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EFFECT OF METAL WIRE MESH ON TENSILE, COMPRESSION AND WATER ABSORPTION FOR BLEND POLYMER

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Abstract: This work aims to enhance the polymeric composite properties by adding Iron wire mesh (Fe) and aluminum wire mesh (Al) as reinforcement materials with various ratios. A polymer blend of the [epoxy (EP)+ polyester (UPS)] as matrix material has been utilized. The hand layup approach has been utilized for manufacturing castings. Epoxy and polyester have been mixed with different volume ratios, involving (95:5,90:10, 85:15,80:20, and 75:25 Vol.%) of (epoxy: polyester). The blend was be reinforced with metal mesh with volume fractions (5,10,15, and 20%). The results show the best ratios of ultimate tensile strength are (95% epoxy + 5% unsaturated polyester), and tensile strength and young modulus increase with increased volume fraction of metal mesh. The best compressive strength (CS) value was obtained for a sample of (95% epoxy +5% unsaturated polyester). The compressive strength increased with increased volume fraction of iron mesh but reduced with used aluminum wire mesh. Also water absorption increased with increased unsaturated polyester, iron mesh, and aluminum mesh percentage.

Keywords: *blend polymer, iron wire mesh, aluminum wire mesh, metal mesh*

1. Introduction

A composite material comprises two components that have distinct physical and chemical characteristics. When they're combined, they form a composite with better properties than the individual components. One of the components has been referred to as the reinforcing phase and reinforced where the matrix surrounds it. The material of the reinforcing phase includes particles, flakes, or fibers. The matrix phase is typically continuous[1]. Polymers are utilized in many different industrial applications due to the fact that they have properties that are not found in other material types (i.e., ceramics and metal). These properties include strength and stiffness combined with lightness [2, 3].

The composites have been recognized due to their ease of manufacturing and lightweight. It has resistance to corrosive solutions and oxidation like acids, alkalines, solvents, and rapid coloring[4]. Additional scientific advancements in polymers opened the door to developing novel polymeric materials with desired properties by physically combining two or more polymers to generate polymer blends. The final mix has similar characteristics in terms of essential components, depending on the polymer quality and mixing method[4]. Polymer blends are binary, triple, or quadrilateral based on the number of polymers in the mix. Khdier, Salih and Ali studied the possibility of enhancing the mechanical characteristics of the EP resin through the blending with poly-carbonate (PC), with various fractions of weight (5, 10, 15, 20,

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25wt.%)[5]. Results have shown developments of the mechanical behavior with the increase in the PC content in the blend from the brittle to the ductile, where experimentations have shown an increase in the elongation values, as well as young modules, impact strength, flexural strength, and fracture toughness, while the decrease in the ultimate tensile strength compared to that of the pure epoxy[4, 6]. Maki, Ahmed, and Abdullah have produced the polymer blend that contains epoxy (EP) and polyurethane (PU) of percentage (90/ 10) % respectively, then reinforced by PVC fibers and aluminum fibers with a fraction volume of (15%). The impact strength has been studied before and after added reinforcement at different temperature degrees (20^o, 40^{o,} and 60^{o}C).[7] The result showed the reinforcing material increased impact strength and with temperatures increase had resulted in an increase of the impact strength values except for the polymer blend reinforced by the PVC fibers that impact strength values lowering[8]. This work aims to study epoxy/UPE and epoxy/Al blend properties at different volume ratios.

2. Materials

2.1. Epoxy (EP)

EP resin (Sikadur-52) has been utilized in the present study; it's a free-flowing, low viscosity and fast curing injection resin and primer/coating, which is based upon a 2-components solvent-free EP resin; which is suited optimally for different building and civil engineering applications in which highly penetrative materials are necessary.

2.2. Unsaturated Polyester (UPE)

UPE resin can be described as a liquid with moderate viscosity. It may be cured to solid-state with the addition of the (Methyle Ethyle Keton Peroxide, also referred to as MEKP) as the hardener. In contrast, the cobalt octoate plays the role of catalyst for the acceleration of the process of solidification. It is made in Saudi Arabia.

2.3. Iron Wire Mesh (Fe)

Iron wire mesh has been used in this work due to its excellent flexibility and softness, suitable for tying applications. It is in the form of an iron woven at an angle (90° - 0°).

- Diameter: 0.12-1.6 mm
- Density of 7.8 g/cm^3

2.4. Aluminum Wire Mesh (Al)

Aluminum has been the preferred choice for selecting the type of metal to be used as reinforcement due to its ease of availability, low density, high strength, low cost, and excellent corrosion resistance**.**

Using aluminum wire mesh the fiber orientation is (0/90)°.

- Diameter: 0.12-1.6 mm
- Density of 2.7 g/cm^3

3. Experimental Work

EP/UPS polymer blends with volume ratios included [(95/5), (90/10), (85/15), (80/20), (75/25)] % were prepared from mixing of epoxy with unsaturated Polyester resin**.** After mixing the two liquid polymers (EP with UPS), the hardener of epoxy was added to the mixture with a 1:2 weight ratio, while the hardener of UPS was added to the mixture with a 2% weight ratio. This mix has been stirred for 10min and cast after that in the mold and at the end left through the night at the room's temperature for the full curing night at the room's temperature for complete curing. Table 1 shows the symbols of the prepared materials.

Table 1. The symbols of the prepared materials

Symbols of specimens	Percentage of each material in the polymer blend
EP	Epoxy
UPS	Unsaturated polyester
B1	Blend (Epoxy 95%+UPE 5%)
B2	Blend (Epoxy 90%+UPE 10%)
B3	Blend (Epoxy 85%+UPE 15%)
B4	Blend (Epoxy 80%+UPE 20%)
B5	Blend (Epoxy 75%+UPE 25%)

3.1. Tensile Test

Tensile strength and elasticity modulus of the PMCs have been found according to ASTM D638M- 87b[9]. For 207 specimens at 25 ºC with a constant strain rate of about (1.5 mm/min), dumbbell-shaped specimens were used, as shown in Figure 1. The tests have been conducted using the universal mechanical testing machine (model TINIUS OISEN H50KT).

Figure 1. Tensile test samples of Epoxy/polyester and Epoxy/polyester composite with iron mesh and TiO_2 particles, respectively.

3.2. Compression Test

According to (ASTM D695-85), Samples were tested at room temperature with a speed rate of about 1mm/min, as shown in Figure 2. The test was performed using the universal mechanical testing machine (TINIUS OISEN RH1 5DZ model). Compressive stress can be calculated by equation[10, 11].

$$\sigma_c = \frac{P_C}{A} \quad (1)$$

where:

σ_c: Compressive Strength (MPa).

Pc : Compressive load (N).

A : Cross-section Area (m^2).

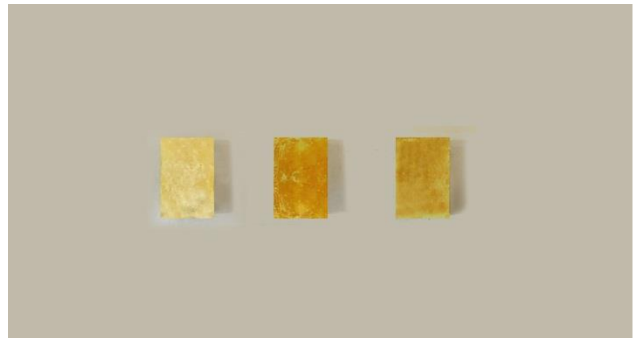


Figure 2. Compression test samples of Epoxy/polyester and Epoxy/polyester composite with iron mesh, aluminium mesh, and TiO_2 particles, respectively.

3.3. Water Absorption

The water absorption experiments on composites were performed following ISO 527. The samples were constructed with distilled water as the medium to test the composite's water absorption capability. The percentage of water intake was estimated using the variation between the ultimate and starting weights after 24-hour immersion in a water bath. The tests were repeated until the percentage of water intake reached a stable level. Equation 1 was used to do the calculation.[12]

$$\%\, Water\ absorption = \frac{Wt_{wet} - Wt_{dry}}{Wt_{dry}} x100 \quad (2)$$

Where Wt_{wet} is the weight of the wet sample and Wt_{dry} is the weight of the dry sample.

Figure 3. water absorption test samples Epoxy/polyester and Epoxy/polyester composite with iron mesh and TiO_2 particles, respectively

4. Results & Discussion

4.1. Tensile Strength

Figure 4 exhibits the values of the ultimate tensile strength of polymer blends (EP + UPS) at different volume ratios. It has been found that the ultimate tensile strength of EP resin decreased with an increase in the concentration of unsaturated polyester**. B1** (23MPa) is the best value of blend ratio. The values of Young's modulus decrease gradually with increasing the ratio of added polymer, as listed in Figure 5. This means the rigidity of epoxy decreases after the blending process, where Young's modulus (E) measures the material's rigidity. This suggests that following the blending process, the rigidity of epoxy drops, where Young's modulus (E) is a measure of material rigidity[13]. The current study results are inconsistent with the findings of Abbas et al.[1]

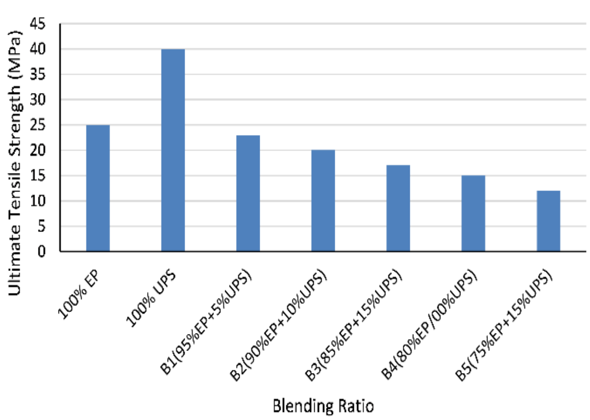


Figure 4. Ultimate tensile strength for different blend ratios

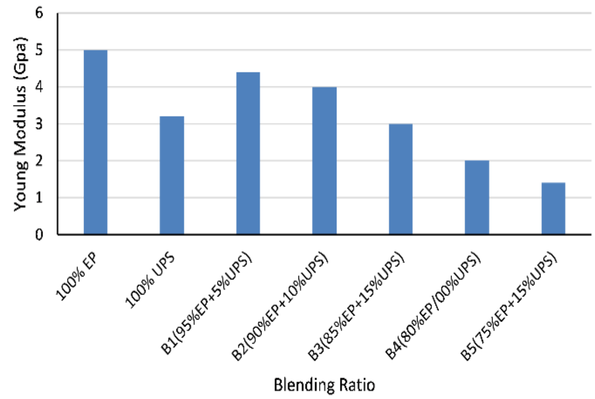
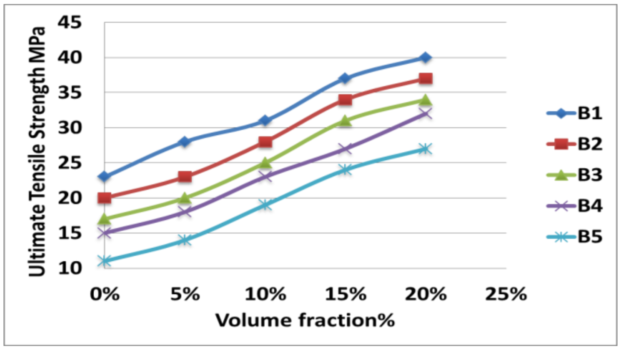
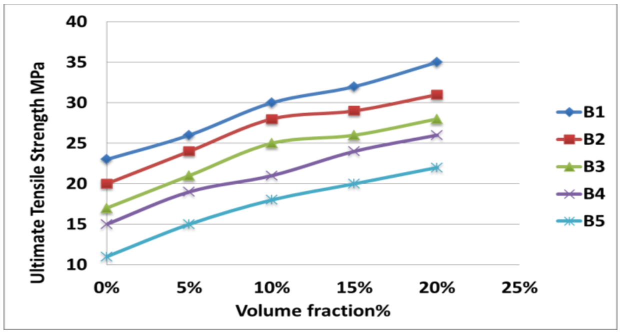


Figure 5. Young modulus for different blend ratios.

Figure 6a and Figure 6b show tensile strength of blending ratios of (EP+UPS) increase with increased volume friction of metal wire mesh. The reason for obtaining high tensile strength values is that the fibres play a basic role in carrying stresses and the presence of mesh metal fibers (0° / 90°) that have symmetrical properties in both directions within the blend matrix. The fibers bear the greater part of the external stress on the composite. Figure 7a and Figure 7b illustrates the tensile modulus for iron and aluminum mesh added to the blend polymer. These figures also show an increase in elasticity modulus with the volume fraction related to the metal mesh. This may be due to the nature of bonding. Also, mesh fiber reinforcing polymer improves the elastic modulus of composite material because the elastic modulus of metal mesh is higher than that for EP and UPE resin. It was also noted that the values of the tensile strength (TS) of the samples reinforced by iron fiber are higher compared to tensile strength values of samples that aluminum fibers have reinforced. The high value for ultimate tensile strength and elasticity modulus is B1(40MPa) 20%Vol,(6.5GPa) 20%Vol for use iron mesh and high value of ultimate tensile strength and elasticity modulus is B1(35MPa) at 20%Vol,(5.3GPa) at 20%Vol for used aluminum mesh. The results agree with the finding of Bolcu et al.[14]

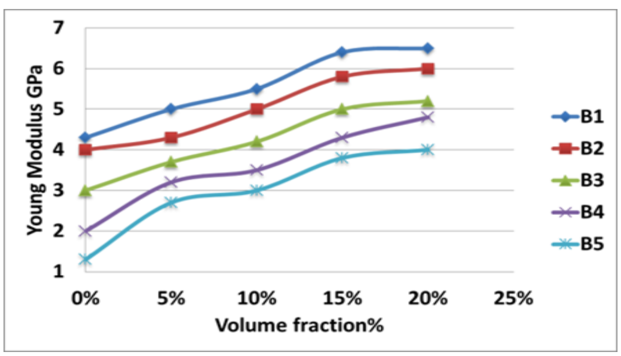


(a)

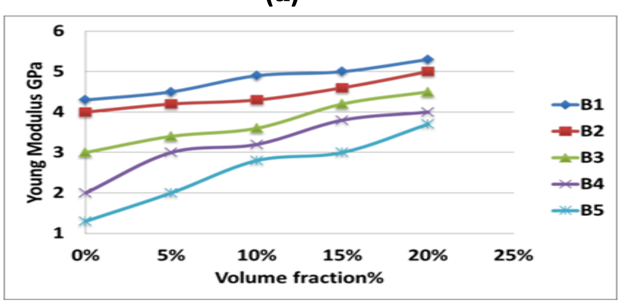


(b)

Figure 6. Impact of reinforcement content on the tensile strength of different Epoxy/UPE blends, as defined in Table 1. Figure (a) For iron mesh and (b) for aluminum mesh reinforcements.



(a)



(b)

Figure 7. Impact of reinforcement content on the young modulus of different Epoxy/UPE blends, as defined in Table 1. Figure (a) For iron mesh and (b) for aluminum mesh reinforcements.

4.2. Compression Test

Figure 8 indicated that the (CS) values decrease with increasing the ratios of added polymer (UPS) with the existence of differences in their values. This means that increased flexibility when the increased percentage of UPS is obtained for each blend under work leads to a decrease in the compressive strength. The experimental result showed that the high value of (CS) is B1(110MPa), and the low value of (CS) isB5(58MPa).[15]

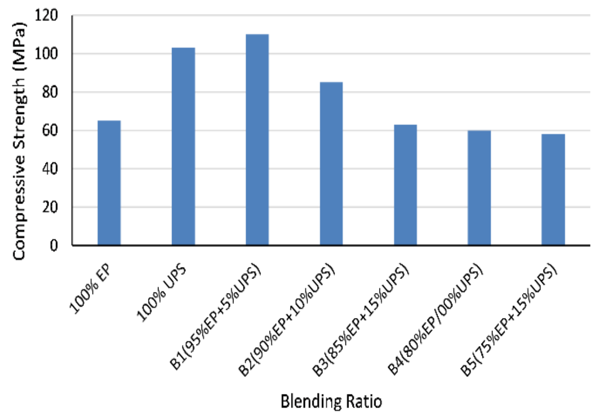
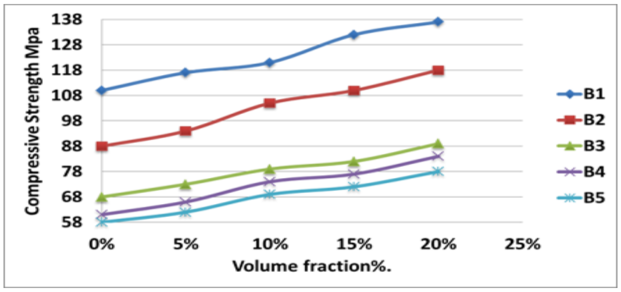
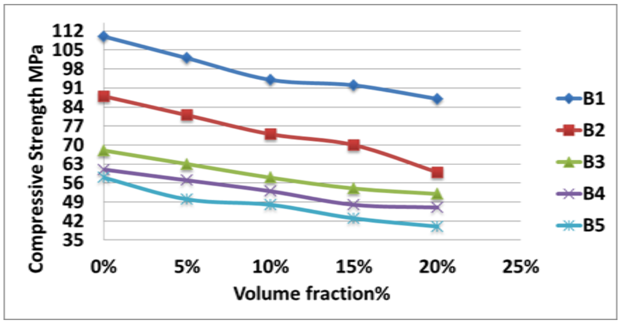


Figure 8. The compressive strength values with different blending ratios. Each column presents a different composite constitution, as defined in Table 1.

Figure 9a and Figure 9b show that the compressive strength is increased with the increase in the volume fraction of iron mesh and reaches the highest amount at B1 (20Vol % iron mesh), which is (138MPa), which may be associated with the mechanism of the strengthening as well as the bonding nature between reinforcement and matrix. Increasing the compressive strength may be attributed to the high compressive strength of fiber material compared to that of matrix material; however, when the volume fraction of aluminum mesh increases, the compressive strength decreases.



(a)



(b)

Figure 9. Impact of reinforcement content on the compressive strength of different Epoxy/UPE blends, as defined in Table 1. Figure (a) For iron mesh and (b) for aluminum mesh reinforcements.

4.3. Water Absorption

Figure 10 shows that the absorption of the water has been increased for the blend with a percentage of UPS. The high value of water absorption is 0.43545% at B5 polymer. This results from increasing overall system polarity and creating free volumes within a matrix, accommodating the water molecules.

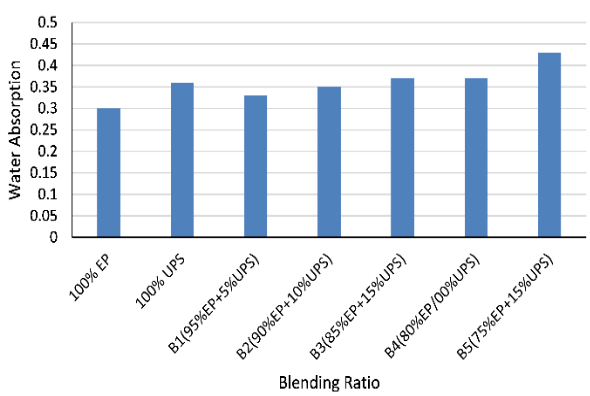
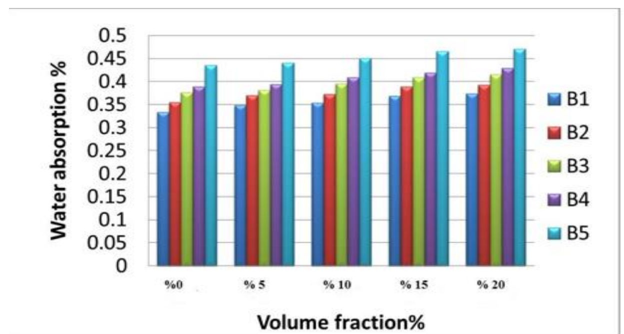
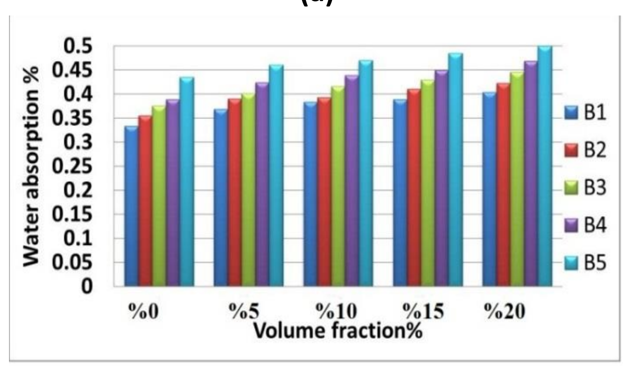


Figure 10. The water absorption values with blending ratios. Each column presents a different composite constitution, as defined in Table 1.

Figure 11a and Figure 11b depicts the effect of metal fiber with different volume fractions on the water absorption of blend polymer at 24 hour. The results revealed that water absorption percentage increased after reinforcing blend with fiber where highest water absorption at 24 hour was the sample (B5+20 %Vol Fe) relative to the iron composite blend and for (B5+20 %Vol Al) relative to aluminum composite blend. Generally, the percentage of water absorption increases after reinforcements with the fibers where fibers have a higher percentage of the water absorption than matrixes. For the blend–Fe wt.% composites, the water absorption increases as the volume fraction reaches its maximum value of (0.47045 %) at 20 Vol% B5. This is because the action conducts the water molecules to the material and fills the voids[16]. These findings are in good agreement with Mohammed and Issa[16].



(a)



(b)

Figure 11. Impact of reinforcement content on the water content of different Epoxy/UPE blends, as defined in Table 1. Figure (a) For iron mesh and (b) for aluminum mesh reinforcements.

4. Conclusions

This study aims to improve the characteristics of polymeric composites by using different ratios of iron wire mesh (Fe) and aluminum wire mesh (Al) as reinforcing materials. As a matrix material, a polymer blend of [epoxy (EP)+ polyester (UPS)] was used. For the production of castings, the hand layup method has been used. Epoxy and polyester were blended in various volume ratios, resulting in (95:5, 90:10, 85:15, 80:20, and 75:25 Vol. percent). The results show that the B1 sample (95%EP+5%UPS) provides the best ratio for tensile (23MPa), and [B1+20Vol%Fe] is the best ratio for metal mesh reinforcement. The B1 sample (95%EP+5%UPS) provides the best ratio of blend at compression test (110MPa) and after reinforcement by metal mesh 138MPa at [B1+20Vol%Fe]. Water absorption increase with an increased volume ratio of UPS, B5 high value of water absorption reaches to is 0.43545 %, after reinforce by metal mesh increase water absorption, [B5+20Vol%Al] is 0.5021 high value of water absorption for composite material.

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Conflict of interest

The authors confirm that the publication of this article causes no conflicts of interest.

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