Studying the Effect of Immersion in Chemical Solutions on Some Structural and Physical Properties of a Polymer-Based Vehicle

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Abstract

This research used epoxy resin as a base phase and glass fibers of the type (Woven Roving) as a cementing phase. Samples were prepared manually with molds that fit the standard dimensions of each examination. Three models were ready to study the effect of immersion conditions in chemical solutions on (structural, spectral, physical, and mechanical) properties. Solutions: NaOH at a concentration of 2% and H2SO4 at a concentration of 20%, and distilled water with a specific range of immersion times, which is (1,3) a week. The results of (AFM) showed that the effect of immersion in water and an acidic solution on the surface is substantial compared to the impact of the base solution., which was very close to the samples before immersion in granular size distribution. We note that the absorption spectrum of UV rays at high wavelengths of the visible spectrum was as high as possible for the basic solution and as low as possible for the acidic solution, while the absorbance of the models immersed in water was at average values close to the absorbance of the models before immersion. As for the IR spectrum of all models, it shows the appearance of the effective bands in a process at different immersion conditions, while we notice a disappearance of the bending band of the amine when immersed in the basic solution in the first week, which indicates the cracking of some bonds of polymer chains. properties to various immersion conditions was positive on both the apparent porosity and water absorption. At the same time, it was negative on the bulk density, where the highest value was (2.921) gm/cm3 for models before immersion. The lowest value was (1.93) gm/cm3 for models immersed in water. In the third week, we also noted that the effect of immersion conditions was positive on slip wear and negative on hardness values.

Keywords: epoxy resin, fiberglass, structural properties, physical properties. Spectral properties.

1. Introduction

In materials science, the base material and the reinforcing material are the components of composite materials, as some of the composite materials have a base and other has a ceramic base. It is involved in aircraft structures, as well as in the marine industry, such as boats and small ships, and the manufacture of sports equipment, as well as in the fields of construction and bridge construction [1,2]. In this research, the type of thermally hardened polymers was used in which the polymeric chains intertwine when treated with heat, becoming insoluble and non-fusing [3]. These polymers have more strength and stiffness than heat-resistant polymers. They can be used at high temperatures, have low shrinkage and good creep resistance, low densities, and have high thermal and electrical insulating properties. Examples of these polymers are epoxy resins, phenol-formaldehyde resins, and polyurethane resins [4]. Thermosetting polymers are widely used in manufacturing composites reinforced with fibers, which bear the force applied to the composite material. For this reason, the fibrous composites have high tensile strength and modulus of elasticity [5,6]... Compound materials supported by fibers have specific properties, which are not fundamental but are affected and depend on several factors related to the composition of the polymer and other environmental factors. [7, 8].

2. Experimental Part

2-1 Fabrication of the composite: The models were prepared by casting method by following the following steps:

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A: selecting the materials included in the composition of the overlapping materials, which are:-(Matrix Material)
In this research, epoxy resin is used, which is a thermosetting resin, the type used in the study is (Sliox Ep 400), and the hardener used is (Metaphenylene Diamine (MPDA)), which is a light liquid substance with a transparent color. (Reinforcement Materials) :- Use of mat-type glass fiber reinforcement material.
B - After the mold manufacturing is completed, we follow the following to complete the practical aspect: - We make molds with dimensions according to the device's specifications for all tests, as shown in Table 1

Table (1) Dimensions of standard models

ASTM	Mold Dimensions (mm)	Examination type
D 570	10×10×4	Absorbance
D5963	20×10×10	Wear Rate
D2240	30×10×3	Surface Hardness

2- We mix the base phase with the hardener dibenzoyl peroxide and add the hardener to the resin in a ratio of (1/3) (1g) of hardener for every 3g of epoxy.
3- To determine the added weight percentage of the reinforcing material, use equation (1) for this purpose [9]: $\Phi = \frac{1}{1+\frac{\psi}{\psi}\frac{\rho f}{\rho m}}$ ---------- (1)
Since:ψ: the weight fraction of the reinforcing material.
(ρm, ρf): the density of the base material and the reinforcement, respectively.
ϕ: The volume fraction of the reinforcing material in the composite material and the value of the volume fraction in this study was (20%).
4 - In the case of fiber reinforcement, it is poured a small amount of the mixture in the form of a liquid placed from one side of the mold (to avoid the occurrence of air bubbles inside the casting, which causes failure in the properties of the final model), and then we start adding until it reaches about half of the mold and works to reverse the tendency of the mold to The material reaches all sides of the mold continuously and regularly, then we put the fibers, then we complete the rest of the mixture until the entire mold is filled and we immerse all the fibers inside the mold and move the fibers with the help of a glass rod to obtain homogeneity of the casting on all sides, Then the molds are left for a period of (2d) to harden
5- We extract the samples and put them in the oven at a temperature (of 60 ° C) for two hours to obtain high-quality samples.
C- Immersion of samples in chemical solutions: This process was done by preparing three solutions, namely (H2SO4) at a concentration of 20% and (NaOH) at a concentration of 3% in addition to (H2O). Samples are immersed in bottles filled with each solution separately. The bottles are tightly closed to prevent evaporation and are submerged for two periods of time, which are (1,3) weeks. All solutions are at room temperature. And every time one of the forms was pulled out for the examination, we used forceps dedicated for this purpose made of stainless steel.

3. Examinations

Examination (AFM):- The atomic force microscope is considered one of the high-resolution microscopes, as its accuracy reaches parts of a nanometer. Hence, it is possible to study the nature of surfaces in terms of roughness rate and grain size [10].In this research, an atomic force microscope (AA 3000 SPM) was used to study the topography of the surfaces of the models.

spectroscopic examinations

Examination UV Visible Spectrum: The mechanism of this examination is to shed light on the material, and the so-called optical absorption occurs, as the incident radiation will lose part of its energy as a result of the interaction of the incident photons with the electrons in the material. The primary interaction that leads to the emergence of the optical properties and the absorption spectrum of the material occurs between the electric field accompanying the electromagnetic rays and the charges in the material. In this research, we will study the absorbance property A, which is defined as the ratio between the intensity of the absorbed radiation absorbed by the membrane (IA) to the intensity of the radiation falling on it (I0), which is a quantity devoid of units of measurement, and is given by the following relationship [11]:
$A = I_A / I_0$ ---------- (1)
To conduct this examination, a UV-VISIBLE-NIR spectrophotometer, known as (UV-1800) from (SHIMADZU) company.

Infrared Spectrum Examination

Infrared spectra were recorded with a type (FT-IR) Infrared spectrophotometer Shimadzu 8400) of Japanese origin. The examination was carried out using (KBr) discs. The examination range is (400-4000) cm^{-1}.

Physical examinations

The physical properties of the polymer-based composites produced by the hand casting method are considered a measure of the success of the resulting model and the possibility of using it in specific applications. The most important physical properties under study are:

Apparent Density

The ratio between the mass and apparent volume includes the actual substance and closed pores.

Apparent porosity

It is known as the ratio of open pores to the total volume of the body. The actual porosity is the ratio of the volume of closed and open pores to the volume of the total material [12].

Water Absorption

The water absorbency ratio is one of the properties of the product type. It is a vitreous product if the water absorbency is less than 1%. If it is higher than 1%, it is a porous product. The absorbance depends on the amount of porosity as it is proportional. Directly, because the amount of water absorbed by the material is by the open pores, the water absorption is affected by the same factors affecting the porosity [13]. The physical properties (visual density, apparent porosity, water absorption) were measured according to the method adopted in international specifications No. (ASTM (373 - 88)) [15,16] as we put the samples in the drying oven for (24h) at a temperature of (100C°). Then we leave it in the oven to cool gradually until it reaches room temperature, and then we use a sensitive scale with four places and take the dry weight Wd Then we put the samples in distilled water at a temperature of (100°C) and leave for (24h) , after which, the samples are extracted from the water and dried with a piece of cotton gently, and we weigh the saturated weight Ws, and then we immerse the models in water and weigh the suspended weight Wi and then calculate the values of the physical properties under study (apparent density, apparent porosity, water sorption) from equations (2), (3) and (4), respectively [14] :-

$$A.D = \frac{Wd}{Wd-Wi}\rho \quad \text{----------(2)}$$

$$A.P = \frac{Ws-Wd}{Ws-Wi} \times 100\% \quad \text{-------- (3)}$$

$$W.A = \frac{Ws-Wd}{Wd} \times 100\% \quad \text{------- (4)}$$

Since: -

Ws: saturated weight / gm

Wd: dry weight / gm

Wi: hanging weight / gm.

ρ: density of water / gm/cm^3

mechanical checks

Wear Rate

Wear is defined as the gradual loss of a substance from one or both of the contacting surfaces when it is under the influence of relative motion and can occur as a result of sliding or rolling contact or due to the impact of liquids or gases containing solids on the surfaces [15]. We will use the English-origin pin-on-disk sliding wear device (ASTM) to obtain contact between the sample and the rotating disk under vertical load. The wear rate when changing the load or when changing the linear speeds for all models at room temperature can be obtained from equation (5) [16]:

$S_D = 2\pi rvt$----------(5)

as

r: the radius from the center of the sample to the center of the disc.

v: linear gliding velocity.

t: test time.

As this equation calculates the sliding distance at each value of the sliding velocity, it is worth noting that the readings were taken for all models at a speed of 60 (cycle/min).

3-4-2 Surface hardness

Surface hardness is one of the properties that determine the surface state of the material because it is a measure of the material's resistance to scratching or penetration on the outer surface of the manufactured material. The smoother the surface, the more interconnected its molecules [17] There are several methods for measuring the hardness depending on the implanting instrument in which the examination is conducted, and it was used in this research by the Shore hardness measuring device. As this device checks the hardness by inserting a steel needle into the model and waiting for (30sec), and then we record the reading that appears on the device screen, and the process is repeated for five different regions of the model, after which the average is taken for the five readings.

4. Results and Discussion

Effect of immersion in different solutions on the results of AFM

From the (AFM) images of Figure (1) of the polymeric composite before immersion between, the surface homogeneity and the distribution of granular sizes were somewhat uniform, while we note the significant difference in the impact of the surface of samples immersed in distilled water for three weeks shown in Figure (2), Between the surface roughness and the size distribution, was The granule is different from what it is superimposed before immersion; the same is the case in the distribution of particle sizes when immersed in an acidic solution, noting a decrease in the surface roughness than it was when immersed in water as shown in Figure (3). Also, Figure (4) indicated that (NaOH) solution was different from other immersion media, giving uniformity in the distribution of granular volumes, close to the distribution of granular volumes before immersion.

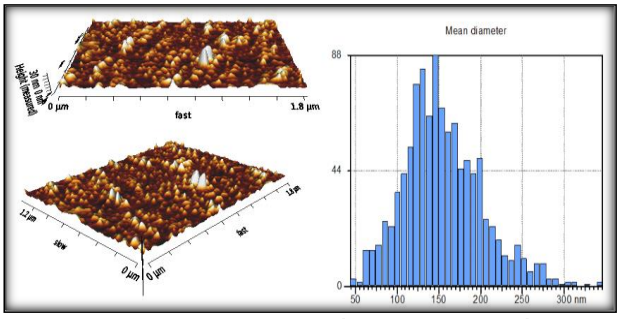

Figure (1) (AFM) image of the samples before immersion

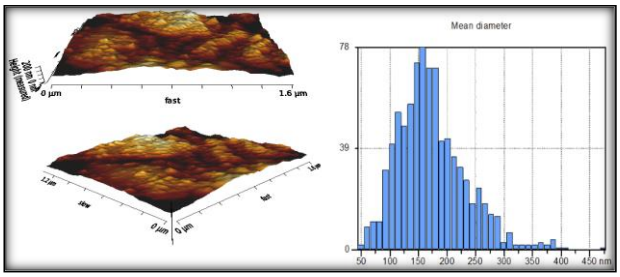

Figure (2) (AFM) image of the samples at immersion (H_2O) for (3week)

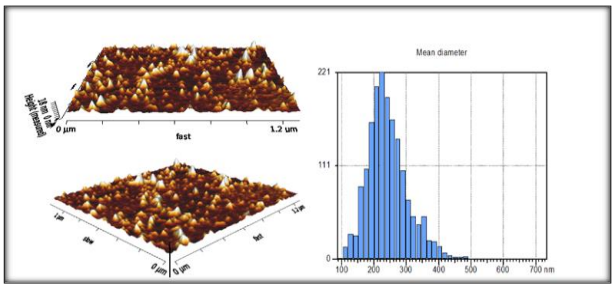

Figure 3 (AFM) image of the samples at immersion in (H2SO4) (3weeks).

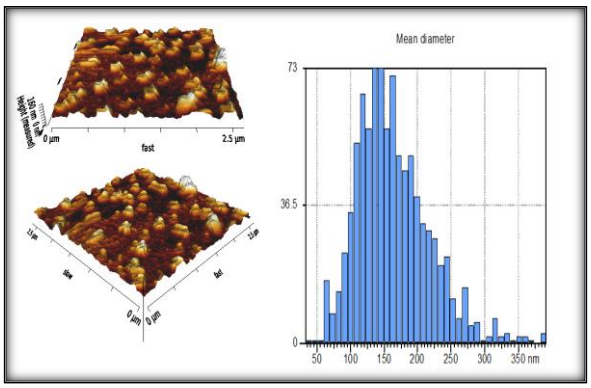

Figure (4) (AFM) image of the samples at immersion in (NAOH) (3weeks)

The effect of immersion in solutions on the absorption of UV rays

The absorbance spectrum of the polymeric compound, when immersed in different media in the first week, is shown in Figure (5), through which we note the absorbance of light at wavelengths ranging from (300 to 400) nm was turbulent and had an undefined behavior. But in general, the absorbance in these areas was the least possible for the overlay before immersion. Therefore we can conclude that the models of the violet and blue colors of the visible spectrum were very turbulent. Then there was a decrease in the absorbance values after wavelength (400) nm until reaching a region of wavelength (500) nm, and we noticed that there is a quasi-stability in the absorbance values; the absorption spectrum was higher for the compound submerged in the base solution, while the water gave a behavior close to the conduct of the compound before immersion in this region, while the effect of acid is the weakest. We also noticed a significant difference in the behavior of the models immersed in different media during the third week of immersion. It is noted from Figure (6) that the disturbance In the conduct of all immersion media, starting from 300 nm and continuing until the wavelength is approximately 550 nm, and after this region of the visible spectrum, there was some stability in the behavior, and the submerged overlay gave the highest values of the absorbance at the base, As for the acidic solution, it was the lowest among all other solutions because the acidic solution is H^+, which does not have any electronic double, unlike the base solution, which formed (OH^-), which has an electronic double that strongly absorbs the photon.

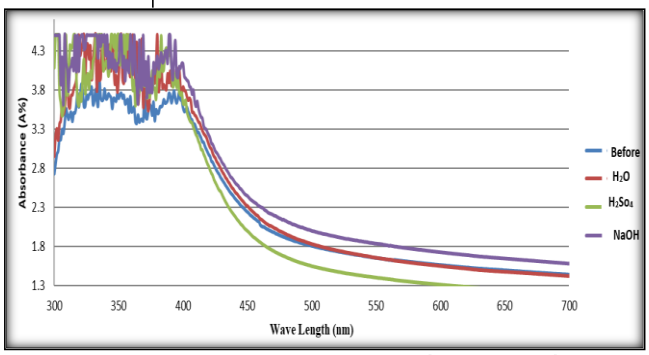

Figure (5) Absorbance spectrum of samples after immersion in solutions for (1 week).

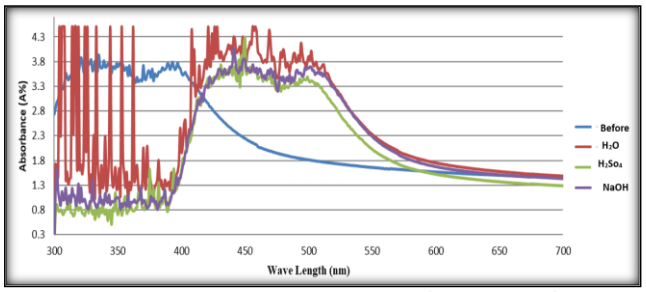

Figure (6) Absorbance spectrum of samples after immersion in solutions for 3 weeks.

Effect of immersion parameters on IR

We note from Table (2) that the hydroxyl stretching band for the Epoxy appeared at the range 3556 cm^{-1} and the stretching band for the amine group appeared at the range (3471-3412) cm^{-1}, and the bending band for the amine group appeared at the range 3037 cm-1 in an average way. These bands all belong to the superimposed Epoxy without immersion, as shown in Figure (7). And when immersed in water for different periods, week(1,3), it was observed that the hydroxyl group appeared in the range (3554-3537) cm-1 in the first week in an average way, and this indicates the occurrence of moisture for the compound, as well as the appearance of the amine group at range (3379-3414) cm-1 and the appearance of Laminar beam at range (3346- 3362) cm-1 as in Figure (8) At three weeks, All the bundles return to what they were in the compound without immersion, except for the hydroxyl group, which appeared in an average form, indicating a slight effect with water. After using the dilute sulfuric acid solution, we noticed during the first week that the hydroxyl group appeared with a fragile intensity, and the appearance of the amine group a powerful with the arrival of bands around the amine group, and this indicates the occurrence of a kind of interaction on the amine group that is the cause of the crosslinking process When the samples are immersed for three weeks, we notice an extreme weakness of the hydroxyl group, as well as a weakness in the strength of the amine group and the appearance of bending bundles of the amine group, this indicates weakness and distortion of the amine group. Due to the entry of part of the acid between the polymer

chains as in Figure (9) While in the case of using sodium hydroxide, we notice the disappearance of the bending band of the amine and the appearance of the stretching band in a powerful form, as well as the appearance of the hydroxyl band in a moderately strong form. When the immersion continues for three weeks, we notice a weak intensity of the amine and hydroxyl groups and the emergence of a second bundle. This is evidence of a divergence between the interlocking polymeric chains, as in Figure (10).

Table (2) shows the locations of the aggregates of the IR spectra of samples immersed in different solutions

Effective totals						Immersion parameters	
OH	-NH	-NH	C-N	C-H	C-O		
3556	3471-3412	3037	1610-1510	2958-2864	1298-1244	without immersion	
3554-3537	3410- 3379	3346-3362	1612-1510	2958-2856	1300-1244	1week	H_2O
3554-3545	3471-3414	3240-3308	1610-1510	2958-2924	1298-1244	3week	
3556	3473-3414	3036-3232	1371-1246	2958-2866	1612-1510	1week	H_2SO_4
3556	3471-3410	3242-3304	1300-1246	2956-2862	1610-1510	3week	
3558	3473-3414	----	1614-1512	2955-2962	1296-1246	1week	NaOH
3556- 3547	3468-3412	----	1612-1510	2958-2862	1296-1246	3week	

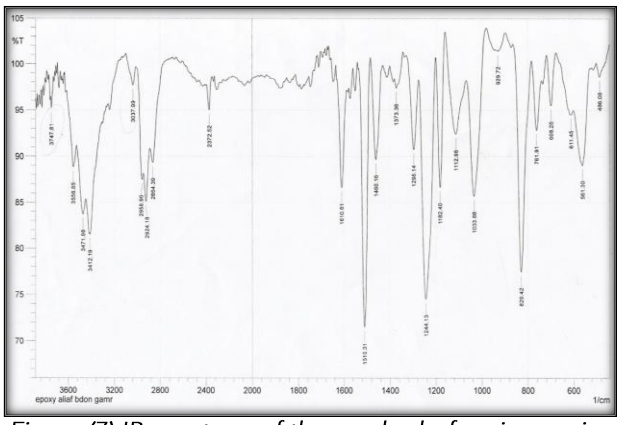

Figure (7) IR spectrum of the overlay before immersion

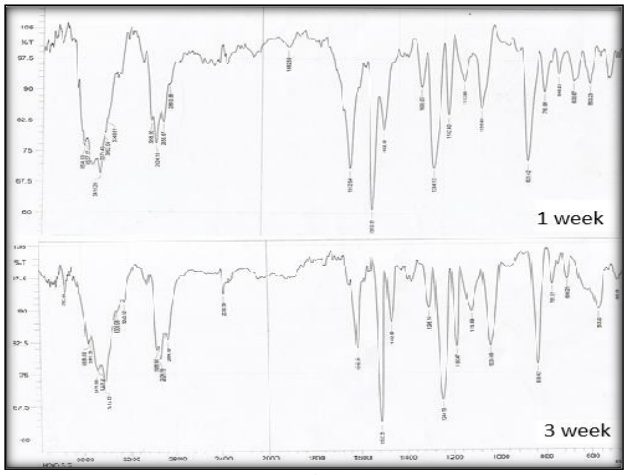

Figure (8) IR spectrum of the superimposed upon immersion in (H_2O) solution.

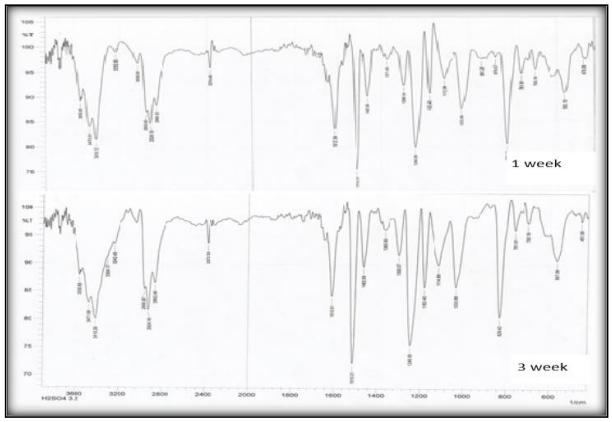

Figure (9) IR spectrum of the superimposed upon immersion in (H_2SO_4) solution.

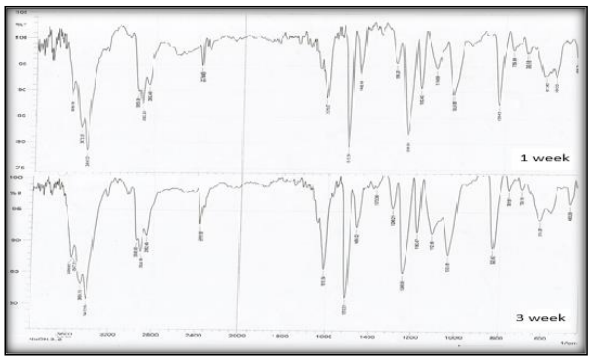

Figure (10) IR spectrum of the superimposed upon immersion in (NaOH) solution.

Effect of immersion in different solutions on the physical properties

The effect of immersion in different chemical solutions at other times on the physical properties (apparent density, apparent porosity, and water absorption) was shown in Figures (11), (12), and (13), respectively, where we notice a different adverse effect by the immersion media on the values of apparent density Figure (11) shows that water is the most effective, followed by the acidic solution, While the effect of (NaOH) is the least effective in the first week, the impact of water and (H_2SO_4) in the third week gives very close values. In contrast, the effect of (NaOH) solution maintained its behavior this week. As for the porosity of the samples, it increased by immersion in water and acidic solution by approximately the same amount in the first week, where the values were (0.371)% and (0.368)% for water and acidic solution, respectively, as shown in Table (3), but the effect of the acidic solution was greater than that of water in The third week. In contrast, the impact of (NaOH) solution was the same behavior at all times and gave a somewhat weak effect on the apparent porosity values , as shown in Figure (12); the positive impact of different immersion media on porosity values is due to surface adsorption and osmosis through the polymer. The increase in porosity naturally affected the increase in water absorption when immersed in different solutions. Still, we note from Figure (13) that the effect of

water was the weakest in the third week of immersion, which gave A slight increase compared to the impact of the acidic solution, which was very large, as shown in Table (3). This is because the acid attacks the polymer strongly. After all, (H+) ions work to form bonds with the end of the polymeric chain and (SO4 -) ions, and thus works to weaken the interfacial region, and this agrees with the researchers [18,9].

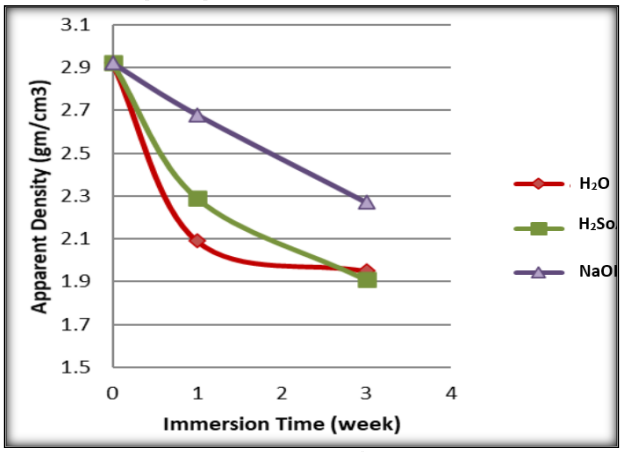

Figure (11) shows the density of polymeric composites under different immersion conditions.

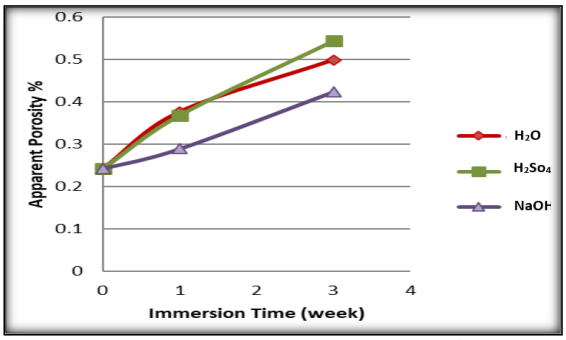

Figure (12) shows the apparent porosity of polymeric composites under different immersion conditions.

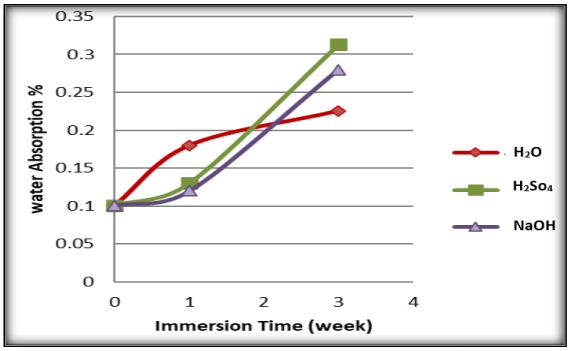

Figure (13) shows the water absorption of polymeric compounds under different immersion conditions.

Table (3) shows the physical properties and their relationship to the parameters of the study

Apparent density		Apparent porosity		water absorption		Immersion type
3week	1week	3week	1week	3week	1week	
2.921		0.242		0.101		before immersion
1.93	2.03	0.498	0.376	0.2255	0.18	H_2O
2.271	2.29	0.423	0.368	0.313	0.13	H_2SO_4
2.15	2.68	0.543	0.289	0.28	0.12	NaOH

Effect of immersion in different solutions on the mechanical properties

The slip wear increased at an increase in the immersion time for all immersion media as shown in Figure (14). Still, we notice this increase became slight at the third week for the two solutions (H2SO4) and (NaOH), since immersion in the first week in acidic and basic media affects Superficial. Therefore the values of slip wear increased. Still, with the progression of time up to the third week, the acidic and alkaline media worked to cause penetration into the pores of the polymeric compound. Hence, its effect on the surface was very little , Table (4) shows that decrease. When immersed in the base solution, the wear value was the highest value of (3.5) kg/m2 x 10-6 in the third week, while in the first week it was (3.1) kg/m2 x 10-6.

From Figure (15) we notice the negative effect on the surface hardness of all solutions. Still, we notice that the basal solution had the weakest effect among the immersion solutions, as shown by the hardness values in Table (1), because in the solutions that have a high acidic function, such as (NaOH) The dominant ion is (OH-) and thus acts as a strong competitor to the negatively charged polymer surface to attract the ion (Na+).Thus, slight adsorption occurs on the surface, while in the solutions that have a low acidic function (H_2SO_4), the dominant ion is (H^+), which tries to unite with the surface of the negatively charged polymer, which leads to strong adsorption by the acid on the surface of the compound that works to reduce the forces of bonds The surface of the polymer, which is reflected on the influence of the hardness values by the different acidic and alkaline media, as shown in Figure (15), and this agrees with the researcher [5] for other materials.

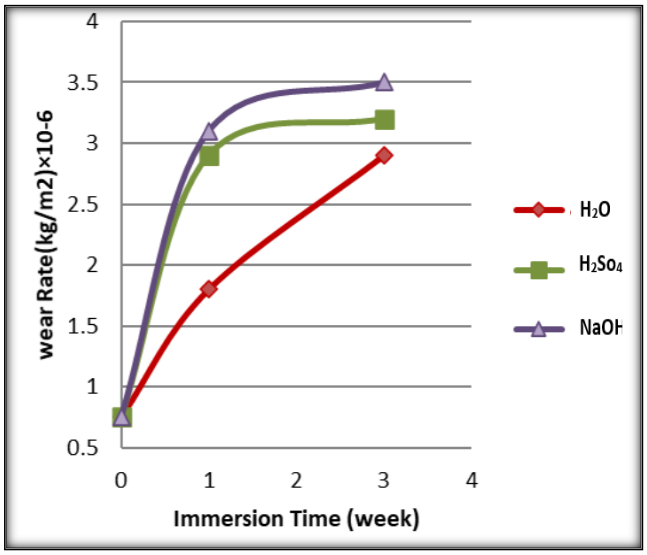

Figure (14) shows the relationship of sliding wear of

polymeric compounds with immersion time when immersed in different solutions.

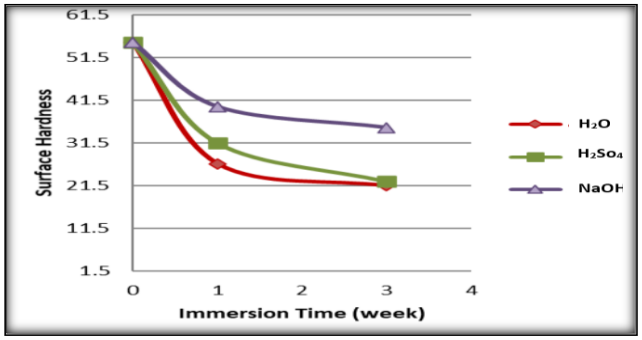

Figure (15) shows the relationship of the surface hardness of polymeric composites with the immersion time when immersed in different solutions.

Table (4) shows the mechanical properties and their relationship to the parameters of the study

Surface Hardnness		Wear Rate $(kg/m^2)\times10^{-6}$		Immersion type
3week	1week	3week	1week	
55		0.57		before immersion
21.4	26.6	2.9	1.8	H_2O
27.5	31.4	3.2	2.9	H_2SO_4
36.7	40	3.5	3.1	NaOH

5. Conclusions

The immersion in distilled water and the acidic solution plays a big role in the surface roughness and the rate of distribution of particle sizes. In contrast, the base solution had a very weak effect on the surface as it was close to the surface of the samples before immersion.

The spectrum of UV absorption at high wavelengths is the highest possible for the base solution and the lowest possible by the acid.

When immersed in acidic and basic solutions, the IR spectrum varies between the appearance of effective bands varying according to the time of immersion. The most important thing is the disappearance of the bending band of the amine when immersed in the alkaline solution in the first week.

Immersion in different solutions and for all immersion times negatively affects the bulk density and positively on both the apparent porosity and water absorption.

High slip wear values for different immersion conditions, but increasing the immersion time leads to a weak rise in the values for different immersion conditions.

Hardness is negatively affected by different immersion parameters, but this effect is uneven

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