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Impact Strength of ZnO and Sand/(Epoxy-Polyester) Blend Composites

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Abstract

This work included preparation five groups polymeric composites. From matrix of polymer blend (Epoxy (EP) 80% + unsaturated polyester (UPE) 20%) with(Nano ZnO) with weight fraction (2%,4%,6%,8%) of zinc oxide (ZnO), with weight fraction (5%,10%,15%,20%), also sand material in three different grain size (53,63,74) μm respectively with weight fraction (5%,10%,15%,20%) and by employing hand lay-up method. First group (G1: nano ZnO): consists of four samples prepared from reinforcing blend (80%EP/20%UPE) with (ZnO powder) in the same above weight fraction. Second group (G2: powder ZnO): consists of four samples prepared from reinforcing Blend (80%EP/20%UPE with (powder ZnO) in the same above weight fraction. Third group (G3: powder Sand) and fourth group (G4: powder Sand) and fifth group (G5: powder Sand) in the same weight fraction. It was found that the reinforcement of the above materials leads to an improvement in mechanical properties and impact resistance of composite materials in normal conditions.

Keywords: Impact resistance, Epoxy, Unsaturated polyester, Blend, Mechanical properties.

الخلاصة

تم في هذا العمل تحضير خمس مجموعات متراكبات بوليمرية مكون خليط بوليمري من رتنج الايبوكسي و البولي استر الغير مشبع بوصفة مادة اساس بنسبة (80%) من الايبوكسي و (20%) من البولي استر الغير مشبع ,وتم تدعيمة بإضافة دقائق مايكروية ونانوية من مادة اوكسيد الخارصين ومادة الرمل لثلاث احجام دقائقية مختلفة هي (74,63,53) مايكرون علي التوالي . باستخدام طريقة القولبة اليدوية. تم التدعيم باوكسيد الخارصين المايكروي بنسب وزنية %(٥،١٠،١٥،٢٠) و اوكسيد الخارصين النانوي وبنسب وزنية %(٢،٤،٦،٨) والرمل ٥٣مايكرون والرمل ٦٣مايكرون والرمل ٧٤مايكرون وبنسب وزنية %(٥،١٠،١٥،٢٠) على التوالي . وقد وجد ان التدعيم يؤدي الى تحسين في الخصائص الميكانيكية المتمثلة بمقاومة الصدمة للمواد المتراكبة في الظروف الطبيعية.

Introduction

Composite materials know as solid systems those resulting from the mixing of two or more different forms or structures, on condition that they do not chemically interact but they have a physical bond between them in order a new different material that differs in its properties from the individual properties of the initial materials[1][2]. Polymer nanocomposite materials possess two phases consisting of inorganic particles of nanometer scale in the range between 1 and 100 nm that are dispersed in a matrix of polymeric material Due to nanometer size of these particles; nanoparticles demonstrate remarkable properties because of their comparative large surface area per unit volume. Such properties are the results of the phase interactions that take place between the polymer matrix and the nanoparticles at the interfaces since many essential chemical and physical interactions are governed by surfaces. The interest in polymer nanocomposites comes from the fact that the addition of nanosized fillers into a polymeric matrix would have a great effect on the properties of the matrix[3][4] epoxy resin systems are increasingly used as matrices in composite materials for a wide range of automotive and aerospace applications, and for shipbuilding or electronic devices. They serve as casting resins,

adhesives, and as high performance coatings for tribological applications, such as slide bearings and calendar roller covers. However, because the polymer matrix must withstand high mechanical and tribological loads, it is usually reinforced with nanofillers[5]. Unsaturated polyesters are sold in a liquid form that requires catalyzation in order to cure[6]. Epoxy- polyester based polymers are enhanced the impact strength according to the percentage concentration of UPE, makes the blend a ductile, good mechanical properties and increase the energy absorption of the sample[5][6]. Particulate chosen as reinforcement are usually harder and stiffer than the polymer matrix, which thus improves the mechanical properties of the polymer composite[7] among the commonly used particulate reinforcement, silica particles reinforcement has gained much attention in recent years due to its availability, low cost and stiffness[8][9].

A major aim of the this work was to improve mechanical properties i.e. (impact) of the Blend (unsaturated polyester and epoxy) the addition effect of ZnO and Sand the reinforcing the Sand at different loading levels and to optimize the effect of loading level of the Sand as well as economic efficiency via using low cost composites materials.

Materials and Methodology

Two different types of the resins were used in the current study. Epoxy resin (Quickmast 105) was used in this research is a two component, low viscosity epoxy resin system in the form of transparent liquid (which transforms into solid state after adding the hardener to it in a percentage of 3:1) as supplied by Don Construction Products Ltd. UK and have a density (1.04 g/cm^3).

Unsaturated polyester (UPE) which has two components composed of a base resin and curing agent (hardener), medium viscosity polyester system in the form of transparent liquid, which transforms into solid state after adding the hardener to it in a percentage of (2%). Which supplied by Saudi Industrial Resins (SIR) Company, Saudi Arabia, the curing agent (hardener) was methyl ethyl ketone peroxide (MEKP).

The properties of epoxy resin and Unsaturated polyester (UPE) used in this work is shown in Table 1 according to the properties of product Company.

Table 1: the properties of epoxy resin and unsaturated polyester used in this work according to the properties of Product Company [5] [10].

Test Methods	Density gm/cm^3	Thermal Conductivity w/m.˚C	Tensile Strength MPa	Percent Elongation (EL%)
epoxy resin	1.04	0.18-0.195	25	<6
unsaturated polyester	1.2	0.17	41.4-89.7	<2.6

Five types of Material were used in this research. These types were Nano ZnO, particulate ZnO and Sand Particles in three different grain size (53, 63, 74 μm), respectively. The Sand were collected and crashed by using an electrical mill. The particulates sand were sieved by vibratory sieve shaker to get a suitable size. The grains size in this research was (53, 63, and 74) μm, that it was resulted from sieve had mesh (270, 230, 200). The Sand Particles were used (10, 15) wt. %. Zinc oxide is an inorganic compound with the formula ZnO. It usually appears as a white powder, nearly insoluble in water. The powder is widely used as an additive into numerous materials and products including plastics, ceramics, glass, cement, rubber (e.g car tyres), lubricants, paints, ointments, adhesives, sealants, pigments, foods (source of Zn nutrient), batteries, ferrites, fire retardants, etc. ZnO is present in the earth crust as a mineral zincite; however, most ZnO used commercially is produced synthetically[10]. Some basic physical parameters of ZnO at the room temperature are presented in the Table 2.

The sand was used in this research as supplied by Don Construction Products Ltd. UK and has a density (2.65 g/cm^3). The composition of this powder is given in the Table 3.

Table 2: Some basic properties of wurtzite ZnO [10].

Property	Value
Stable crystal structure	wurtzite
Density	5.606 gm/cm^3
Melting point	1975 ˚C
Dielectric constant	8.66
Bulk Young modulus	111.2±4.7 GPa

Table 3: Chemical analysis of sand.

Z	Symbol	Element	%
14	Si	Silicon	6.558
11	Na	Sodium	0.327
13	Al	Aluminum	0.5179
19	K	Potassium	0.6870
20	Ca	Calcium	0.2649
22	Ti	Titanium	0.1122
26	Fe	Iron	0.1752
38	Sr	Strontium	0.01689
56	Ba	Barium	0.0376

Hand lay-up molding was used in the process of preparing the samples under test, thus five samples were prepared as follows:

1. Epoxy resin mixed with hardener (3:1) ratio.
2. Polyester resin mixed with hardener to it in weight ratio of (98: 2).
3. The mixture in the step (1) mixed with the mixture in the step (2).
   (EP 80% +UPE 20%) in order to prepare the polymer blend.
4. The polymer blend in the step (3) reinforced by (10% ZnO, 8% Nano ZnO and Sand Particles) in three different grain sizes (53, 63 and 74 µm).
5. Five groups for composites materials prepared:

The mixed of composites was poured into the mold according to test. The dimensions of test samples were in accordance with ASTM[6].
Mechanical properties were measured at room temperature (25-30 ˚C) using different types of mechanical testing instruments as follow:
Charpy impact test instrument, manufactured by the Testing Machines AMITYVILLE INC, New York, was used for the sake of performing impact test on the prepared samples. This test was done in room temperature; impact strength is calculated from the relation[8].

$$E = mg\,(h - h') \qquad (1)$$

Where; m is the mass of pendulum and g is the gravitational acceleration. The geometry of 55 mm long, standard Charpy test specimen is given in Figure 2.

$$U_c = \frac{E}{A} \qquad (2)$$

Where: $\boldsymbol{U_c}$ = impact strength, E = Energy of fracture in (J), A = Cross section area in (m^2**).**

Results and Discussion

Figure 1, show that Impact strength increase with increasing weighted fraction of ZnO nanoparticles, mobility of polymer chains because of hard ceramic nano filler can be the reason for high Impact strength exhibited by slabs at 8% filler content. Higher surface area of ZnO nanoparticle reinforces larger volume of resin matrix and stress can be moved to nanoparticles more competently owing to high interfacial area between resin and filler. , this behavior is in good agreement with the behavior obtained by R.V. Hussein K. H. [14]. The impact strength has a higher value volume fraction of ZnO nanoparticles, in 8% Wt of ZnO nanoparticles.

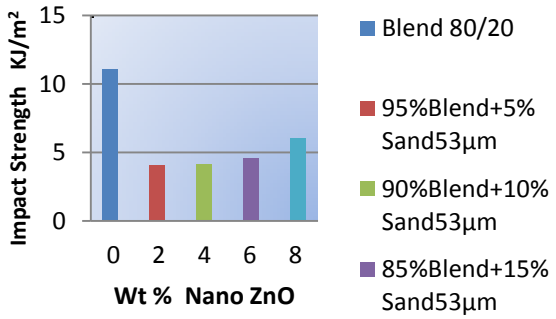

Figure 1: Impact strength versus ZnO nanoparticle weighted fraction of (Blend) EP/UPE and (Blend + ZnO) nanocomposites.

Figure 2 illustrates the behavior of variation impact strength of Blend/ZnO microcomposites vs., ZnO microparticles weighted fraction. The impact strength of Blend/ZnO microcomposites reduce with increasing the concentration of ZnO microparticles. The impact strength has a higher value weighted fraction of ZnO

nanoparticles, in 10% Wt of ZnO microparticles. . By comparison, we notice that the values of Impact strength for particles of ZnO have maximum values of Impact strength more than samples of nano ZnO.

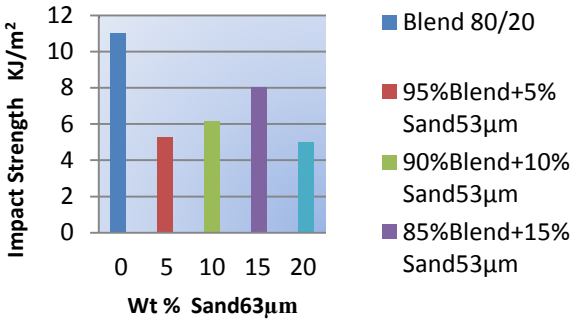

Figure 2: Impact strength versus (Sand 53 µm) weighted fraction of (Blend) EP/UPE and Blend + Sand 53 µm microcomposites.

Figures 3, 4 and 5 illustrate the behavior of variation impact strength of Blend/ Sand53µm, blend + sand 63µm and blend + sand 74 µm microcomposites vs., sand microparticles weighted fraction. The Impact strength of blend / sand 53 µm microcomposites reduce with increasing the concentration of Sand microparticles. The impact strength has a higher value weighted fraction of Sand 53 µm microparticles, in 10% Wt of Sand microparticles. The impact strength have a higher value weighted fraction of sand 63µm and sand 74µm microparticles, in 15% wt. of Sand microparticles. While, impact strength reduces with increasing the concentration of Sand63µm and Sand 74 µm microparticles, minimum value was (4.977 J/m^2) for Sand 63 µm and for Sand 74 µm (7.026 J/m^2) at 20% wt. By comparison, we notice that the values of impact strength for particles of sand 53 µm have maximum values of impact strength more than that other in sand 63 µm and sand 74 µm, because of the properties of micro particles surface (low porosity) where approximately the interactions of Blend with the surface of micro particles are very poor. Also, micro particles size rise space distance among Blend chains which leads to increment bad bonding between Blend chains, these reasons perform to reduce Impact strength of blend + sand 63 µm micro composites with increasing the concentration of sand (53,63 and 74 µm) microparticles.

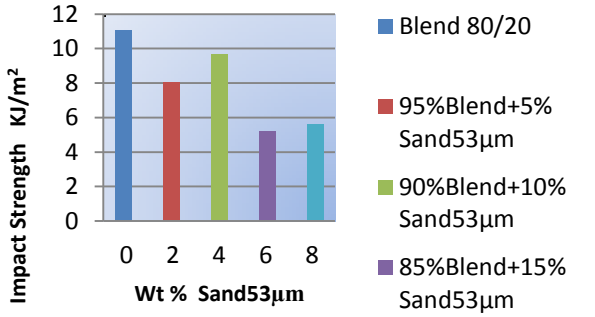

Figure 3: Impact strength versus (Sand 63 µm) weighted fraction of (Blend) EP/UPE and Blend + Sand 63 µm microcomposites.

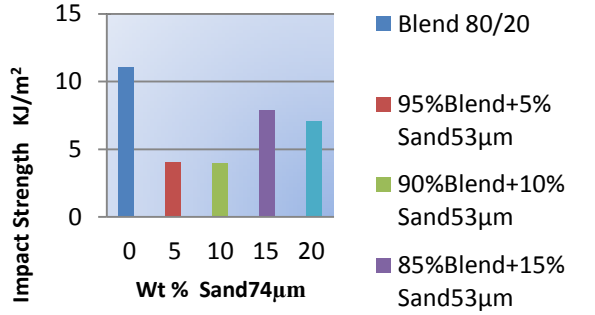

Figure 4: Impact strength versus (Sand 74 µm) weighted fraction of (Blend) EP/UPE and Blend + Sand 74 µm microcomposites.

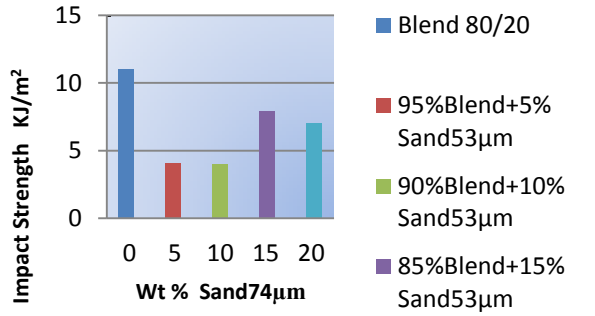

Figure 5: Impact strength versus (Sand 74 µm) weighted fraction of (Blend) EP/UPE and Blend + Sand 74 µm microcomposites.

From Figures 1, 2, 3, 4 and 5 and Table 4, we see that the (I.S) decreases with increasing weight fraction for all samples ,The reason for this is due to the increased weight fraction leads to increased fragility of the material and therefore reduce durability under fast mechanical movements and easily broken.

Table 4: Shown the values of Impact Strength for all samples.

	sample	Impact Strength U_c, KJ/m^2
	Matrix Blend 80/20 (EP/UPE)	11.0192
G1	Matrix Blend Reinforced with 2% by nano-ZnO 30 nm	4.02
	Matrix Blend Reinforced with 4% by nano-ZnO 30 nm	4.105
	Matrix Blend Reinforced with 6% by nano-ZnO 30 nm	4.574
G2	Matrix Blend Reinforced with 8% by nano-ZnO 30 nm	6
	Matrix Blend Reinforced with 5% by ZnO µm	7.978
	Matrix Blend Reinforced with 10% by ZnO µm	8.956
	Matrix Blend Reinforced with 15% by ZnO µm	7.95
	Matrix Blend Reinforced with 20% by ZnO µm	7.894
G3	Matrix Blend Reinforced with 5% by sand 53 µm	8.025
	Matrix Blend Reinforced with 10% by sand 53 µm	9.642
	Matrix Blend Reinforced with 15% by sand 53 µm	5.204
	Matrix Blend Reinforced with 20% by sand 53 µm	5.566
G4	Matrix Blend Reinforced with 5% by sand 63 µm	5.257
	Matrix Blend Reinforced with 10% by sand 63 µm	6.157
	Matrix Blend Reinforced with 15% by sand 63 µm	8.03
	Matrix Blend Reinforced with 20% by sand 63 µm	4.977
G5	Matrix Blend Reinforced with 5 % by sand 74µm	4.041
	Matrix Blend Reinforced with 10 % by sand 74µm	3.979
	Matrix Blend Reinforced with 15 % by sand 74µm	7.901
	Matrix Blend Reinforced with 20 % by sand 74µm	7.026

Conclusions

In this research, has been that deviation increases with increasing force meted and the increase in the concentration of ZnO in all the samples. The matrix blend 80/20 (EP/UPE) has high values for Impact test. Impact test results under normal conditions (room temperature) indicate decreases with the increasing of ZnO concentration in all samples, and its value in the samples of ZnO Powder) is larger than it in the samples of (Nano ZnO). Impact increases with increasing in the concentration of Sand in all samples. The best value with weighted fraction of ZnO nanoparticles was (6 kJ/m^2) for 8% wt.. The best value with weighted fraction of ZnO micro particles was (8.956 kJ/m^2) for 10% wt.. The best value with weighted fraction of Sand 53 µm particles was (9.642 kJ/m^2) for 15% Wt., the best value with weighted fraction of Sand 63 µm particles was (8.03 kJ/m^2) for 15% Wt., the best value with weighted fraction of Sand 74 µm particles was (7.901 kJ/m^2) for 15% wt.

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