Effect Gamma rays effect on Wear rate and Hardness of (Ep-SiC) Nanocomposites for Industrial applications

A K Aobaid and T Y Alqaisy
University of Anbar - College of Education for Pure Sciences - Department of Physics – Iraq.
Ibnaalanbar664@gmail.com.

Abstract: The aim of this research is to measure the hardness and wear rate for epoxy resin as a base material, nano ceramic powder (SiC) with particle size (64.85nm), were used as a reinforcement materials in composites preparation in different weight fractures (2%, 4%, 6%), hand-casting method was used in preparation the research samples. Mechanical properties were measured after irradiation of gamma rays emitted from the CO$^{60}$ with energy rate of 1.33MeV and different irradiation doses (6,8,10) K Gy. The results showed an increase in the hardness values after the irradiation compared with the results before irradiation while wear test showed a decrease in the values in normal conditions compare with the result after irradiation.

Keywords: Gamma rays, Hardness, Wear, Epoxy resins, Silicon Carbide.

1. Introduction

In the recent years, modern materials have been needed that will have a lasting impact in modern applications. The need for radiation therapy as an important means of modifying nanoscale structures in the manufacture of high performance polymer compounds has important advantages such as high corrosion resistance, high hardness, and low cost. Due to the extensive use of polymeric materials in coating, packaging, shipbuilding and aircraft wings, as well as their use in various fields of life. These materials are exposed to the sun and the various environmental conditions, and because of this importance in our daily life, it is necessary to study the effect of radiation on composite materials. The use of polymer materials composite of our time a significant shift of the characteristics of these materials of many characteristics led to the use of wide and in various fields. These characteristics include the low cost of fabrication, durability, low density, high thermal and electrical insulation, resistance to chemicals and moisture, corrosion resistance, shapes and sizes, and high surface strength [1,2].

As already mentioned, it is necessary to study the mechanical and physical properties of these materials so that researchers can develop them and use them in their practice fields [3]. Polymeric polymers can be defined simply as those systems resulting from the mixing of two or more substances with specific rules to obtain new materials possessing distinct physical and mechanical properties that differ radically from the properties of their basic material [4,5]. At present the effect of radiation on composite materials, whether ionizing radiation or non-ionizing radiation. Ionizing radiation results in wide variations in the properties of composite materials. Radiation has a significant effect on radiation when it penetrates the radiation, causing a change in the order of atoms and molecules in the composition of matter [6]. The effect of photon radiation in the composite material causes changes in the structure of these materials as a result of the interaction between the photons and their absorbent material. The reaction type depends on the energy of the photons and the atomic number of the target [7]. The evolution of the use of composite materials in the development of advanced computer science and software has motivated scientists to create specialized software in the design and analysis of composite materials and test most of their properties without resorting to traditional methods [8].

This research was carried out to determine the hardness and wear rate property pre-and to post exposure gamma which emitted from the cobalt source (Co $^{60}$) for the SiC composites and study the effect of these rays in different doses (6, 8, and 10) K Gy on these properties. The effect of these radiations varies depending on the then mixed together of the materials to these rays.
2. Experimental Part

2.1. Matrix material
Epoxy Sikadur-52, manufactured by Henkel, Australia, is used as a base material in the preparation of composite material. Epoxy resins are characterized by transparent liquids and a density of 1.1-1.4 g/cm$^3$. The epoxy resins are converted to the solid state after the addition of a metaphenylene Diamine (MPDA) and a plant of the same company by 1:2.

2.2. Reinforcing material

2.2.1. Silicon Carbide (SiC)
The SiC powder used in this study is the β type (EV NANO) Technology Co., Ltd. particle size (64.85nm), purity (99%), Density 3.22g/cm$^3$.

2.3. Specimens Preparation:
Hand lay-up molding method was used for preparing the samples, as follows:

1-The samples which composed from silicon carbide (SiC), were prepared as a reinforced material (2%, 4%, 6%), with epoxy resin as a base material mixed with a (1:2) compound. The mixture is then poured into the mold until the mixture leaks all over the mold and leaves for (48) hours to solidify.
2-After 48 hours, samples were placed in the convection oven at a temperature of (50 °C) for (6) hours. This reduces the internal stresses produced during shrinkage, as well as obtaining the best interlock and completing the solidification process.
3-The samples were left in the convection oven after it is extinguished until it returns to its normal temperature to obtain a good crystallization of the samples [9].
4- The dimensions of the hardness and wear test samples are thickness 20mm x 10mm x 10mm.

3. Mechanical Tests

3.1. Hardness Test: The surface hardness of the samples had been calculated via used (shore D) method utilizing the tester of (shore D) hardness th210, an average of three readings were take from each test.

3.2. Wear Test: Wear was using performed the slipping wear device used steel disc with a hardness of (269) hb and constant rotational speed of (500) RPM according to the following equation(1):

\[ \text{Wear Rate (W.R)} = \frac{\Delta W}{S_D} \text{ (g/cm) } \] ………….. (1)

Where; $\Delta w$ is a mass quantity difference.

$S_D$ is sliding distance [cm].
\[ S_D = 2\pi r n t \] 

Where: \( r \)-the distance from the sample to the disc center (7cm).
\( n \)-number of disc rotations. \( t \)-test time.

4. **Gamma ray Instrument**: In this research, we used a gamma ray emitted from \( \text{(Co}^{60} \text{)} \) source with an energy rating (1-33-1-17) MeV in order to irradiant the samples.

5. **Radiation Effect on The Polymeric Composite Materials**:

The radiation (natural or industrial) is classified according to its effect in two types [10,11]

**A- Ionizing Radiation**: This type of radiation has the ability to ionize the atoms passing through it such as electromagnetic radiation (x-rays, ultraviolet rays, and gamma rays) and particle radiation such as particles of alpha, beta, neutrons and protons. The radiation is in the form of a cosmic or wave emission and its effect in the medium that penetrates depends on energy radiation and its nature where particles and radiation emit different cards and decay over a given time and according to the following equation:

\[ A_t = A_0 e^{-\lambda t} \]  \( \ldots \ldots \) (3)

\( A_0 \): the radioactivity of the element at time t.
\( A_t \): Radiation activity at primary time.
\( \lambda \): the decay constant and given by the relation:

\[ \lambda = \frac{0.693}{T_{1/2}} \]  \( \ldots \ldots \) (4)

\( T_{1/2} \): Is the half-life of the radionuclide.

**B- Non-Ionizing Radiation**: This type of radiation does not have the ability to ionize the atoms passing through it such as infrared waves (IR), lasers, visible light, radio and television waves, radar waves and microwave wavelengths.

6. **Results and discussion**:

6.1. **Hardness and wear before irradiation**.

The hardness values of all composites prior to irradiation were increase with the increase of the weight fractures(2% 4% 6%). The maximum hardness values were at the weight fracture(6%) as shown in figure 1. The addition of silicon carbide nanoparticles, a high hardness ceramic material and resistance to plastic deformation, has led to the penetration of the base material into the core and into the probe and the interstitial spaces formed during the preparation process. This penetration has helped to increase the contact area between overlapping materials and increasing bonding Which leads to the addition of a bonding link in the polymer network, which increases the hardness of the surface [12].
The wear rate values of all composites prior to irradiation were decreased with the increase of the weight fractures(2%, 4%, 6%). The maximum wear rate values were at the weight fracture(6%) as shown in figure 2. This is due to the fact that the minutes of the material play an important role in carrying the large part of the stresses resulting from the load between the surfaces and increase the hardness of the surface of the overlapping random materials distributed randomly as obstacles to distort the base material through pregnancy because of its high strength and lead to increase the severity of the polymer body Its durability and increased thermal expansion coefficient due to the high hardness of (SiC)[13,14].

![Graph](image1.png)  ![Graph](image2.png)

**Figure 1.** The relationship between hardness and weight fraction(2,4,6)%  

**Figure 2.** The relationship between wear and weight fraction(2,4,6)%

### 7. Hardness and Wear after Irradiation:

The exposure of polymeric composite material to gamma radiation with high energy leads to happened excitation and ionization of molecules, this causes broken in chemical bonds and leading to the production of free radicals, and the effect of radiation on the properties of polymeric materials [15].

**Hardness:** From the figures 3 we observe an increase in hardness values by increasing the rate of radiation doses for SiC composite samples gamma ray irradiation led to increased decomposition and generation of free radicals, which in turn led to an increase in cross-linking between the bonds of the base material and the supporting materials and thus increase the surface hardness of all samples [16].

**Wear rate:** From the figure 4 we observe a decrease in wear rate values by increasing the rate of radiation doses for SiC composite samples because the gamma absorption of gamma leads to the bonding of the bonds, which means increasing the hardness of the samples and therefore less wear. The greater the irradiation period, the gamma rays absorbed by the sample will increase, which leads to the overlap of the material affects the decomposition of the material and thus increase surface resistance and then wear the sample little [17].
8. Conclusion:
The hardness of the (EP+SiC) composites increased when radiation doses increase. The hardness of the composite (EP+SiC) increases by increasing the reinforcement ratios, results from others at weight fracture (2%, 4%, 6%).
The wear rate of the (EP+SiC) composites decreased when radiation doses increase. The wear rate of the composite (EP+SiC) decreases with increasing the reinforcement ratios, results from others at weight fracture (2%, 4%, 6%).

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