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Effects of nanoparticles and fiber type on Hybrid blend Composite materials Behavior of epoxy and phenol formaldehyde.

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Abstract:
Composite materials are quite common today and are used in nearly every segment of civilian and military industry. The idea of reinforcement is not new. Over the centuries natural fibers, have been used to improve the strength and to lessen shrinking of pottery prior to firing and increase the strength in mud houses. This idea in the present form has been exploited with the development of glass, carbon and later of aramid .fibers Phenol formaldehyde resins were mixed with epoxy resins in different proportions to form a hybrid mixture of composite materials. It was reinforced with carbon fiber, glass fiber and Kevlar fibers, as well as reinforced with magnesium oxide (MgO) and zirconia (ZrO_2) nanoparticle particles, to study the effect of fibers and nanoparticles on the behavior of hybrid composites, namely, tensile, bending, hardness, Toughness. The results showed an improvement in the properties of the hybrid mixture after the use of fibers and nanoparticle enhancement.

Keywords: *Hybrid Blend, Behavior, Nanoparticles, Fiber, Phenol Formaldehyde Resin, Epoxy Resin.*

Introduction:

Metal matrix composites (MMCs), like most composite materials, provide significantly enhanced properties over conventional monolithic materials, such as higher strength, stiffness, and weight savings, while continuous fiber reinforcement provides the most effective strengthening, particle reinforced materials are more attractive due to their cost-effectiveness, isotropic properties, and their ability to be processed using similar technology used for monolithic materials[1, 2].Metals are reinforced to increase or decrease their properties to suit the needs of design, like elastic stiffness and strength of metals. Large coefficients of thermal expansion, thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide. (MMCs) have several advantages over (PMCs), like, higher elastic properties, high service temperature, in sensitivity to moisture, better wear and fatigue resistance [3, 4]. Figure (1-a) shows the classification of composite materials. Composite materials are used not only for their mechanical properties, but also for electrical, thermal, technological, environmental and other applications, and composite materials are usually optimized to achieve a certain balance in properties for a particular set of applications. Considering the wide range of uses through which composite materials can be designed, however, the applications of these materials have increased after strengthening them with fibers and nanoparticles [5, 6].

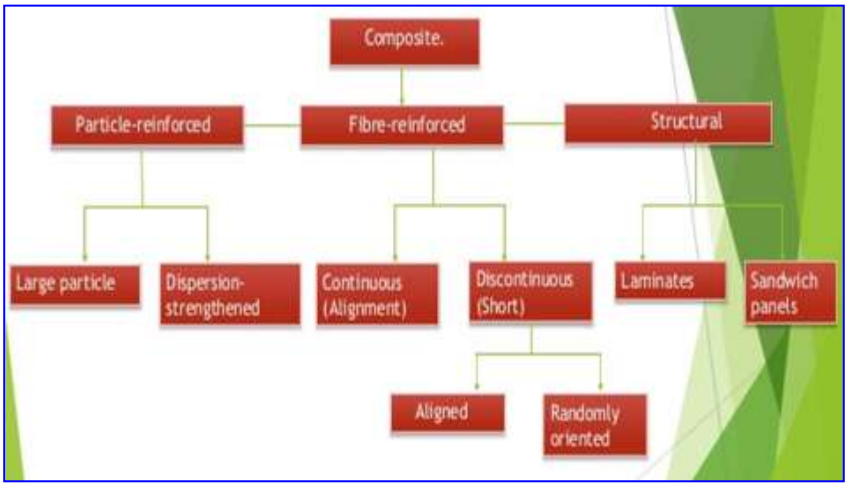

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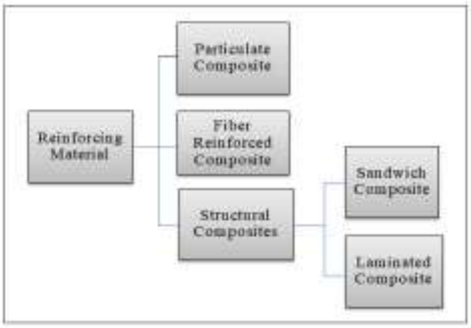
Figure (1-a): Types of composites.

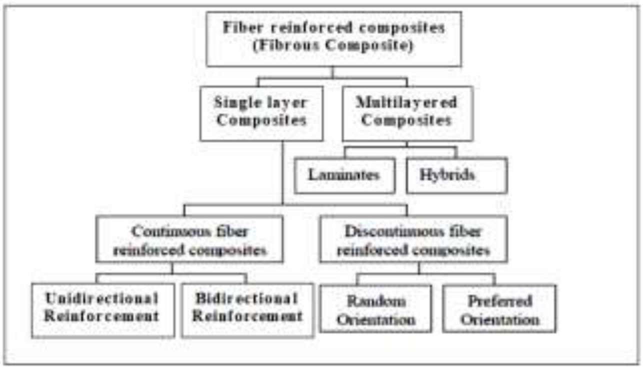
They are categorized in terms of length as short, long or continuous fiber which offer the highest mechanical properties, and give the possibility of using specific orientations to give the composite its directional properties. They are available as lengths of fabric in different direction, all of which have different properties, processing characteristics and costs. These include unidirectional, biaxial, multiaxial, quadric axial and random orientation [4]. Based on the types of reinforcement used, the composites are classified as shown in figure (1-b).

Figure (1-b) Classification of reinforcing material [4].



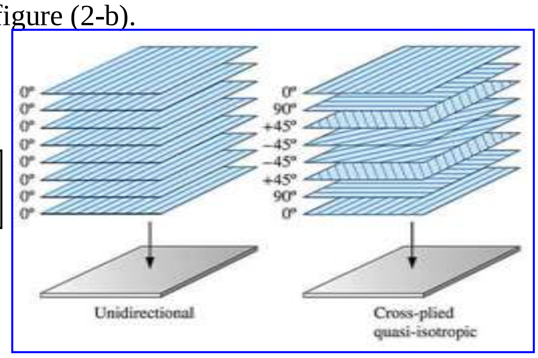
Fiber reinforced composite materials in a single layer composite could be short or long related to its overall dimensions. Composite materials using long fibers are called continuous fiber reinforced composite materials and composite materials using short called discontinuous fibers reinforced composite materials as it shown in figure (2-a). Continuous fibers reinforced composite materials in single layer composites may be all aligned in one direction to form unidirectional composite materials. Such composite materials are made-up by laying the fibers parallel and saturating them with any resinous materials. A single layer in mutually perpendicular directions to form the bidirectional reinforcement materials such as in a woven fabric. The bidirectional reinforcement materials strengths in two perpendicular directions are almost equal. Discontinuous fibers cannot be simply controlled the composite materials orientation. Therefore discontinuous fibers may be either randomly oriented or preferred oriented. [5].

Figure (2-a): Classification of fiber reinforced composites [5].



The fibers can be oriented in any direction in the lamina. The fibers can be arranged in different directions in different laminas as shown in figure (2-b).

Figure (2-b) Unidirectional and multidirectional laminates [6].



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The Aim of the research:
The general use of composite materials depends largely on the mechanical and physical properties of these materials. Therefore, the study of these properties under the influence of the forces and loads of different types of fibers and the reinforcement of nanoparticles is of great importance to determine the suitability of these properties to the workplace in these materials. The epoxy was mixed with phenol formaldehyde resins, according to different mixing ratios for the purpose of manufacturing the test samples needed to obtain the mechanical properties and analyze them and compare them to the best.

Experimental Procedure:
Materials: epoxy resin, phenol formaldehyde (resole) resin, carbon fibers, glass fibers and kevlar fibers. Preparation of samples and properties of tensile, impact and hardness: epoxy resin and phenolic formaldehyde resin were mixed with different weight fractions as shown in table (1a), Tensile strength samples were manufactured according to ASTM D 638, and the tensile test used the universal testing device as shown in figure (3). While hardness samples with a diameter of (25mm) and a thickness of (10mm) were used to test for hardness shore (D) according to ASTM D790 by using the testing device as shown in figure (4). The chirpy durability test was in accordance with ASTM E23 by using the testing device as shown in figure (5). With root radius (0.25 mm) and a depth

Ratio	Tensile Test		Bending Test		Impact Energy (Joule)	Shore D Hardness
	Stress (Map)	Strain	Stress (Map)	Strain		
0%	25.40985	3.378	0.21684	34.31733	0.37	68
5%	26.01369	1.7106	0.2597	33.60467	0.15	70.2
10%	24.26089	3.0093	0.30076	41.04733	0.133	64.6
15%	11.12752	2.168	0.10888	35.772	0	62.8

of 0.5 mm and table (1b) shows the mechanical properties (tensile, bending, toughness, hardness) of the composite material according to the mixing ratios between epoxy and phenol formaldehyde.

Table (1a): Composition of epoxy- phenol formaldehyde hybrid blend

Sample No.	Composition
E1	(Epoxy/Resole) (85/15)%
E2	(Epoxy/Resole) (90/10)%
E3	(Epoxy/Resole) (95/5)%
E4	(Epoxy/Resole) (100/0)%

Table (1b): Testing of epoxy with phenol formaldehyde at different ratio.

Epoxy risen and Resole resin preparation: firstly epoxy resin and resole resin are weighted for suitable mixing ratio and manually mixed then epoxy resin and resole resin were mixed by magnetic stirrers at 800 rpm for 15 minutes and finally add the hardener with suitable mixing ratio to have good homogeneous of hybrid resin as table (2).

No.	mixing ratio of Epoxy risen	mixing ratio of Resole resin
1	100%	0%
2	95%	5%

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3	90%	10%
4	85%	15%
5	80%	20%
6	70%	30%
7	60%	40%
8	50%	50%

Table (2): Hybrid Blind mixing ratio of Epoxy risen and resole resin

Composites Preparation: Hand lay-up technique was used to prepare sheets of epoxy composites pure or reinforced with many types of fibers mat and with nanoparticles filler. The casting mold consists of glass plates with dimensions (200 x 200 x 4 mm) and under the casting mold putted Nylon sheets to prevent adhesion of the composite material. All the test specimens are finished by abrading the edges on a fine carborundum paper. Neat epoxy preparation; firstly epoxy resin and hardener are weighted for suitable mixing ratio, and manually mixed then epoxy resin and hardener were mixed by magnetic stirrers at 800 rpm for 15 minutes to have good homogeneous between epoxy resin and hardener. The mixture was combined with Kevlar fibers, glass fibers and carbon fibers to determine the effect of fibers on the characteristics of hardness and impact. The two-layer reinforcement was shown in figure (5), where (95%) of epoxy resin and (5%) formaldehyde resin as the best mixing ratio in terms of the mechanical characteristics. After selecting this best percentage, it was reinforced with fibers to determine the effect of the fibers type on the properties of hardness and impact as shown in table (2). The Nano magnesium oxide particles and nanoparticles of zirconium oxide were then amplified to demonstrate the effect of nanoparticle reinforcement on the electrophoresis of the hybrid mixture.

Fig. (3a) Tensile Test

Fig. (3b) Bending Test

Fig. (4) Hardness Test

Fig. (5) Impact Test

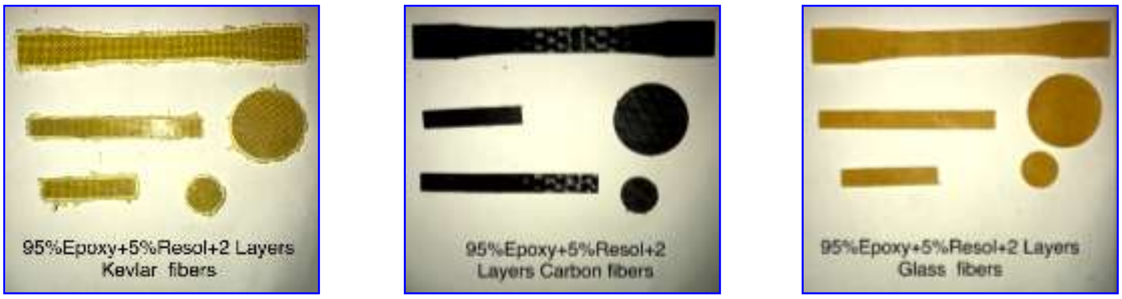

Figure (6): Tensile, toughness and hardness test sample with different type of fiber (carbon, glass, Kevlar).

The fibers reinforcement materials are:

i. Glass fibers (E-glass fiber, Glass Fiber Biaxial Fabric 0/90), the basis of textile-grade glass fibers is silica, SiO_2.

ii. Carbon fibers precursors for the production of carbon fiber include polyacrylonitrile (PAN), isotropic pitch, mesosphere pitch, and regenerated cellulose, among others.

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iii. Kevlar fiber (Kevlar-49 fiber), Materials used as thermoplastic matrix are: (i) P1 - thermoplastic (Styrene Acrylonitrile), (ii) P2 - ASTALAC® ABS (Acrylonitrile Butadiene Styrene) 2029-2, and (iii) P3 - DOWLEX® Polyethylene Resins. The fiber materials used in this work are shown in figures (7) and table (3-a)

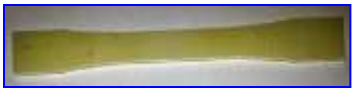
Table (2): Hardness and impact properties at different fibers.

Fibers	Hardness	Impact (J)
Kevlar Fibers	70.1	3.4
Glass Fibers	72.6	2.5
Carbon Fibers	80.1	1.3

Table (3-a): Tensile, Compressive, Elastic modulus , Density properties at different fibers.

Property	Tensile strength	Compressive strength	Elastic modulus	Density (g/cm3)
E-glass	3445(MPa)	1080(MPa)	73(GPa)	2.58
Carbon fiber	(3–7 GPa)	(1–3 GPa)	(200–935 GPa)	1.75–2.20
Kevlar fiber	2757.9(MPa)	517.1(MPa)	151.7(GPa)	1467(kg/m3)

Table (3-b): Tensile test Samples of different types of composite materials.

Symbol of Samples	Tensile Tests Sample	Symbol of Sample	Tensile Test sample
ER		ER/PF/CF	
95% ER/ 5% PF		ER/PF/KF	
90% ER/ 10% PF		ER/PF/ZrO/GF	
85% ER/ 15% PF		ER/PF/ZrO/CF	
80% ER/ 20% PF		ER/PF/ZrO/KF	
ER/PF/ZrO		ER/PF/MgO/GF	

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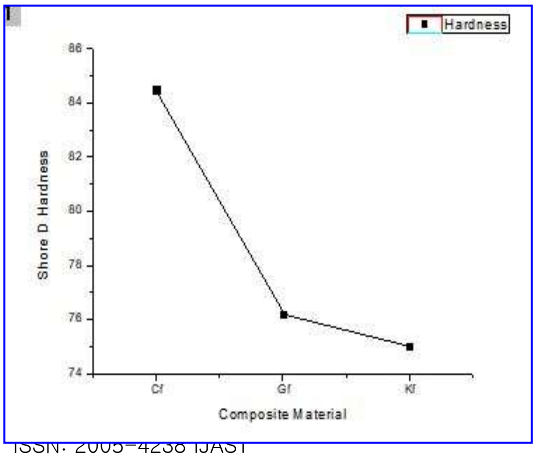
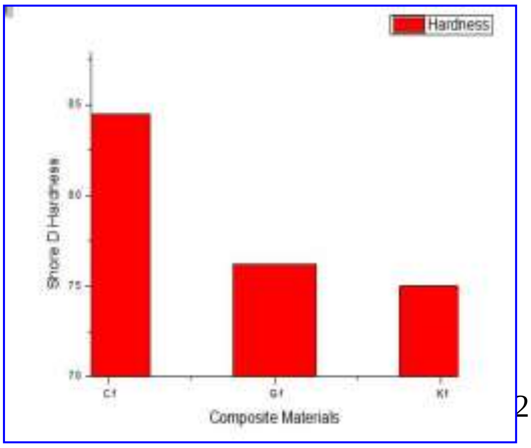
ER/PF/MgO		**ER/PF/MgO/CF**	
ER/PF/GF		**ER/PF/MgO/KF**	

Zirconium dioxide (ZrO_2), which is also denoted to as zirconium oxide or zirconia, is an inorganic metal oxide that is largely used in ceramic materials. Many different ways of producing ZrO_2 Nano size powders, such as hydrothermal processing sol-gel processing and ion exchange manufacture methods [7]. Pure ZrO_2 exhibits three crystalline forms. Pure zirconia is monoclinic (M) at room temperature. This phase is stable up to (1170 ^oC). It will transform into a tetragonal (T) phase under higher temperatures and later into a cubic phase (C) at (2370 ^oC) which illustrate ZrO_2 nanoparticles in three main crystalline structure phases: (a) cubic, (b) tetragonal and (c) monoclinic [8]. Zirconia is used in different fields of chemistry such as ceramics and catalysis. Nano-zirconia ceramics are of great attention for their obvious enhancement in strength and toughness. Its high hardness, low reactivity and high melting point (2715 ^oC) which change mechanical property, thermal performance, electrical performance and optical performance of ceramic components [9]. The magnesium oxide (MgO) is a very suitable material for insulation applications due to their low heat capacity and high melting point (2850 ^0C). MgO is obtained by thermal decomposition of different magnesium salts. The crystal structure of magnesium oxide is cubic. MgO is used as dielectric layer due to its excellent properties such as high dielectric constant (~9.8), large band gap in the range of (7.3 eV-7.8 eV) and higher breakdown field (12 MV/cm) compared to commonly used dielectric layer . Magnesium oxide nanoparticles can be applied in electronics and coatings fields [10].

Results and Discussions

The most common mechanical properties for the purpose of the examination of any material, the hardness is the resistance of the material to penetrate by an earlier material, but durability is the ability of the material to absorb the impact of the impact and formation of a formation before the occurrence of fracture [7, 8]. The resin is fragile and its resistance to external loads is very low. But when phenol formaldehyde is added, the resistance to composite material will improve significantly because it is characterized by its low elasticity. This resistance is increased by increasing the added weight ratio because it occupies more space inside the resin, allowing better distribution of the load. It is known that fragile materials contain a small elastic deformation area. The elasticity coefficient values increase with the increase in the ratio of the reinforced material due to the increase in bonding density, which greatly affect fibers elasticity, so that the material becomes solid at low voltage rates, increasing the elasticity coefficient. As for the hardness characteristics of the mixtures, the resin is a low-hardening material, but when reinforced with fibers, the hardness properties of the compound material are clearly improved because they occupy more space within the resin, allowing better distribution of the load. Figure (7) shows the hardness of composite materials by type of fibers, where it is observed to be fairly close, and the highest values of the hardness were composite materials supported by carbon fibers followed by glass fibers and then Kevlar fibers [9].





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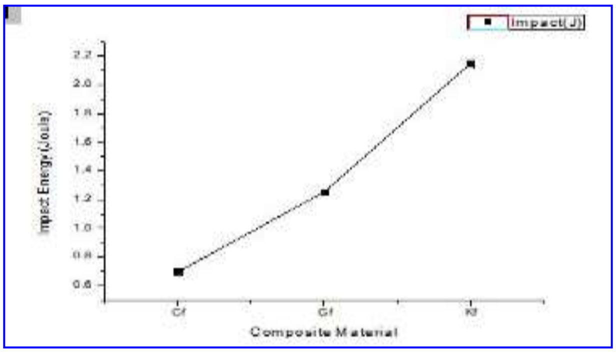
The nature of fibers ss, because the hardness of these fibers vary by while the other fibers are made of polymeric materials. The hardness test was carried out by regression method and by four readings per sample. This was the most suitable method for measuring hardness, because the hardness values obtained reflect the condition of the material as a whole and not just the surface state. Fibers orientation has an influential role in hardness values. The statistical pattern (90° - 0°) gave the highest values of hardness compared to samples of random pattern. This indicates that the use of fibers in a concrete pattern gives more positive results in the reinforcement process. It is also noted that the fibers reinforcing system increases the hardness value of the fracture specimens. Its total volumetric volume increases this hardness value with increase the number of layers of reinforcement, which confirms the positive effect of the arming process with these fibers [10]. Figure (8) illustrates the impact of fibers on impact resistance. Kevlar fibers gave the highest impact values of glass fibers and carbon fibers. The reason for this is that Kevlar fibers had the greatest ability to absorb shock energy. The shock test is one of the most dynamic mechanical tests in which the material is subjected to rapid engine load. Shock testing of charpy samples is performed at room temperature, where the value of shock resistance decreases as the volumetric fraction of the supporting molecules increases because they are weak in tolerance of the permissible load [11].

Figure (7): The hardness of compound materials by fibers type.

Figure (8): The impact of compound materials by fibers type.



The failure of the non-reinforced resin material under the impact of the shock test results in the breakdown of the bonds or forces in the polymer by the growth of the initial cracks that arise as a result of the impact of the shock pressures. These cracks grow and multiply rapidly towards the interfaces between the polymer fibers because the forces between these fibers are (vander waal), which require a small amount of energy to overcome them, and the cracks extend in a direction perpendicular to the direction of polymer fibers to break these fibers during the propagation process, it is worth mentioning that this requires more energy to overcome covalent bonding. Figure (9) shows the tensile relationship of the stress curve of the composite material to the epoxy resin with phenol formaldehyde resin by 5% and the reinforcement of the various nanoparticles (Magnesia and Zirconia Oxide) resulted in improved properties. Zirconia oxide particles gave the best resistance to stress through the stress curve compared to the magnesium oxide and composites without addition, because polymer nanoparticles as an interactive mixture of polymer with nanoparticles are characterized with a small size of fillings leading to a widening of the interstitial area, thus creating a large part of the polymer's interaction with nanoparticles in the structure of polymeric molecules, which play an important role in enhancing the strength of the polymer structure, Polymeric nanomaterials improve the mechanical, thermal, electrical and optical properties clearly, without increasing the density[12].

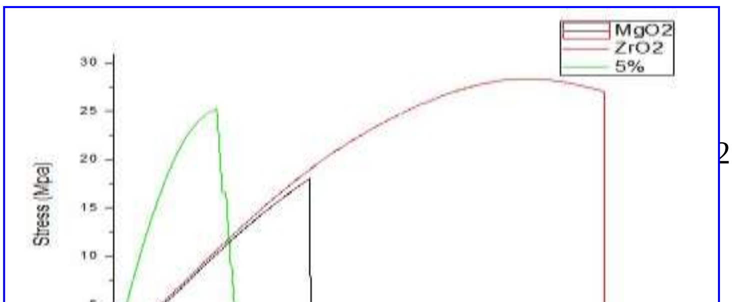


Figure (9) the tensile stress-strain curve of compound materials by nanoparticle's type.

strain(%)

Figur[e] ... of the stress-stress curve to the composite material contained on epoxy resins with phenol formaldehyde by 5% and the reinforcement of various nanoparticles (magnesium oxide and zirconia oxide). Zirconium oxide nanoparticles gave better bending resistance than magnesium oxide particles and composite matter without addition, assuming that the properties of the material were uniform by uniformly distributed power.

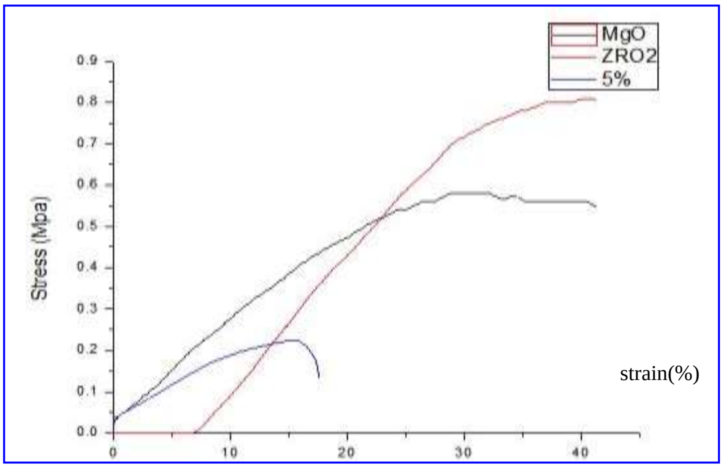


Figure (10) the bending stress-strain curve of compound materials by nanoparticle's type.

Conclusions

1- Toughness increases with increased weight ratio of fibers.
2- The elasticity value increase when fibers are reinforced due to increased bonding density.
3- Fibers-reinforced leads to a decrease in material hardness due to the generation of pores.
4- The cracks grow and multiply rapidly towards the interfaces between the polymer fibers because the forces between the fibers are strong Vander Waal.
5- The reinforcement of the various nanoparticles (Magnesia and Zirconia Oxide) resulted in improved properties.
6- Zirconium oxide nanoparticles gave better bending resistance than magnesium oxide particles and composite matter without addition.

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