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Study of The Wear Rate of Some Polymer Materials In Different Conditions

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Abstract

The current investigation is interested by study of the wear phenomenon for two polymeric materials (Epoxy and Unsaturated polyester) resins, the prepared specimens were tested at room temperature by using two different loads(10,20)N for various testing times with different sliding distances. The resulted wear rates were calculated for each sample apart with.

Variation the previous variables. To produce more precise idea about the wear characteristics of both above materials when immersed them in water environment, the study of wear rates was carried out for different immersion times at different temperatures when the above mentioned variables were fixed. It was found after comparing the results which obtained from the wear test in air that Epoxy resin undergoes higher wear rates than unsaturated polyester resin in general with variation the testing parameters, while the results of immersion in water which acts as plasticizing factor for polymers exhibited different effect on the wear behavior of the materials under study.

Keywords: wear rate, resin, Epoxy, Unsaturated polyester, immersion

دراسة معدل البلى لبعض المواد البوليمرية في ظروف مختلفة

الخلاصة

يهتم بحثنا الحالي بدراسة آلية حدوث ظاهرة البلى لمادتين بوليمريتين وهما راتنجي الايبوكسي والبولي استرغيرالمشبع , وبعد تحضير النماذج وفحصها عند درجة حرارة الغرفة باستخدام حملين مختلفين (20,10) N وعند ازمان اختبارمختلفة ولمسافات انزلاق مختلفة , تم حساب معدلات البلى (Wear rate) الحاصلة لكل نموذج على حدة مع أختلاف المتغيرات السابقة . ولاعطاء صورة ادق عن خصائص البلى للمادتين اعلاه عند غمرهما في بيئة مائية, اجريت دراسة معدلات البلى عند ازمان غمر مختلفة وبدرجات حرارية مختلفة مع تثبيت المتغيرات المذكورة اعلاه .وقد وجد بعد مقارنة النتائج المستحصلة من اختبارالبلى في الهواء بان راتنج الايبوكسي يعاني من معدلات بلى اعلى من راتنج البولي استرغيرالمشبع بشكل عام مع تغيرمحددات الفحص. في حين اظهرت نتائج الغمربالماء الذي يمثل عامل ملدن (plasticizing factor) للبوليمرات تأثيرا متباينا" على سلوك البلى للمادتين قيد البحث.

Introduction

Wear is” the removal of material from or the impairment of The solid surface resulting from friction or impact. Wear is an important phenomenon that occurs in all polymer applications in one form or the other. However, important link between materials properties and wear remain illusive [1]. Three basic mechanisms of wear in polymers: (1) Adhesive wear, (2) abrasive wear, (3) fatigue wear. Each of

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these mechanisms can reasonably be expected to be dependent on the conditions of sliding, that is, load, speed, and time [2]. Abrasive wear is the most common mechanism of materials loss by wear. Generally two modes of abrasion are operative: two- and three-body abrasion. In two-body abrasion, abrasive particles are attached to a surface which brings them in to contact with the wearing surface and, in three –body abrasion, abrasive particles are loose. Real- life abrasion involves lose abrasives more often than stationary particles, as in the mining industry, agricultural applications; etc [3].Several authors studied the wear debris generation mechanism for polymers by nanoscratching tests. The scratch damage surface was analyzed using an atomic force microscope and a scanning electron microscope to investigate the material removal phenomenon for the selected material. They noted that the hardness of the polymer has a counter effect on wear as higher hardness tends to reduce the toughness property in polymers which leads to microcracking and further wear debris generation [4]. Pihtili studied the effects of resin content on the wear of woven roving glass fiber–epoxy resin and glass fiber–polyester composite materials. These composites were tested under different conditions. Glass fiber-epoxy resin composites generally showed higher and minimum wear when compared with glass fiber-polyester resin composites [5]. Another authors studied the effect of time variation on the wear sliding behavior of composites (polyester /E-glass fibers). They prepared these composite materials by using different number of fiber layers (3, 6, 9, and 12). All experiments were conducted under dry conditions. The results showed that the wear volume increases for all examined composites, as the statically load increases [6]. The aim of this work is study the wear rates of the Epoxy and Unsaturated polyester resins before and after the immersion into the tap water at various times and temperatures.

Experimental part

1- **preparation of samples:**
Epoxy (EP) supplied by Don Construction Prodcts (DCP), commercially known as Quickmast 105 and unsaturated polyester (UPE) supplied by (SIR) company, Saudi Arabia were used in this work. The addition ratio of hardener to the (EP) resin is (1:3) while to the (UPE) resin is (2%) with addition an accelerator material with ratio (0.5%) to the resin. After the mixing process for each resin apart, these mixtures were cast in a metal mould with dimensions (12, 10, and 3) cm^3 at room temperature. After solidification, the casting sheets were released from the mould and placed in an oven with (Temp= 50°C) for (1 hour) to post-cure the castings. The specimens were cut from these sheets according to the specification (ASTM-D695) [7].

2- **Wear test technique :**
(Pin - on – Disc) test apparatus which produced by local company named(Al furat al awsat company)was used to measure the wear rates of the previous prepared samples, the used disc in this work is made from steel material with hardness (55HRC). The wear tests were performed in air at room

temperature ~ (25°C) with different variables included:-

- The applied loads: (10, 20) N, respectively.
- The distance from the centre of sample to the centre of disc :(3,5,7)cm , and
- The testing time (t): (2, 4, 6, 8, 10) min.

The wear test were repeated after immersion of the specimens into the tap water at different temperatures (25, 40, 50) °C ±5 °C for (1, 2, 3) hour respectively. In this case, it is worth mentioning to show that the previous variables were fixed at load (20N) and distance (7 cm) for (10) min.

The wear rates are calculated according to the following equation [7]:-

$$\text{Wear rate (W.R)} = \Delta W/S_D \quad ....(1)$$

Where:

ΔW: is the weight loss of the specimen before and after the wear test (gm), $\Delta W=W_1-W_2$.

S_D: is the sliding distance (cm). [7].

$$S_D = 2\,\pi Nrt \quad .....(2)$$

Where (t): is the sliding time (min).

The sliding velocity is evaluated from the relationship:- [7].

$$Vs= (\pi DN)/60 \quad ..... (3)$$

Where:

D: is the circular sliding diameter (cm).

N: is the no. of revolutions of the rotating disc (rev. /min).

It is necessary to mention the following:

- The surface of all specimens under study were cleaned and grinded to become smoother (without scratches) before the test.
- Sensitive electronic balance (type- AE160, Metler, 4 digits) was used to measure the weights of samples before and after the wear test.

Results and discussion

The relations of wear rate (W.R) versus sliding velocity data for (EP and UPE) resin at load (10, 20) N are shown in Figs. (1, 2, 3, 4) respectively. Generally, the wear rate increases with increase of the applied load for each resin apart. When the applied load equal (10N), it is found that the wear rate increases with the increase of the linear velocity of sliding (Vs) in the range (1.57-2.62)m/s but after that, it decreases with increasing (Vs) to about (3.66) m/s .This relation is more clear for (UPE) than (EP) resin as shown in Figs.(1,2), while at higher load (20N), it is observed that the wear rate increases as (Vs) is increased for both above materials as shown in Figs.(3,4). This result is corresponding with the study [8] which was indicated that when the material is in the elastic deformation range, the bond breakage and subsequent crack propagation does not occur and thus the wear loss is negligible (zero wear). When the material enters into plastic deformation region either due to the increased normal load or due to the rising sliding velocity, then cracks grow via atomic bond rupture and therefore wear loss become significant.From Fig. (1), it can be noticed that the wear behavior is different at the times (2,10)min comparing with other times

(4,6,8)min, this variation in the behavior may be related to nature of crack propagation within the material as mentioned above.

From previous studies [3], the specific wear rate is given by the equation:

$$Ws = C_1 \frac{V_C}{V_S} \frac{m}{EHe_f} \qquad \text{……. (4)}$$

Where V_S is the sliding velocity, V_C is the crack propagation velocity , E is the elastic modulus , H is the hardness ,e_f is the failure strain , and C_1 is a parametric constant incorporating the effect of roughness , debris geometry , adhesion coefficient and material /system constants , m is a numerical factor equal to the friction coefficient . According to the above wear equation (4), the contact temperature rises and a thermal activation of (V_C) takes place. Hence W_S rises with the increase of (V_S) at high velocity region, since V_C rises when thermal heating effect becomes large [3, 8, and 9]. Tables. (1) And (2) indicate to the relation between the values of the wear rate (W.R) with the immersion times of specimens into the water. It is observed at the low temperature range (25-40)^{o}C±5^{o}C, the (W.R) increases with increasing of immersion time , the reason behind that is the possibility of permeating of the water molecules into these materials[10,11], which may leads to a reduction in the mechanical properties and then (W.R) will be increased. But at higher temperature (~50)^{o}C±5^{o}C, it can be noted that the (W.R) decreases with increasing of immersion time, this phenomenon may be related to the increasing of cross-linking of the polymer molecular chains which causes an increasing of wear strength of resins under study and then the (W.R) will be decreased [3,9,12].

Conclusions

The following points can be concluded from the present study:

1- It can be noticed that the (EP) resin has higher wear rates in air compared with the (UPE) resin, but after immersion them in water, the (EP) resin has resistance to the wear phenomena more than the (UPE) resin.

2- The wear rates increases for both materials with increase of the applied load, at higher applied load, the wear rates of the two materials under study increase when the sliding velocity is increased.

3- It is clear that the order of magnitude of experimental wear rates is about in the range (10^{-9}) gm/cm.

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Table (1) Effect of water immersion on the wear rates of (EP) resin at different temperatures.

Time of immersion (hour)	Wear rate *10^{-9} (gm/cm)		
	Room Temp.	$40^oC\pm 5^oC$	$50^oC\pm 5^oC$
1	9	15	90
2	27	41	67
3	30	49	20

Table (2) Effect of water immersion on the wear rates of (UPE) resin at different temperatures.

Time of immersion (hour)	Wear rate $*10^{-9}$ (gm/cm)		
	Room Temp.	40°C± 5°C	50°C± 5°C
1	19	71	40
2	92	70	28
3	102	89.6	27.5

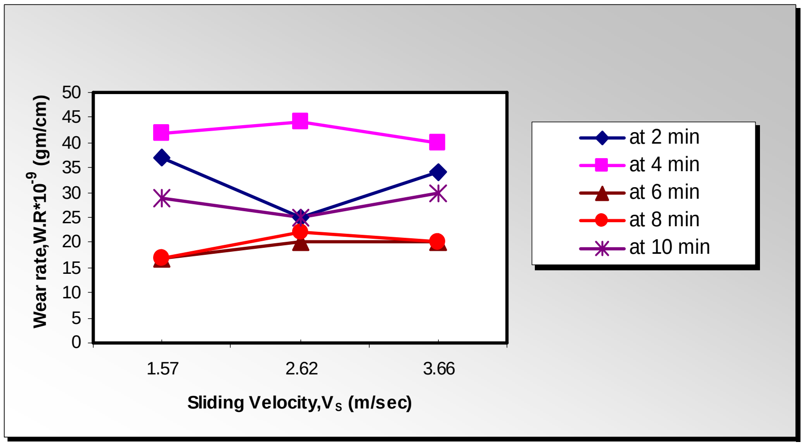

Figure (1) Wear rate versus sliding velocity data for (EP) resin under (10N) load in air.

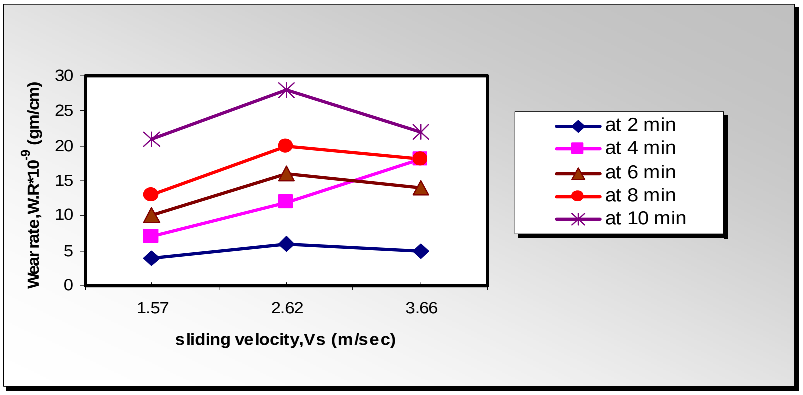

Figure (2): Wear rate versus sliding velocity data for (UPE) resin under (10N) load in air

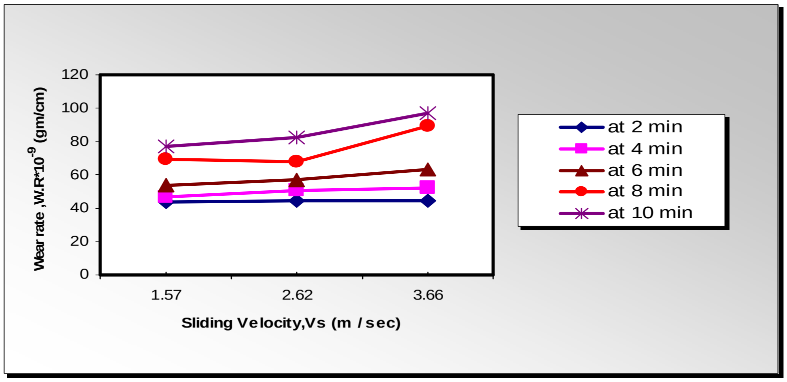

Figure (3) Wear rate versus sliding velocity data for (EP) resin under (20N) load in air.

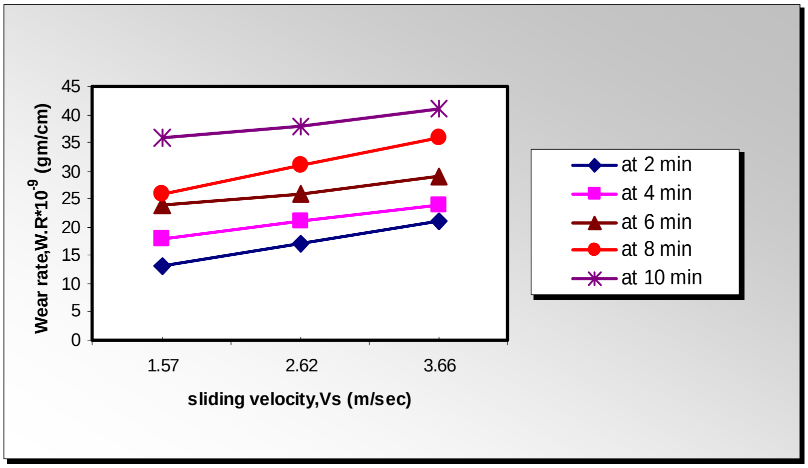

Figure (4) Wear rate versus sliding velocity data for (UPE) resin under (20N) Load in air.