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The Effect of Palm Fronds Waste Ash Particulate on the Mechanical, Thermal and Acoustic Insulation Features of Polymeric Composites

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Abstract

We have used Palm frond base Ash Waste Particles as a natural, safe, and non-toxic reinforcing material to enhance and improve the characteristics of the epoxy polymer matrix. We utilized Palm frond base Ash Waste Particles as a natural, safe, and non-toxic reinforcing material to enhance the characteristics of the epoxy matrix. Ash Waste Particles were used in weight fractions of 0, 2.5, 5, 7.5, and 10%. The outcomes showed that the process of reinforcing with Ash Waste Particles increased the tensile strength from 8.782 MPa to 23.253 MPa. Additionally, the hardness value increased from 58.875 (Shore D.) to 74 (Shore D.). For the pure sample, the thermal conductivity has decreased to 0.135 $Wm^{-1}°C^{-1}$ from 0.158 $Wm^{-1}°C^{-1}$. The transferred acoustic energy from side to side of the specimens (Acoustic Insulation Character) has reduced from 103.3 to 94.7 W/m^2 s. Finally, at the 10% weight fraction, the specimen's density value decreased from 1.557 to 1.208 g/cm3.

Keywords: Mechanical characteristics, thermal conductivity, acoustic insulation, palm frond waste.

1. Introduction

Composites are materials that have physically formed from two or more distinct phases, and the end product's material features are superior to those of the original materials that produced these composites [1-4]. In industrialization and engineering disciplines, composites find widespread application. Society's expanding needs dictate the use of these materials, such as metal, polymers, and ceramics, to achieve the best features [5, 6].

Composites have been used in multiple fields worldwide, including panels, frames, interior components, and other vehicle and machinery parts. Bridges, roads, and buildings are only a few applications for composite infrastructure [7, 9].

Polymer composites offer excellent mechanical strength, stiffness, and corrosion resistance. Compared to other materials used in a variety of applications, polymer materials have benefits. One of the beneficial characteristics is the combination of lightweight and strong strength, which reduces the overall weight to about 40% [10, 11]. Many benefits exist, such as low cost, easy processing, design flexibility, the ability to do many process cycles quickly, the ability to achieve strict dimensional stability, low thermal expansion, and very good resistance to fatigue and fracture [12–14].

Composites-based carbon has become a crucial component in various applications such as military, civilian, energy, medical, and environmental fields in recent times. Indeed, one can easily obtain a variety of polymer composites using inexpensive materials and equipment, which are characterized by easy processability and cost-effectiveness [15–18].

Physically combining two or more phases produces a composite material with exceptional features compared to its components. We produce composite materials by combining or integrating separate components or quantities that are independently distinct [19–23]. Contrary to metallic alloys, every component of a composite material has its own distinctive physical, chemical, and mechanical attributes [24, 25]. When compared to other materials, composite materials' main advantages are their extremely good strength and stiffness, which enable the final product to be lighter overall [26–28].

The physical morphology of the reinforcement material distinguishes two subcategories of composites: particulate-reinforced and fiber-reinforced composites. Very small particles in the microscale and nanoscale ranges reinforce the matrix in the particulate-reinforced composite. Physically, the particles could take the form of powder or flakes [5, 29, 30].

Particle size, particle-matrix interfacial adhesion, and particle loading all play a significant role in determining the mechanical properties of particulate polymer composites. Particle size affects these mechanical properties. For instance, filled polypropylene composites with smaller calcium carbonate particles have greater strength at a given particle loading [13, 31, 32].

Epoxy composites have a wide range of uses, particularly in high-performance, inexpensive, and lightweight goods that need to be strong and durable. Certain components of automobiles, boats, airplanes, and windmills are among the applications where using a material with higher strength and durability may be necessary due to the mechanical stress subjected to it [15, 20–25, 33].

The aims and objectives of this investigation are to improve the thermal, mechanical, and acoustic insulation properties of epoxy composites using palm fronds as base waste ash particulates. These particulates are a by-product of burning palm fronds as base waste, which results from the annual cleaning process of palm trees. This disposal method not only increases environmental pollution rates, but also provides a haven for harmful snakes, rodents, and scorpions that can cause harm or death to humans.

2. Materials and Methods

We prepared the Palm Fronds Base Waste Ash Particles (PFBWAP) by washing, drying, and completely burning the palm waste in a new meat grill. We then dried it at a temperature of 70 °C to eliminate any moisture. We ground the resultant powder several times using an electric industrial grinder until it reached a fine powder. We periodically flip the powder to ensure it remains fine.

We cut the palm tree waste into small pieces, washed it well several times with distilled water and a brush, and then washed it again with methyl alcohol to remove any dirt and dust that had adhered to it. The next step was to completely burn these pieces without using any other additives in a new meat grill until the material turned into ash and to ensure that there was no charcoal in the burned powder. Following the burning process, we ground the ash powder in an industrial grinder and sieved it through a laboratory shaking device. The laboratory sieve, which had a particle size of 75 micrometers, was used several times until it reached a fine powder. After that, it was dried at a temperature of 70°C to remove moisture, and the ash powder was periodically flipped in the oven.

We used a homemade scale with four digits, a plastic bottle (made from a cut-off plastic soft drink bottle) to measure the mass of samples submerged in water, distilled water, a glass platform to place the plastic bottle on, and a boiled potato masher with a plastic bottle cap attached to its top to measure the mass of samples in the air.

3. Result and Discussion

This section displays the mechanical, thermal, acoustic, and physical test results from the research. We will examine and conduct a scientific analysis of the research findings. In **Figure 1**, the X-ray diffraction diagram shows that the symbol (Ac) stands for the pure polymer sample and the symbol (P) for the polymeric composite sample that is strengthened by the ash powder of palm frond base waste particles. The symbol (A) indicates the ash powder sample used in the reinforcement process.

The reinforcing powder represents a multiphase or polycrystalline substance, whereas the epoxy material represents an amorphous phase. Regarding the polymeric composite sample, the amorphous phase (epoxy) was the primary phase. The regularity or crystallinity of the reinforcing particles influenced the polymer's qualities, particularly its thermal properties.

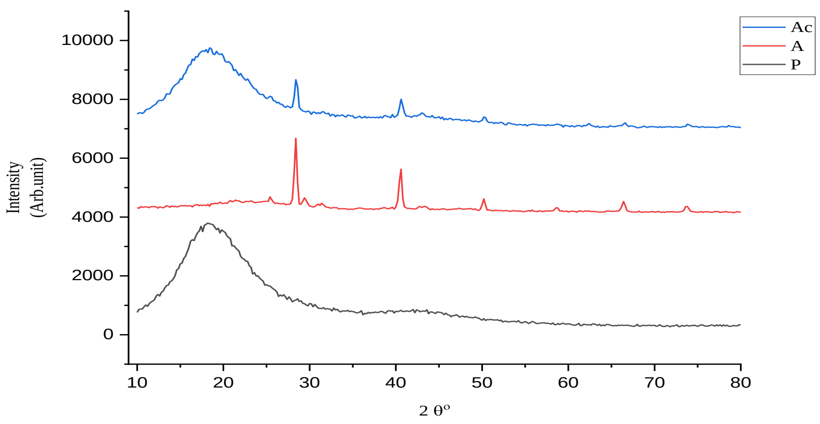

Figure .1. X-Ray Diffraction Diagram.

3.1. Mechanical Tests

The following shapes illustrate the behavior of the samples reinforced with Fronds base waste: The type (composition) of reinforcing material significantly impacts the properties of composite specimens. The type of reinforcement material (composition) has a significant impact on the prepared specimens' qualities, as the following figures demonstrate. In the pure polymer sample of epoxy, failure happens when the bonds in the epoxy matrix break down during the growth of primary cracks caused by outside stresses. The presence of reinforcing waste particles makes the composite materials better at absorbing energy and spreading it around.

This is because the polymer (matrix material) will be under most of the load. The polymer and other material particles will store most of the energy of the composite material's elastic tension (elastic strain). This is because they make the material harder to break and stop small cracks from spreading after being hit. As a result, the presence of reinforcement particles in the composite material increases its resistance to shock. **Figures 2** and **3** display the stress-strain curves of the tensile, tensile strength, and bending tests, respectively [34].

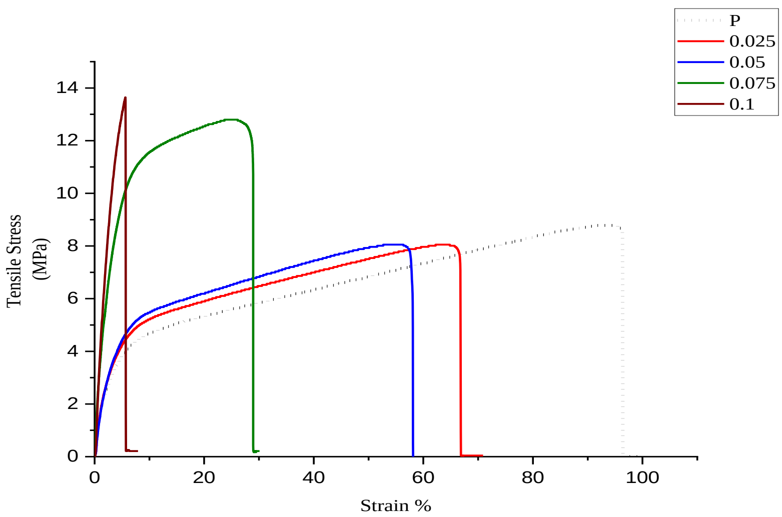

Figure 2. The Tensile Stress opposite Strain Diagram.

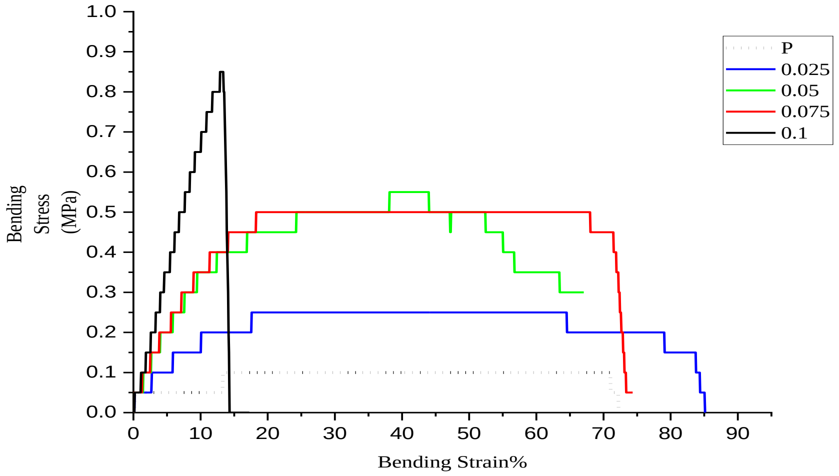

Figure 3. The Bending Stress opposite Strain Diagram.

It is also evident that the reinforcement process has led to an increase in the maximum tensile strength and a decrease in the ductility of the prepared samples. This is due to the breaking of the polymeric chains, the dispersion of the supported material particles, and the reduction of external forces and stresses. **Figure 4** displays the tensile strength of the specimens.

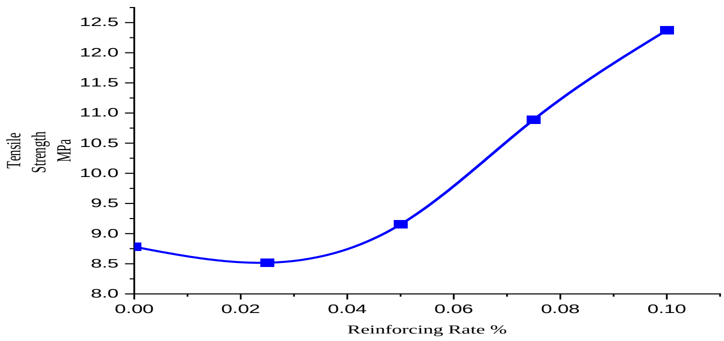

Figure 4. The Tensile Strength opposite Reinforcing Rate Diagram.

The effect of the polymeric chain breaking and the voids caused by the presence of the support particles at a ratio of 0% (pure sample) resulted in a stronger adhesion force between the support particles and the polymer particles than the increase in adhesion force caused by the mechanical bonding. As a result, the porosity overcame the forces of reinforcement; however, the mechanical bonding force grew as the reinforcement ratios increased, reaching its maximum value at the ratio.

The reinforcement process led to more than one effect at the same time. On one hand, the reinforcement strengthened the binding between the polymer molecules and chains with the strength of adhesion, which improved the mechanical properties of the samples in general. At the same time, the reinforcement created gaps and voids at the surface, which led to an increase in the wear rate of the samples, but the binding force increased with an increase in the reinforcement rate, which again led to a decrease in the wear rate. **Figures 5** and **6** show the wear rate behavior and hardness curves, respectively [16].

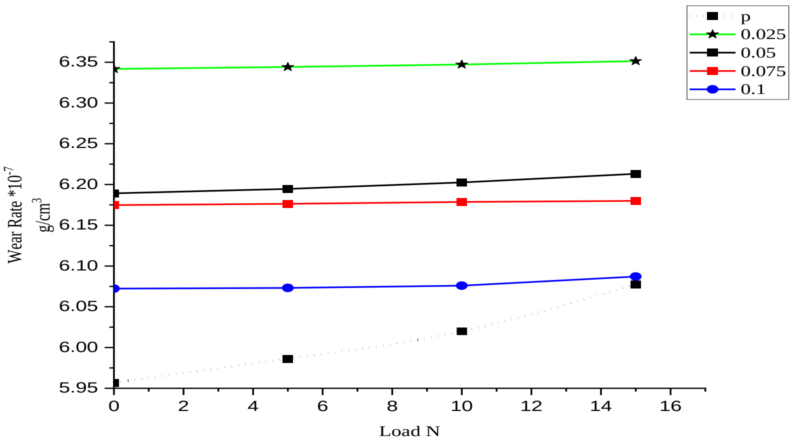

Figure 5. Wear Rate Opposite Reinforcing Rate.

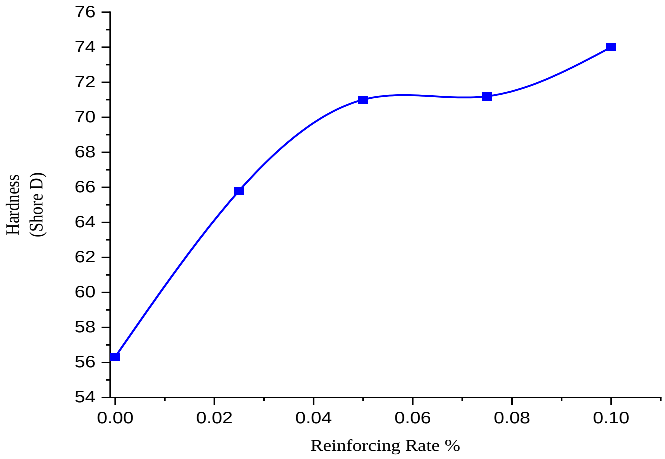

Figure 6. Hardness Opposite Reinforcing Rate.

3.2. Thermal Conductivity

The presence of voids and their subsequent size increase cause the reinforcement ratio to decrease the thermal conductivity value. This is because the absence of free electrons prevents or restricts the movement of phonons, responsible for the transfer of thermal energy within the insulating material [13].

The mixing process creates pores and voids, and the process of moving polymer particles and polymer chains away from each other or breaking the polymer chains makes the composite samples less heat-conductive [8], as shown in **Figure 7**.

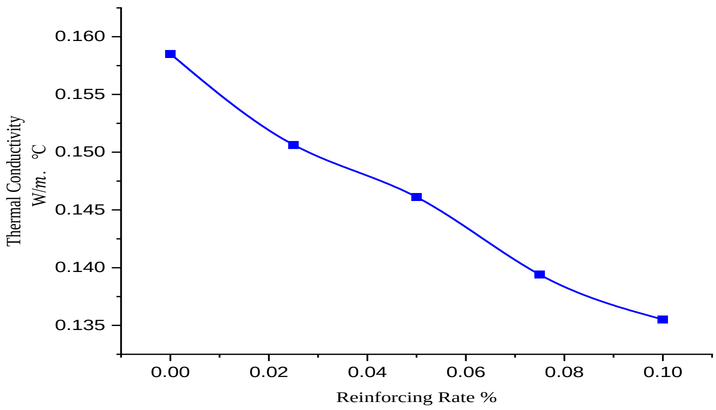

Figure 7. The Thermal conductivity opposite Reinforcing Rate.

3.3. The Density

The Archimedes method has been used to measure the density of the pure polymer specimen and the reinforcing specimens with different weight ratios. The results show that as reinforcement rates were increased, the density value decreased due to the low density of the reinforcing material (Ash) and the formation of porous and voids during the blending process. The pure specimen's density value decreased from 1.557 g/cm^3 to 1.208 g/cm^3 at the 10% weight fraction, as illustrated in **Figure 8**.

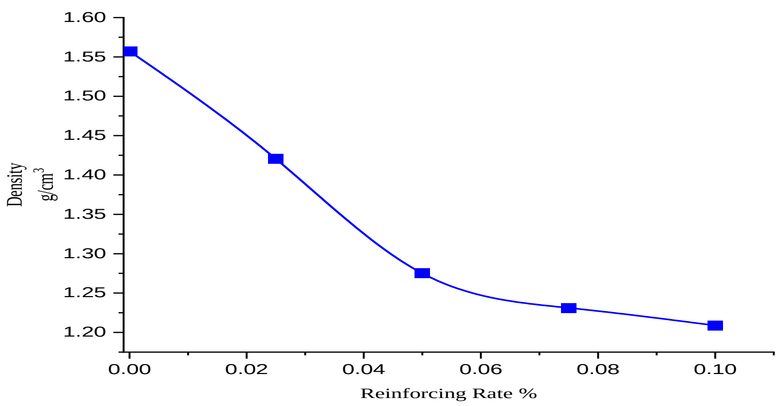

Figure 8. The Density opposite reinforcing rate.

3.4. Acoustic Insulation

The particles in the reinforcement material act as dispersal centers for acoustic energy passing through the sample. This makes the sample more acoustically insulating by slowing down the transfer of acoustic energy through it and, as a result, slowing down the transmission of energy to the other side of the sample, as shown in **Figure 9**.

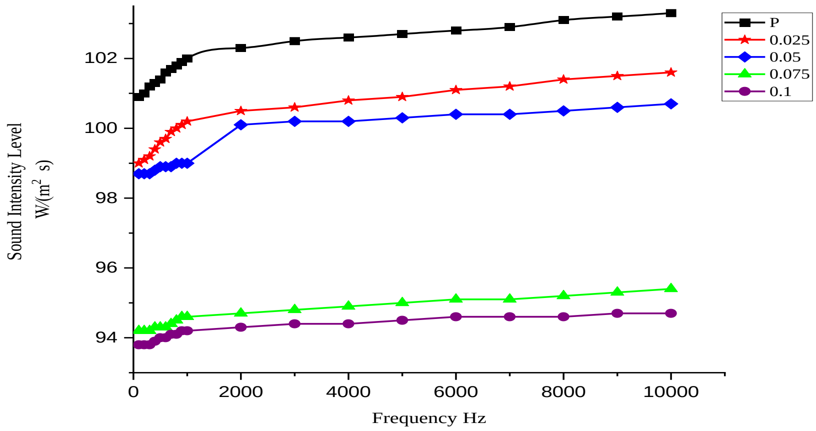

Figure 9. Sound Intensity Level Opposite Frequency.

4. Conclusion

In the current study, we concluded that the Palm Fronds Waste Ash Particulate (PFWAP) is a multiphase or polycrystalline material. By adding PFWAP to epoxy resin to make composite samples, the mechanical properties of the epoxy improved, such as its tensile strength, bending strength, wear rates, and hardness. However, the polymer became less flexible and less able to conduct heat. At the same time, the reinforced process has reduced acoustical energy transfer.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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