Studying of Wear Rate for Ternary Polymer Blends under the Influence of Chemical Solutions

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ABSTRACT
This work has been done with use of Epoxy and Novolac resins mixed with either polyurethane (PUR) or polysulphide(PSR) rubbers to compose ternary polymer blends. Two groups of samples are prepared:
1. Blend A (70% Epoxy +15%Novolac+15%PUR).
2. Blend B (60% Epoxy +20% Novolac +20% PSR).
These blends were tested by wear instrument, This test is carried out on samples under the influence of normal conditions (room temperature) and after immersion of blend samples in chemical solutions (H_2O, H_2SO_4 and KOH) for (15, 30 and 45) days. The normality for these chemical solutions is (0.2N). After immersion the blend samples in chemical solution, their wear resistance decreased. The properties of blend that contains polyurthane rubber were affected more. The test results are affected by all the chemical solutions, but the alkaline solution KOH is the most effective solution. For wear test, results show that wear rate increases with increasing applied load, and increases or decreases with sliding velocity (depending on if it is high or low respectively).

Keyword: polymer blends, wear rate, diffusion, Epoxy, polysulfide, polyurethane.

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دراسة معدل البلى لخلائط بوليمرية ثلاثية تحت تأثير المحاليل الكيميائية

الخلاصة
اجري هذا البحث باستخدام راتنجي الايبوكسي و النوفولاك واللذين مزجا مع مطاط البولي يورثان مرة ومطاط البولي سلفايد مرة اخرى لتكوين خليط بوليمري ثلاثي. تم تحضيرمجموعتين من النماذج:
1. الخليط البوليمري A (الايبوكسي70%+النوفولاك15%+مطاط البولي يورثان15%).
2. الخليط البوليمري B (الايبوكسي60%+النوفولاك20%+مطاط البولي سلفايد20%).
تم اختبار نماذج من هذه الخلائط على جهاز البلى واجريت هذه الاختبارات على النماذج تحت تأثير الظروف الطبيعية(درجة حرارة الغرفة) وبعد غمر النماذج في المحاليل الكيميائية (KOH,H_2SO_4,H_2O)

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و لمدة (45,30,15 يوم) .العيارية المستخدمة للمحاليل الكيميائية مساوية الى (0.2N). بعد غمر نماذج الخلائط في المحاليل الكيميائية , لوحظ نقصان مقاومة البلى .خصائص البلى للخليط البوليمري الذي يحتوي على مطاط البولي يوريثان كانت الاكثر تأثراً.تأثرت نتائج الاختبارات بالمحاليل الكيميائية كلها, لكن المحلول القاعدي KOH كان له التأثير الاكبر من بينها. اظهرت نتائج اختبار البلى زيادة معدل البلى مع زيادة الحمل المسلط, كما ان معدل البلى ازداد او قل مع زيادة او نقصان السرعة الانزلاقية.

INTRODUCTION

The subject of polymer blends has been one of the primary areas in polymer science and technology over the past several decades[1]. Polymer blends offer versatile industrial applications through property enhancement and economic benefits [2]. Polymer blends are defined as any combination of two or more polymers resulting from common processing step [3]. These blends are used to improve some thermal, physical and mainly mechanical properties of polymer [4]. The use of polymer blends and alloys has grown so fast compared with other polymeric materials system mainly because of their low cost and their acceptable performance [5]. In general, blends are made by mixing of homo polymers or copolymers which have different chemical structures. The blends may be named as binary, ternary, quaternary depending on the number of polymeric components, which comprise them [6]. Polymer can be blended with other polymers or with some other materials. The physical properties of the resulting blends depend directly on several factors, namely the properties and the percentages of the original components, degree of compatibility and dispersion, the nature of interaction between the mixed materials and on the industrial processes that are utilized to produce those polymers[7]. Rubber modified thermosets are prepared from a homogeneous solution of an elastomer in a thermosetting resin, which in the course of polymerization precipitates a discrete, randomly dispersed rubbery phase. The presence of the second phase introduces a toughening effect, increasing the energy required to maintain a given crack-growth rate [8]. In recent years, polymer is extensively utilized in sliding component such as gears and cams because of their self-lubrication properties, lower friction coefficient, and higher wear resistance [9]. Wear is a progressive loss of material from surface as a result of sliding or rolling contact between surfaces or from the movement of fluids containing particles over surface [10].

EXPERIMENTAL PART

In this work, mechanical mixing was used to prepare ternary polymer blends from (EP, Novolac) resins with two types of rubbers (PUR, PSR).
Two kinds of samples are prepared; the optimum mixing ratios (OMR) were selected based on best adhesion between the phases and highest impact strength for each blend. These samples are:
Blends A (EP/NOV/PUR) &B (EP/NOV/PSR)(Table.1): In these samples, the ternary blend is obtained by adding (Epoxy polymer) which is still in a liquid state to (Novolac) which is in a liquid state and mixed well by using mechanical mixer to form a binary blend then polymer-rubber- (Polyurethane or Polysulphide) liquid is added to the binary blend to form a ternary blend. Casting sheet was left inside the mould at room

temperature about (72h) for both blends. After solidification, the casting sheets were released from the mould and placed in an oven at (50°C setting temperature) for (3h) to post cure the considered sheets. The wear testing samples were obtained by cutting the cast sheets according to the relevant ASTM standard (G-99) (L: 2L).

Table (1) Number and Ratios of Mixture of the Prepared Samples.

Sample No.	Concentration %			
	EP	Novolac	PUR	PSR
A	70	15	15	0
B	60	20	0	20

Three types of chemical solution are used in this work (Acid: H_2SO_4, Base: KOH, Water: H_2O). The normality for acid and base is equal to (0.2 N).The samples are being immersed completely in these chemical solutions for (15, 30 and 45 days). All properties were measured at room temperature (25-30) °C.

MEASUREMENTS
Wear test: A pin-on-disk test setup was used for slide wear experiments. The pin assembly was initially weighed using a digital electronic balance (0.1mg accuracy). The test was carried out by applying normal loads and run for a different sliding distance at different sliding velocities. At the end of the test, the pin assembly was again weighed in the same balance. The difference between the initial and final weight was a measure of slide wear loss. A minimum of three trials was conducted to ensure test data repeatability. Test was carried out by applying normal loads and run for a different sliding distance at different sliding velocities. The weight method was used to calculate the wear rate by using the following equations[11]:

$$W_R = \frac{\Delta W}{S_D} \qquad \dots (1)$$

$$\Delta W = W_1 - W_2 \qquad \dots (2)$$

$$S_D = 2\pi r n t \qquad \dots (3)$$

Where, W_R is wear rate in (gm/cm), W_1, W_2 are the weight of specimens before and after wear test in (gm), S_D is sliding distance in (cm), r is disc radius in (cm), n is number of disc cycle (500 rpm),and t is time of test in (10 min).
Sliding velocity can be calculated from the following [11]:

$$V = \frac{\pi N D}{60} \qquad \dots (4)$$

Where V is sliding velocity in (m/sec), D is sliding diameter in (m), and N is disc's velocity (rpm).

RESULTS AND DISCUSSION

The wear rate of blends was studied after immersion in different chemical solutions (H_2O, H_2SO_4 (0.2N) and KOH (0.2N)) under varying conditions of load and sliding velocity. The blends were soaked in these chemical solutions for different periods (15, 30 and 45 days) at room temperature.

Effect of Applied Load: The effect of applied load on the wear rate was studied after immersion in chemical solutions for both blends. Experimental data on the slide wear rate of blends samples are shown in Figures (1, 6) for different loads (5, 10 and 15N) with different sliding distance (SD_1=3141.59 cm). The results reveal that the wear rate increases with increasing applied load irrespective of the sliding distance. By comparing these results with the results of effect of load on wear rates before immersion in chemical solutions, we notice a higher increase in wear rate after immersion in all solutions, but the rate of increase is different for the two blends. Chemical solutions primarily influence wear via their effect on the transfer film formation. Water and aqueous solutions inhibit the formation of transfer films on metal counterface. In contrast, the effect of the plasticization of polymers may be caused by absorption of chemical solution. The mechanical strength of polymers may be reduced by the plasticization of polymer surface because of the permeation of chemical solutions [12]. Then the fracture toughness will decrease, and since the fracture toughness is proportional inversely with wear rate, then there is an increase in wear rates as noticed [13]. The chemical solutions cause degradation in the surface of material, and this will increase the roughness of the surface of pin which increases the wear rate. The rate of increase in wear rate for blend (B) is lower than for blend (A), and this is due to that blend (B) contains polysulphide rubber which has good resistance for chemical solutions than polyurethane rubber in blend (A).

Effect of Sliding Velocity: The effect of sliding velocity on the wear rate was studied after immersion of both blends in chemical solutions.

Experimental data on the slide wear rate of blend samples are shown in Figures (7, 12) for different sliding velocities (5.235, 3.926 and 2.617 m/sec) with load (5N).

The results reveal that the wear rate decreases with increasing sliding velocity at the beginning of the wear test, then increases with continuation of the test. By comparing these results with the results of effect of sliding velocity on wear rate before immersion in chemical solutions, we can notice a higher increase in wear rate after immersion in all solutions, but the rate of variation in wear rate is different for the two blends. The extent of the swelling of a blend in a chemical solution depends on the structure of the polymer phases and can be related to the properties of the polymer chains, such as molecular mobility and phase interaction [2].Sliding velocity is particularly important because of its major role in both the viscoelastic response to stress and the generation of frictional heat. As our blends contain an elastomer in its structure, the sliding velocity is most significant through viscoelastic effects on friction and strain-rate effects on mechanical strength. Polymers absorb chemical solution into the surface layers, which changes the mechanical properties and so, in turn, influences friction and wear [14]. In general, the rate of increase in wear rate for blend (B) is lower than for blend (A), and this is due to the same reason mentioned before.

CONCLUSIONS

1. The wear rate increases with increasing applied load.
2. The wear rate of blend samples is higher after immersion in chemical solutions than in normal condition.
3. There are two behaviors for values of wear rate vs. variation in sliding velocity for cases (in normal condition and after immersion in chemical solutions), one, the wear rate increases with increasing sliding velocity and other decreases with increasing sliding velocity.
4. Generally, the rate of increase in wear rate for blend (A) is lower than for blend (B), after immersion in chemical solutions.

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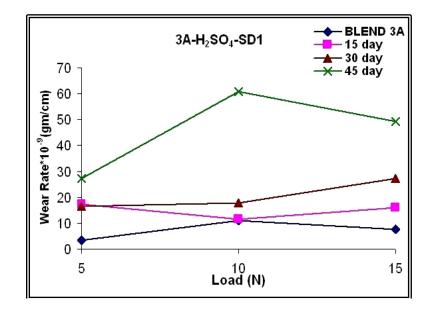[14].Dickens, P. M., and Sullivan, J. L., "J. Wear", Vol. 112, No. 3, 4, pp. 273-289, 1986.

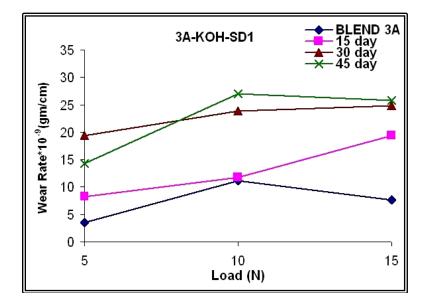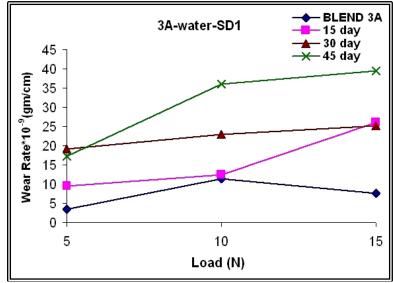**Figure (1) Wear Rate vs. Load for Blend (A) after Immersion in H₂SO₄.**

**Figure (2) Wear Rate vs. Load for Blend (A) after
Immersion in KOH.**

**Figure(3) Wear Rate vs. Load for Blend (A) after
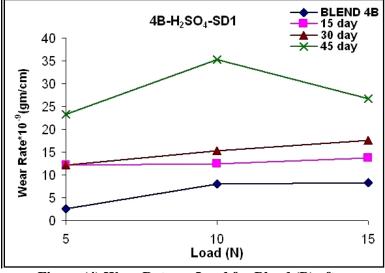Immersion in H_2O.**

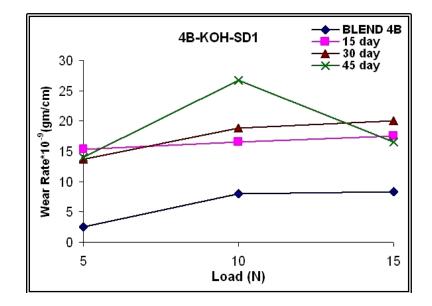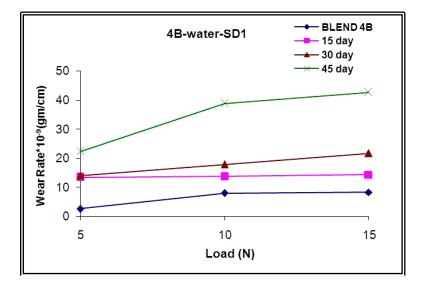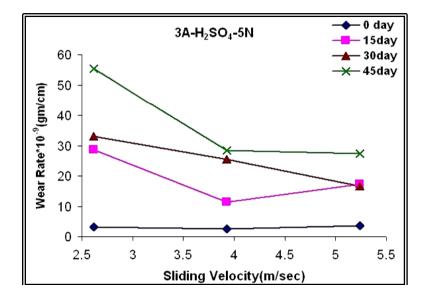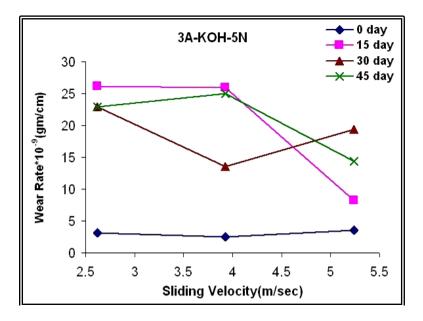**Figure (4) Wear Rate vs. Load for Blend (B) after
Immersion in H_2SO_4.**

Figure (5) Wear Rate vs. Load for Blend (B) after Immersion in KOH.

Figure (6) Wear Rate vs. Load for Blend (B) after Immersion in H_2O.

Figure (7) Wear Rate vs. Sliding Velocity for Blend (A) after Immersion in H_2SO_4.

Figure (8) Wear Rate vs. Sliding Velocity for Blend
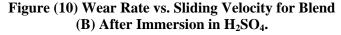
(A) after Immersion in KOH.

Figure (9) Wear Rate vs. Sliding Velocity for Blend
(A) after Immersion in H₂O.

Figure (10) Wear Rate vs. Sliding Velocity for Blend (B) After Immersion in H$_2$SO$_4$.
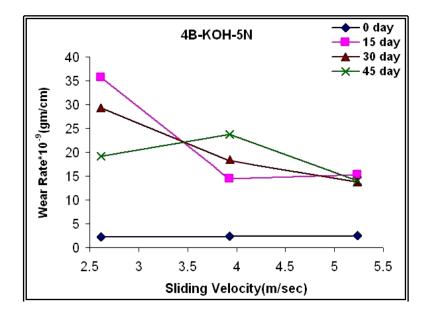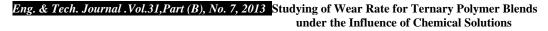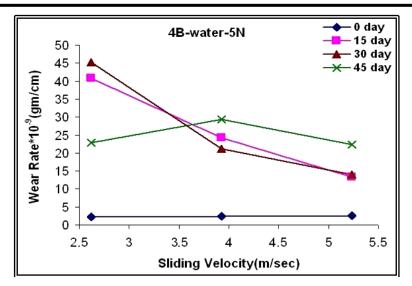

Figure (11) Wear Rate vs. Sliding Velocity for Blend (B) after Immersion in KOH.

Figure (12) Wear Rate vs. Sliding Velocity for Blend (B) After Immersion in H$_2$O.