

Hardness And Wear Resistance Of Composite Materials Supported By Graphite And Silica Particles And Reinforced By Cuffler Fiber

Eng. Faten Rashid Al Khalidi, Dr. Mustafa Ahmed Rajab

M.Sc. of Civil Engineering / Ministry of Education.

Assistant professor. Iraq / Central Technical University. Technical Institute –Baqubah / Mechanical Department

Corresponding author: Dr. Mustafa Ahmed Rajab

ABSTRACT: *The research aims to study the mechanical properties (Hardness and Wear Resistance) of composite materials (epoxy resins with phenolic formaldehyde resin) supported by graphite or silica particles or both, and reinforced with Cuffler fibers, Hardness values reached their highest value when increasing the volume fraction to 15% and then decreased to their lowest values at the volumetric fraction (20%), the rate of wear and tear when immersed in chemical solutions was the effect of acid solution less than in the base solution.*

Date Of Submission: 15-11-2018

Date Of Acceptance: 29-11-2018

I. INTRODUCTION:

The main functions of the fiber in a composite are to carry most of the load applied to composite and provide stiffness. For this reason, fiber materials which have high tensile strength and a high elastic modulus are often used for the fiber in composite [1]. Carbon Fibers (CF) appeared in the market in 1960 and are produced from organic fibers (rayon, acrylics, etc.) or from remaining of petroleum or tar distillation. [2]. Carbon fibers are the strongest and stiffest reinforcing fibers for polymer composites, these fibers are the most commonly used after glass fibers. Carbon fibers can give galvanic corrosion in contact with metals. They're generally used together with epoxy, phenols, polyester, where high stiffness and strength are required, i.e. space and automotive applications [3]. Another mechanical property that may be important to consider is the hardness, it is a measure of a material's resistance to localized plastic deformation. Shore hardness is measured with instrument known as a durometer and is also named durometer hardness [4]. In the current study wear test, this method was adopted because it is easy method and can be inference the wear rate because it gives the amount of wear debris. This method is summarized by weighted of the sample before and after the test, and the difference between the two weights represents the amount of wear debris. [6,5]. Carbon has two natural crystalline allotropic forms: graphite and diamond. Graphite derives its name from the Greek word "graphein" [7]. Graphite is defined as an allotropic form of the element carbon consisting of layers of hexagonally arranged carbon atoms in a planar condensed ring system (grapheme layers, these planes also called basal plane). The layers are packed parallel to each other in a three dimensional structure. The atoms within the rings are bonded covantly, whilst the layers are loosely bonded together by Van der Waals forces [8]. The high degree of anisotropy in graphite results from the two types of bonding acting in different crystallographic directions. For example, graphite's ability to form a solid film lubricant comes from these two contracting chemical bonds. The fact that weak Van der Waals forces govern the bonding between individual layers permits the layers to slide over one another making it an ideal lubricant. Graphite is generally grayish-black, opaque and has a lustrous black sheen. It is unique in that it has properties of a metal and a non – metal. It's flexible but not elastic, has a high thermal and electrical conductivity, and is highly refractory and chemically inert [9]. Silica occurs commonly in nature as sand stone, silica sand or quartzite. It is the starting material for the production of silicate glasses and ceramics. Silica is one of the most abundant oxide materials in the earth's crust. It can exist in an amorphous form (vitreous silica) or in a variety of crystalline forms. Often it occurs as a non – crystalline oxidation product on the surface of silicon or silicon compounds [10,11]. The mechanical strength of polymers can be improved by reinforcing the polymer matrix by the addition of filler materials like (

silica, alumina, zirconia). These composite materials are stronger than the bulk (un-reinforced) polymers as a result of the high-strength reinforcement phase obliging the applied loads[12]. Composite materials in this regard represent nothing but a giant step in the ever- constant endeavor of optimization in materials. Strictly speaking, the idea of composite materials is not a new or recent one. Nature is full of examples wherein the idea of composite materials is used[13]. Phenol formaldehyde resins is a type of polymer is made from two main substances: phenol and formaldehyde. Phenol is a colorless solid compound, but when exposure to oxidation in the air its colored by pink Then brown. It has strong odor and penetrating. Phenol is widely used in the manufacture of materials for plastics, including drinking water bottles, as well as in the clothing industry. Phenol is used in the installation of nylon. It has medical uses, it is used in the manufacture of disinfectants, lotions, ointments, topical anesthetics and the pharmaceutical industry[14]. The water solution which contains a concentration of 40% formaldehyde is called formalin. this is used as a preservative for tissues and in embalming, with a boiling point of 21 ° C, it is used in veterinary and in dentistry as well as in the production of chemicals and polymers and is often used in the manufacture of coatings and explosives [4].In general, phenol-formaldehyde produced by two ways, for manufacture two types of polymers, namely Novolac and Resole [15]. Novolac is a type of polymers produced by mixing formaldehyde (37% water solution) with phenol by added an acidic helper (sulfuric, phosphoric or oxalic acid), and heated to the required degree and then equivalent the reaction mixture, and remove the water by distillation (in its final stages under discharge) to a temperature Estimated 160 ° C . Resole is a type is produced by added basic helper with more formaldehyde relative to phenol. Initially, its consists (Oligomer) is called a resole and it is not needed to a hardener (HMTA) but it need just heat treatment [3, 6]. In (2013), Hamid S., studied the mechanical properties (tensile, bending, and hardness) of unsaturated polyester resin reinforced with silica particles in different weight fractions (10, 20, 30 and 40) %. Results showed decreasing in tensile strength and flexural strength with increasing particle concentration, increasing in hardness, tensile modulus and bending modulus with increasing in particle concentration [16]. In (2015), A.Vikram et al, studied the influence of different content ratios and lengths of carbon fiber reinforced epoxy composites. Carbon fiber is taken in the 3, 5, 7 % weight in order to suspend on epoxy resin with different fiber lengths such as 1, 2, and 3 cm. Moreover they studied the thermal properties such as TGA and DSC to investigate the influence of change in fiber length on Carbon fiber–epoxy composites. Significant improvement in tensile and flexural strengths of Carbon fiber–epoxy composites has been observed by the different fiber lengths. Flexural strength, flexural modulus, tensile strength and modulus were increased correspondingly up to 5%wt and 2 cm length of carbon fiber reinforced epoxy and decreases with further addition of fiber contents i.e., 7% wt. they concluded that Carbon fiber–epoxy composites can be used for high strength, stiffness, and bending applications in aerospace, automobile, and marine and lightweight article applications. Overall studies indicated that the carbon fiber reinforced composites at 2 cm length of carbon fiber and 5%wt loading are promising candidates for structural applications where high strength and stiffness is indispensable[17]. In (2015), Jweeg et.al. designed a new athletic prosthetic foot. The foot was manufactured by using epoxy reinforced by carbon fibers and that gives good mechanical response. The impact tester was designed and manufactured to perform the test. For the same dropped level, the impact response of the samples with glass fiber and carbon fiber have the same peak load for different drop angle but. In addition, it was clear that the responses of the sample manufactured with carbon fiber were more smoothness than the sample manufactured with the glass fiber [18]. In (2016), Jagadale U.S. and Raut L.B., investigated the mechanical properties (tensile strength and shear strength) of glass fibers reinforced polymer matrix with different fibers volume fraction (40, 50 and 60) %, hand lay-up and compression molding were used to prepare the samples. Results showed better mechanical properties at volume fraction (50%), further increase in the fiber content leads to increase in the mechanical properties but the composites start to delaminate [14].

II. XPERIMENTAL PROCEDURE:

Materials used: The materials used in this work are: (1) Epoxy resin supplied by (Sikadur®-52 Injection Type N), the base used to mix is mixed 3 gm. of resin with every 1 gm. of the hardener. Table (1) shows the properties of the epoxy resin.

Table (1) the properties of epoxy resin used in this research [23].

Properties	Values
Tensile Strength	44 Mpa (at 25 °C)
Flexural Strength	67 Mpa (at 25 °C)
Compressive Strength	58 Mpa (at 25 °C)
Density	1.7 Mpa (at 25 °C)
viscosity	431 mPa.s (at 25 °C)

2. Resole resin: Is consists of one part only. Resole resin was the first wholly synthetic polymer to be commercialized [7]. It has become one of the most widely utilized synthetic polymers since Baekeland developed a commercial manufacturing process in [5]. Resole is synthesized under basic conditions with the formaldehyde (F) and phenol (p) molar ($F/p > 1$) [9].
3. Cuffler fiber: The type of Cuffler fiber used in this work as reinforced materials.

Table (2) the properties of Cuffler fiber used in this research [2,4].

Properties	Values
Compressive strength	1578Mpa
Tensile strength	6521Mpa
Young modulus	71.8Gpa
Poisson's ratio	0.21
Density	2.9g/cm ³

The practical part includes the preparation of the raw materials and how to prepare them in addition to the mechanical tests carried out on the composite material. These materials were mixed with different weight. At first, the substance was mixed with phenol formaldehyde resin, called resole. Different mixing ratios were used to obtain the samples. For the purpose of making samples for the necessary tests to obtain the mechanical properties and analysis and compare them with the mechanical properties of the alloy, which is the part of the original, which was chosen for the purpose of replacement of the alloy composite material used in the search for weight loss and improve mechanical properties.

Technical Testing Procedures:

There are several instruments and equipment utilized to measure and determine the mechanical properties of the materials under investigation. Mechanical properties were measured at room temperature (25)^oC.

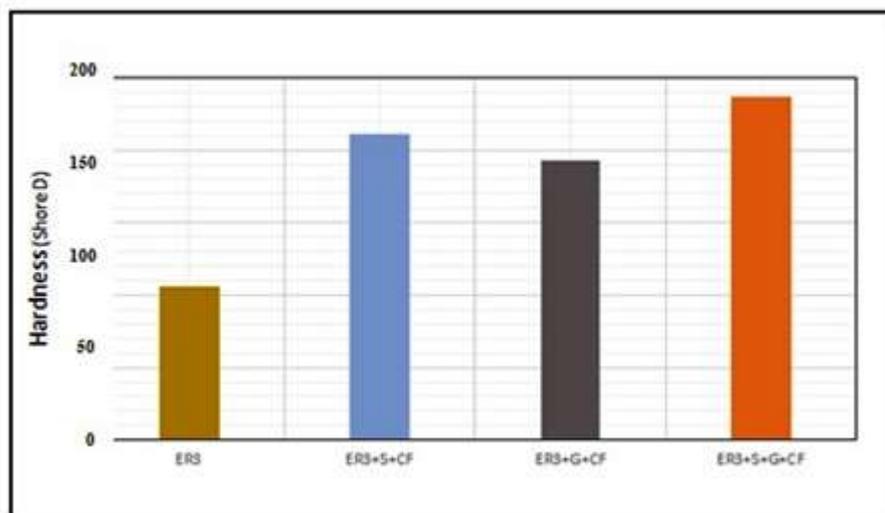
Hardness: The hardness is the ability of a material to resist penetration, the shore D hardness values showed that the results of the different mixing ratio.

Wear Test Instrument: The pin-on-disk instrument is popular wear testing apparatus. This instrument consists of electrical motor which rotates at angular velocity, the motion is transferred from the electrical motor to the disc. The disc has angular velocity of (720 rpm).

III. RESULTS AND DISCUSSIONS:

Hardness Test : The concept of hardness can be counted as a measure of the plastic deformation that the material can suffer under the influence of external stress. Thus, particle reinforcement (silica or graphite) increased the hardness of the material due to increased resistance to plastic deformation. It has been found that the increase in the reinforcement materials and then the Cuffler fiber armament, led to an increase in the hardness of the material, this may be due to the fact that the hardness is a property of the surface, so this behavior is expected to hardness. It is known that most tests of hardness depend on the material resistance to penetrate at the outer surface and there are different ways to evaluate the hardness, in the current research has been the hardness test using the hardness (Shore Durometer) type (shore D), and through the results note that the hardness values of samples are increasing with Increase the fractional fraction of the supported particles (graphite, silica), especially if the particle size is small, and the homogeneous distribution is distributed within the floor. The studies indicate that the hardness values reached their highest value when increasing the volume fracture to 15% and then decreased to their lowest values at the volumetric fraction (20%). This is due to the high viscosity gained by the prepared material when adding high ratios of the particles of graphite into the base material, which is in the liquid state, which caused the difficulty of penetration of the base material into the interstitial fissure of the fibers and porous interstices within the composite material, resulting in creating a lot of gaps in the prepared material and despite attempts to get rid of gaps and aerobic space I kept some of them p Since the hardness of the surface of the material and the presence of particles of graphite and silica at the surface of the material and the properties of these particles of hardness, the resistance to the force exerted on them are few, so the increase in the values of hardness Be few with increased particle fracture. The effect of particle sizes on hardness values is that hardness values increase with low particle size (graphite or silica) and this is due to the use of particles in small sizes, which facilitates the process of penetration into the base material and into the fiber network interface and into the pores that which was made during the process of preparing the overlays, all of which helped to increase the area of contact between the components of the composite material prepared and then increase the interdependence between them and in an integrated, which gave more positive values when examining the hardness and, conversely, when the presence of large particles will be a barrier either flow of material And the fiber nature has a great role in determining the values of prayer, because the hardness of those fibers vary according to the type of fiber. Because some of them are made of ceramic materials while other fibers are made of polymeric materials. The hardness test was performed by a regression method with four

readings per sample. The most suitable method for measuring the hardness was the hardness values obtained from them, which reflect the condition of the material as a whole and not just the surface state. It is mainly dependent on the amount of energy absorbed by it. Absorbs a greater amount of energy, which leads to the bounce of the ball to a higher altitude than if the material is solid, in which case will return to the rise of the largest result of absorption of less energy and the results obtained confirm this. Fiber orientation has an influential role in hardness values. The calcium-reinforced samples (90o-0) gave the highest values of hardness compared to random-pattern samples. This indicates that the use of standard-size Cuffler fibers gives more positive results in the reinforcement process, And it is noted that the lattice system in fiber reinforcement increases the hardness values of the samples with the total volume fracture, and these hardness values increase with the number of reinforcing layers, which confirms the positive effect of the arming process with this fiber [8].



Effect of periods of immersion and its solutions in the rate of wear:

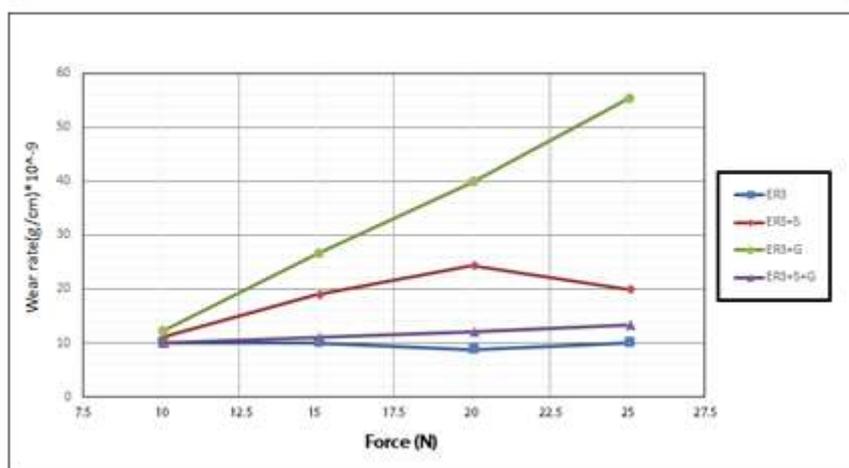
First: Effect of immersion periods:

The results of the studies conducted at (3.1415m / sec) and the hardness of the iron tablet (269 HB) and the loads (20,15,10) N and the hydrolysis (HCl) and the base (NaOH) and the concentration of (0.5 N) The immersion is then relatively stable until it reaches the steady state. The lack of resistance to wear and tear during the period of immersion in the first immersion stages of the test until reaching the stable state is due to the formation of a thin layer of material corroded between the protrusions of the disk surface, which contributes to the surface adjustment over time. As well as that the continued slide leads to an emotional hardening of the sample surface. The cause of the oscillation in the wear test is due to the phenomenon of sliding over the debris of the adhesive stick (Stick-Slip) as a layer of debris from the polymer sample on certain areas of the sample path on the disk without the other areas.

Second: the effect of solutions immersion:

The chemical uptake rate and its quantity by the composite material are controlled by several factors: chemical composition of the resin, bonding factor, bonding strength and adhesion strength of the materials involved in the composition of the overlapping material ie the efficiency of the interstitial surface and the solutions applied to the polymer mixture cause dimensional changes, Internal stresses resulting in a decrease in the performance of mechanical properties [18]. The rate of wear and tear of plastic materials immersed in chemical solutions is greater than it is in normal conditions (without immersion). This is due to several factors including. Due to insufficient shrinkage and saturation between the base material and the additives (the supporting materials) to form the mixture during the molding process, where small cracks can occur on the surface and gaps appear in the base material. When exposed to the chemical environment, the chemicals spread in the base material, The gaps formed during the molding phase, resulting in processes: absorption, cracking of bonds, plasticity and finally decomposition material at long immersion periods, and when the load on this material, the cracks formed on the surface and inside unite and merge and this facilitates the absorption of solutions The penetration of molecules of chemical solutions into the material works on the surface of the material as a result of the breakdown of Vanderfals between the polymer chains, which reduces the energy barrier of the movements of the parts of the chains and this leads to an increase in the elasticity of the material and thus increase the rate of wear and tear [10]. The second reason is that the surface membrane between the

two surfaces in the dry state reduces the rate of wear and tear, while in the case of immersion in chemical solutions, the presence of these solutions prevent the formation of surface membrane between the model and the surface resistant (turntable) and thus increase the rate of wear and tear [9]. The results of the wear test after immersion in acid solution (HCl) and NaOH (0.5 N) showed that both solvents had an effect on increased wear and tear. The results showed that the rate of wear and tear in the acid solution is lower than in the base solution and within the same time period. This means that the acid solution of the polymer mixture used in the research and under the wear test is less than that of the base solution. And change in the color of the models immersed in solutions. The decrease in wear and tear observed in some models after immersion is due to the fact that the particles of the penetrating liquid are inter-phase between the matrix material and the surface area separating the substrate and the intermediate phase material, causing a decrease in strength Internal shear [8]. The two surfaces are composed of protrusions and grooves and the beginning of contact between the two surfaces occurs at the sharp protrusions, and under the impact of pregnancy, the stress is concentrated on the sharp protrusions, which leads to a deformation of these stenosis and increase the pregnancy lead to increased deformation at the tops of protrusions and the region near The surface is drilled as a result of the impact of the minutes resulting from the surface crust crash. The small cracks accumulate together, leading to the removal of the surface layers of the debris formed in the form of thin minutes. This increases the plastic deformation with the increase of the load. That the sliding surfaces at low loads leads to the formation of a protective surface membrane reduces the contact between the two surfaces and therefore the force required to cut the bond between the protrusions less than the force required to cut the molecular bonding of the chains of the mixture and thus less wear rate, but increase the load is getting cracking surface membranes and adhesion is strong between the two surfaces and therefore the force required to cut the connected protrusions is higher than the force required to cut the molecular bonding of the mixture chains so the wear rate increases. And the strength of friction between the two surfaces affect the rate of wear and tear by getting emotions as a result of the generation of pressure stress resulting from the shedding of pregnancy and these emotions cause the transfer of part of the surface of the sample contact the surface of the disk and therefore the contact area will increase continuously, leading to increased wear and tear [3]. Moreover, the temperature has an effect on the rate of wear and tear and the increase in temperature increases the softness of the material and this leads to increased adhesion between the protrusions of the two surfaces and thus increase the rate of wear and tear. There may be a decrease in the rate of wear and tear as a result of the stress on the model works on the surface of sharp protrusions, which reduces the rate of wear and tear, but increase the burden of pregnancy leads to the formation of sharp bumps again and increase the rate of wear and tear [5]. It is noted that all of the above-mentioned machineries have obtained the models used and the transition from wear transition to severe wear, indicating that wear and tear increased with increased load, or transition from transition Wear) to moderate wear (Mild wear), is due to the phenomenon of emotional dependence and the transition of wear and tear from one stage to another depends on the test conditions and chemical composition of the mixture. This is what the researcher (Hallel) found that the rate of wear and tear of pure epoxy increases with the increase of the load [10]



IV. CONCLUSIONS:

- 1 - Hardness values reached their highest value when increasing the volume fracture to 15% and then decreased to their lowest values at the volumetric fraction (20%).
- 2 - Note that the rate of wear and tear when immersed in chemical solutions was the effect of acid solution less than in the base solution.
- 3- The rate of wear and tear in the dry state is less than in the case of immersion in chemical solutions and Note that the rate of wear and tear when immersed in chemical solutions was the effect of acid solution less than in the base solution.

REFERENCES:

- [1]. Dr. Mustafa A. Rajab, Ekhlal I. Kader, Ali A. Hamod, Abdul Hameed I. Hameed "Mechanical properties of silica, graphite and carbon fiber reinforced composites", International Journal of Engineering and Technology (IJET) , Vol. 9 No 5 Oct-Nov 2017.
- [2]. Materials design, "Effect of resin molecular Architecture on Epoxy thermoset mechanical properties", materials Design, Inc., (2013).
- [3]. Dr. Mustafa A. Rajab, Dr. Ali Adwan Hammoud, Dr. Ekhlal I. Kader, Abdul Hameed I. Hameed. ((Mechanical properties (Tensile, Hardness and Shock resistance) for the phenol formaldehyde resin with Epoxy resin.)) , Diyala Journal of Engineering Sciences 4 (2018) 55 – 60.
- [4]. Zakya Rubab, Adeel Afzal Humaira M. Siddiqi, and Shaukat Saeed, "Augmenting thermal and mechanical properties of epoxy Thermosets: The role of thermally-treated versus surface-modified TiO₂ nanoparticles", material express Vol.4, No.1, pp.54-64, (2014).
- [5]. Dr. Mustafa A. Rajab, Ekhlal I. Kader, Ali A. Hamod, Abdul Hameed I. Hameed ", Mechanical Properties of Silica, Graphite and Carbon Fiber Reinforced Composite Materials", International Conference on Contemporary Global Challenges of Interdisciplinary Academic Research and Innovation Cairo, Egypt on October 27-28, 2017.
- [6]. A.H. Conner, "Wood: Adhesives," Encyclopedia of materials: science and technology. Amsterdam; New York: Elsevier Science, Ltd., 2001, pp. 9583-9599.
- [7]. Dr. Mustafa A. Rajab, Abdul Hameed I. Hameed, "Hardness and Wear Resistance of Composite Materials Reinforced by Silica, Graphite and Carbon Fiber", Fourth edition of the International Congress of the Water Management, Energy, Food and Agricultural Techniques Istanbul Turkey, 7-10 November 2017.
- [8]. Urmimala Maitria, K. Eswas Prasad, U. Ramamurthy and C. N. R. Rao, "Mechanical Properties of Nano Diamond-Reinforced Polymer Matrix Composites", Solid State Communication Journal, Elsevier Ltd., 2009.
- [9]. Dr. Mustafa A. Rajab, Dr. Ekhlal I. Kader, Abdul Hameed I. Hameed., " FLEXURAL AND SHOCK STRENGTH OF SILICA, GRAPHITE AND CARBON FIBER REINFORCED COMPOSITE MATERIALS", 5th International Conference on Innovation Challenges in Multidisciplinary Research Practices (ICMRP-December 15-16, 2017) Singapore.
- [10]. P.K. Mallick "Fiber-Reinforced Composites: Materials, Manufacturing, and Design", 3rd Edition, CRC Press, 2007.
- [11]. Dr. Mustafa A. Rajab, Ekhlal I. Kader, Abdul Hameed I. Hameed "Study the Mechanical Behavior of Advanced Composite Materials ", Second Scientific Conference - Faculty of Bilal Rafidain - University , 18-19 April 2017, Iraq.
- [12]. Jean-Marie Berthelot, "Composite Materials: mechanical behavior and Structural analysis", Springer, USA, (1999).
- [13]. Dr. Mustafa A. Rajab, Ekhlal I. Kader, Abdul Hameed I. Hameed "Study the Thermal Behavior of Advanced Composite Materials ", The First International Scientific Conference for Graduate Student Research, 24-25 May 2017.
- [14]. Dr. Mustafa A. Rajab, Ali I. Al-Mosawi, Ekhlal I. Kader, Shaymaa A. A. Abdul Hameed I. Hameed", Characteristics of Toughness and Flexural of Composite Materials Supported by Silica, Graphite and Carbon Fiber Reinforced" Conference of the College of alkitab- University – 18 October 2017 , Iraq.

Dr. Mustafa Ahmed Rajab "Hardness And Wear Resistance Of Composite Materials Supported By Graphite And Silica Particles And Reinforced By Cuffler Fiber "American Journal of Engineering Research (AJER), vol. 7, no. 11, 2018, pp.317-322