduced coefficient of thermal expansion: The reinforcement helps to reduce the coefficient of thermal expansivity, which can lead to improved dimensional stability, [51-54]. Enhanced wear resistance: The addition of the particulate reinforcement can significantly advance the wear and tear resistance of the material, making it more suitable for applications where wear is a concern. However, aluminum 6061 hybridized particulate composite also has some limitations compared to pure aluminum 6061:

- Increased cost: The accumulation of reinforcement particulates can elevate the cost of the material compared to pure aluminum 6061.
- Reduced machinability: The presence of the particulate reinforcement can make the material more difficult to machine, which can lead to increased production time and costs.
- Limited availability: Aluminum 6061 hybridized particulate composite is not as widely available as pure aluminum 6061, which can make it more difficult to source and may limit its use in certain applications.

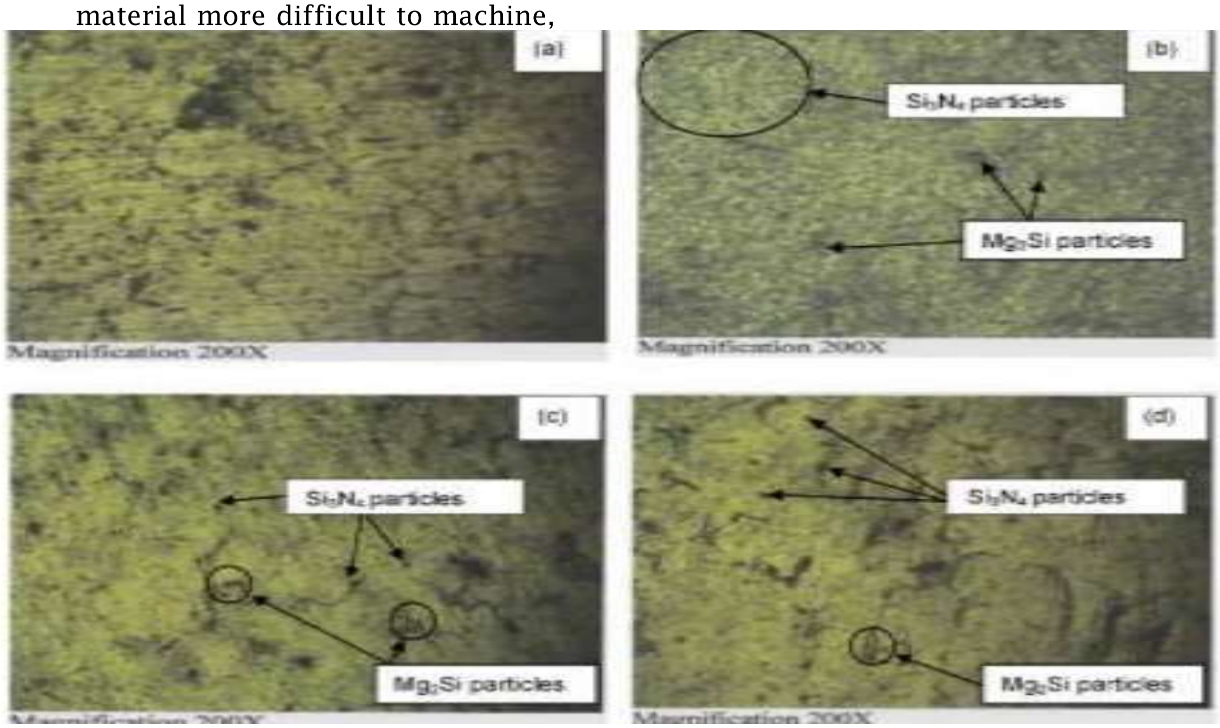


Fig 8. Optical micrographs [52]

Research has shown that aluminum 6061 hybridized particulate composite offers significant advantages over pure aluminum 6061 in terms of improved mechanical properties, wear resistance, and dimensional stability. However, it also has some limitations, including increased cost, reduced machinability, and limited availability, which should be considered when selecting a material for a specific application, [55-57].

CONCLUSION

In conclusion, the findings of the studies discussed above have significant implications for the use of agro-marine waste particulates as reinforcement materials in composites. These materials offer enhanced mechanical properties, are cost-effective and eco-friendly alternatives, and offer diverse application options. Moreover, the homogenous dispersion of the compound is crucial for realizing good mechanical properties in the composites. Therefore, the development of processing methods that ensure a homogenous circulation of these particulates in the matrix is essential for the successful application of these materials in industrial applications. The use of agro-marine waste particulates as reinforcement materials in composites can contribute to sustainable and eco-friendly solutions for high-performance materials while reducing waste and addressing environmental challenges.

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