Studying the effect of the weight fractions of different powders on the mechanical behavior of an epoxy blend risen

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Abstract:

This research studies the effects of filler loadings of many powders such as Nickel Oxide (NiO), Zinc Oxide (ZnO), Alumina (Al_2O_3), and Carbon Nano Particles (CNP) on the mechanical properties of a polymeric blend of two types of epoxy resins. which was used as a matrix. Research samples were prepared by Handle Lay-Up Modeling. The fillers added separately with different ratios as (10 wt.%, 20 wt.%, 30 wt.%, 40 wt.%, 50 wt.%). Tensile Strength, compression strength, hardness tests, and the study of surface topography were conducted using a scanning electron microscope (SEM). The (SEM) of (NiO) and (Al_2O_3) composite powders, showed a smooth surface with a chance of forming very few voids, blisters, and a conglomeration on the surface of the sample, which increased with the increase of the weight fractions of the filled powder. While the composites filled with (ZnO) and (CNP) powders show a rough surface filled with undulations, blisters, some micro-cracks, agglomeration, and clusters, whereby, as the weight concentrations of powders rise, transform to a smooth surface free of microcracks and voids; spatially, the composite comprising (ZnO) powder, while the surface of (CNP) has more voids. The results also showed that these powders' strengthening enhances the mechanical characteristics, especially in the case of reinforced by (ZnO) and (CNP) powder as recorded highest tensile strength (1.252 MPa) and (1.061 MPa), respectively, after increasing the weight fraction to (20-50 wt.%), While it was less so in the case of increase of weight fractions, the compression strength equal to (13.72 MPa) and surface hardness was (12.25 MPa). Other types of powder such as (Al_2O_3) and (NiO) led to a decrease in tensile strength, and an increase in shore D hardness and compression strength.

Keywords: Blends, Polymer Composite, ZnO Powder, NiO Powder, Al_2O_3 Powder, Carbon Nanoparticles (CNP), Mechanical Properties, Tensile Test, Compression Test, Hardness Test.

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1. Introduction

Industrial and technological development of the modern world is witnessing advancement in various material fields, especially the advanced materials used in high technology. Therefore, there was a need for materials and with high quality and low costs to be used hence various industrial applications such as aircraft, radars, ships, vehicles, other Composite materials were developed. The powder composite materials, with a polymeric basis, are considered one of the most important advanced materials that contribute to solving intractable problems in several areas of life and industry [1]. For polymeric composite materials with certain specifications, which cannot be obtained from the use of one type of polymers, numerous attempts to mix the two or more types of polymers and get the blend with the desired industrial specifications to be used as a matrix material [2]. Polymer blending is one of the most common techniques employed for developing new polymeric materials, in which two or more polymers are blended together to create a new material with different physical properties. They combine in an advantageous manner the properties of the alloying components and in some cases, the properties of the blend are superior to those of the individual components. The properties of polymer blends strongly depend on the proportions of the basic components [3-5]. The development of polymer composites from blended polymer materials has

increased considerably during the last few years. Inorganic fillers are incorporated mainly to improve service properties depending on the source of fillers, type of filler, method of preparation, and treatments [6-8]. The dispersion of the various filler within the polymer matrices leads to large interfacial contacts between the organic-inorganic phases, which generated an interfacial material that has a quite different morphology, and also has properties that are excellent to those of the bulk polymer phase [9]. As a result, considerable improvements in the properties of composites may recognize even at a minimum level of filler loadings [10-12]. Additives of particles with a small amount (<5 wt.%) to a matrix can probably increase the strength, dimensional stability, and resistance to thermal degradation without increasing the weight or processability of the composite. This idea of infusion of particles into a polymer by low volume or weight fraction forms the basis of structural composites synthesis [13].

2. Practical Part

2.1 Materials Used

Samples were prepared in this research using two different types of polymeric substrate (epoxy resin). Epoxy resin (22240 Innopure Floor Epoxy) manufactured by a Turkish company, is characterized as a light liquid with a dark yellow color and low density and viscosity. At a given temperature, the hardener-to-epoxy resin ratio is (3:2), and the density at (20 ℃) is (1±0.05 Kg/It). This Epoxy resin blended with epoxy Casting resin (LS800) is manufactured by the (Shenzhen BKC Testing) Company, it can be cured under normal temperature and high temperature, with the feature of the good flowing property, natural defoaming, anti-yellow, high transparency, no ripple, bright in surface. After adding the hardener to the resin, it solidifies. Hardener type (22240 Innopure Floor Epoxy) manufactured by a Turkish company is used for both Epoxies.

Supporting materials (fines) are:

Nickel Oxide (NiO): This is nickel's principal oxide [14]. It is classified as a basic metal oxide. It's provided by Hopkin and Williams LTD (British origin), and it has a particle size of 33 μm.

Carbon Nanoparticles (CNP): These are nanometer-scale substances made entirely of carbon atoms. These molecules have attracted the interest of scientists because of their unique structures in addition to their particular chemical and physical properties [15], It's provided by CNP (Any color) (Chine's origin), and its particles are 89.77 nm in size.

Zinc Oxide (ZnO): is an inorganic compound used as an additive in numerous materials and products including cosmetics, food supplements, rubbers, plastics, ceramics, glass, cement, and so on. Although it occurs naturally as the mineral zincite, most zinc oxide is produced synthetically [16], It's provided by Hopkin and Williams LTD (British origin), and has a particle size of 42 μm.

and Aluminum Oxide (Al_2O_3): It is the most commonly occurring of several aluminum oxides, it is commonly called alumina and may also be called aloxide, aloxite, or alundum depending on particular forms or applications [17], was used in the fabrication of composites. It's provided by (BDH LTD) (British origin), and its particles are 31μm in size.

The powders used to create the overlapping samples are shown in Figure 1.

a: NiO b: CNP c: ZnO d: Al_2O_3

Figure 1: Shows the powders used to produce the overlapping samples

2.2 Preparation of Samples

The samples were created using the hand-lay-up molding method, which has numerous advantages. For example, unlike other, more complex methods, this method allows for the preparation of large-volume, complex-shaped samples with the required dimensions without restrictions on the sample size as shown in Fig 2.

Figure 2: plate template used for sample preparation

After drying in the oven, all fillers were sieved to granule size, and the required number of fillings are been produced using an electric balance with an accuracy of (0.001g). Composite samples were made by combining blended epoxy resin with five different weight percentages (10, 20, 30, 40, and 50 wt. %) calculated using equation 1 [18]:

$$Wt\% = \frac{w_P}{w_c} \times 100\% = \frac{w_P}{w_P + w_m} \times 100\% \qquad (1)$$

For a suitable mixing ratio, blend epoxy is weighted using an electrical balance with sensitivity (4-10 g).

Powders were added to the epoxy resin and gently stirred for (15) minutes in a clean container using a mechanical mixer to achieve reasonably equal powder dispersion.

After that, the hardener was gradually added to the mixture while constantly stirring to avoid forming air bubbles within the sample. The thoroughly mixed mixture was then cast in a plastic rectangular mold with a circle shape (10mm * 2mm). To complete the hardening process, the samples were left at room temperature for (24) hours before being heated in an oven at (60 ℃) for (1 hour) to complete the polymerization. The entire assembly was then released and allowed to cure for (10) days at room temperature.

3. Mechanical Tests

The behavior of materials under the influence of loads and external forces is determined by their mechanical characteristics. The durability and strength of the material in use are measurable and play a significant role in the creation of tools, machinery, and architectural constructions. The intended service establishes the mechanical properties and depends on the applicability. In this research, we will study the tensile strength, Compression strength, and hardness test according to the measurements and samples in the table (1).

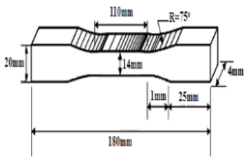
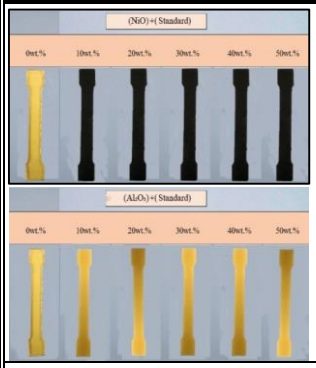
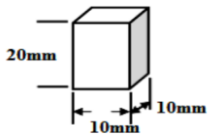
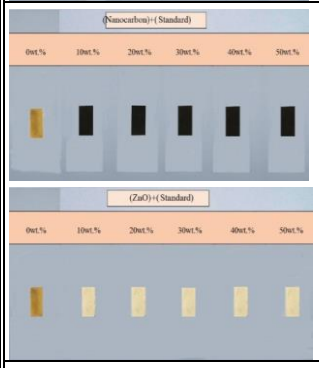
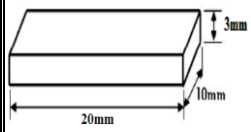
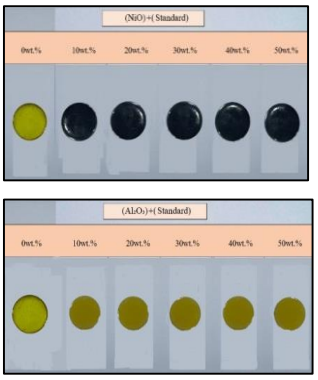
Mold type	Mold Dimension (mm)	International Standards	Sample schematic diagram	Prepared Samples Image
Tensile	4*(14*25)*180	ASTM-D 638-87		
Compression	10*10*20	ASTM-D695		
Hardness	3*10*20	ASTM-D2240		

Table 1: Show the sample schematic diagram

3.1 Compression Strength Test

Compression strength represents the maximum applied stress that a solid can withstand under vertical pressure. The compressive strength can be determined from the equation (2):

$$C.S = \frac{P}{A} \qquad (2)$$

Where $C.S$: Compressive Strength (MPa).

P: Maximum sustained load (N).

A: Section Area (mm^2)

The compression strength of the composite material was tested using a hydraulic piston type (Universal Testing Machine" Ley Bold Harris"), as shown in figure 3, and the load was applied to the sample gradually until it failed and the Compressive strength was determined. The maximum load that the sample can withstand (when failure) represents the maximum value for its compressive strength, and it was calculated using the equation (2), the young modulus is set compressibility [19]

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Figure 3: Compression Test Device

The test samples are attached to a plastic holder made to the company's specifications (phywe) so that they can be placed in the stand, which moves separately or in conjunction with the Geiger counter and has an angle relationship between the counter and the sample. Samples are shown in figure (4).

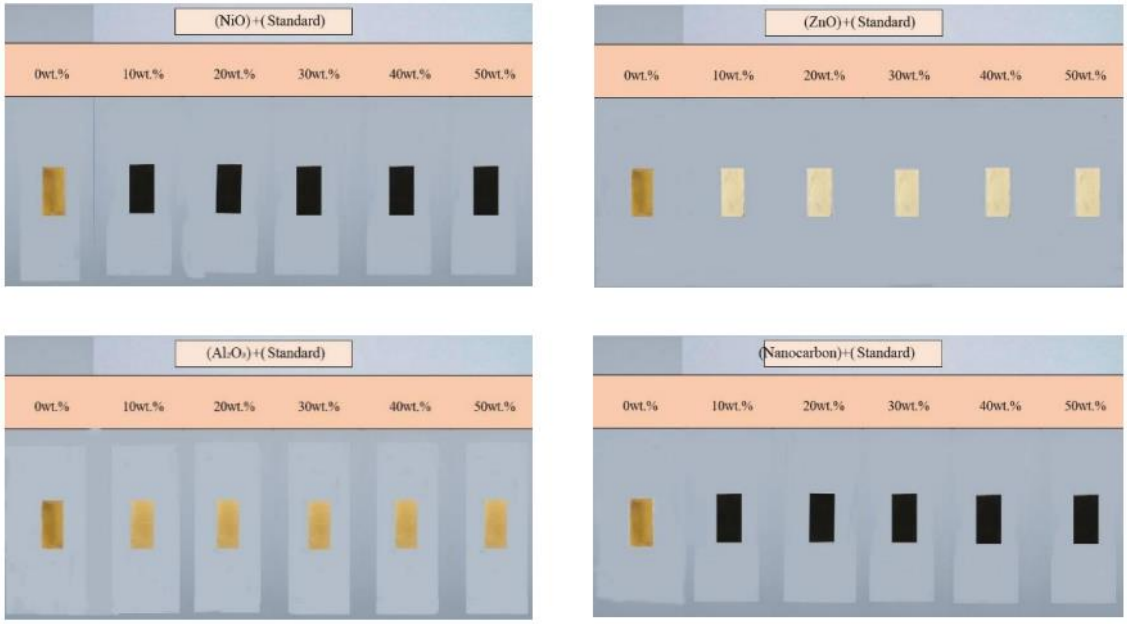


Figure 4: Compression Strength samples

3.2 Tensile Strength Test

Tensile Strength is the maximum applied stress that a solid can withstand when subjected to vertical pressure. As shown in figure 5, the Tensile Strength of the composite material was tested using a hydraulic piston type (Universal Testing Machine "Ley Bold Harris"), and the load was applied to the sample gradually until it failed and the Tensile Strength was determined. The maximum load that the sample can withstand (before failure) represents the maximum value for its Tensile Strength, which was calculated using the equation (3).

$$T.S = \frac{P}{A} \qquad (3)$$

Where $T.S$: Tensile Strength (MPa).

P: Maximum sustained load (N).

A: Section Area (mm^2).

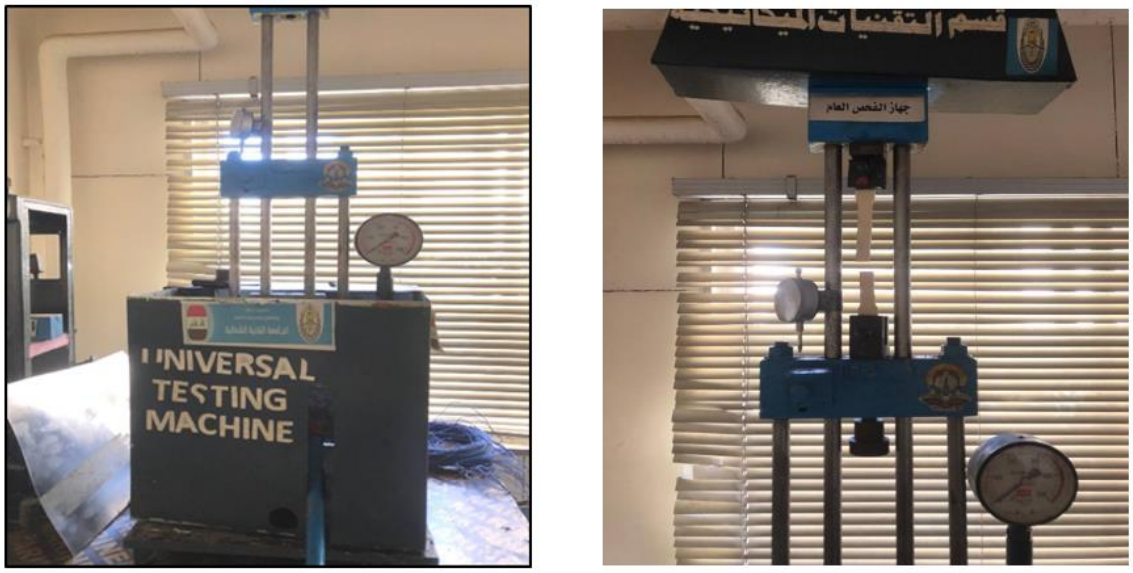


Figure 5: Tensile Test Device

Tensile tests were performed at room temperature using the tensile specimens shown in figure 6 in accordance with ASTM standards.

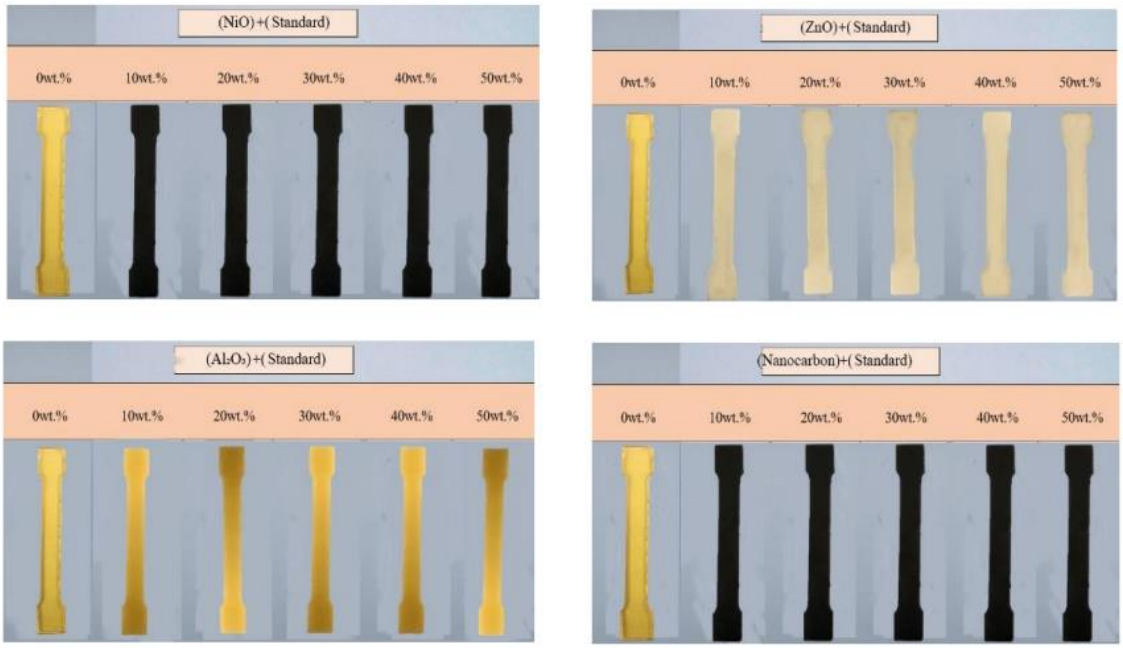


Figure 6: Tensile Strength samples

3.2 Hardness Test

This test was conducted using a Chinese-made Digital Micro Shore D (Durometer) (QUALITEST HPE) as shown in figure 7 instrument that complies with ASTM D2240 as shown in figure 8. To get the average value, eight measurements of hardness were taken at various locations on the specimens.

Figure 7: Shore D Hardness Tester

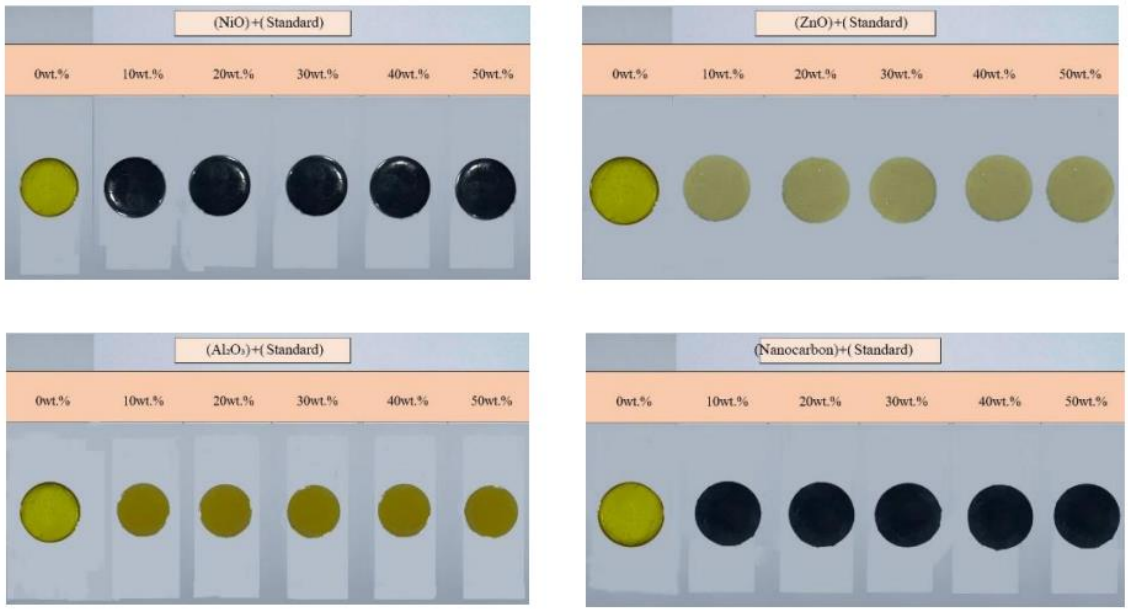
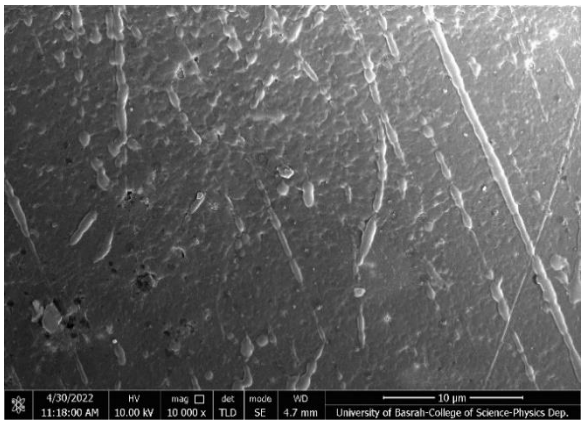


Figure 8: Hardness Tests samples

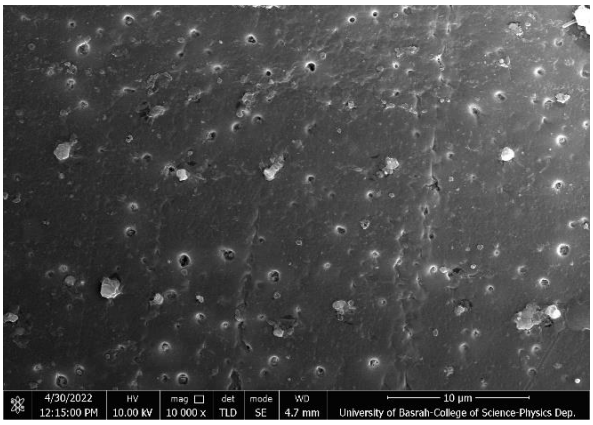
4. Results and discussion

SEM images of blended epoxy resin reinforced with various weight fractions of Nickel Oxide (NiO), Carbon Nanoparticles (CNP), Zinc Oxide (ZnO), and Aluminum Oxide (Al_2O_3) powders are presented in figure 4, figure 6, and figure 8. Using this technique, the powders used may be recognized, and the dispersion of those particles in the final mixes can be estimated. A scanning electron microscope is used to carry out the microscopy research (FEI Nova NanoSEM 450) as shown in figure 9.

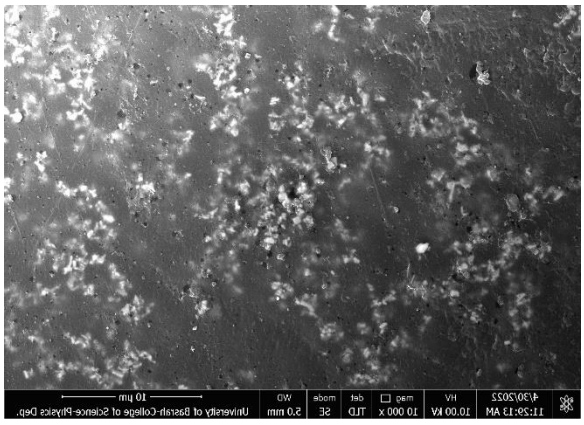
Figure 9: SEM Device



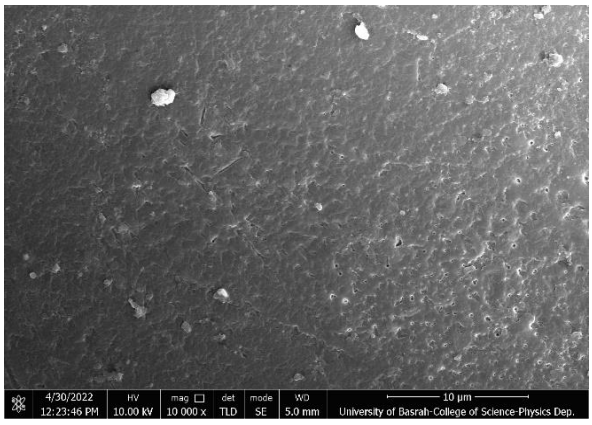
a: NiO



b: CNP



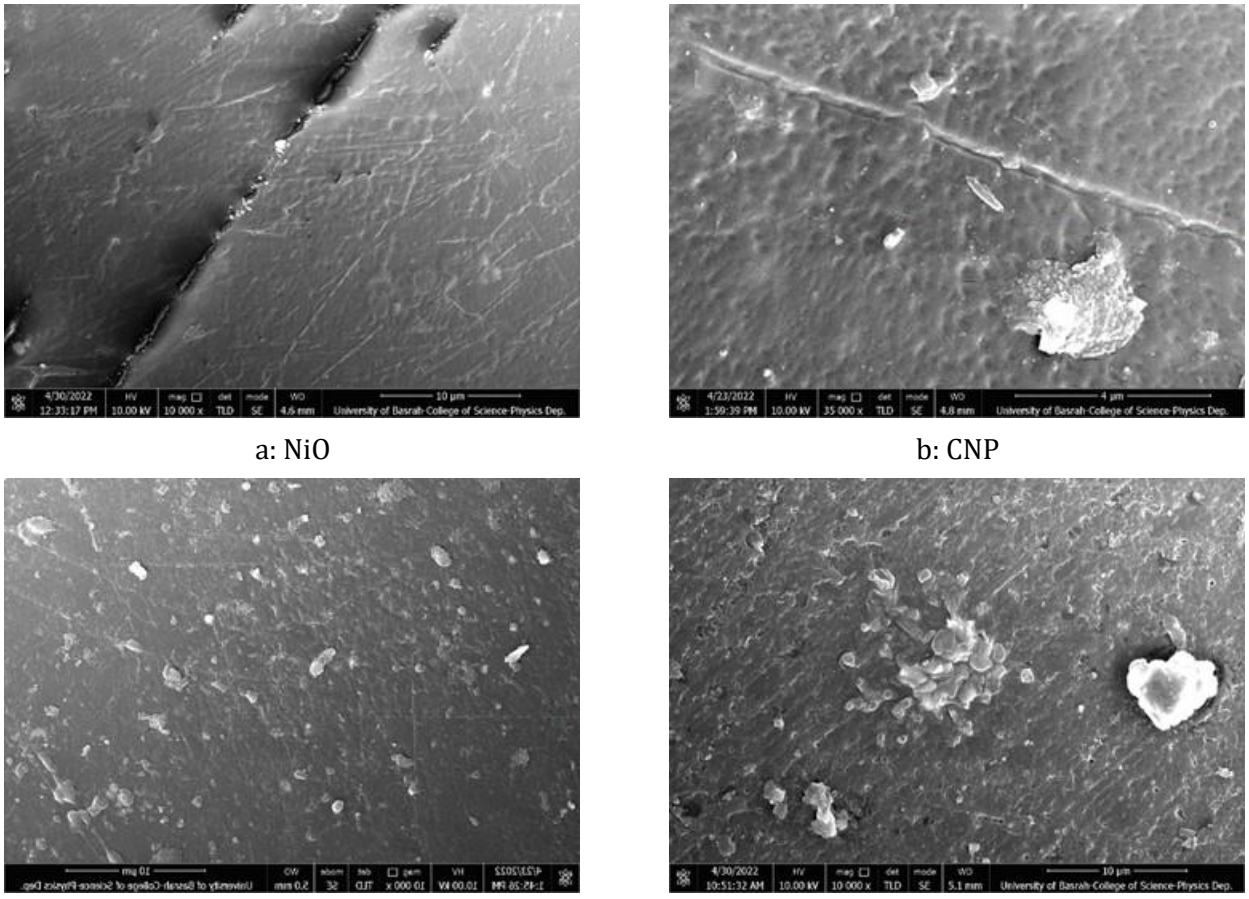
c: ZnO



d: Al_2O_3

Figure 10: Microstructure of blend epoxy reinforced with 10 wt.% of different powders.

The extrusion of (NiO, CNP, ZnO, and Al_2O_3) minerals from the epoxy surface can be seen in Figure 10, along with certain voids that can be identified in Figures (a), (b), and (C). Compared to sample (d), samples (a, b, and c) had surfaces that seemed wavy and rougher overall. which may indicate a higher viscosity. Sample (d) exhibits better than the other samples.



a: NiO b: CNP

c: ZnO d: Al_2O_3

Figure 11: Microstructure of blend epoxy reinforced with 50 wt.% of different powders.

The surface of composites appeared to grow waved and rougher after increasing the weight percentage of reinforcing powders, as shown in figure (11a).

The filler particles scattered across the dark blend epoxy matrix are represented by the light patches. As seen in figure (11b), non-uniform dispersion caused some agglomeration and clusters.

Figures (11c) and (11d) exhibit hazy patches that distinctly illustrate the presence of certain minor filler agglomerations with micro voids.

4.1 Compression Strength

Figure 12 shows that the composite material containing aluminum powder gave higher compressive strength values than those observed for the unreinforced substrate and those reinforced with other powders. It also increases with the increase in the weight fraction of the other types of reinforcement particles because the increase in powder content will increase the material's ability to absorb the compressive energy and thus increases compressive strength.

The tested composites' compressive stress resistance is increased by the addition of aluminum powder, and it was discovered that the compressive strength of samples reinforced with aluminum powder increased more quickly than that of unsupported samples reinforced with other powders, reaching its highest value at the weight fraction (50 wt. %), which is (20.09 MPa) for aluminum, compared to the compression strength of the neat (14.21 MPa).

The distribution of the reinforcement particles between the polymeric chains during preparation prevented (inhibited) the movement of these chains, increasing the stability of the tested compound. This improvement is attributable to the characteristics of the aluminum particles, which are characterized by their resistance to compressive load.

Additionally, the composite material, which contains nickel powder at a concentration of 10%, increases, and decreases at a concentration of 20%, thus, making it unstable. This occurred as a result of the reinforcing particles' decreased ability to moisten with the liquid base material, which caused numerous gaps and bubbles.

With the decrease in the zinc oxide (ZnO) and Carbon Nanoparticles (CNP), the nanocarbon composite matrix's compression strength value. The low value of compression strength is caused by the weak contact between the blend of epoxy resin and particle matter.

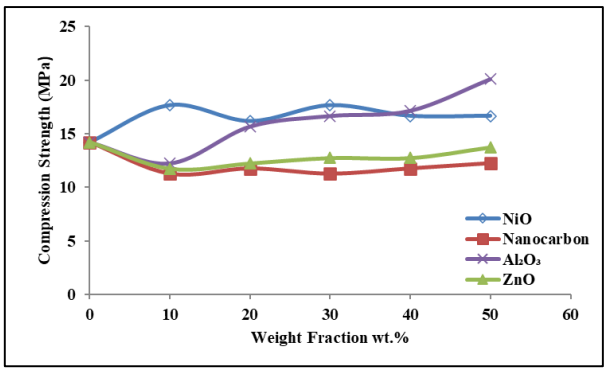


Figure 12: Effect of weight fraction on the compressive strength of blend epoxy resin reinforced with nickel oxide, Carbon Nanoparticles, zinc oxide, and aluminum oxide.

4.2 Tensile Strength

Figure 13 shows the results of tensile samples of the blended epoxy with different percentages of powders. We observe that when the weight fraction of the reinforcement materials, NiO and Al_2O_3, are increased, the tensile strength decreases. This decrease is attributed to several reasons, the higher concentration of cementing powders, the composite material became more fragile. This made it harder for the base material to penetrate between the concreting particles, which increased the formation of air gaps, weakened the bond between the components of the composite material, increased friction between those components, and ultimately caused particle separation.

Failure and cementing of the tested composite material under axial tensile stress, also, the increased interface areas between the powders and the base material as a result of the increased powder concentration increased the density of air bubbles or gaps formed along with the powders, which weakened the interconnection between the components of the prepared compound and concentrated stresses at the weak spots.

For Nanocarbon and ZnO, we see that the breaking point tensile stress increases with the weight fraction of the reinforcing elements, peaking at (1.252 Mpa) at a weight concentration of (50%) ZnO, compared to the tensile strength of the neat (1.361 MPa).

when powders are added to the blending polymer substrate, the tensile strength increases, and the high bonding strength between the base material and the nickel oxide or Carbon Nanoparticles particles, which reduced the slip (movement of particles) between the particles during tensile, is one of the most significant factors that contributed to the improvement in the tensile strength of these composites.

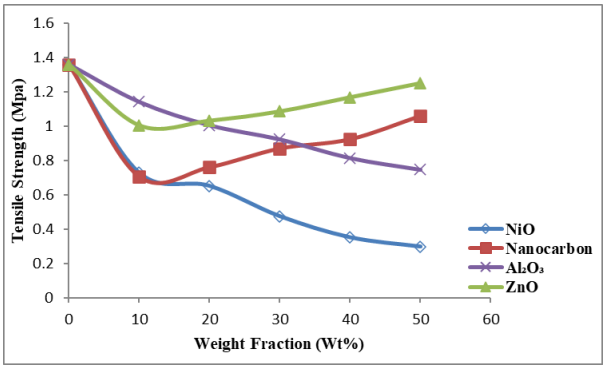


Figure 13: Effect of weight fraction on the tensile strength of blend epoxy resin reinforced with nickel oxide, Carbon Nanoparticles, zinc oxide, and aluminum oxide.

4.3 Hardness Test

As a function of the stress needed to cause particular types of surface deformation, hardness is a measure of the resistance to penetration of the surface [20].

Figure 14 indicates the relation between the hardness of shore D and a weight fraction for NiO, CNP, ZnO, and Al_2O_3 that are added to blended epoxy.

Results show a higher value for hardness shore D is (87.8 at 50%), (38 at 50%), (85.2 at 50%), and (95 at 50%) for NiO, CNP, ZnO, and Al_2O_3 respectively, compared to the hardness shore D of the neat (63.7).

Due to increased crosslinking and stacking of the blended epoxy resin (which decreases the movement of polymer molecules), which led to increased resistance to scratching material and cutting, hardness values increased for all samples strengthened by NiO, CNP, ZnO, and Al_2O_3.

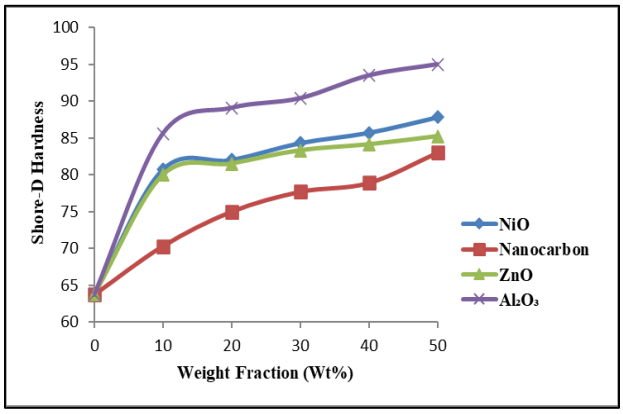


Figure 14: Effect of weight fraction on the Hardness D shore of blend epoxy resin reinforced with nickel oxide, Carbon Nanoparticles, zinc oxide, and aluminum oxide.

5. Conclusion

According to the findings of the present study:

1- SEM images of blended epoxy resin reinforced with various weight fractions of Nickel Oxide (NiO), Carbon Nanoparticles (CNP), Zinc Oxide (ZnO), and Aluminum Oxide (Al_2O_3) powders, The samples (NiO, Nanocarbon, and Zinc) exhibited surfaces that seemed wavy and were generally rougher than the sample (Al_2O_3). It can be a sign of increased viscosity. (Al_2O_3) displays better than the other samples.

2- omposite material containing aluminum oxide (Al_2O_3) gave higher compressive strength values than those observed for the unreinforced substrate and those reinforced with other powders. Which reaches its highest value at the weight fraction (50 wt. %), which is (20.09 MPa)

3- The breaking point tensile strength increases with the weight fraction of the reinforcing elements, peaking at (1.252 MPa) at a weight concentration of (50%) Zinc Oxide (ZnO).

4- Hardness shore D increase with an increase in the weight fraction of added blended epoxy resin. (Al_2O_3) gave higher hardness values than others.

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