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Study Tensile Strength and Wear Rate for Unsaturated Polyester Resin and Nitrile butadiene Rubber Polymer Blend

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Abstract

Binary polymer blend was prepared by mechanical mixing method of unsaturated polyester resin with Nitrile Butadiene Rubber (NBR) with different weight ratios (0, 5, 10 and 15) % of (NBR). Tensile characteristics and wear rates of these blends were studied for all mixing ratios. The microstructure of fracture surfaces of the prepared samples were investigated by optical microscope. The results were showed that strain rates of the resin material increase after blending it with rubber while the ultimate tensile strength and Young's modulus values of it will decrease. It is also noticed that the wear rate of resin decreases with increasing of (NBR) content.

Keywords: *Polymer Blend, Tensile Strength, Wear Rate, Unsaturated Polyester, NBR.*

1. Introduction

Development of new resin systems to meet demands for high performance materials would undoubtedly take too long and would certainly be too expensive since it would require huge investments in totally unexplored technologies and new plant facilities. An alternative to the development of new polymers is the development of alloys and blends that are a physical combination of two or more polymers to form a new material [1].

Two or more existing polymers may be blended for various reasons. One reason is to achieve a material that has a combination of the properties of the constituents, e.g. a blend of two polymers, one of which is chemically resistant and the other tough. Another reason is to save costs by blending a high-performance polymer with a cheaper material. A very important use of blending is the combination of an elastomer with a rigid polymer in order to reduce the brittleness of the rigid polymer [2, 3].

Abi Santhosh Aprem *et al.* investigated the influence of hygrothermally -degraded polyester urethane HD-PUR on cure characteristics, mechanical, dynamic-mechanical and morphological characteristics of chloroprene rubber (CR). The presence of primary and secondary amines in HD-PUR, did not increase the cure rate of CR. The mechanical properties of chloroprene vulcanizates were improved upon HD-PUR addition. The strain-induced crystallization of CR did not show any deviation upon the addition of HD-PUR. Crosslink densities calculated from swelling studies, stress–strain behavior and modulus measurements are found to increase upon HD- PUR addition and showed similar trend. Scanning electron microscopic studies have been done in order to have an insight into fracture behavior of the samples and to analyze the microstructure of the blends [4].

Soares *et al.* studied the influence of dynamic vulcanization and blend composition on the free volume properties of polypropylene (PP)/ nitrile butadiene rubber (NBR) blends by using a novel technique based on positron annihilation lifetime spectroscopy (PALS). The results indicate that the PP/NBR blends are so incompatible that the dynamic vulcanization was not enough to improve the mechanical properties. However, there are morphological differences at the molecular level with the vulcanization, which can be easily detected by the PALS technique [5].

Antaryami Mishra prepared a composite from epoxy with weight percentages of 10, 15, and 20 % of rubber dust (weight fractions of 9, 13 and 17 % respectively). The pins were tested in a pin-on-disc wear monitor to determine the co-efficient of friction and weight losses with varying speeds, loads and time. The wear volume and wear rates have also been found out for all these three specimens. It is observed that all the specimens have exhibited very low coefficient of friction and low wear rates under dry sliding condition. Out of the above three samples tested, the specimen with 10 % rubber dust by weight has shown lowest wear rates. However a peculiar result i.e decreasing trend has been obtained with 20% reinforcement of rubber in epoxy while rubbed against steel at varying speeds [6].

Onyeagoro studied the cure characteristics and mechanical properties of reactive compatibilized natural rubber (NR)/carboxylated nitrile rubber (XNBR) blends using maleic anhydride-grafted-polyisoprene (MAPI) and epoxy resin (EPX) dual compatibilizers. The results show that MAPI/EPX dual compatibilizers exhibit beneficial effect by decreasing the cure time and increasing the scorch time of the NR/XNBR blends and increasing compositions of XNBR brought decreases in tensile strength, tear strength and elongation at break. However, these properties increased in the presence of MAPI/EPX dual compatibilizers [7].
This paper reports a study on the effect of adding nitrile butadiene rubber (NBR) on the tensile properties and wear rate of unsaturated polyester resin (UPE).

2. Experimental
2.1. Materials

- Unsaturated polyester resin (UPE) and its curing agent, methyl ethyl ketone peroxide (MEKP) was supplied by Saudi Industrial Resins (SIR) Company, Saudi Arabia.
- Nitrile butadiene rubber (NBR) was supplied by Babylon Tires Factory in Babylon, Iraq. Toluene was used to dissolve the pieces of rubber (NBR) for 24hour in sealed container.

2.2. Preparation of Samples

The polymers used in this work for preparing blends are unsaturated polyester resin, which mixed with 2% of hardener and 0.5% of accelerator, and Nitrile butadiene rubber (NBR) which dissolved in toluene. Binary polymer blends specimens were prepared at different weight fractions of (0, 5, 10 and 15) % of NBR. Mechanical mixer was used to prepare binary blend and after that the blend poured in a mold which made from Aluminum with dimensions (14×12×4) cm. When the solidification process was completed the samples were cut according to the standard procedure for fulfilling the specific tests. Figure (1) shows photographs of tensile and wear specimens.

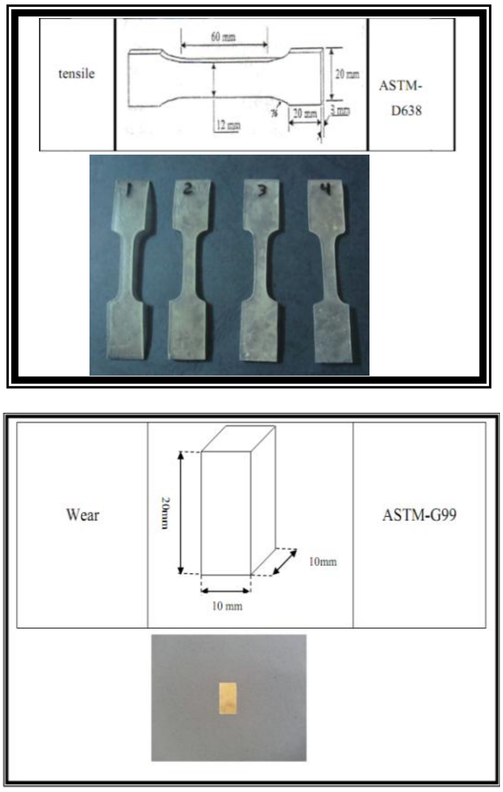

Fig. 1. Samples dimensions and photographs of tensile and wear samples.

2.3. Mechanical Properties

The tensile properties were measured using an Instron machine at a crosshead speed (4 mm/min) according to ASTM D638.

2.4. Wear Test

Wear test for binary polymer blend have been conducted using (pin –on –disc) testing according to ASTM G99. The disc has angular velocity (500rpm) and manufactured from toolset with (55HRC) hardness. Wear test have been carried out under the normal load (5N) with varying time and pin weight loss has been measure by using sensitive electronic balance (type-AE160 Metler,4 digits). The wear rates are calculated according to the following equations [8]:-

$$W_R = \frac{\Delta W}{S_D} \quad \text{... (1)}$$

$$\Delta W = W_1 - W_2 \quad \text{... (2)}$$

$$S_D = 2\pi rnt \quad \text{... (3)}$$

where:-

W_R: is the wear rate (g/cm)

W_1, W_2: are the weights of specimens before and after wear test (g)

SD: is the sliding distance (cm)

r : is the disc radius (7cm)

n: is the number of disc cycles (500 rpm)

t: is the time of test

2.5. Optical Microscope

Optical microscope (Japanese type) was used for studying the morphology and fracture surfaces for samples at a magnification of 400X.

3. Results and Discussion

3.1. Stress-Strain Behavior

Tensile properties of pure polymer and its blends are present in Figure (2) from this figure it can be notice that the (stress-strain) behavior of pure (UPE) is linear because of the brittleness of this resin, but after blending it with (5, 10, 15) wt. % of NBR, the behavior become non-linear this related to the nature of added rubber (NBR) which transform the material from elastic state to plastic one. Figure (3) shows that the UPE has higher value of tensile strength and this value decrease with increasing of NBR content, this may be related to the fact that polyester resin are more rigid than NBR which is soft and elastic and behaves as viscoelastic material so that the increasing of weight percentage of NBR lead to decrease value of tensile strength for unsaturated polyester.

The results for Young's modulus (E) are shown in Figure (4), it can be noticed that the (E) value of UPE decreases when rubber content increased, this is due to that elastomers have characteristic low modulus[9] as well as Unsaturated polyester have high stiffness than that for NBR[10].The results of this test agree with that for Paulo at el.[11] who investigated the modification of Unsaturated polyester by adding rubber powder produced from scrap tires and study its mechanical properties. The results clearly show that decrease in modulus due to the introduction of a soft rubber phase which has lower modulus and higher ultimate strain value compared with unsaturated polyester.

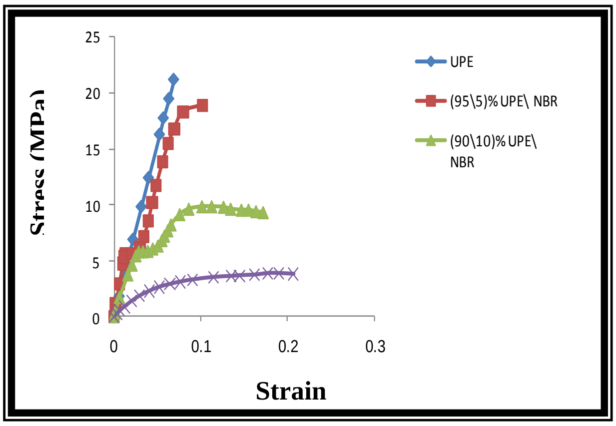

Fig. 2. Stress-Strain curve for UPE and its polymer blends.

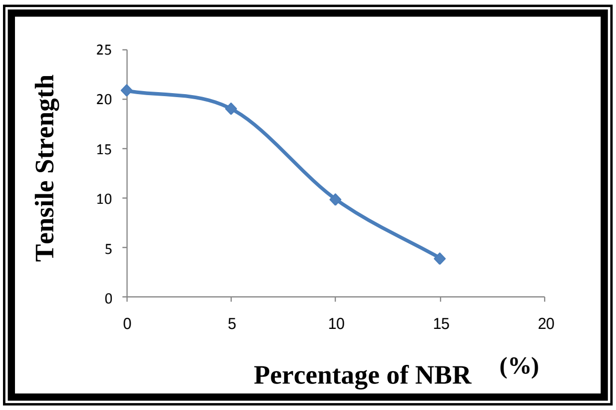

Fig. 3. Tensile strength of Nitrile Rubber (NBR) modified resin (UPE).

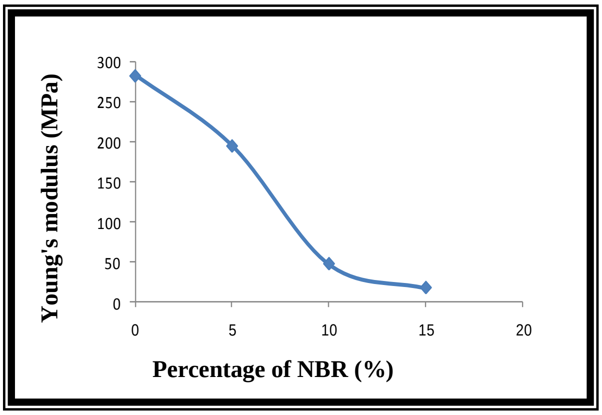

Fig. 4. Young's modulus of Nitrile Rubber.

3.2. Wear Rate

Figure (5) shows the variation of wear rate with sliding time. From this figure, it can be observed that the Unsaturated polyester resin have high wear rate when compared with blend this may be attributed to the generation heat of friction during sliding motion that made the specimen softer. The generated heat softened and removed the surface layer of material during the sliding test [12]. Generally the value of wear rate decrease with increasing of NBR content when time of sliding will increase. It is necessary to mention that the sample with ration (15%NBR) failed under wear test; this may be related to the nature of interpenetrating between the two polymers networks at this percentage which is defined (incompatible polymer blend) leading to decrease the mechanical properties of material [13].

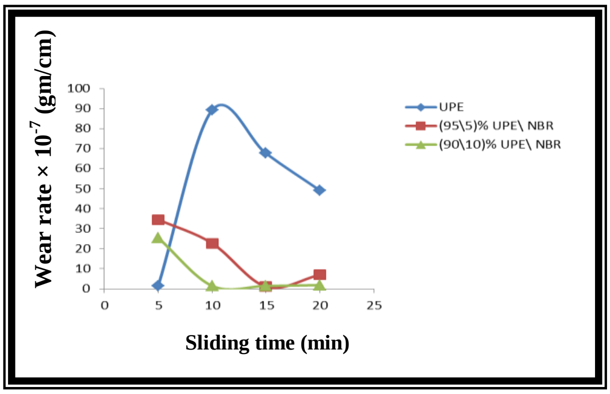

Fig. 5. Variation of wear rate with sliding time for Nitrile Rubber (NBR) modified resin (UPE).

3.3. Optical Microscope

From Fig.s (6 and 7), it can be noticed that the nature of fracture surfaces for (pure UPE) and the blend with (5% of NBR) are smooth, bright like mirror which indicates to the brittle fracture where cracks spread rapidly with little or no plastic deformation while it is clearly that the fracture surface will change to become dull and fibrous after blending (UPE) with (10 and 15)% of (NBR) as shown in Fig.s (8 and 9), this means that the material behavior could be transformed to become ductile at these ratios of mixing. Also, it is obviously that there are two regions were found (white and dark) as shown in Fig.(9) where the white region is a brittle material (UPE matrix)while the dark region is (NBR rubber). This phenomenon means that the rubber particles agglomerate as spheres forms at this ratio of mixing (15%) which lead to little plastic deformation before facture of sample because of these particles act as an energy absorber and improve the toughness of material. These results were similar to those reported in the literature [14].

Most authors have used a nucleation-growth mechanism to describe these morphologies which lead to the phase separation between the two polymers [15].

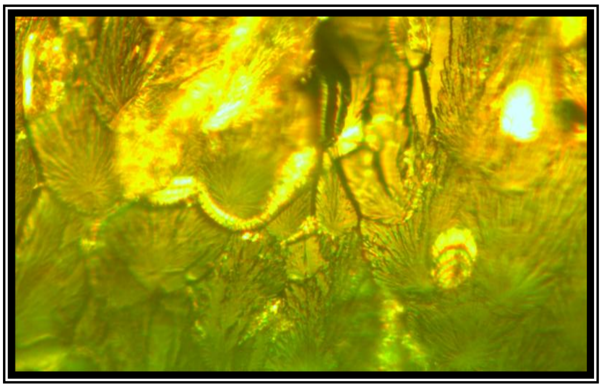

Fig. 6. Optical micrograph of fracture surface for pure(UPE) after tensile test.

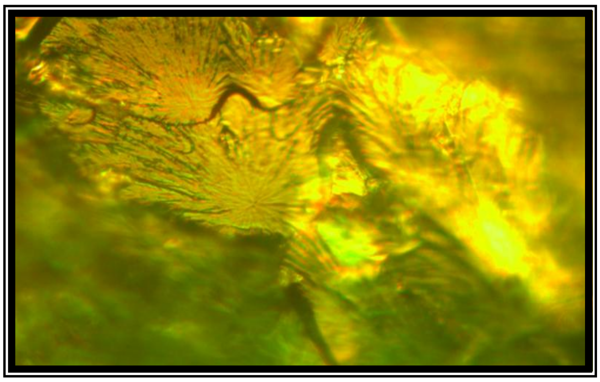

Fig. 7. Optical micrograph of fracture surface for Nitrile Rubber (5%NBR) modified resin (UPE) after tensile test.

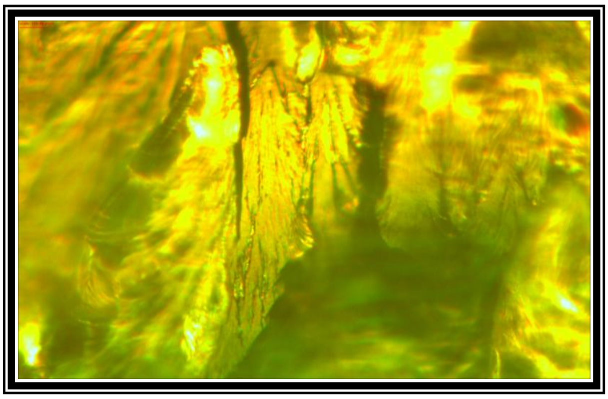

Fig. 8. Optical micrograph of fracture surface for Nitrile Rubber (10%NBR) modified resin (UPE).

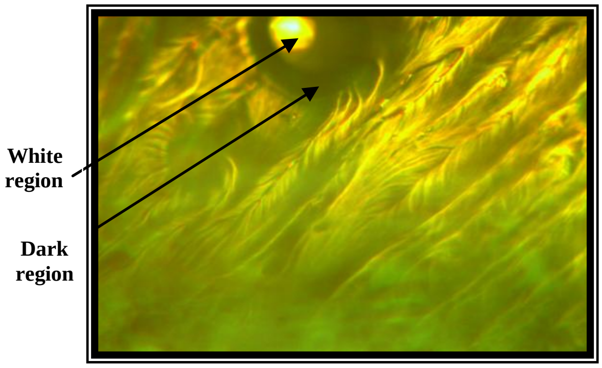

Fig. 9. Optical micrograph of fracture surface for Nitrile Rubber (15%NBR) modified resin (UPE).

4. Conclusions

1- It can be obtaining on toughened (UPE) by mixing it with weight ratios ranged (10-15) %wt. of (NBR).
2- The values of tensile strength and Young's modulus of (UPE) decease after blending it with (NBR).
3- Wear rates of (UPE) with sliding time of (UPE/NBR) blend decrease compared with its value for pure resin (UPE).
4- From micrographs of optical microscope, it is clear that the transformation of material behavior is obtained at mixing ratio more than 10%wt. of (NBR).

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دراسة مقاومة الشد و معدل البلى لخليط بوليمري من راتنج البولي استر غير المشبع ومطاط نايترايل بيوتاديين

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الخلاصة

تم تحضير خليط بوليمري ثنائي بطريقة الخلط الميكانيكي لراتنج البولي استر غيرالمشبع مع مطاط (نايترايل بيوتاديين) وبنسب وزنية مختلفة من المطاط (٠ ،٥،١٠،١٥) %. وقد تم دراسة خصائص الشد ومعدلات البلى لتلك الخلائط لجميع نسب الخلط . واستخدم المجهر الضوئي لفحص البنية المجهرية لسطوح الكسر للنماذج المحضرة . اظهرت النتائج بان معدلات الانفعال للمادة الراتنجية تزداد بعد خلطها مع المطاط في حين تنخفض القيمة القصوى للشد ومعامل يونك لها. كما لوحظ بان معدل البلى يتناقص مع زيادة محتوى المطاط (NBR).