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RESEARCH ARTICLE - ENGINEERING

Chemical Immersion Effects on Wear Property of Epoxy Reinforced Copper Powder Composites

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Abstract

In this research, the effect of chemical solutions: (sulfuric acid H_2SO_4, sodium hydroxide NaOH) at (5 M) and distilled water were studied on some mechanical properties. Especially the wear resistance by pin-on-disk and hardness properties for neat epoxy composite and (epoxy - copper powder) composite. That has been prepared by hand mixing (weight ratio = 20%). The samples were immersed in these chemical solutions for different periods (7, 14, and 30) days. Then the hardness by the Shore D method was measured before and after immersion of the samples in acidic, neutral, and alkali solutions. Whereas the hardness was measured by the Vickers method for the wear disk. Wear rate was measured for all samples. The results showed that the neat epoxy composite was more affected by the alkali solution, followed neutral solution, and then the acidic solution by increasing the radius of wear disk (3, 5, 7, 9, and 11) cm, t= 15 min. and the load 5 N. In contrast to the composite material that was more affected by the alkali solution than the acid, neutral solution.

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Keywords: Epoxy; Composite Material; Chemical Solution; Roughness; Hardness; Wear Rate.

1. Introduction

One of the advantages of composite materials is corrosion resistance [1]. Polymer composite material has a not linear highly wear manner [2]. To improve wear rate, it is required to decrease adhesive force among its components [3], surface roughness is the important parameter effect on the accelerated wear by increasing it [4] and it is dependent on solution chemical type immersed it [5]. Fernanda Regina Voltarelli et al (2010), the evaluation of the brush simulation for the roughness of the surface of five composite materials, and the results showed that the surface roughness of the resin materials superimposed differently with food simulation solutions, depending on the immersion medium [6]. Ji-Deok Moon et al (2015), water is a good solvent for epoxy compounds that absorb water and different types of colorants. The composite material absorbs these solutions, which leads to chemical decomposition and surface erosion [7]. Y. Şahin et al (2015), the dry corrosion of PTFE compositions reinforced with bronze, glass, and carbon was tested by a die casting method with different sliding conditions, and the Taguchi L27 method was used for contrast analysis. And decrease relatively little with increased tensile strength [3]. Daniel Pink et al (2016), a comparative study of the characteristics of the fine stiffness and wear resistance of two composite materials (polymer - ceramic), and the results proved that the wear resistance increases with the decrease of the granular size [8]. AM Amaro et al (2013), the increase in the damaged parts of the surface of (epoxy - glass fibers) composite after immersion with sulfuric and hydraulic acids for different periods proved to decrease their resistance with the increase of the impacted load [9]. Bin Wang et al (2021), the strength of reinforced polymer compounds (FRP) is highly dependent on chemical reactions between the molecular chain of the epoxy resin matrix and the water molecules or alkaline groups on water absorption, mechanical compositions, and epoxy microstructures. The results showed that the compound material significantly affected the alkaline solution more than the aqueous solution [10].

In this paper, the effect of chemical solutions (acid, basic and neutral) on wear resistance in a manner (Pin- on- Disk) was studied for the surface of a polymer-based compound material (epoxy - copper powder) and for different periods preceded by measuring the surface roughness and measuring the hardness by Shore D method for each of the compound material while it was measured for metallic wear by Vickers method.

Nomenclature & Symbols			
L	Sliding Distance	ρ	Material´s Density (gm/cm^3)
Δm	The difference in weight before and after immersion (gm)	A	Surface Area of the Sample (cm^2)
r	Radius of Wear Disk (cm)	n	Rotators Number (rpm)
t	Test Time (min)		

2. Materials and Methods

2.1. Materials

The neat epoxy composite and hardener were supplied by the Ciba-Geigy company, the copper powder of granular size (53µm >), sulfuric acid, and sodium hydroxide were supplied from CDH company, distilled water.

2.2. Devices Used

Wear measurement device is locally manufactured according to the specifications of (ASTM G99), surface roughness measurement device model Taly surfy4, Vickers macro hardness model Z323 in the Department of Production and Metallurgy Engineering, University of Technology and hardness-Durometer-HT-6510 D and sensitive balance in Department of applied science.

2.3. The method of work

Neat epoxy composite and hardener were mixed in a ratio of 3: 1 and copper powder was added by weight ratio of 20%. The mold required for the casting process was prepared with dimensions of (2.5 * 15 * 25) cm to prepare and pour the composite material, and then the curing process was carried out at 60°C. After that the cast of the composite material was cut into cylindrical samples with dimensions of (10, 20) mm as a (diameter and length) respectively. The rotational speed of the disc was (510 rpm). Then the hardness by the Shore D method was measured before and after immersion of the samples in acidic, neutral, and alkali solutions, while the Vickers method was used for the wear disk. The surface roughness of the composite material and the metal disk of the device was also measured. Sulfuric acid was diluted with a ratio of (1:1), the samples were immersed with chemical solutions for different periods (7, 14, and 30) days where the samples were weighed before and after immersion. The wear rate was calculated at a different radius of wear disk and constant time according to the following relationship [11]:

$$\text{wear rate} = \frac{\Delta m}{\rho * L * A} \quad (1)$$

Where:

Δm: The difference in weight before and after immersion (gm).
ρ: material´s density (gm/cm^3).
L: sliding distance (cm).
A: surface area of the sample (cm^2)

Sliding distance (L) was calculated from equation [12]:

$$L = 2\,\pi\, r\, n\, t \quad (2)$$

Where:

r: radius of wear disk (cm).
n: rotators number (rpm).
t: test time (min)

3. Results and Discussion

3.1. Hardness test

The results proved that the hardness (Shore D) values before immersion (77.6, 79.4) for the epoxy and composite material, respectively. The hardness values after immersion in acid solution (77.25, 76.82, 76.6) and (78.13, 76.55, 74.4) at periods time (7, 14, and 30) days for epoxy and (epoxy – Cu powder) composite material respectively, but in neutral solution (78.4, 78.95, 79.8) and (79.38, 79.29, 79.2) at periods time (7, 14 and 30) days for epoxy and composite material respectively, while in alkali solution (75.87, 75.04, 73.83) and (77.41, 76.81, 74.86) at periods time (7, 14 and 30) days for epoxy and composite material respectively. Note that the hardness values decrease with increasing immersion period; the hardness values before immersion are higher than after immersion in the three solutions (acid, neutral, and alkali). The reason for this is that the increase of viscosity of particles in both the neat epoxy composite and the composite material is strong, resulting in a closed space leading to an increase in the hardness values. Through the results, we find that the hardness values after immersion in distilled water are higher than after immersion in the acid and alkali solution; it is a result of breaking the bonds between molecules due to the spread of chemical solutions inside the material, which increases the porosity, thus increasing the absorption of the substance of the solution [13,14], while wear disk hardness was (32 HV).

3.2. Roughness test

In contrast to the hardness test, we find that the surface roughness increases with the increase in the immersion time. Before immersion, the surface roughness of the epoxy and composite material was (0.045, 0.056) µm respectively, but it was (0.9, 1.9, 4.2) µm and (0.6, 3.9, 4.8) µm after immersion in an acidic solution for (7, 14 and 30) days for epoxy and composite material respectively. Also, these values were (0.3, 1, 4.32) µm and (0.43, 1.2, 3.86) µm after immersion in neutral solution and (0.61, 1.5, 4.11) µm and (0.8, 1.73, 4.37) µm after immersion in alkali solution for epoxy and composite material respectively at (7, 14 and 30) days. The reason is due to the occurrence of water absorption and diffusion into the polymer (epoxy) and the filler (Cu powder) surface - as the water absorption dissolves the chemical bond between the neat epoxy composite and the copper powder, which causing to displace and form fine cracks, resulting in a rough surface that is easy to corrode. Also, the reinforced materials tend to degrade after exposure to the other two solutions, due to polymer corrosion [15,16].

3.3. Wear test

After completing the hardness and roughness tests of the polymeric material and the composite material, a wear test was performed, and the results were as follows:
From fig. 1 notice that the wear rate increases with the increase in the radius of the wear device disk, and thus the sliding distance increases, as with the movement of the disk small particles of the sample are transferred to the resistant surface (disk surface), resulting in the material being attached and appearing in a dark groove in the form of lines whose direction is in the direction of movement of the disk at the bottom surface of the sample.

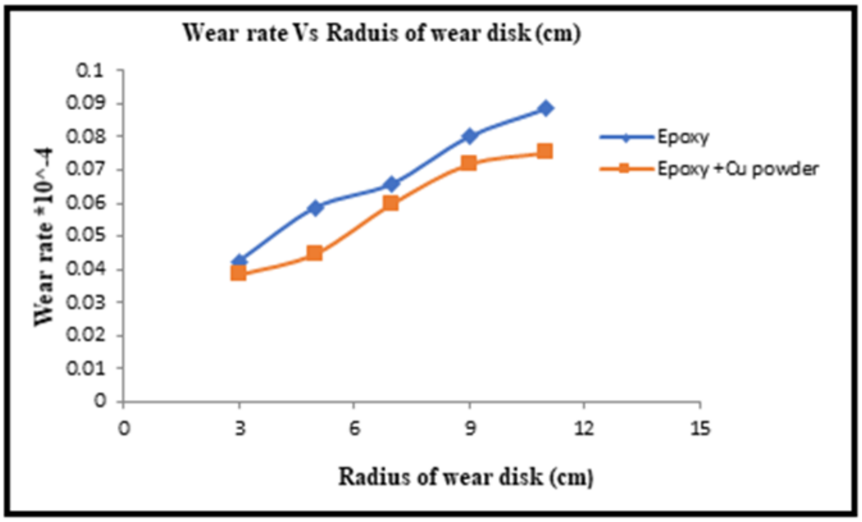

Fig 1. Wear rate Vs the radius of wear disk (cm) before immersion chemical solution

3.3.1. Wear test after immersion neat epoxy composite in chemical solutions

Fig. 2 Shows that the wear rate decreases with increasing the sliding distance as well as by increasing the period for immersion in the acid solution. The reason for this is that the presence of the chemical solution will reduce the adhesion of the protrusions of the two surfaces (the surface of the sample and the surface of the wear device disk) due to the penetration of the solution particles into the sample's material (neat epoxy composite), which helps to plasticize the surface of the sample and create a thin layer of the surface film, which reduces the friction of the two surfaces.

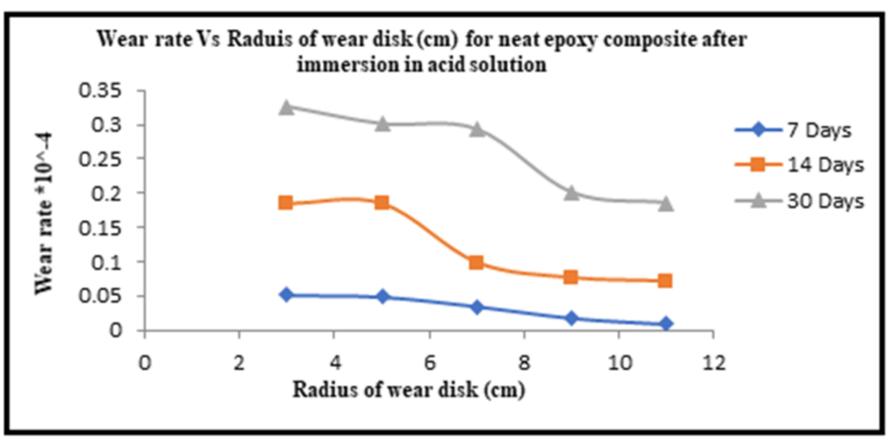

Fig 2. Wear rate Vs radius of wear disk (cm) for neat epoxy composite after immersion in acid solution

From fig. 3, notice that the wear percentage decreases with the increase in the radius with the increase in the period of immersion of the epoxy material sample in distilled water, where we notice the decrease in the wear percentage at (7) days, which is linear, while for the period (14 and 30) days, the decrease is gradual and then the decrease in the wear rate becomes almost stable, the reason is a decrease of adhesion of the protrusions of the two surfaces that are in contact, which is due to the decrease of diffusion of water and its penetration into the particles of the epoxy sample.

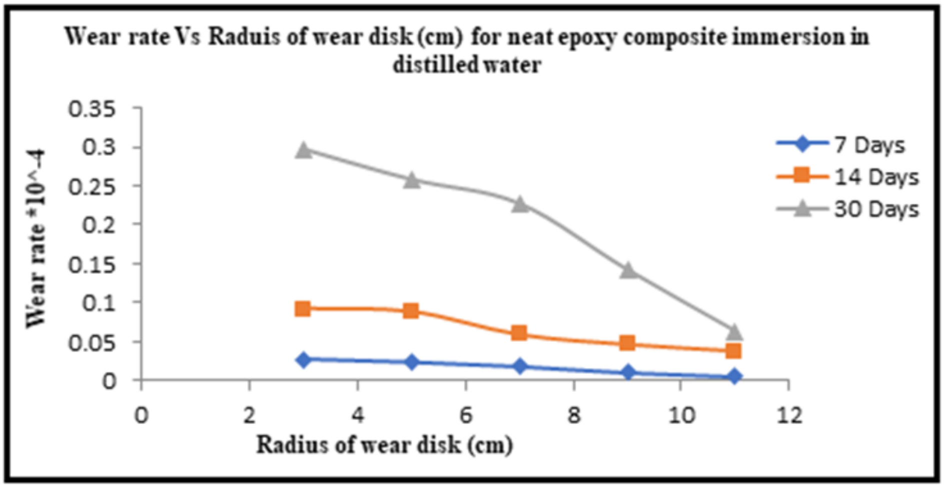

Fig 3. Wear rate Vs radius of wear disk (cm) for neat epoxy composite after immersion in distilled water

As for the immersion of the epoxy sample in the alkali solution, fig. 4 shows the decrease in the percentage of wear with the increase in the radius with the increase in the period of immersion in the alkali solution. The reason is that the spread ability of the alkali solution with epoxy is higher than when immersed in distilled water when the ability of diffusion is less in the acid solution. Also, we notice the intersection of the two values of the wear ratios at the radius (11cm) for the immersion period (7and14) days.

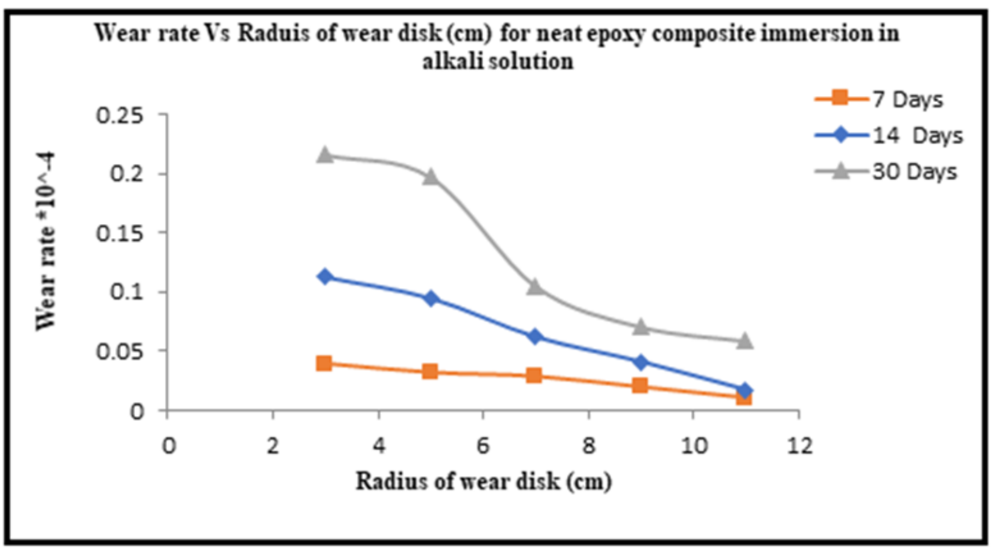

Fig 4. Wear rate Vs radius of wear disk (cm) for neat epoxy composite after immersion in alkali solution

3.3.2. Wear test after immersion composite material in chemical solutions

Fig. 5 shows the extent of the noticeable improvement in the decrease of the wear ratio with the increase of the radius of the wear disk of the compound material when immersed in the acid solution for a period of (7, 14, and 30) days, as it is considered the extent of the spread of the acid solution inside the composite sample, which leads to the reduction of friction stresses.

Fig. 6 Refer to that the spread of distilled water inside the sample of the composite material is relatively better, which led to an increase in its annealing, meaning that the temperature increase generated during the test is ineffective. There is also, a great convergence of the wear ratio in the immersion periods (7 and 14) days.

Fig. 7 shows the effect of the base solution similar to the effect of the previous two solutions, which is the decrease of the wear ratio with the increase in the sliding distance, where the clear role of the spread ability of the alkali solution appears in the epoxy sample reinforcement by copper powder, which leads to the occurrence of corrosion of the surface of the sample even if it is less than it is when immersed in the solution acidic.

Through the above results, we find that the best results were obtained when immersed in distilled water. This is what the ref. [14] shows, as it shows that the wear ratio increases according to the pH value of the solution, but it is better when the solution is neutral.

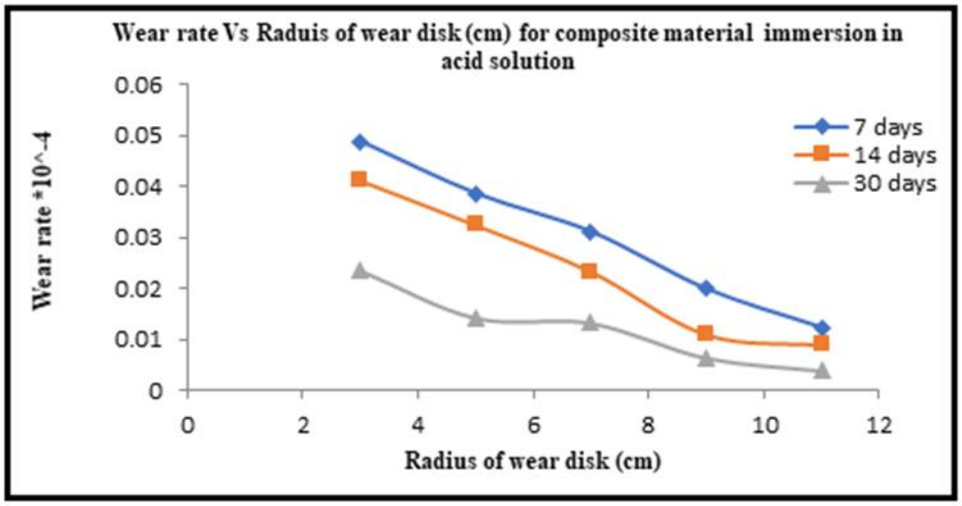

Fig 5. Wear rate Vs radius of wear disk (cm) for composite material after immersion in acid solution

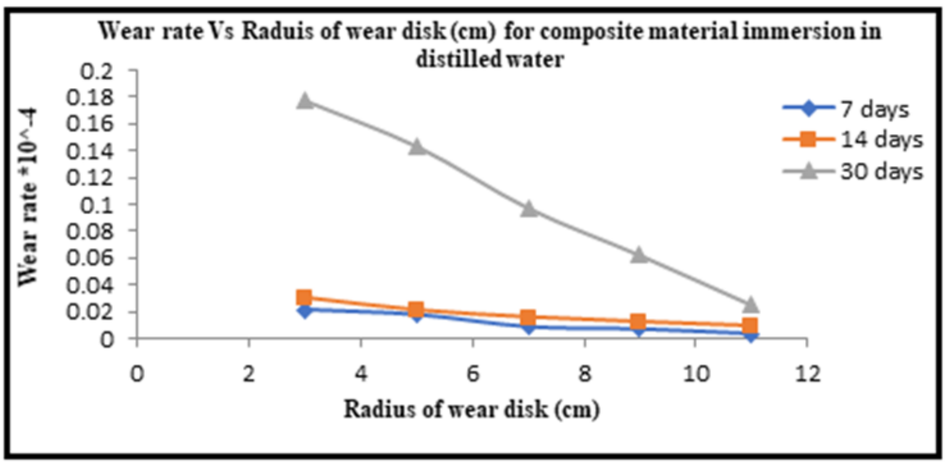

Fig 6. Wear rate Vs radius of wear disk (cm) for composite material after immersion in distilled water

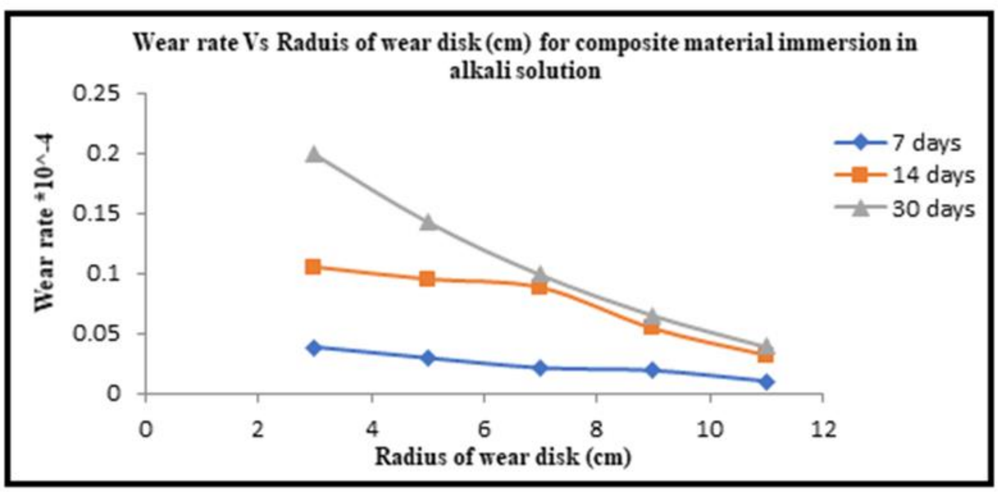

Fig 7. Wear rate Vs radius of wear disk (cm) for composite material after immersion in alkali solution

4. Conclusion

From the above results, we find that the reinforcement of neat epoxy composite with copper powder helps to improve its resistance to wear in different chemical mediums. The neat epoxy composite was more affected by the alkali solution than the neutral solution, and the acidic solution by increasing the radius of wear disk at 15 min. and the load 5 N, while the composite material was more affected by the alkali solution than the acid, neutral solution.

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