Absorption characteristics of composite materials reinforced by zinc oxide nanoparticles and Kevlar fibres.

Z A Abed¹, M A Rajab² and A K Asfor¹.

¹Assistant lecturer, physics department faculty of science university of Diyala Iraq
²Assistant professor technical institute of Baqubah middle technical university Iraq
³Assistant lecturer, physics department faculty of science university of Diyala Iraq
E-mail: mustafaalnajar677@yahoo.com

Abstract. The research aims to study the effect of zinc oxide nanoparticles and Kevlar fibres on the absorption property of composite materials consisting of epoxy resins and phenol formaldehyde in different proportions. The results showed: Epoxy resins are not absorbed without adding phenol formaldehyde, which means an increase in the absorption property with an increase in the proportion of phenol formaldehyde increases. The fibre strengthening also increases the absorption, so Kevlar with fibres gave the highest absorption; However, the absorption property decreases when the compounds are enhanced with zinc oxide nanoparticles as compared to the effects seen in the non-reinforced compounds.

Keywords: Hybrid blend, Absorption Characteristics, Kevlar Fibres, Zinc oxide Nanoparticles, Mixing Ratio.

1. Introduction.
Most composite materials are made to improve mechanical properties such as resistance, hardness, durability, and high temperature performance. It is natural for as to study composite materials that have a common strengthening mechanism so that the reinforcement mechanisms depends on the engineering of reinforcement, so [1].

![Classification scheme for the various](image)

Figure 1. Classification scheme for the various

Metal compounds (MMCs), like most composite materials, have significantly improved properties compared to traditional monolithic materials, such as high resistance, hardness and weight saving while; continuous reinforcement of fibres provides more effective reinforcement, and particle reinforced materials are more effective because of their effectiveness in terms of cost, in addition to the
characteristics its ability to process through modern technology [2]. The materials are hardened to increase or decreases their properties to suit design needs, such as hardness, elasticity and resistance, as well as to reduce thermal expansion coefficients and thermal and electrical conductivity by adding fibres such as silicon carbide. MMCs have many advantages, such as high elastic properties, high service temperature, moisture sensitivity, corrosion resistance and pressure [3]. Combined materials reinforced with fibrous materials containing high-strength fibres and high guarantee factor In the model, the fibres retain their physical and chemical properties, but they combine a set of properties that cannot be performed with any of the components that work alone [4, 5]. In general, fibres are the main components that bear external loads, act as a means of transporting loads between them and resist parts form external damage caused by high temperatures and humidity. The commercial fibres used are various types such as glass, carbon and Kevlar [6, 7]. Micro and nanoparticles are also used to reinforce composite materials to improve their properties; such as boron, silicon carbide, and aluminium oxide. In limited quantities, and the fibres may have continuous lengths of fibres or have intermittent (short) lengths. Continuous fibres are the most commonly fibres in composite materials, especially in structural applications. They are manufactured by stacking a number of thin layers of any type of fibre and combining them with each other in the required thickness [8, 9]. Fibre reinforced composites are generally classified as single or multi-layer layers, and each layer has a similar or variable direction depending on the design, as shown in in Figure (2) [10]. The uses for these properties under the influence of importance to determine the suitability of these properties for the application of these materials for required applications. In this study, an epoxy mixture with formaldehyde resins in different mixing ratios was examined for the purpose of taking a sample to determine various mechanical properties and absorption properties under the influence of Kevlar fibres and zinc oxide nanoparticles in order to determine their effect on the material’s absorbance properties. The current study is directed towards its materials’ use in the production of plastic tubes that are resistant to stress, can withstand shocks, and have little efficacy to minimal interaction with liquids passing through them; accordingly they have shown, a decrease in the absorbency property in water was sought.

2. Experimental Procedure.
LEYCO-POX 103 epoxy and phenol formaldehyde Resins Were used. The epoxy resin and phenol formaldehyde were mixed at different proportions, the epoxy resin (EP) is a solvent-free component, low viscosity, and the phenol formaldehyde resins acted as an second is the activator of the first component, and the mixing ratio of the first component to the second component is being A: B = 2: 1. Kevlar fibres and zinc oxide nanoparticles Were added as reinforcement phase in the research as shown in Table (1).
Composite materials are prepared to make the as panels used in research in molds made from glass panels with dimensions (200 x 200 x 4) mm. Nylon sheets are placed at the bottom of the molds for easy removal of the pattern, the epoxy and hardened resins are determined added in the required proportions and then the reinforcement with Kevlar fiber and Zinc oxide nanoparticles, as shown in Table (2).

Table 1. Mechanical properties of the Kevlar fibre used.

| Property       | Tensile strength (MPa) | Compressive strength (MPa) | Elastic modulus (GPa) | Density (kg/m³) |
|----------------|------------------------|----------------------------|-----------------------|-----------------|
| Kevlar fiber   | 2757.9                 | 517.1                      | 151.7                 | 1,467           |

Table 2. Hybrid Blind mixing ratio of Epoxy resin and

| No. | mixing ratio of Epoxy resin wt.% | mixing ratio of Resole resin wt.% |
|-----|---------------------------------|----------------------------------|
| 1   | 100%                            | 0%                               |
| 2   | 95%                             | 5%                               |
| 3   | 90%                             | 10%                              |
| 4   | 85%                             | 15%                              |
| 5   | 80%                             | 20%                              |
| 6   | 70%                             | 30%                              |
| 7   | 60%                             | 40%                              |
| 8   | 50%                             | 50%                              |

The mold made of glass panels was manufactured with dimensions (20 * 15 * 4) mm. It is a mold under which nylon sheets are placed to prevent the adhesion of the sample. As for the composites they are epoxy resin + phenol formaldehyde resin95% epoxy resin with 5% resin were mixed by hand and a mixing machine at a certain set rotation speed for 15 minutes to obtain good homogeneity between the hybrid and hardened resins and remove the air bubbles trapped in the sample. The weighted fraction of the materials used was obtained by weighing the Kevlar fibers in the mixed resin mixture. Then the mixture is spread in the mold symmetrically onto the hybrid resin, then put the first layer of mat added on top then spread, another layer of the hybrid resin. After that, a toothed steel cylinder was used to obtain homogeneity in the thickness of the throughout mixture layer, and poured at room temperature and left the mixture for 24 hours. Finally, it was removed from the mold to obtain the plate of each hybrid mixture (epoxy and phenol formaldehyde) to be later cut into test samples using computer numerical control machine (CNC).

2.1 Absorption Test:

The absorption test for hybrid composites reinforced with Kevlar fibres and zinc oxide nanoparticles according to (ASTM 570) was performed by immersion in distilled water at room temperature; then samples were taken periodically immediately after the water was immediately wiped from the sample surface, and these were weighed using an accurate scale. To check for all absorbed water content, samples were weighed regularly at different time intervals.

2.2 Absorption Test Samples:
Several The equipment has been used to prepare the fiber- and nanoparticle-reinforced hybrid materials and nanoparticles:

2.2.1. A sensitive electronic scale: It is an important equipment in scientific laboratories, to determine the required mass for the materials used in the composite materials. It contains a digital counter. The model used had a digital counter that gives the results of weight directly and with high accuracy, and uses based on a sensor scale (KERN PLE) with sensitivity equal to (10^-3g).

2.2.2. Magnetic mixer: The magnetic mixer is a laboratory equipment that mixes chemical solutions. The mixer consist of using an electric motor equipped with a permanent magnet; also had thermal panels to heat the liquid, and it has a high efficiency in the mixing process low noise level and small size.

2.2.3. Micrometre: The micrometre is a precise measuring instrument used to obtain accurate measurements with an accuracy of about (0.01 mm), the distance between the measuring faces of the instrument (spindle and anvil) is set by (0.5 mm) and is used to measure the thickness of the sample at many multiple points and get an average thickness.

2-3. Hand Lay-Up Method:

The basic method for making composite materials is by hand laying method, which consists of placing layers of composite material after being mixed with nanoparticles in the mould nanoparticles after preparing it and then strips of fibers to form the sheet group of the composite material; after which, a cylinder is manually rolled with a roller to distribute the resin and remove the air pockets. This procedure is repeated for each layer until the required thickness is reached the basic method is simply to allow the occurrence at room temperature, and heat can be applied to speed up the process, usually with the oven, and this method does not require special treatment. However, variations in the viscosity of the resin cause problems In a good wetness. where, the first layer of fiber is placed, and the resin mixture is spread uniformly over it with a brush and then the second layer of fiber is put the resin mixture; spread uniformly above it after the second layer to enhance impregnation, a steel toothed roller was used to roll the fiber layer before applying a mixture of Rat Naj and the same procedures are used with the nanoparticle samples, where the mixture was treated at room temperature until the compound material dries completely, and it depends on the type of hybrid compound and the weight of the reinforcing material, as shown in Table (3) and finally it was removal from the mold to obtain On an a accurate finished composite plates.

| Symbols of Samples | Composite Materials |
|--------------------|---------------------|
| ER/PF/ZnO          | 95% Epoxy / 5% Phenol / 1% ZnO |
| ER/PF/KF           | 95% Epoxy / 5% Phenol / 1% Kevlar fibers |
| ER/PF/ZnO/KF       | 95% Epoxy / 5% Phenol/ 1% ZnO / 1% Kevlar fibers |

All these procedures should be in a laboratory free from dust, clean, and dry, with appropriate precautions taken by wearing protective gloves, goggles, and procedure masks at good ventilated room as well as ensuring proper ventilation.
2.4. Specimen Cutting:

The composite materials were cut according to American Society for Testing and Materials (ASTM) to prepare for preparing specimens for mechanical and physical tests. Specimens were cutting by computer numerical control (CNC) machine containing a rotary head a drill piece for cutting various hard materials.

3. Results and Discussion.

3.1. Absorption Test

The water absorption tests for the ER/PF mixture according to (ASTM 570) were perform by immersion in distillate, as shown in Figure (3). And its stability for some time as the mix it approaches equilibrium. Generally the water absorption rate is greatly influenced by the density of the mixture and the void content, resulting in an increase in the water absorption rate compared to when 10% by weight of the PF content [7].

![Figure 3. The water absorption tests of various mass](image)

3.2. Physical Properties of a Reinforcement Composite Material

Absorption test of the immersed samples in distilled water was executed in at laboratory temperatures. When we see the figures (4) and (5), we notice all samples (reinforced and non-reinforced samples) are increased in weight in immersion distilled water for mass fractions of 30% and 40%. We weighed the samples every 24 hours at the first four days from immersion, because the composite material absorbs the bigger amount from water at immersion start and a fin this time, these days we calculated the weight every (24) hours. Where we took out the sample from water and dry them well then weight them to calculate the absorbed water volume amount during the immersion period later we weighed the samples were measured every (24) hours for (21) days to calculate the samples’ full absorption, for distilled water as shown in figures (4) and (5).
Figure 4. The water absorption tests of various fibers with blend ER/PF

Figure 5. The water absorption tests of Nano -ZnO with blend ER/PF

Figure 6. Plastic pipe accessories and plastic drainage pipes made from composite material.
The results showed that Kevlar fibers gave a high value of absorbance as a result of their low density in addition to containing a high percentage of void percentage, as shown in Figure (5). The results also showed a similarly in the water absorption when reinforcing with Kevlar fibers and nonmagnetic oxide magnesium particles, with high absorbance value and changes in dimensions as shown in Figure (5). The current study is directed towards its use in the production of plastic tubes that are resistant to stress, withstand shocks, and have little efficacy to interact with liquids passing through them, and they have shown a decrease in the absorbency property in water. As for Figure (6) it shows a decrease in the absorbance property in the water, supporting with Kevlar fibers using ZnO nanoparticles due to the high surface area of the nanoparticles. The stress can be transferred to the nanoparticles more efficiently due to the high interlayer area of the resin and filler, and this reduces water immersion.

4. Conclusions.
1- The lack of absorption of epoxy resins without adding phenol formaldehyde, which means an increase in the absorption property with an increase in the percentage of phenol formaldehyde.
2- Fiber strengthening increases absorption; Kevlar fibres gave the highest absorbency.
3- The absorption property decreases when compounds are reinforced with zinc oxide nanoparticles as compared to the non-reinforced compounds.
4- Strengthening with fibers and nanoparticles gave less absorbency.

5. References.
[1] Rajab M A, Hamod A A and Hameed A I 2017 Mechanical properties of silica, graphite and carbon fibre reinforced composites, International Journal of Engineering and Technology (IJET), Vol. 9.
[2] Abdullah M N, Rajab M A and Salman S A 2019 Using Epoxy-Phenol Formaldehyde Hybrid Blend as an alternative to the Materials used in the Manufacture of the Oil Pan in the Vehicle's Internal Combustion Engine, INDIAN JOURNAL OF NATURAL SCIENCES, (IJOS) Vol. 9, ISSUE 52.
[3] Vodyanitskii, Y.N 2006 The composition of Fe-Mn nodules as determined by synchrotron X-ray analysis (Review of publications). Eurasian Soil Sc. 39, 147–156 https://doi.org/10.1134/S1064229306020050
[4] Rajab M A, Salman S A and Abdullah M N 2018 Absorption of Composite Material Epoxy-Phenol Formaldehyde Hybrid Blend Journal of Research in Mechanical Engineering, Volume 4 Issue 1 pp: 18-22.
[5] Al-Safi R A. 2001 Study the Thermal and Mechanical Properties of Novolac and his composites, M. Sc, Department of Applied Science, University of Technology, Baghdad.
[6] Rajab M A, Salman S A and Abdullah M N 2018 Mechanical Behavior of Epoxy-Phenol Formaldehyde Hybrid Blend International Research Journal of Innovations in Engineering and Technology (IRJIET), Volume 2, Issue 6, pp 1-4.
[7] Montemurro M P, Houde, M J L and Hansen J S 1993 Finite Element Analysis of the Impact Response of Composite Structures, Institute for aerospace studies, University of Toronto, Toronto.
[8] Kadhim T R 2015 Erosion Wear, Mechanical and Physical Properties of Nano and Micro Materials Reinforced Polymer Composites, M. Sc. Thesis, Materials Engineering Department, University of Technology, Baghdad.
[9] Abdullah M N, Rajab M A and Salman S A 2019 Using Epoxy-Phenol Formaldehyde Hybrid Blend as an alternative to the Materials used in the Manufacture of the Oil Pan in the Vehicle’s Internal Combustion Engine INDIAN JOURNAL OF NATURAL SCIENCES, (IJOS) Vol. 9, ISSUE 52

[10] Rajab M A, Abdullah M N and Salman S A 2019 Electrical behavior of hybrid blend reinforced by fibers with different mixing ratios International Journal of Research Vol.7 (Iss.7) pp 93-101.

[11] Bardelli, F., Barone, G., Crupi, V. et al 2011. Combined non-destructive XRF and SR-XAS study of archaeological artefacts. Anal Bioanal Chem 399, 3147–3153 https://doi.org/10.1007/s00216-011-4718-8