Study of the Effect of Micro Particle Size on the Adhesive Wear of Polymeric Blend Reinforced with Sand Particles

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Abstract

In this paper, the effect of reinforce with sand particles of different micro-granular size on the wear rate of a polymeric blend consisting of epoxy resins, with unsaturated polyester (EP/UPE) and a mixing ratio of (80/20) was studied. The polymeric composites were prepared by hand-lay up technique by adding sand particles to the mixture in weight fractuer (0%, 5%, 10%, 15% and 20%) for different particle size (53 µm and 63 µm).
Adhesion wear test was conducted on samples before and after UV irradiation for periods of time (24, 48, 72) hours. The results of the study showed that the wear rate depends on the concentration of the additive, its granular size, and the time of exposure of the sample to ultraviolet rays. It was also noted that the samples that were irradiated with UV -radiation for 24hrs had the highest wear resistance compared to the other samples.

Key Words: Sand Grains, Wear Rate, Epoxy Resin, Unsaturated Polyester Resin, UV Rays.

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Introduction

Polymer blends have seen great interest, and rapid growth in comparison to other polymeric systems; Because of its high performance in most applications, and its low cost [1].
Polymer mixtures are made by physical mixing of two or more different polymers; To produce a mixture of desired mechanical properties [2]. The compatibility between the components of the polymeric mixture is determined either from determining the degree of glass transition Tg of the mixture, or from mechanical-kinetic measurements of the mixture, or from microscopic examinations, and x-ray scattering for small angles. The dynamic - mechanical measurements method is widely used to determine the compatibility of polymeric mixtures. If the mechanical properties show a significant increase, this means that the mixture is compatible [3].

The phenomena of wear and friction are among the most important and biggest problems experienced by all operating systems with sliding, reciprocating, and rolling motions that include polymeric materials and their compounds; This is because of its negative impact on the performance and work accuracy of these machines, which can reduce their practical ability, or their production efficiency, in addition to the severe losses resulting from the repair and rebuilding of damaged devices [4]. **Pogosyan**, et. all. (2002), studied the effect of adding TiO_2 particles on the tribological properties of a composite material with a polymeric basis, and the results of their tests showed that the wear resistance property of the matrix improved, significantly as a result of the addition of TiO_2 particles [5].

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Gongde et. all. (2004), Compared the behavior of the adhesive wear rate between two types of composites, one of them is composed of a mixture of high density polyethylene (HDPE) polyethylene with polypropylene (PP) polypropylene, and the other is composed of polyethylene only. Where the researchers found that the wear resistance of composites made of polymer mixture was better than that of composites with single polymer [6].

Bilqis and Ahmed. (2011) by study the adhesive wear properties of a polymeric blend reinforced with silica powder with a granular size of 30 µm, and alumina powder with a granular size of 63 µm, with volume ratios of 20%. The research results showed that the wear resistance of silica powder reinforced mixture is better than the wear resistance of alumina powder reinforced blend. [7].

Jawad. (2010), by studying the behavior of the wear rate as a function of grain size and weight fraction of unsaturated polyester resin reinforced with SiO_2 silica particles. The researcher used two different sizes of silica particles (25 µm and 125 µm) to reinforce the unsaturated polyester resin in percentages by weight (%5, %10, %15, %20). The researcher found that the rate of wear decreases with increasing weight fraction and decreasing particle size of the reinforcement material [8].

(Alaa). (2016). studied the effect of adding natural materials with a grain size of (300, 450, 600) µm and (%0, %8, %13, %18) wt on the wear and hardness properties of the epoxy. The researcher concluded that the wear resistance increased with increasing weight percent and decreasing particle size of the additive. [9].

Suhama. et. al. (2017). By studying the wear rate behavior of a binary polymer blend reinforced with zirconia ZrO_2 nanoparticles, and hydroxyapatite nanoparticles, with different weight fractions. The researchers found that the wear rate decreases with increasing concentration of the additive[10].

Adhesive Wear

Wear is defined as the erosion of the surface of a solid as a result of its impact on the surface of another material; due to the relative motion between them [11]. There are several variations of the wear mechanism; As a result of direct contact between surfaces, or by the action of liquids and gases that contain solid particles, we mention ital. wear, erosion wear, surface fatigue wear, erosive wear, blister wear, and a dhesive wear [12].

A dhesive wear is the result of adhesion micro-joints. The load applied to the contact ribs is so great that they deform and join together to form microjoints. The movement of the contra bodies in friction results in the rupture of the micro joints. The weld roughness is broken in the undeformed (not cold worked) regions. Thus, part of the material sent by its counterpart. This effect is called fixation or excoriation. When friction surfaces are considered and friction is attached, a resistance of bodies can be presented to the zone of counter compatibility of a body. Figure (1) shows the Adhesive wear [13].

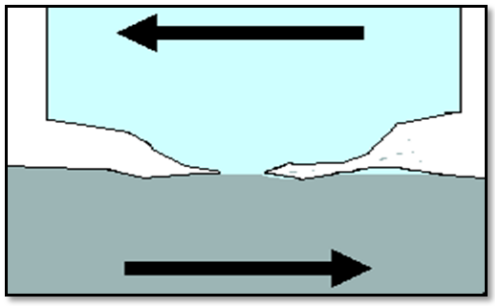

Fig. 1. Adhesive wear [14]

Ultraviolet Radiation (UV)

UV radiation are invisible electromagnetic radiation with a wavelength shorter than visible light but longer than X-rays. Ultraviolet radiation are divided into three different wavelengths:

1. Long-lived (UV-A) A with a wavelength between 315 and 400nm It is close to the visible spectrum and is responsible for the pigmentation of human skin and is responsible for the black color.
2. Medium-range". (UV-B) wavelengths between 290 and 315 nanometers. cause skin cancer and are responsible for most of the photochemical processes that occur in plastics."
3. Short-wavelength ultraviolet (UV-C) wavelengths ranging from 200 to 290 nanometers, which is very high energy and close to X-rays, and this type of radiation is one of the most dangerous types and affects life on Earth's surface."

"The wavelength of ultraviolet radiation, which varies from 200 to 400 nm, which is part of the spectrum, is what most affects the properties of the polymer, as the bonds that unite the atoms of the polymer chain with energy to decompose are found in this spectrum range." [15].

The Aim of Research contributes to improving the wear-resisting property of a binary polymer blend

prepared from epoxy and unsaturated polyester resins by reinforcing it with two different sizes of sand grains, and with different weight percentage in order to be used in suitable industrial applications. The research also aims to study the effect of ultraviolet irradiation (UV) with different periods of time on the wear resistance property of the prepared samples.

Experimental Methodology

Matrix Material

- **Unsaturated Polyester Resin (UPE):** Unsaturated Polyester Resin Used in this study was manufactured by the Saudi company SIR. Transforms into solid after adding (2g) Per (100g) of hardener methylethylketone peroxide (MEKP) at the laboratory temperature. Polyester is consider one of a thermoset polymers type. Its density is (1.2 g/cm^3).
- **Epoxy Resin (EP):** Epoxy used in this study is Sikadur-52, which was manufactured by the Australian company Sika. This type of epoxy is characterized by low viscosity, its density is (1.1 g/cm^3), hardened when added hardener Metaphenylen Diamine (DPDA)) by ratio (2: 1) to it at the laboratory temperature. Epoxy is consider one of a thermoset polymers type. "The properties of epoxy resin and unsaturated polyester (UPE) used in this work" are shown in Table 1.

Table 1. Epoxy resin and unsaturated polyester Properties

Type	Density ($\frac{gm}{cm^3}$)	Thermal Conductivity ($\frac{W}{m.^oC}$)	Tensile Strength (MPa)	Percent Elongation (%)
UPE	1.2	0.17	41.4-89.7	<2.6
EP	1.1	0.19	25	<6

Reinforcing Material

The Sand is". supplied by Don Construction Products Ltd. UK", and have a density (2.65 g/cm^3). Table 2 illustrated its chemical composition, as given by the company.

Table 2. Chemical analysis of sand

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

In this study, two types of reinforcement materials were used from sand grains with a grain size of 53 µm and a grain size of 63 µm, and they were obtained through the use of special sieves for that (shaker sieve) in order to separate the required size in this study. "Scanning electron microscopy (SEM)" was used to capture the mages of 80% EP / 20% UPE sand particles. Using (TESCAN Vega3 SEM produced by the company of the Czech Republic.

Preparation of Composite Materials

The hand-laying method was used to prepare the compounds, and according to the following procedure: (i) the epoxy resin was first prepared with the hardener in a ratio of (3:1); (ii) Prepare polyester resin with the hardener in a ratio of (98:2); (ii) They are mixed together in a ratio (EP 80% + UPE 20%) to obtain a blend polymer (iv) Then, the polymer mixture is hardened with sand with a granular size (53 µm) and a granular size (63 µm).

Method of Wear Measurement

The use of wear device sliding which consists of a metal arm flat contains a holder to install the sample and disc of iron, hardness (9269 HB) roundabout connection with an electric motor, an disk speed (500r/min) and this speed is The sample rotation speed.". There are several ways to measure wear rate." and one of these methods (Weight method) that were used in our research.

Weight Method

This method consists of weighing a model before and after testing, calculating the weight difference and calculating the wear rate from the following equation [17]:

$$W_r = \frac{\Delta W}{S_D} \text{ (g/cm)} \qquad (1)$$

where:

$\Delta W = W_2 - W_1$. S_D = Ss.t, ".$S_D = 2\pi r\ n\ t$."

".SD= Sliding distance (m).", Ss= ". Linear sliding speed (m/sec).", D = ".sliding circle diameter(cm)." t = ".sliding time (min).", ". N = iron disk speed."

In this paper, wear tests were carried out on samples with a laboratory temperature of 25±3 in the two cases:

I. Before UV irradiation (natural conditions).

II. After irradiation with UV rays, for periods of time (24, 48, 72) hours.

Results and discussions

In this research, a study was conducted that raises the weight percentage, and a grain size of the sand particles added to the polymeric mixture on the wear rate before irradiation, and after irradiation with ultraviolet rays for different periods of time (24,48,72) hours. Under excitation constant firing conditions over the length of the experiment are: applied load 10N, test time 10min, slip radius 6cm, iron disc hardness 269HB.

From Table (3) and Figures (2) and (3), it shows that adding sand particles in different weight percentages (20%,15%10%,5%) to the composite materials led to a decrease in the wear rate, and this decrease increases with the increase in the weight percentage. for the additive; The reason for this is due to the mechanical properties of sand grains, and the addition of sand particles to the composite materials increases the stacking and interlocking between the polymeric chains, and thus the material's resistance to scratching and cutting increases due to its increased hardness, and this leads to an increase in its resistance to plastic deformation [4].

Table 3. Effect of a grain size on wear rate before and after UV irradiation

Grain Size	Composite Materials	Wear Rate * 10^{-8} (gm/cm)			
		Before Irradiation	After Irradiation		
			24hr	48hr	72hr
53 µm	blend (pure)	3.65	3.23	3.41	3.73
	95% blend+5% sand grains	2.89	2.52	2.70	3.02
	90% blend+10 % sand grains	2.76	2.34	2.55	2.94
	85% blend+15 % sand grains	2.39	2.16	2.28	2.61
	80% blend+20 % sand grains	2.05	1.67	1.82	2.14
63 µm	95% blend+5% sand grains	3.07	2.78	3.14	3.26
	90% blend+10 % sand grains	2.92	2.51	2.86	3.10
	85% blend+15 % sand grains	2.54	2.34	2.39	2.75
	80% blend+20 % sand grains	2.30	2.15	2.22	2.53

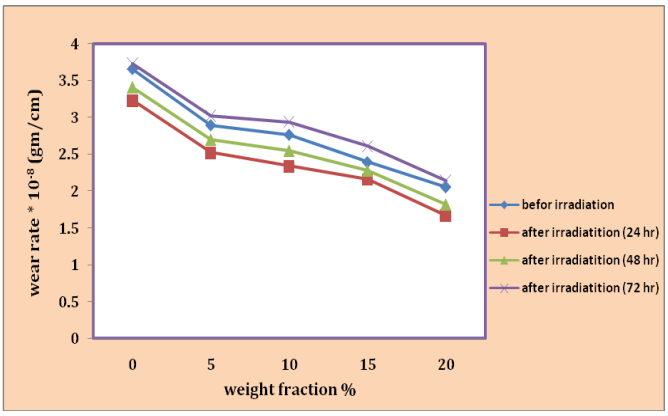

Figure 2. Behavior of wear rate of samples reinforced with a grain size of 53µm before and after irradiation

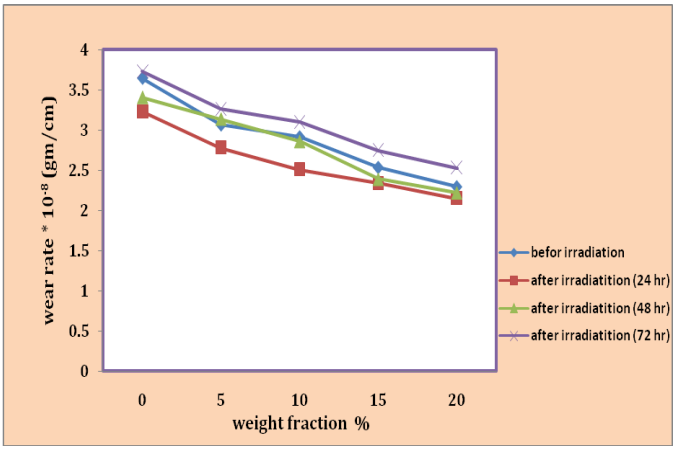

Figure 3. Behavior of wear rate of samples reinforced with a grain size of 63µm before and after irradiation

Figures (4), (5), (6) and (7) show that a grain size has an effect on the wear rate of the polymeric mixture, as the wear rate decreases with the decrease in the particle size of the added sand the reason for this is due to the penetration of sand particles with a grain size of 53um within The polymeric mixture and its uniform distribution is better than sand particles with a grain size of 63 um, thus increasing the agglutination between the components of the composite material, which increases its hardness, and also the relative roughness of sand particles with a grain size of 63um, as the increase in the roughness of the grain size increases the size of the separated particles from the surface of the sample due to slippage and thus The amount of plastic deformation increases [13-17].

And samples reinforced with sand particles have the lowest wear rate when exposed to ultraviolet rays (UV) for a period of 24 hours compared to the wear rate of samples before irradiation in normal conditions, while the values of the wear rate increased after exposing samples to irradiation for

periods of 48 and 72 hours than the values of the wear rate of samples before irradiation in natural conditions; The reason for this is that ultraviolet rays during a period of (24 hours) worked on the bonding of the branched polymer chains, as well as led to an increase in the bonding at the interface area between the substrate and the additive due to heat treatment. As for the (48,72) hour irradiation periods, The rays worked on the appearance of some cracks on the surface of the sample model as a result of a breakdown in some areas of interconnection between the matrix and the reinforcing material, as well as between the polymeric chains themselves because the energy of ultraviolet rays approximates the energy of breaking the bonds between the chains.

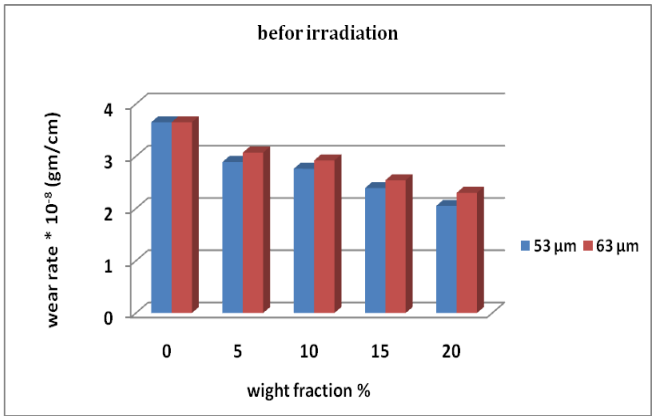

Figure 4. The effect of a grain size on the wear rate of samples before irradiation

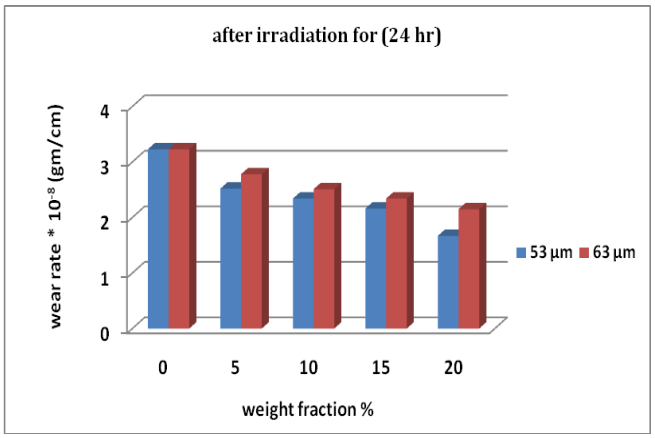

Figure 5. The effect of a grain size on the wear rate of samples after irradiation for a period of 24 hours

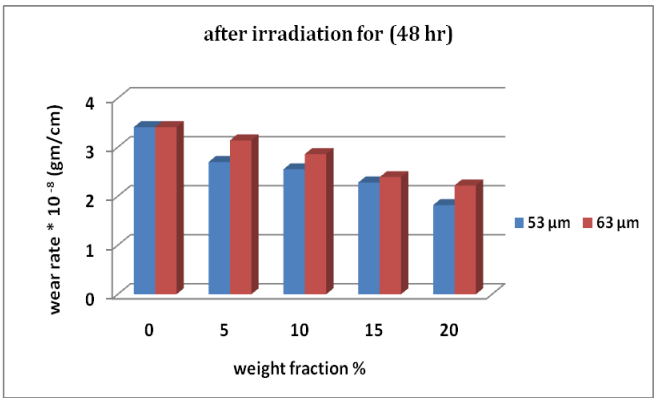

Figure 6. The effect of particle size on the wear rate of samples after irradiation fora period of 48 hours

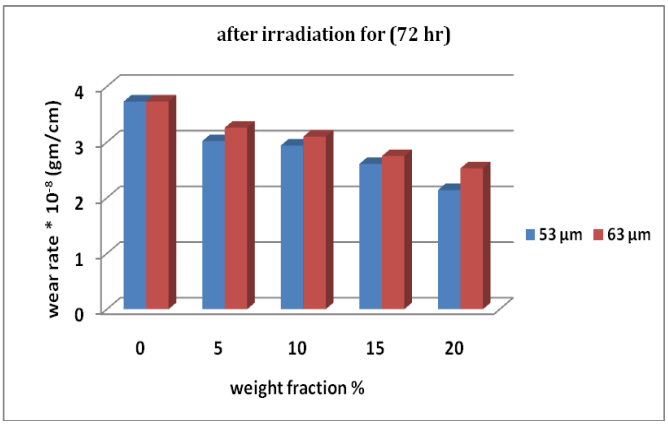

Figure 7. The effect of a grain size on the wear rate of samples after irradiation for a period of 72 hours

From figure(8) The SEM image of distribution of sand53 (10 %wt) particles in blend. In the case of sand53 µm /blend composites with sand of 10wt%, from the SEM image for composites, it was shown that the filler was well dispersed in the polymer blend. As shown in the figure, the silica particles are evenly distributed in the matrix, revealing several cavities on the surface of the 53 µm mixed sand composite. These cavities are created by the exfoliation of sand particles and induce the performance of the matrix after excessive exfoliation of the particles, and the matrix next to the cavities looks very flat.

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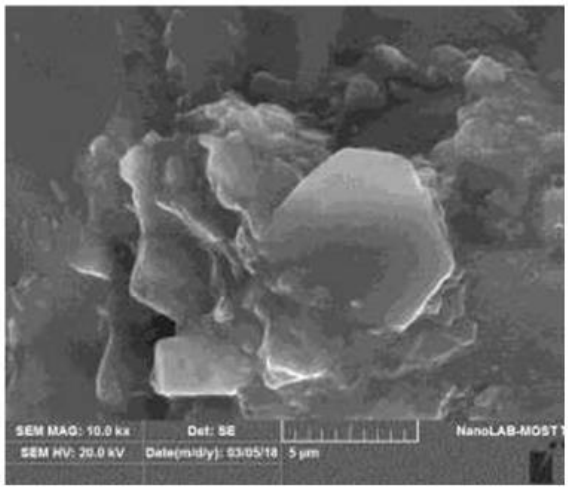

Figure 7. 10% sand53µm/Blend

Conclusions

The most important conclusions that were reached during this research are summarized as follows:

1. The addition of sand particles improved the wear resistance property of the polymeric blend.
2. The increased concentration of sand particles added to the mixture led to a decrease in the wear rate.
3. The highest wear resistance was for samples reinforced with a grain size of 53 µm, which had a better wear resistance than samples reinforced with a grain size of 63 µm.
4. Samples that were irradiated for 24 hours had high wear resistance compared to samples irradiated for periods of 48 hours and 72 hours and samples under natural conditions (N.C).

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