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INVESTIGATION OF MECHANICAL CHARACTERISTICS OF (EPOXY-RESOLE BLEND) MATRIX HYBRID COMPOSITE

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Abstract: This research aims to investigate the impact of fibre reinforcement on the mechanical properties of hybrid polymer matrix composites. The samples made of a hybrid polymer composite were made from the reaction of two polymers, 90% epoxy resin and 10% Resole resin, and were reinforced with two types of reinforcements. The reinforcement used for the current research was carbon and Kevlar fibers. The fibers were in plain weave and were added in volumetric fractions. This research assessed mechanical characteristics like tensile strength, hardness, and impact strength in two cases: one for epoxy/Resole blend only and the other for a hybrid composite material. The addition of fibre reinforcement improves the mechanical properties of the epoxy. Kevlar fiber provides the best mechanical properties for the epoxy/Resole blend when reinforced with two layers of kevlar fibers.

Keywords: *Epoxy Resin; Resole Resin; Hybrid composite material; Tensile; Impact; Hardness.*

1. Introduction

Composite engineers are now concentrating on developing new tougher, stronger, lighter structural materials that enable the newest design concepts and technologies for complicated shape structures, such as automotive structures, aircraft, and big wind turbine blade structures[1].

Composite materials from polymers increase their efficiency by reinforcing two or more fiber layers in the polymeric matrix, resulting in hybrid composites, an advanced material system with a wide range of material properties[2]. The significant difficulty can only be overcome by comprehending the links between material architecture and mechanical properties. Except for the fracture energies, none of the mechanical parameters suggests a favorable hybrid effect[3]. Zhang and Chaisombat et al. [4] used various topologies and glass/carbon ratios to study the woven hybrid composites' flexural, tensile, and compressive responses. They discovered that the 50:50 ratio of glass/carbon FRP composites enhanced the flexural, tensile, and compressive strength significantly. The mechanical properties of polymers without reinforcement limit their utility as structural materials. However, reinforcing polymers with strong fibers allows the construction of the polymer matrix composites (PMCs) having stronger properties[5]. Higher mechanical strength, less weight, sufficient dimensional stability, stronger dielectric strength, corrosion resistance, and flexibility to modify designs are advantages of fibre-reinforced PMCs over standard

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materials[6]. The effectiveness of reinforcement is largely determined by matrix-fiber adhesion. The matrix-fiber adhesion is critical in determining the composite material's final qualities, particularly its mechanical properties[7]. Fibrous materials like carbon fiber and kevlar fiber were frequently employed as fillers in composites. Aramid-fiber has been commonly utilized in the automotive sector due to its good mechanical properties, such as high specific modulus and strength, lightweight, excellent chemical inertness, and thermal resistance. The rather weak mechanical characteristics of the monolithic epoxy had been discovered to limit its usage in components that require high mechanical strength.[7] As a result, various particle/whisker-type fillers have been used in multiple experiments on reinforcing polymer-based materials in order to get insight into how to overcome this issue[8]. The main function of fibers in the composite is carrying the majority of the weight and providing stiffness. As a result, fiber materials have high elastic modulus and tensile strength[9]. As a result, fabric reinforcement composites dramatically improved abrasive wear resistance[7].

The current research aims to determine the mechanical characteristics of the hybrid matrix composite material and investigate the impact of the different quantities of the carbon and Kevlar fibers reinforcement.

The current research's novelty is using multiple layers of fibers to the epoxy resin to produce a fibre-reinforced composite with better mechanical properties than the epoxy resin.

2. Materials and Methods

2.1. Materials

Kevlar and carbon fibers have been chosen to reinforce the epoxy/Resol polymer. Quickmast 105® provides epoxy resin and hardener are shown in Figure (1). The Resole was provided from Al-Taji Refinery/ General Company for Mining Industries-Iraq. Resole is made under basic conditions using molar amounts of formaldehyde and phenol. The molar ratio of the formaldehyde to the phenol is greater than one. The mixing of these two materials cures by heating, as shown in Figure (2). The bi-directional woven carbon fibers used in the current study have a density of 1.82 g/cm^3. The bi-directional woven Kevlar fiber (1.44 g/cm^3 density) was also employed as reinforcement. Figure (3) depicts the kevlar and carbon fibers used to manufacture hybrid fiber-reinforced composites.

Figure 1. Epoxy resin.

Figure 2. Resole resin.

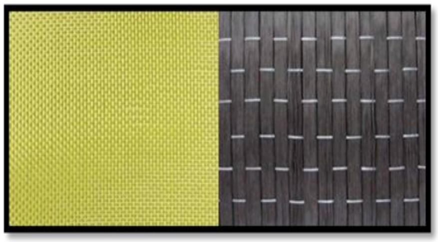

Figure 3. Kevlar and Carbon Fibers.

2.1.1 sample Preparation

In this work, the epoxy resin and the hardener (90 vol% - 135.45 gm) were combined with the Resole resin (10 vol% - 15.06 gm). First, the epoxy resin was mixed with the hardener. Then, the Resole resin was added to the mixture and mixed for two hours to ensure homogeneity and to remove any bubbles that may have formed during the mixing process[8]. The mixture is kept at room temperature. The epoxy / resole blend was reinforced by cutting the fibers to the same dimensions of the mold. The fiber was weighed, and the mixture law was used to add a volumetric fraction of 5 percent and 3 percent of the total weight of the blend. The procedure consists of pouring a portion of the blend into the mold, adding the first layer of fiber, pouring another portion of the mixture, and finally creating a composite material reinforced by 3 layers of fibers[9].

The types of samples utilized in the present work have been listed in Table1. A glass plate was placed over the mold to prevent fiber layer adhesion and the formation of air bubbles between the layers. The resulting composite was left at room temperature for 24 hours before being ejected from the mold and placed in the oven to complete the curing process and eliminate any stresses that could have formed throughout the solidification process. Ultimately, samples are sliced according to the instructions of each test [7-9].

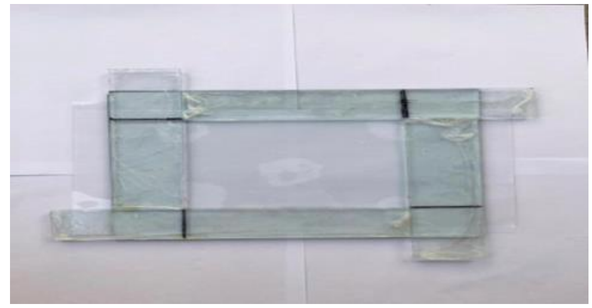

Figure 4. Casting mold used to prepare the samples

Table 1. Types of mixtures.

Samples of various kinds	Content
B1	Epoxy (90 vol%)+Resole (10 vol%)
B2	2 layers of carbon fiber and 1 layer of kevlar fibres are used to reinforce B1 (5 percent)
B3	2 layers of Kevlar fibre and 1 layer of carbon fiber reinforce B1 (3 percent)

2.2 Methods

2.2.1 Tensile Test

The tensile test was performed using a WDW-50 tensile machine (computer-controlled universal testing equipment) following the ASTM-D638 standard specifications[10].

2.2.2 Hardness Test

Hardness can be defined as a surface mechanical quality that describes the resistance of a material to penetrating or deforming plastically[11]

2.2.3 Impact Test

Impact testing was performed with a Charpy impact test apparatus. Model IMI was developed to determine the impact fracture energy of the polymeric materials in compliance with industry standards of ISO- 179[12].

3. Results and discussion

3.1 Tensile Test

According to the experimental results in Figure (4), adding 5 vol% and 3 vol% of carbon and Kevlar fibers to an epoxy-resole blend matrix increases tensile values to 534 MPa for sample B2 and 380 MPa for sample B3. Resin is a brittle material with low tensile strength, such as the blend of epoxy and resole. When the blend is reinforced with fibers, the tensile strength increases significantly. The fiber bears a large portion of the load, increasing the composite material's tensile strength[13].

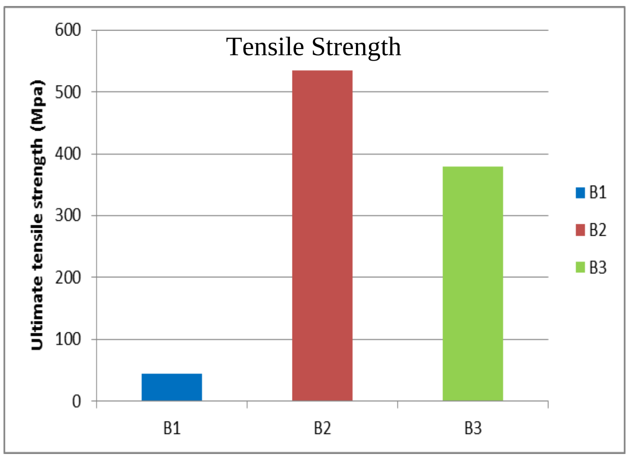

Figure 4: Hybrid polymer blend matrix composites' ultimate tensile strength. B1, B2, and B3 refer to the samples.

3.2 Hardness Test

The experimental results in Figure (5) reveal that adding 5 percent and 3 percent carbon and kevlar fibers to the 90 vol% epoxy / 10 vol% resole blend matrix increases the hardness to 80 for sample B2 and 79.3 for sample B3. Non-reinforced resins have a lower hardness compared to reinforced resins. The hardness of the resin increases due to the distribution of load on the fiber, limiting the penetration rate of the surface of the composite material and enhancing the values of the hardness[13]. Additionally, an increase in composite hardness indicates effective bonding between the blend matrix and fibers[10].

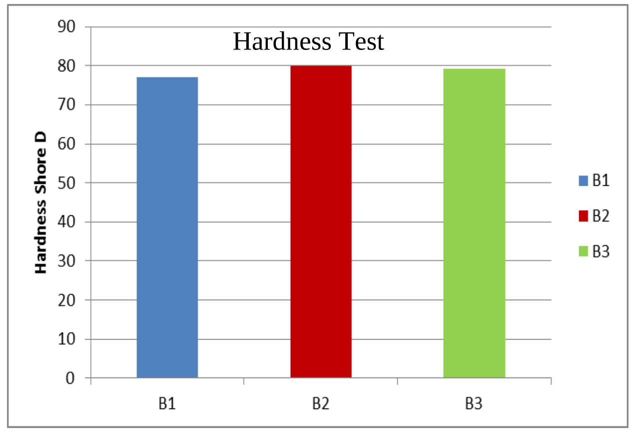

Figure 5: Hybrid polymer blend matrix composites are subjected to a hardness test. B1, B2, and B3 refer to the samples.

3.3 Impact Test

The experimental results presented in Figure (6) show that adding 5 percent and 3 percent of carbon and kevlar fibers to a 90 vol% epoxy / 10 vol% resole blend matrix increases impact resistance to 198.351 KJ/m^2 for sample B2 and 226.746 KJ/m^2 for sample B3. Impact strength testing is one of the practical methods for determining the fracture strength of a material and its resistance to fracture under high-speed stress[14]. The energy required to fracture the sample before reinforcement was 0.36 J, whereas the energy required to fracture the sample after fiber reinforcement was 2.2 J for B2 and 3.4 J for B3. This increase in energy is because fibers of various types store the majority of the elastic energy of the composite material, as they bear the majority of the stress ratio to the matrix material. As a result, the fiber distributes stress over a greater area and lowers the probability of stress concentration in a single region. Moreover, the fibers are acting as crack propagation barriers and limiting the spread of small fissures caused by impact

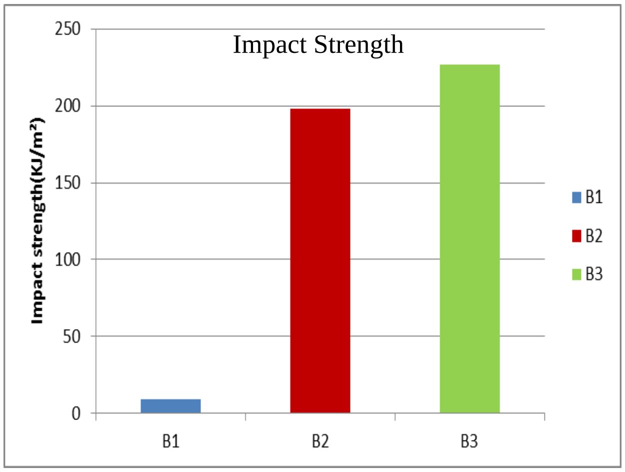

Figure 6: Hybrid polymer blend matrix composites' impact strength. B1, B2, and B3 refer to the samples.

4. Conclusion

The mechanical properties like hardness, tensile strength, and impact strength of the epoxy–resole blend are low. The current study aims to improve the mechanical properties of the fiber by adding two kinds of reinforcements, Kevlar and Resol. The tensile strength, hardness, and impact strength values increased after the blend (epoxy-resole) was reinforced with fibers. When the blend is reinforced with two layers of carbon fibers, it enhances the mechanical properties. Compared to other combinations, Kevlar fiber provides the best mechanical properties when reinforced with two layers.

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Conflict of interest

There is no conflict of interest in the current project.

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