PREPERATION AND CHARACTERIZATION OF EPOXY RESIN AND WOOL FIBRE COMPOSITE

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Abstract

The idea of employing natural components from animal products (wool) to reinforce the epoxy resin was investigated in this study. The hand lay-up method was used to prepare composite material specimens. These specimens were represented by composite materials consisting of epoxy resin as a material matrix reinforced with wool in various volume fractions (0 %, 2.5 %, 5%, 7.5 %, 10%, 12.5%, 15%). Mechanical (bending) and physical (thermal conductivity) testing were performed. All of the tests were carried out at the lab's temperature. The findings of the specimen testing revealed an improvement in mechanical characteristics (bending) when reinforcing fibers were added, while physical tests revealed a modest rise in Conductivity values. Thermal visual examination of the samples was performed and we noticed that there is a good distribution of fibers in the prepared samples.

Keywords: composite materials, Bending Test, Thermal Conductivity, wool

Introduction

Since the previous decade, much research has focused on the creation of sustainable bio-composite materials in response to growing environmental concerns [1]. Bio-composites are composite materials made from living organisms. containing at least one biologically derived phase In terms of content, Plant fibers are commonly used to strengthen bio-composites[2][3]. Flax, bamboo, and hemp are examples of plant fibers, as are animal fibers like feathers [4][5]. wool received far less attention than other natural fibers among them.

Sheep wool is a material that is frequently utilized in the garment and textile industries. Except for the major wool production from pure Merino sheep , which ends up in the wool textile sector, huge volumes of coarse or semi-coarse type sheep reared in South Europe and Mediterranean countries lack the necessary nutrients textiles[6]. of high quality breeds' mean diameter fibers are not suited for garments because they belong to the dairy type. industry. These massive quantities of sheep wool can be considered a renewable resource because they are produced on a yearly basis. the waste that has been discharged into the environment. In Greece, about nine million dairy sheep are sheared once a year at the start of summer, resulting in an estimated13,000 tons of waste being abandoned in landfills or burned on the farm, increasing the environmental impact of the farms. The wide range of applications indicated by the abundance of fleece around the world . The idea of using wool to make composite materials is both ecological and environmentally benign because wool is a renewable resource. It encourages people to recycle[7].

Epoxy resin

Epoxy resin belongs to the group of thermosetting resins, where these resins are not able to be reformed by heat after turning into a solid material as a result of the formation of long polymeric chains intertwined with each other, which is called cross-linking. The epoxy resin has two or more Epoxide groups, each of which is made up of an oxygen atom bound to two carbon atoms, and the epoxy group is chemically coupled to other molecules to form a three-dimensional network that is cross linked during the curing process[8] .

Epoxy resin has a relatively high hardness and chemical resistance, as well as a high specific adhesion, due to the chemical composition of this resin, which is represented by ethers, hydroxyl groups, and polar groups, which provide durability and high adhesion, as well as give the material hardness and strength, so it is used in applications requiring high functional performance. These resins interact with hardeners during treatment, and the reaction does not emit water or liberate any by-products, resulting in little volumetric shrinkage (less than 2%), and the resin acquiring high strength and mechanical qualities. the treated epoxy resins have high strength, cross-linking sites, and Elephian chains inserted into them [8].

Experimental Work

1-The practical part includes the following:

a- Epoxy Resin: In this research, epoxy resin was used as the base material, which is a type of thermoset polymers. The type used (Epoxy Sikadur 52 LP) is of

Bahraini origin and is characterized by being a transparent liquid with low viscosity. Add the hardener in a ratio of 2:1 and a reaction occurs between them at room temperature. The mixture is thoroughly mixed with a metal rod for (5) minutes at a low speed until the mixture is uniformly homogeneous and prevents the appearance of bubbles.

b-Wool Sheep In this research, local natural wool was used as a reinforcing material, after cleaning it from dust and dirt and cleaning it with lukewarm water and cleaning means to get rid of fats and salts, then drying it at room temperature.

Preparation of Composites

The Hand Lay (Up Molding) technique was followed in the sample preparation process. Two types of materials were manufactured in the beginning. The composite materials were prepared without reinforcement. Then the composite materials were prepared by reinforcing the wool in different proportions. As for the manufacturing process for all, it was carried out as follows:

1-Make a basic template out of a clear polymer sheet (acrylic) with dimensions of 15 * 15 cm.

2- Cut 15 * 15 cm acrylic slices to use as a frame for storing the mixture while pouring.

3- Using fasteners (clamps or screws) to secure the acrylic slides to the base plate to avoid mixture leaking and to make it easier to remove the samples after they have hardened by simply removing the fasteners

4-A 2:1 ratio of epoxy resin to hardener was utilized, meaning that each (two gm) of epoxy resin corresponded to (one gm) of hardener.

5-The volume percentages added to the wool were used to weigh the quantities of the mixture of ingredients (epoxy, reinforcing material) (0, 2.5 ,5 ,7.5 ,10 and 15 %)

6- In a glass jar, combine these quantities. To avoid the emergence of bubbles, the mixing action must be slow and continuous for a period of five minutes until the mixture is well homogeneous. This liquid is poured in stages into the molds that have been prepared ahead of time, and pouring must be done slowly to avoid bubbles.

7- After pouring, the mold lid is installed and forcefully pushed with (clamps and screws) to eject excess epoxy from the mold and to keep it in place a constant sample size.

8- After the solidification process, which took 48 hours, the samples are removed from the molds.

9-The samples were removed from the molds and heated in an electric oven at 60 °C for two hours to reduce internal tensions, remove bubbles, and finish the crosslinking process between the polymeric chains.

10- They were cut into standard dimensions for mechanical and physical tests using a CNC machine and according to the specifications of the device used for examination, then the samples were smoothed with manual files to clean the edges and remove defects and scratches on the surface to be teady for the test.

Preparation Specimens Test

1-Bending Test Instrument

Bending test samples have been manufactured according to the standard specifications (ASTM-D790) shown in Figure (1). The curvature is tested using a three-point bending device as in Figure (2), in which the sample to be examined is fixed from its two ends on the two fulcrum points the masses is gradually applied to the holder in the middle of the sample between the two supports. Through a computer connected to the bending device, it can be read The deviation of the sample with known dimensions and then the calculation of the Yong coefficient for the samples.

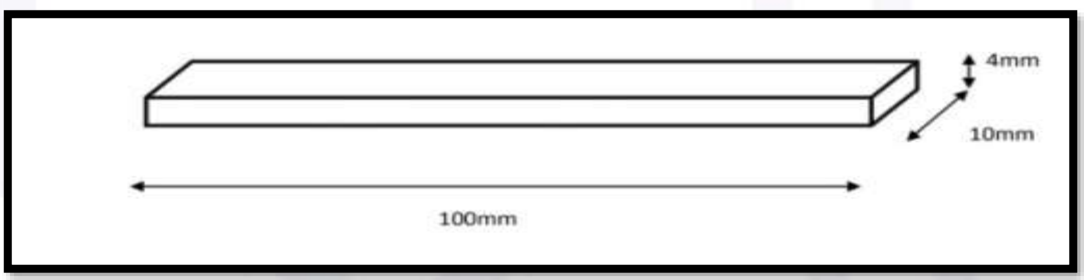

Figure (1): bending resistance test sample

$$E = \left(\frac{mass}{deflection}\right)\left(\frac{gl^3}{48l}\right) \quad (1)$$

(mass/deflection):Represents the slope calculated from a curve (mass/deflection).

I: represents the geometric bending moment, which is given by the following equation [10]:

$$I = \frac{bd^2}{12} \quad (2)$$

b = width of the sample (m).

d = thickness of the sample (m).

Figure (2) Bending test device

2- Measurement of the Thermal Conductivity

The standard specification (Lee Disk's) was approved in the manufacture of thermal conductivity test samples shown in Figure (3). Fourier's law can be used to calculate the thermal conductivity coefficient (k) and this law states:

$$K\left[\frac{T_B-T_A}{d_s}\right]=e\left[T_A+\frac{2}{r}\left(d_A+\frac{1}{4}d_s\right)T_A+\frac{1}{2r}d_ST_B\right] \qquad (3)$$

e : represents the amount of energy and heat passing through a unit area of disk material per second ($\frac{w}{m^2.C}$).

$$IV=\pi r^2 e(T_A+T_B)+2\pi re\left[d_AT_A+d_S\frac{1}{2}(T_A+T_B)+d_BT_B+d_CT_C\right] \qquad (4)$$

(T_A ،T_B، T_C): represents the temperature in each disk (A, B, C) respectively

(d_C ,d_B ، d_A): represents the thickness of the samples for the copper disks.

ds : thickness and amount of samples (12.5 mm).

r : the radius of each disc (mm).

I : the current through the heater (Amp).

V: the supplied voltage (Volt).

d : Sample thickness (mm).

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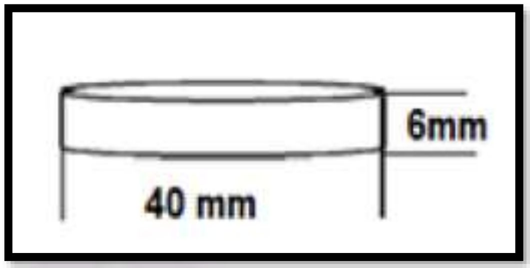

Figure (3): Conductivity Thermal test sample

Figure (4) shows the Heat Conduction Unit, which is manufactured by P.A.Hilton Ltd England.

Figure (4): Thermal conductivity measurement device

Optical Imaging Technique

The optical microscope (Max-See) is an updated version of the optical microscope, and the optical microscope is one of the most important devices that contributed to the development of science and scientific research due to its large number of uses. The particle size and the shape, as well as the directions of crystals and knowledge of their construction methods, and how they are distributed, and identifying and knowing the phases formed, as well as through which it is possible to study the different stages that make up a particular alloy, in addition, it is possible to determine whether the material contains any impurities, It is also possible used to determine the type of heat treatment that the material has undergone, and it is also possible to determine how the breakdown occurred in the material and the type of fracture or failure of the material during mechanical examination or during work. There are two types of microscopic examinations of the material, namely: [12]

A- Macroscopic examination: In this case, the examination is performed with a small magnification power, usually ranging (from 5 to 20).

B - Microscopic examination: In this case, the material is examined with a magnification much greater than the macroscopic examination. In this case the magnification power ranges (from 20 to 2000).

Results and Discussion

Mechanical Properties

Bending Test Result

The bending test differs from the impact test by the rate of stress, where the samples in the bending test are subjected to a slow loading rate, which allows cracks to interact with the particles, and also differs from the tensile test by the nature of the forces that affect the sample during the examination process. Where the models suffer from tensile strength and pressure at the same time instead of tensile strength only. The bending resistance can be defined as the resistance of the material to the external load applied to it, and the bending resistance depends on some important factors that affect the results, including: The type of load, its rate and the strength of bonding between the components of the material.

The main objective of the bending test is to know the linear behavior or what is sometimes called (Hooken Behavior) of the material under the influence of a load applied in the direction perpendicular to the plane of the sample surface [9].

Figure (5) shows the relationship between the applied load (force) and the deflection, which is directly proportional to the force of the load applied to it within the limits of the elastic point. When the applied load is removed, the material returns to its original state and the material is subject to Hookes Law, represented by the linear relationship between force and deflection, which represents the slope of the straight line and the Yong's coefficient was calculated from this test for all samples at laboratory temperature based on the two relationships(1)(2)

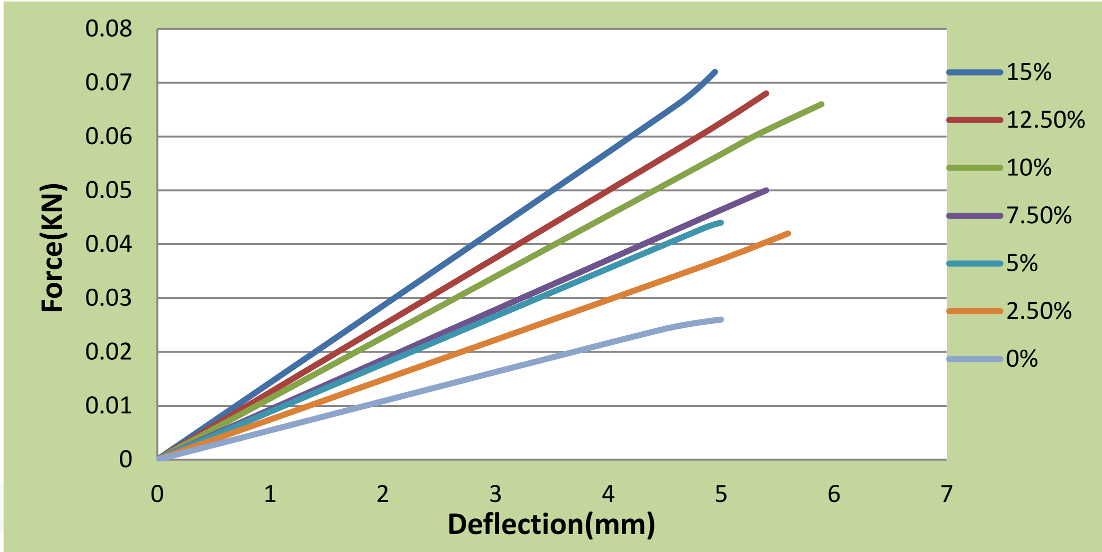

Figure (5) The relation between applied force and deflection of epoxy models reinforced with natural wool is bending test

Material	Volume (%) Fraction	Bending (KN/mm²) Strength
Epoxy	0	0.049
Epoxy+ Wool	2.5	0.0496
Epoxy+ Wool	5	0.051
Epoxy+ Wool	7.5	0.053
Epoxy+ Wool	10	0.055
Epoxy+ Wool	12.5	0.056
Epoxy+ Wool	15	0.059

Table (4-3) shows the increase in the bending strength of the epoxy composite samples reinforced with natural wool fibers with the increase in the percentage of addition. The maximum bending strength were shown at the ratio at (15%) reached $(0.059\frac{KN}{mm^2})$ which is a higher value than the bending value for unreinforced epoxy (pure epoxy), which reached $(0.049\frac{KN}{mm^2})$. The polymeric

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material within this region suffers an elastic deformation caused by the stretching and elongation of the polymeric chains without breaking the bonds. This indicates that epoxy and wool are considered as brittle materials with high hardness and little ductility.

Table (1) values of bending strength of epoxy samples reinforced with wool fibers

Figure (6) shows the effect of the different Volume Fraction of the fibers on the (flexural strength) of the prepared composite materials used. It leads to an increase in the bonding strength and cohesion between the stiffeners and the base material, and this in turn had a significant impact in giving the models at these ratios high values for bending strength.

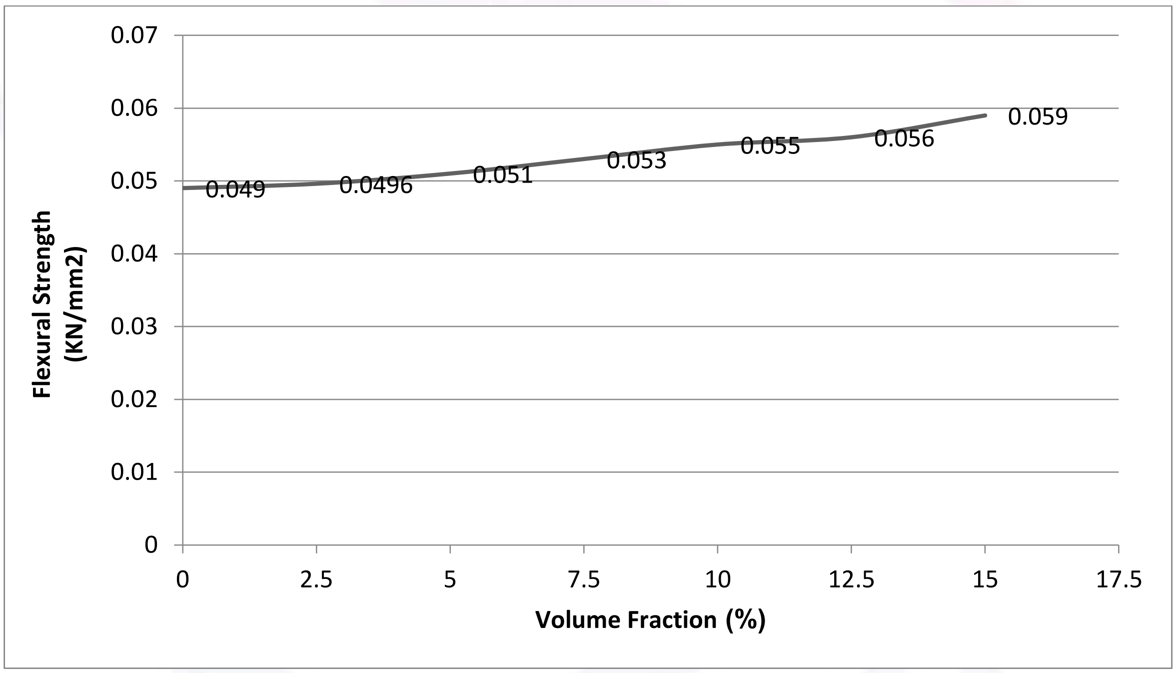

Figure (6) Relation between the bending strength and volume fraction of natural wool

Thermal Conductivity Test Result

conductivity directly depend on the temperature in addition to the type and nature of the substance and its chemical composition A significant and fundamental effect on the difference in the values of thermal conductivity coefficient (K) between random and crystalline polymers [11]. The thermal conductivity of all samples was measured by Lee's-disk method and the table (2) in the below shows the change in thermal conductivity values with different volume fraction of the reinforcing materials.

Table (2) The change in thermal conductivity values with the volume fraction of wool fibers

Material	volume fraction (%)	$K(\frac{Watt}{m.°C})$
Epoxy	0	0.293
Epoxy +Wool	2.5	0.336
Epoxy +Wool	5	0.363
Epoxy +Wool	7.5	0.411
Epoxy +Wool	10	0.449
Epoxy +Wool	12.5	0.495
Epoxy +Wool	15	0.514

By noting Table (2), we find that the addition of reinforcing particles to the epoxy resin led to an increase in the thermal conductivity values, where the highest value was at the percentage (15%), reaching (0.514watt / m .°C.) while the lowest value was when unreinforced epoxy resin (pure epoxy) reached (0.293watt /m.°C). Figure (7) shows the effect of adding reinforcing fibers on the thermal conductivity, as we notice that the conductivity values increase with the increase in the reinforcement fraction, although the increase was slight, but there is a change in the conductivity values, the explanation of this is due to the fact that the reinforcing particles have a higher thermal conductivity than the resin Epoxy when comparing them, as the thermal conductivity values depend on the type of reinforcement material and its ability to conduct.

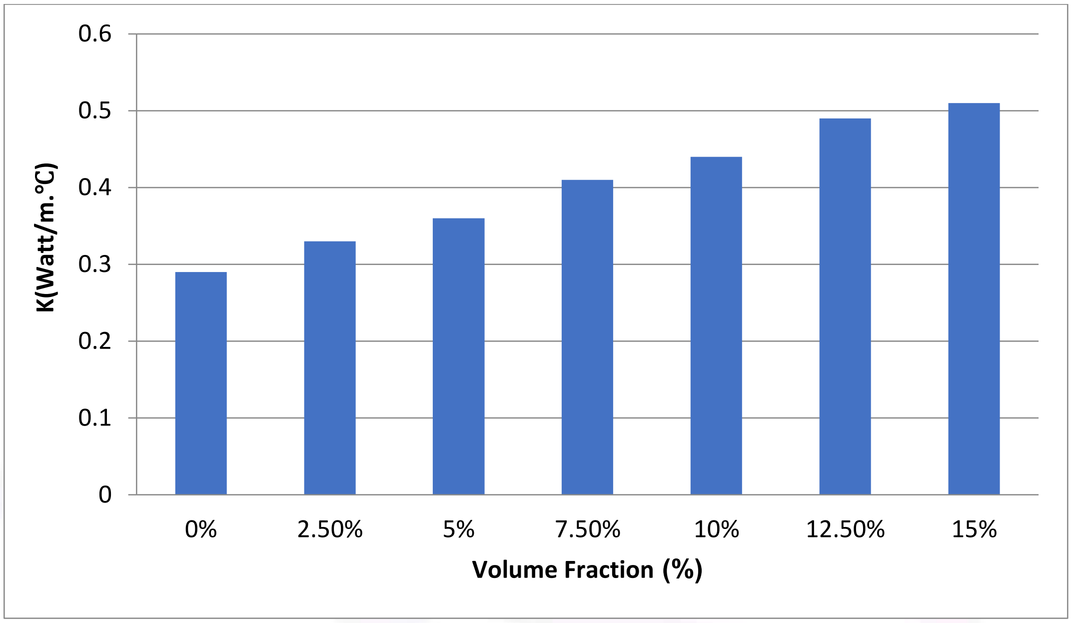

Figure (7) The relation between thermal conductivity and volume fraction of wool fibers

Optical Microscopic Image Test(OM)

The nature of the surface and the type of fiber distribution in the composite materials depends on the type of polymeric materials and their components, the type of reinforcing materials included in them, and the percentage of the reinforcing material, whether these ratios are volumetric or weight. Using an optical microscope (OM) with a magnification of (400X) where the image appears clearly with good homogeneity and clear adhesion between the overlapping material and the reinforcing material. Figure (8) shows the microscopic image with a magnification of (400X), where the image of a pure unreinforced epoxy sample appears. Figure (9) shows the microscopic images of the sample of the composite material with a volume ratio of (15%) showing the homogeneity and good adhesion between the reinforcement material of wool fibers with the base material (epoxy) due to the good viscosity of epoxy resin during preparation and before it hardens, taking sufficient time during preparation For overlays to exit bubbles.

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Figure (8) shows an optical microscope of a pure epoxy sample

Figure (9) shows the microscopic images of the epoxy sample reinforced with wool (15%).

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Conclusions

Through the results obtained from the thermal conductivity test and the bending test applied to the epoxy resin before adding wool to it and after that, several conclusions were reached:

1-It was discovered that increasing the wool content in the matrix material improved the bending test significantly.

2- Increasing the value of the thermal conductivity coefficient of epoxy resin with increasing temperature after adding wool.

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