Study of physical properties of unsaturated poly ester Composites reinforced by Natural Fiber.

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Abstract

The research aims is to study the effect of natural fibers (palm fiber and eucalyptus leaves) as reinforcing Materials, with different volume creation, on the properties of the polymeric composite material of unsaturated polyester. Hand lay-up molding method was used to prepare research samples that were cut according to the standard specifications. Tests of thermal conductivity, acoustic insulation and water absorption were conducted. The results showed an increase in the thermal conductivity of the composites compared to the unsupported polymer and in proportion to the volume fractions and the duration of immersion in water. on the other hand, it was noted that reinforcing the polymer with natural fibers impedes propagation of the sound waves through the composite material at a fixed frequency of the sound source and increasing the volume fraction. while the acoustic insulation decrease for the fibrous composite and increases for the polymer with increasing sound frequency.

Key words:

UPE, Natural fiber, Volume fraction, thermal conductivity, Acoustic insulation, water absorption.
1- Introduction

Composite materials appeared in response to the requirements of tremendous industrial and technological development in contemporary life as alternative materials to alloys and metals. The composite material is a solid system consisting of two or more substances that do not react chemically but combine physically, and has improved properties from the properties of the materials involved in its individual composition[1]. The final characteristics of the composite material depend on three basic elements: 1- matrix material 2 - Reinforcement materials 3 - interface. The Matrix material can be metal, ceramic, or polymer, but polymer-Matrix composite materials are most commonly used for their high strength, light weight, good thermal, electrical and acoustic insulation, and their resistance to surrounding environmental conditions and damage for a long time making them the best in the manufacture of composites depending on the nature of the polymer and the type of Reinforced Material. [2] The reinforcement material can be synthetic fiber or natural fiber (fiber plants. The selection of natural fiber in the manufacture of composite materials such as a new trend for the use of natural resources as renewable materials (long-term sustainable materials) for low-cost and environmentally friendly materials.[3]

- Advantages and disadvantages of natural fiber composites:
  Natural fiber Reinforced have many advantages over industrial fiber Reinforced such as 1- lightweight 2 - low cost 3 - quality rigidity 4 - greater resistance to abrasion 5 - regeneration viability 6 - biodegradability 7 - good thermal, acoustic and electrical insulation 8 - reduce skin and respiratory irritation. [4]
  On the other hand, there are defects in the use of natural fiber in polymer Reinforced, including: 1- Incompatibility between

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hydrophilic natural cellulose fiber and hydrophobic polymers, which weakens fiber's attachment to polymer. 2- Irregular shape, i.e. natural fiber does not have the same cross sections along the fiber and this makes predicting mechanical properties difficult. 3- Its high absorption of moisture leads to a reduction in the treatment temperature and makes it unhelpful in high temperatures due to decomposition, which explains the overall properties of the overlapping material. (deterioration of mechanical properties). [5]

The presence of these defects makes the use of natural fiber overlays industrially limited, so it is required to evaluate and select the best components for natural fiber overlays in order to achieve better performance of these environmentally friendly materials to expand their applications in various fields of industry.

Studying the thermal properties of polymeric composite is important to determine the suitability of practical applications when used as thermal insulators, one of the most important thermal properties, is thermal conduction coefficient(K), polymers are poor in free electrons so heat transmission will depend on the vibration of or rotation polymer chain molecules and the nature of the reinforcement materials. Heat transfer is carried out by elastic waves called photons. It follows the Law of Fourier's law as in eq. (1). [6]

\[
Q = - KA \frac{dT}{dx} \quad \text{........................(1)}
\]

Where Q: quantity of heat (W)
K :thermal conductivity coefficient (W/m.\(^0\)K )
A:section area of heat flow (m\(^2\))
\[\frac{dT}{dx}\]: thermal gradient ( \(^0\)C/m )
When the sound falls on a substance, such as a separation wall, one part of the sound energy is reflected, another part is absorbed and another passes through the wall material to the other side. The ability of any material to pass the sound is called sound transmission, and the ability of the material to disperse the transmission of sound energy through it is called acoustic insulation, and is expressed by the Logartmi scale, and its unit of measure is (db). Acoustic insulation can be measured by a general law depending on mass of dividing barrier per unit of area and frequency adopted, and by eq (2) [7].

\[
\text{TL} = 20 \log(F \times m) - 48 \quad \text{.......................... (2)}
\]

Where : \text{TL} : \text{Acoustic Insolation (db)}

\text{m : mass per unit area (kg/m}^2\text{)}

\text{f : frequency (Hz)}

Polymer-matrix composite materials have more liquids absorption than metals and ceramics. Liquid molecules spread through the interface region or through cracks already present in the composite material and the weak bonding area between the polymer and reinforcement materials, in accordance with the First Ficks law. The amount of liquid absorbed increases linearly with the square root of the immersion period gradually and slowly until saturation is reached [8].

\[
F_x = -D \frac{dc}{dx} \quad \text{..........................(3)}
\]

Where: \text{F}_x : \text{flux of molecules (mol/cm}^2\text{.s)}

\text{D : diffusion coefficient}

\[
\frac{dc}{dx} = \text{concentration gradient}
\]
2. Materials and methods

2.1 Samples preparation

Unsaturated polyester resin was used as a matrix material, manufactured at Saudi Industrial Resins Company Ltd. And it is a transparent pink liquid, viscous at laboratory temperature, and thermosets polymers. Its density ($\approx 1-1.3 \text{gm/Cm}^3$), and turns into a solid state by adding the Hardener at $2 \text{gm per 100gm of resin}$ and after mixing the mixture well the polymer becomes ready. Palm fibers powder and eucalyptus leaves were used in a particle size less than or equal to $(212 \ \mu \text{m})$ and two volume fractions $15\%$ and $25\%$ as a reinforcement materials and after adding powders to the polymer and performing manual mixing and using an ultrasound device and conducting the necessary heat treatment, the research samples were cut according to the standard specifications and prepared for tests.

2.2: The Tests

- Thermal conductivity

A Lee-s Disc instrument manufactured at Griffin and George co. was used to set thermal conductivity coefficient ($K$), $K$ values were calculated by eq. (4) and (5)[9]

$$k \left\{(T_B-T_A)/ds\right\} = e \left[T_A+2/r (d_a+\frac{1}{4}ds) T_A+\frac{1}{2} r \ ds \ T_B\right] \ldots \ldots \ldots \ldots (4)$$

: $e$ Represents the thermal energy passing through the unit area per unit time ($\text{w/m}^2.0\text{C}$), and calculated using eq. (5)

$$H = IV = \pi r^2 e \ (T_A+T_B) + 2\pi r e \ [d_A T_A + ds\frac{1}{2}(T_A+T_B) + d_B T_B + d_C T_C] \ldots \ldots \ldots \ldots (5)$$

Where: $H=$ thermal energy generated in the heater ($J$)

$I :$ current passing through the circuit ($A$)
V: Applied voltage (V)

\[ T_A, T_B , T_C : \text{Temperature of the discs A,B,C respectively}(\,{}^\circ\text{C}) \]

\[ d_A, d_B, T_C : \text{Thicknesses of the copper discs A,B,C respectively (mm)} \]

\[ ds : \text{thickness of the sample (mm)} \]

\[ r : \text{disc's radius (mm)} \]

- **Acoustic insulation**

A special device was used to assign the part of the sound energy passing through each sample to the other side, including the identification of the acoustic insulation of the sample material by dropping sound waves and at a frequency that starts (100Hz) to (1000Hz) and using equation (2) the acoustic insulation of polymer samples and composites can be calculated.

- **Water Absorption**

To show the absorption of natural fibers overlays of water, the mass of each sample was set before immersion with water, then the samples were flooded in tap water and then set the sample mass after each time period and periodically for 4 weeks, using a balance that senses 0.0001gm. The percentage increase in the sample mass or the so-called profit in the mass is determined by eq. (6) [8]

\[
W.G = \frac{m-m_0}{m_0} \times 100 \quad \text{(6)}
\]

Where : W.G % : Weight Gain percentage

\[ m_0 : \text{mass of sample before immersion (gm)} \]

\[ m : \text{mass of sample after immersion} \]
3. Results and Discussion

* thermal conductivity

It is noted from figure (1), before immersion, that the thermal conduction coefficient $K$ for composite samples is higher than for unsupported polyester [$K = 0.4012 \text{ w/m}^2.\text{0C}$ with $5\% \ V_F$ and $(0.4457)$ for $25\% \ V_F$] supported by eucalyptus leaves powder, and [$K = 0.3688$ for $15\% \ V_f$, and $0.4053$ for $25\% \ V_f$ ] supported by palm leaf powder, while $K$ values of the unsupported polyester sample $(0.3541)$. presence of agglomerates of powders act as bridges that transfer phonons, so the thermal conductivity increases.$[10]$ Therefore, it must be ensured that the spread of powder particles in the polymer is homogeneous. After immersing the samples In water it was noticed that $k$ values were high for both polymer and composites. samples and were the highest for composite samples. Natural fibers are characterized by containing water-loving cellulose (Hydrophilic) and this facilitates the spread of water in the composite material and through the interface region and to the weak bonding areas of the matrix material, causing the bonds between polymer chains to relax and increase plasticity, which leads to weakening of the composite material and facilitates the movement of phonons, increasing the thermal conductivity transmitted by the vibrational and rotational motion of polymer molecular chains$[11]$
Fig. 1: variation of $K$ vs immersion time in $H_2O$

- **Acoustic insulation**

The results in figure (2) showed that the adding palm vibers powder and eucalyptus leaves to the polymer increased the acoustic insulation of the composite material in proportion to the volume fraction, and sound frequency stability. Acoustic insulation of polymer and composites decreases with increasing sound frequency, attenuate sound waves and cause them to scatter, thus increasing the resistance or impediment to the passage of sound through the composite material, thus increasing the acoustic insulation. On the other hand, acoustic insulation decreases by increasing the frequency, increasing frequency leads to an increase in the velocity of the sound waves passing through the material, so the impedance of the sound decreases and its waves flow and pass easily to the other side without dispersal, weakness or attenuation and thus the acoustic insulation decreases. [10]
Table 1 shows that the percentage of absorption of composites (W.G%) is higher than that of unsupported polyester, that polymers are inherently Hydrophobic while natural fibers are characterized by containing percentages of hydrophilic cellulose.[5] in addition to the fibrous composite have capillary property, which facilitates water permeability, as will as, its permeability through the micro-cracks originally present in the composite material, For all these factors, the water absorption rate of the composite material increases[8] It is also noted from the table that the mass of the composite supported by eucalyptus leaves powder with volume fraction of 25% after immersion is less than that of the sample with a volume fraction 15% and this is due to the occurrence of decomposition process of the substance (degradation).

**Water Absorption**

Fig. 2 : variation of Acoustic insulation VS Sound source frequency
Table 1: change of percentage of water absorption VS immersion time

<table>
<thead>
<tr>
<th>Sample</th>
<th>Immersion Time (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7</td>
</tr>
<tr>
<td>UPE</td>
<td>0.6415</td>
</tr>
<tr>
<td>UPE + Palm fiber powder 15%</td>
<td>2.537</td>
</tr>
<tr>
<td>UPE + Palm fiber powder 25%</td>
<td>4.376</td>
</tr>
<tr>
<td>UPE+ eucalyptus Leaf Powder 15%</td>
<td>3.0566</td>
</tr>
<tr>
<td>UPE+ eucalyptus leaf powder 25%</td>
<td>0.3782</td>
</tr>
</tbody>
</table>

Conclusions:

1- Reinforcing polymer with natural fibers and exposing them to water increases their thermal conductivity.

2- The acoustic insulation of polymer composites reinforced with natural fibers increases with the stable frequency of the sound source, while decreases with increases sound frequency.

3- Water absorption of the polymer reinforced with natural fiber increases because the added fibers contain hydrophilic cellulose.

4- Possibility of employing natural fibers in the manufacture of composite materials for industrial, constructional and environmentally friendly.
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