P- ISSN 1991-8941 E-ISSN 2706-6703 Journal of University of Anbar for Pure Science (JUAPS) Open Access
2020,14 (2):51-54

Wear Rate Behavior of Unsaturated Polyester Reinforced with (Glass and Rock Wool Fiber) under the Influence of Chemical Solutions

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ARTICLE INFO

Received: 21 / 5 /2020
Accepted: 8 / 7 / 2020
Available online: 1 / 12/ 2020

DOI: 10.37652/juaps.2022.172387

Keywords:
unsaturated polyester, wear rate. glass fiber, rock wool fibers. chemical solutions.

ABSTRACT

In this research, the adhesive wear of a composite material consisting of unsaturated polyester has been studied as a matrix material reinforced by glass fiber and rock wool fibers. The wear rate property is compared in the normal condition and after immersion in (NaOH) and (HCl) solutions at normality (0.3N) and the laboratory temperature (25 ºC) for 30 (days) and with a fixed volume fraction of (20%). The results showed that the wear rate decreased with increasing number of reinforcement layers before and after immersion and for all samples. However, it is noted that immersion in chemical solutions leads to an increase in wear rate compared that of the normal condition and for all samples.

1. INTRODUCTION

As a result of scientific research, the need arose for polymeric materials with specific specifications that cannot be obtained from one type of materials but from mixing multiple materials. For this reason, attempts appeared to mix two or more types of materials to obtain a polymeric mixture for the desired industrial applications [1]. Composites materials are defined as "a building consisting of two or more materials with different specifications that are bound together in a specific way to give the desired composition [2]. That this merging process leads to obtaining a new material with engineering and physical properties that differ from the properties of the materials included in its composition. And thus combining the good properties of the various materials included in its composition, in addition, to rid of the defects in it to be more suitable for industrial applications.

Composite material consists of two phases: the first phase (matrix material), and the second is the (reinforcement materials). Those two phases are bound together by a binding surface called the interface region [3]. Recently, interest has appeared in the study of the phenomenon of wear, which clearly shows its role in the operations of multiple mechanical systems[4].

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1.1. Theoretical Part

The wear is a very important phenomenon due to its negative impact on the accuracy of the performance of the polymeric parts in machines. Wear is defined as "the process of losing material in one or both surfaces when they are under the influence of a relative movement. It is also known as "the stripping process of the surface of a solid material due to its effect on the surface of another solid object". And the wear is divided into the following types, **corrosive wear, adhesive wear, abrasive wear, erosion wear, fatigue wear** [5].

The study examined the adhesion wear where it occurs in the case of sliding surfaces on one another, under the influence of, (time 5 min, radius or rotation 5 cm, no of the turns 600 r/min, normal load 20 Nt, And type of disk iron).

There are several ways to measure the rate of wear, and one of these methods (Weight method) as showing in figure (1), that is used in this research. It is one of the easiest methods used to measure the wear rate, and this method includes the weight of the sample before and after testing. Then by calculating the difference in weight and wear rate as shown in the following equation [6]:

$$\text{Wear rate} = \frac{\Delta w}{sd} \text{ (gm/cm)} \quad \ldots\ldots \ldots. (1\text{-}1)$$

where, $\mathbf{\Delta W} = W_2 - W_1$, $\mathbf{Sd} = 2\pi r\, N\, t$, Sd= Sliding distance (m), **t**= sliding time (min), and **N** = no of disc rotations.

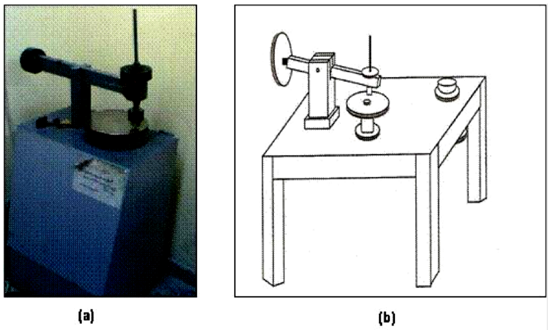


Fig :1: Method of measuring the wear rate, (a) Wear device, (b)Schematic diagram of the wear device

2. EXPERIMENTAL PART
2.1. Used Materials
2.1.1 Matrix Material

The matrix material used in this study is unsaturated polyester resin (Siropol-8341) produced by the Saudi (SIR) Company for Resins. This resin turned into a solid-state by adding its hardener (Ethyl peroxide methyl ketone) at a rate of (2g) for each (100g) of polyester to interact at room temperature. The properties of unsaturated polyester resin in this study are shown in table (1) according to the product company.

Table 1: The properties of unsaturated polyester resin [6]

Properties	Quantity
Density	1.2 – 1.5 (g /cm^3)
Young's Modulus	2000 – 4500 (Mpa)
Tensile Strength	40 – 90 (Mpa)
Poisson's Ratio	0.37 – 0.39
Heat distortion temperature	50 – 110 (°C)
Thermal conductivity	0.2 ($Wm^{-1} K^{-1}$)
Coefficient of thermal expansion	100 – 200 ($10^{-6} K^{-1}$)

2.1.2. Reinforcement Materials

Glass fiber: The glass fibers were used to support the unsaturated polyester resin type (E-glass) Woven Roving. This type of fiber is considered the most common for the in industrial uses because of its good durability, toughness, ease of production.

Rock wool fiber: Rock wool fibers are made from basalt rocks in a form of long fibers or intermittent fibers, and have a density of (0.7 g /cm^3). Rock wool fibers are a thermally insulating material due to its high thermal resistance and high chemical resistance. Table (2) shows the chemical composition of rock wool used in this study.

Table 2: Rock wool components [7]

SiO_2	CaO	Al2O$_3$	MgO	Fe_2O_3	Na_2O	K_2O+ Mn_2O + TiO_2
47-51%	16-24%	11-15%	12-16%	3-15%	1-2%	Trace

2.1.3. Immersion Solutions

The immersion solutions which were used in this study are NaOH and HCL solutions with a normality (0.3N). These solutions have been prepared in the laboratories of Anbar University (college of science). All specimens were immersed in NaOH and HCL solutions for 30 days.

2.2. Specimens Preparation

The method (Hand lay-up molding) is used in preparing of the samples because it is one of the easy, successful and common methods. Unsaturated polyester resin is prepared by adding a hardener to ratio (2g hardenes:100 g UPE) and well mix it by the electric mixer for a homogeneous mixture. Glass fiber and rock wool fibers were cut in (20 cm x 20 cm) dimensions, and added to unsaturated polyester with a volumetric fraction of (20%). The molding process carried out using two glass panels with dimensions of (30 cm x 30 cm x 0.6 cm), where one represents the base on which the casting was made and the other represents the cover, and left for (72) hours at room temperature (25 ºC) for solidification. Specimens were then extracted from the molding and heat-treated in the oven at (50 ºC) for (6) hours for (Curing). The composites were cut into samples according to the international standard specifications, as shown in table (3). And then after the process of smoothing and polishing the samples through using the silicon carbide sheets with different degrees of smoothness. Table (3) shows the standard dimension2s of the wear test, and figure (2) shows a photographic image of the wear samples.

Table 3: Shows the standard dimensions of the wear test.

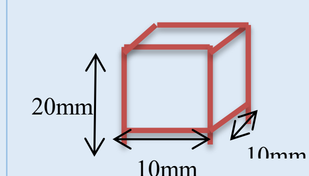
Standard Specifications	Sample's dimensions	Test
ASTM		wear

Fig. 2: Wear test samples

3. RESULTS AND DISCUSSION
3.1. Wear Rate Test Results in Natural Conditions

The wear rate test for samples is measured in normal conditions and after immersion in (NaOH) and (HCl) solutions at laboratory temperature (25 ºC), the experimental results are shown in table (4). From table (4) we noticed that the wear rate values decrease with the reinforcement layers of the glass fiber and rock wool fibers as shown in fig (3), this behavior agrees with results [7].

Table 4: Wear rate results in natural conditions and after immersion in (NaOH) and (HCL) solutions.

Sample No.	Sample composition	Wear rate $*10^{-8}$ (gm/cm)		
		N.C	Immersion Time (30 days)	
			NaOH	HCL
1	UPE+1Layer G.F+1Layer R.W	5.2	5.7	5.8
2	UPE+2Layer G.F+1Layer R.W	3.9	4.5	4.7
3	UPE+3Layer G.F+2Layer R.W	2.4	3.0	3.1
4	UPE+4Layer G.F+3Layer R.W	1.5	2.0	2.12

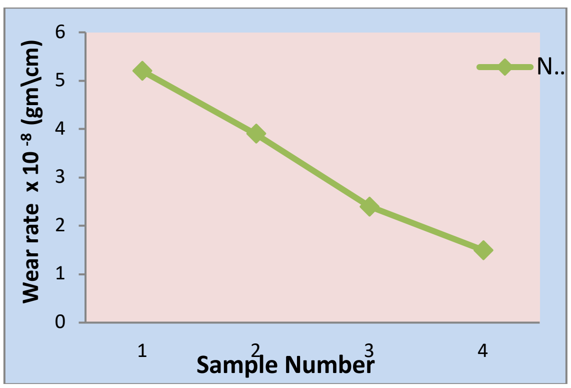


Fig :3: Wear rate values with sample numbers under normal conditions.

From table (4) and figure (3), we noticed that the wear rate decreases with increasing reinforcement with glass fibers and rock wool fibers and for all samples, due to the good properties of these fibers. As the fibers worked to reinforce (tangle) the resin, which led to filling gaps and voids and strengthening the composites, thus impeding the progress of cracks and gaps. Also, the process of friction of the sample surface with the surface of the iron disc generates heat and this temperature leads to the coherence of polymeric composites, and this leads to a decrease in the wear rate [7,8].

3.2. Wear Rate Test Results After Immersion in (NaOH) and (HCl) Solutions

The experimental results of the wear rate test after immersion in (NaOH) and (HCl) solutions with normality (0.3N) for (30) days at laboratory temperature are shown in table (4). From table (4) it is noted that the wear rate values increase after immersion in chemical solutions compared to the normal case as shown in fig (4).

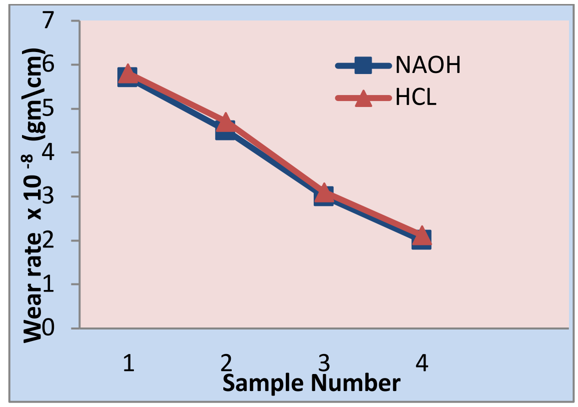


Fig:4: Variation wear rate with sample number after immersion in NaOH and HCl.

Figure (4) shows that the wear rate increase after immersion in (NaOH) and (HCl) solution due to several factors including: (NaOH) and (HCl) solutions attempt to penetrate the interface through the bumps, gaps, and voids formed during the molding process. Which leads to the slide of polymeric chains and separation from each other, which leads to the disintegration of the composite material and thus increase the wear rate [9]. In addition the entry of (NaOH) and (HCl) solutions into the composite material lead to the separation of the matrix material from the reinforcing material (fibers), which leads to the dissolution of the fibers and thus an increase in wear rate. Also, other factors that increased the wear rate are that the (NaOH) and (HCl) solutions leads to the destruction of (Vandervals forces) between the polymeric chains, which leads to a reduction in the energy barrier and thus the movement of the parts of the polymeric chains, which leads to an increase in the plasticity of the material and thus an increase in wear rate[9]. The experimental results, as shown in figure (4), showed that the wear rate in the (NaOH) solution is lesser than in the (HCl) solution and within the same time. And this means that the effectiveness of the (HCl) solution is used in the research and under the wear test is more than the effectiveness of the (NaOH) solution.

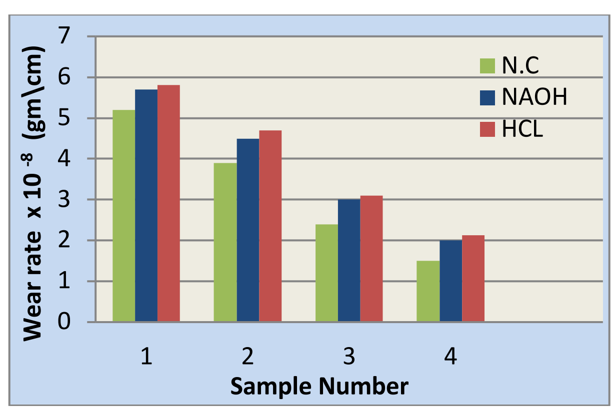


Fig:5: Comparison of the wear rate values with sample number in natural condition and immersion in the (HCL) and (NaOH) solution.

4.CONCLUSIONS

The wear rate decreases with increasing the number of layers of reinforcement with glass fiber and rock wool fibers, the immersion in the (HCL) and (NaOH) solutions lead to an increase in wear rate compared to the normal condition. And we noticed that the wear rate in the HCl solution is higher when immersed in the NaOH solution.

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سلوك معدل البلى لراتنج البولي استر غير المشبع المقواه بالألياف الزجاجيه والياف الصوف الصخري تحت تأثير المحاليل الكيميائية

مصطفى حمدي إسماعيل و فائق حماد عنتر
قسم الفيزياء / كلية العلوم / جامعة الانبار / العراق

الخلاصة

في هذا البحث تم دراسة البلى الالتصاقي لماده متراكبه تتكون من البولي استر غير المشبع كماده أساس مدعمه بالألياف الزجاجية وألياف الصوف الصخري، حيث تم مقارنة معدل البلى في الظروف الطبيعية وبعد الغمر في محلول (NaOH) و (HCl) بعياريه (0.3N) وبدرجة حرارة المختبر ولمدة (30 يوما) وبكسر حجمي ثابت (20%). اظهرت النتائج ان معدل البلى يقل مع زيادة طبقات التدعيم قبل وبعد الغمر ولجميع العينات، في حين لوحظ ان الغمر في المحاليل الكيميائية يؤدي الى زيادة في معدل البلى ولجميع العينات.

الكلمات المفتاحية: بولي استر غير مشبع, معدل البلى, الالياف زجاجيه, الياف الصوف الصخري, المحاليل الكيميائية.