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Study of Wear Rate and Some Mechanical Properties for Nanocomposites (Blend\SiC–PZT)

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Abstract: A polymer blend was prepared from epoxy resins and unsaturated polyester. The blend was supported with two nano-ceramic (SiC and PZT) of 2, 4 and 6% weight percentages (wt.). Wear rate, impact strength and surface hardness of the blend samples and composites had been studied prior to and after immersion in water for 11 weeks. The results showed that the highest wear rate was for the polymeric unsupported blend while the support reduced the wear rate for the composites as the addition rate increased. Alternatively, the support increased the surface hardness and reduced the impact strength of composite material. Impact strength for composites which was smaller the one of the blend. It was also observed that immersion in water increased the wear rate and reduced the impact strength and surface hardness for the blend as well as the composite equally. The SiC improved the characteristics of composite better than PZT.

Key words: Wear rate, impact, hardness, blend, epoxy, polyester, SiC, PZT

INTRODUCTION

Because of the great technological and industrial development that the world is witnessing in all fields, the need emerged for finding materials that contains several industrial uses with high quality and low cost. The trend was to introduce the so-called composite materials (Schwartz, 1984). The polymeric composite material has great importance because of its characteristics that suit several construction and industrial applications (such as high quality and durability performance and electrical-thermal characteristics). Such materials have developed into the cornerstone in several applications (Kang, 2010). To have polymeric composite materials with certain qualifications which cannot be obtained from one type of polymers many attempts were made to blend many types of polymers to have a blend that met the desired qualifications as base material (Rudin and Choi, 2013). Nano-composite materials of polymeric bases are among the mainly significant advanced materials that contribute in solving difficult problems in several fields of life and industry. The form and size of added particles, its way of contribution in the basic material in addition to region interface and nature of linking between the particles and basic materials are all elements that influence the final characteristics belong to composite material (Al-Rawi and Abdulwahid, 2015).

The researcher's interest has been recently increased towards the study of friction, lubrication and the wear which has a clear role in the operation of multi-mechanical systems. In materials science, wear is erosion or sideways relocation of material from its "subordinate" and unique position on a solid surface made via. the activity of another surface. Also, wear occurred as a result of interaction between the solid objects with the surrounding conditions such as temperatures, liquids, gases and etc. (Dara, 2008). Wear is classified into the following: abrasive wear, erosive wear, surface fatigue wear and adhesive wear.

In this study, adhesive wear was investigated which occurred as a result of surfaces slipping among one another due to the load influence. The pressure on the protrusions which are in contact, makes local plastic distortion and adhesion. High quality adhesion occurs among few protrusions because of an attraction force among the surface's atoms. And because the real contact distance is much smaller than the apparent contact distance, the pressure gets higher at the paramount of the weak contacted protrusions. There are many methods to measure the wear rate of which weight method is the easiest (Dheyaa and Mnajid, 2012) which is also used in this study.

The impact test mains toughness of materials in other words, the ability of material to absorb energy during plastic distortion, static tension tests of unnotched samples don't generally reveal the susceptibility of a metal to brittle fracture, this factor is determined by impact test (Dheyaa and Mnajid, 2012).

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To measure the toughness of material a stander machine of testing uses a pendulum to hit a notched sample determined cross-section and distort it. The Charpy and Izod notched impact strength tests are typical ASTM tests used to determine toughness. Some of the polymeric materials become ductile under the impact of static tension but they look brittle under the impact quick tensions (Baijal, 1982). This test relies upon the fact that some of the primary potential energy existing in the hammer is absorbed by the sample before the fraction occurs and this absorbed energy depends on the components that is used in manufacturing the composite and its ability to resist the external stress (Schaffer *et al*., 1995).

Hardness refers to a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied. Similarly it gives a good idea about the durability as well as coherence of the substance. Hardness characteristic is very important for parts exposed to slippery friction (Zones and Shen, 2008).

MATERIALS AND METHODS

Used materials

Matrix material: A blend of epoxy resin and unsaturated polyester [Ep80+UPE20%] was used in this experiment. The epoxy used (Swiss made by Swiss Chem of type Euxit50) is thermally hardened polymer, transparent liquid, adherable with little refraction. It possesses a density of (1.05 g/cm^3) and can be transformed to the solid state by addition of the hardening with a blending rate of 3:1 in lab temperature. The used polyester (manufactured by Saudi Company of Industrial Resin Ltd.) is a thermally hardened polymer, observed as a yellow transparent liquid with density of 1-1.3 g/cm^3. The polyester is treatable in lab temperature to the solid state by adding the hardening agent with rate of 0.02/1g.

Reinforcement materials: Nano Silicon Carbide powder (SiC 50 nm, grayish white powder that is characterized by its strength and hardness) was used with a density of 3.22 g/cm^3) and purity of 99% as a primary reinforcement material. Nano lead zirconium titanite powder (PZT 10 nm, a white brittle powder) with a purity of 99% and elevated density of 7.5-8 g/cm^3 as a secondary reinforcement material.

Samples preparation: Hand Lay-up molding was used to prepare the following research samples:

- Unsupported polymeric blend samples (Ep+UPE)
- Supported polymeric blend by nano (SiC) with weight fraction of 2, 4, 6 wt.%
- Supported polymeric blend by nano (PZT) with weight fraction of 2, 4, wt.%

Once the fulfillment of the casting procedure and heat cure needed for the completion of the polymerization process, the samples were sliced to shapes in addition to dimensions for each test, according to the standard specifications (ASTM).

Tests

Wear test: Wear test was performed using the slipping wear device using steel disc with a hardness of 269 HB and constant rotational speed of 500 rpm according to the following Eq. 1:

$$\text{Wear rate} = \frac{\Delta W}{S_D}(\text{g/cm}) \quad (1)$$

where, ΔW is mass quantity difference (g) Eq. 2:

$$W_1 - W_2 \quad (2)$$

where, S_D is Sliding distance (cm) Eq. 3:

$$2\pi rnt \quad (3)$$

Where:

r = The distance from the sample to the disc center 7 cm
n = Number of disc rotations
t = Test time

Three loads were used (5, 10 and 15 N) applied vertically in one time 10 min with constant slipping distance.

Impact test: Impact strength test was performed for the samples using Charpy device type (Amityvileeinco, New York) and 2J hammer. Impact strength was calculated as follows:

$$\text{I.S} = \frac{U_c}{A}\text{J/mm}^2 \quad (4)$$

Where:

I.S = Impact Strength (J/mm^2)
U_c = Absorbed energy (J)
A = Cross section Area (mm^2)

Hardness test: The surface hardness of samples had been calculated via. Shore D method utilizing the tester of Shore D hardness TH210 (a device with a penetration instrument in the form of a needle that penetrates the sample surface). An average of three readings were taken from each test.

RESULTS AND DISCUSSION

Finding of the test stated that support by SiC and PZT decreased the wear rate for the composite. It had

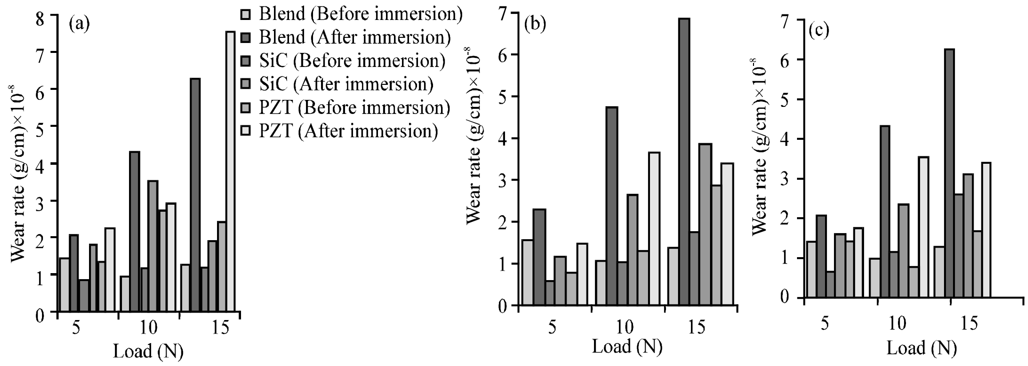

Fig. 1: Variation of wear rate with applied load before and after (11 week) immersion in water: a) Sample of 2 wt.%; b) Sample of 4 wt.% and c) Sample of 6 wt.%

been noticed that increasing the support rate increases the material wear resistance as the supported composite, exhibiting a ratio of 6 wt.% has less wear rate ($0.51*10^{-8}$g/cm) while the wear rate of the composite exhibiting a ratio of 2 wt.% was ($0.86*10^{-8}$g/cm). Whereas the unsupported polymer blend possessed the highest wear rate ($1.41*10^{-8}$g/cm) as shown in Fig. 1. The reduction of the wear rate belong to composite material was the result of the high strength and hardness for the two supporting materials which led to increased wear strength for the composite material. Particles of the supporting material do a significant function in the endurance of the tension resulting from the projected loads among the contacted surfaces and increase the composite surface hardness (Vijayasrathy, 2013). It was noticed that the wear rate raised along with increasing of the projected load as a result of the friction-generated heat (friction force (F) proportional to pressure force (N)) Eq. 5 (Bhargava, 2012):

$$F \propto N \rightarrow F = \mu N \tag{5}$$

where, μN is friction coefficient. SiC effect on reducing the rate of wear was better than that of the PZT. On the other side, emmersing the samples in water increased the wear rate due to water particles influence on the polymer where the bonds that connect the polymer chain are broken. This in turn weakens the substance cohesion as well as creates protrusions at the sample surface which increases the friction between the substance along whith the disc. Thus, the wear rate increases (Abbass *et al*., 2015).

Impact strength: The results demonstrated that the impact strength belong to polymeric blend is more than the composite as shown in Fig. 2. This is attributed to the verity which the ceramic particles function as centers for fatigue collections and the emergence of cracks and gaps which caused the material brittleness. In addition, it had been noticed from the figure that the impact strength from the sample supported by SiC is higher than that supported by PZT as SiC particles have higher strength than the particles of PZT which are characterized through the brittleness and fragility. The brittle fraction essence of the reinforcement material functions significant part for determining the impact energy (Aigbodion and Hassan, 2010) (Fig. 2).

Then again, the emersion of sample in water led to great decrease accord to the impact strength of the sample in addition to the composite. The extent was higher for the blend than the composite. The penetration of water in the blend and composite filled the gaps with water which led to failure of collaboration between the polymer and the supported material in the interface location which caused brittleness of the sample (Dheyaa and Mnajid, 2012).

Surface hardness: It was observed from Fig. 3, that the composite hardness be more than the blend in a degree that is proportional with the addition ratio and that is attributed to high hardness for the particles of the two supporting materials. The spread of the ceramic particles and its penetration in the gaps (which emerged during the composite preparation) and distances inside the matrix material helps in increasing the contact area between the composite components of the materials and increased the connection between them which led the composite to be hard (Ozsoy *et al*., 2015). Furthermore, the immersion of sample in water caused decreasing of hardness values for the sample on a higher degree for the blend than for the composite. Hardness reduction was due to water penetration to the interface and the gaps which made an increment in material ductility and consequently the reduction of material hardness (Abdulhussein, 2015).

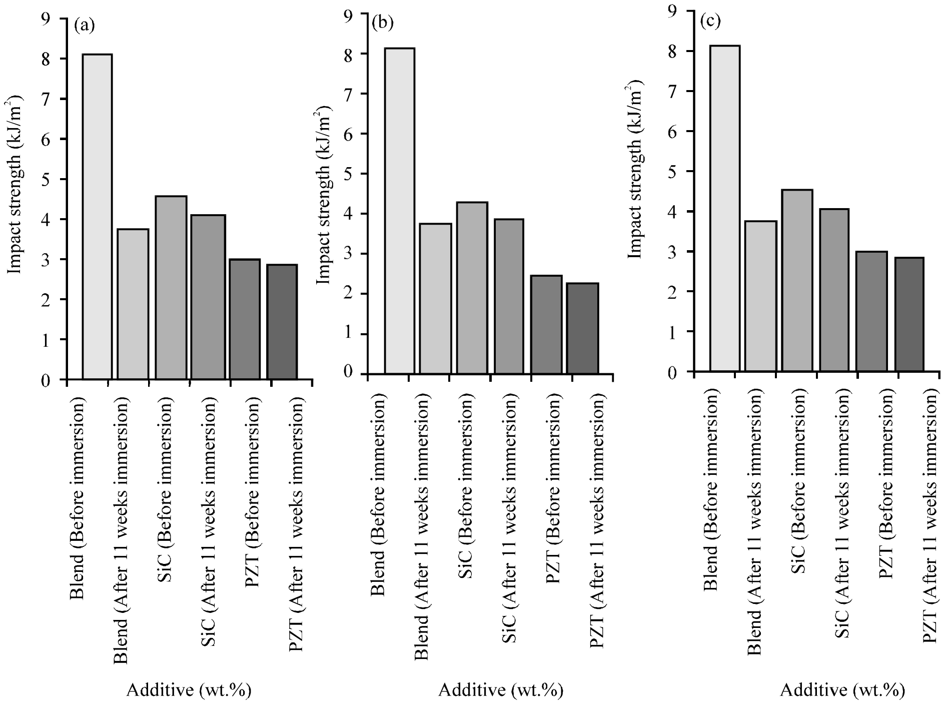

Fig. 2: Variation of impact strength VS wt.% additive before and after (11 week) immersion in water: a) Sample of 2 wt.%; b) Sample of 4wt.% and c) Sample of 6 wt.%

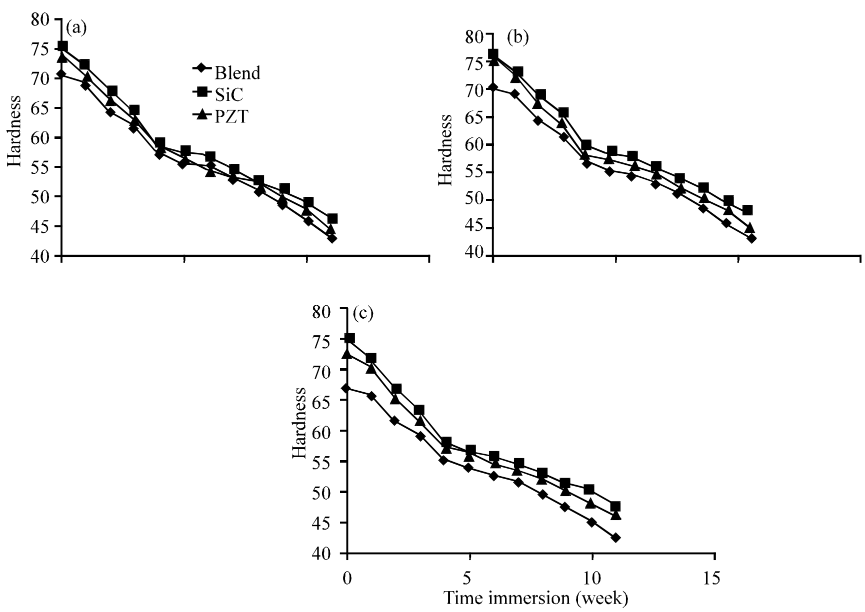

Fig. 3: Variation of Hardness before and after immersion in water: a) Sample of 2 wt.%; b) Sample of 4 wt.% and c) Sample of 6 wt.%

CONCLUSION

From the analysis of results we conclude the following; the process of adding SiC and PZT ceramic powder caused decreasing in the wear rate and an increase of hardness for the composite in comparison with the polymeric blend. Whenever the added ratio is increased, the hardness and wear strength is also increased. There is an increment in the rate of the wear along with an increment in the projected load and the immersion in water.

Support with SiC and PZT powders led to brittleness in the composite material and consequently decrease in the impact strength.

Exposing the polymeric blend and its composite to water immersion affected its mechanical characteristic (reduction in harness and impact strength and an increment in wear rate) negatively.

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