

Study the Rheological and Mechanical Properties of PSR / NR Rubber Blends

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Abstract

A perfect adhesion between the rubber of a tire and the reinforcing polymeric cord is crucial for the overall tire performance and safety. The problem of bonding rubber to textile cords is due to the big difference between the surface properties. Blending of polymers has obtained much attention because, it can be used to obtain new polymeric materials with particular properties suitable for some special purposes. The blends of Natural rubber (NR) / Polysulfide rubber (PSR) has been prepared with a variety weight ratios (100/0, 90/10, 80/20, 60/40). The characteristics of the prepared blends were investigated, such as rheological, mechanical and damping properties. It was found that the increasing of the weight percent of PSR in the blend compositions leads to the increase its adhesive strength with nylon 66 cord and also increase the hardness of the resultant blends. On the other hand, the curing time, tensile strength, elongation at break and rebound resilience were decreased.

Key Words:-Natural rubber, Polysulfide Rubber, Blend, Rheology.

الخلاصة

ان تحقيق التصاق مثالي بين المطاط وخيوط التقوية البوليميرية تعتبر أمرا حاسما في أداء وسلامة الإطارات. ترجع مشكلة ربط المطاط مع خيوط نسيج التقوية الى الفرق الكبير بين الخصائص السطحية لكل من المطاط والنسيج. تكنولوجيا الخلانط البوليميرية حصلت على اهتمام كبير نظرا لإمكانية استخدامها للحصول على مواد بوليميرية جديدة ذات خصائص فريدة مناسبة لكثير من الأغراض الخاصة. في الدراسة الحالية تم تحضير خليط من مطاط طبيعي / مطاط البولي سلفايد وبنسب وزنيه متنوعة (100/0 20/80 10/90 0/100) وتم دراسة الخواص الريولوجية والميكانيكية للخلانط المحضرة وكذلك خواص التخميد. وحد ان صلادة الخليط وقوة التصاقه مع خيوط النايلون 66 تزداد بزيادة النسبة الوزنية للبولي سلفايد كما لوحظ ان مقاومة الشد والصلادة والاستطالة وكذلك زمن الانتعاج والارتدادية تتخفف بزيادة النسبة الوزنية للبولي سلفايد.

الكلمات المفتاحية: - المطاط الطبيعي ، المطاط البولي سلفايد ، الخليط ، الخواص الريولوجية .

1. Introduction

The use of blends of elastomers is almost as old as the synthetic rubber industry and generally stems from an understandable desire to combine the best technical features or economic of two elastomers (Tinker and Jones, n.d.). If the elastomer is the major phase and the plastic is the minor phase, this blend will have the properties of the reinforced elastomer, but if the plastic is the major phase, then the obtained blend will be toughened plastic material lends as new high-performance materials (Puyvelde, Moldenaers, & Leuven, 2005). The blending of different types of rubbers and then curing into the final fabricated parts such as automotive tires has long been known in the rubber industry (Khalaf *et.al.*, 2012)(Tinker and Jones, n.d.).

Blending of immiscible polymers can produce materials with a broad range of mechanical and other properties that would be hard to obtain with their monophasic counterparts. In addition to desirable final properties, improved processing behaviour and cost reduction have also contributed to the success of polymeric blended parts such as automotive tires, which has long been known in the rubber industry (Utracki, 2002).

When two immiscible polymers mixed, the size, shape, and distribution of one phase into the other depend on material parameters (i.e., blend composition, viscosity ratio, elasticity ratio, and interfacial tension) as well as on processing conditions (i.e., temperature, time, intensity of mixing, and the nature of the flow). Therefore, the greatest challenge in the field of multiphase polymer blend research is the manipulation of the phase structure via a judicious control of the melt flow during

processing and the interfacial interactions between the components (Charef Harrats • Sabu Thomas Gabrie, 2006).

Polysulfide rubbers (PSR) contain a substantial proportion of sulfur in their structure. For example, the polysulfide rubber made by reacting dichloroethane with sodium tetrasulfide contains about 80% sulfur by weight. This results in high density (1.34 g/cm³) and outstanding resistance to ketones, esters, and most solvents. Major uses of polysulfide rubbers include permanent putties for fuel tank sealants, fuel hose liners, and gaskets(Campion *et.al.*, 2002).

Nylon 66 based materials is widely used in automotive industry as fibers because of its high mechanical strength and great rigidity(Ou, Sahli, Barrière, & Gelin, 2014). The critical challenge is in achieving an optimum adhesion between these fibers and rubber matrix (Ramazani, 2010), (Ou *et.al.*, 2014).

The focus in this study is to investigate the influence of blending natural rubber (NR) with a various weight percent of polysulfide rubber (PSR) on the mechanical properties and on the adhesive strength between nylon 66 cords and rubber composites.

2. Experimental work

2.1. Materials

Natural rubber (NR), polysulfide and nylon 66 cords were purchased from Babel Company for the tire industry. The Tg of NR is about -70 °C. NR contains small amounts of fatty acids and proteinaceous residues that promote sulfur vulcanization, NR macromolecules are susceptible to fracture on shearing (Campion *et.al.*, 2002).

Nylon 66 is obtained from the polycondensation of hexamethylene diamine and adipic acid, each monomer containing six carbon atoms so giving the designation of nylon 66 (Wootton, 2001).

Chemical structures of both NR and PSR are shown in Figure (1).

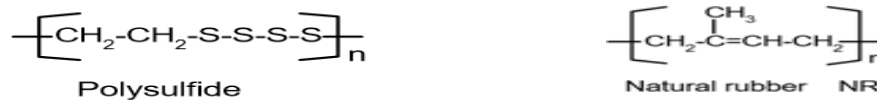


Figure 1 Chemical structure of polysulfide and natural rubber

2.2. Samples Fabrication

Rubber have been prepared with various ratios of natural rubber and polysulfide rubber and with fixed percent for other ingredients, **Table (1)** these ingredients were added to the rubber blends on twin-roller as (ZnO 10, N330 70, Sulfur 4.5, Stearic acid 4and Felcaset 1.4 %).

Preparation rubber composites begin by mixing and homogeneity of all the constituents used during mastication process by using laboratory mill. Firstly, natural rubber was passed between mill rollers at 70 °C, then polysulfide rubber, carbon black, processing oil , stearic acid, and zinc oxide were added respectively. Finally, the rubber composite is cooled to the room temperature and adds the sulphur.

Table 1 Recipes compounds

Compounding Ingredients	Compound 1	Compound 2	Compound 3	Compound 4	Compound 5
Natural rubber	100	90	80	70	60
Polysulfide rubber	0	10	20	30	40
Zinc oxide	10				
N330	70				
Sulfur	4.5				
Stearic acid	4				
Felcaset	1.4				

Samples for hardness test were prepared and measured in accordance with ASTM D-2240 while samples for strength and elongation at break according to ASTM-D3182 and D-13192 respectively using an INSTRON tensile testing machine model 1195. The measurement was carried out on dumbbell shaped specimens of 4 mm width and 50 mm length.

To prepare samples for adhesion test according to ASTM D2229 by using nylon 66 fibres coated with polyamide. Nylon fibres lay out the cut length of the fibres on a clean surface. The fibres should be touched only at their ends. After full chock, the ingot with rubber the fibres were put between two sheets of rubber at depth 300 mm and the other side typically 500 mm still outside the rubber, preheated mold which includes top and bottom plates. The rubber composites were placed into the mold under hot press at temperature of 165°C for 75 min.

3. Results and Discussion

3.1. Curing time

Figure (2) shows the relationship between the PSR content in the prepared blend with the curing time. Increasing the weight percent of PSR caused decreasing curing time linearly from 1.82 min for natural rubber to 1.26 min for (40/60) blend, this behavior is due to the additional sulfur amount in the prepared blend. This extra amount provided from the heat degradation of PSR during vulcanization process. As shown previously in figure 1, PSR contains a lot of sulfur atoms.

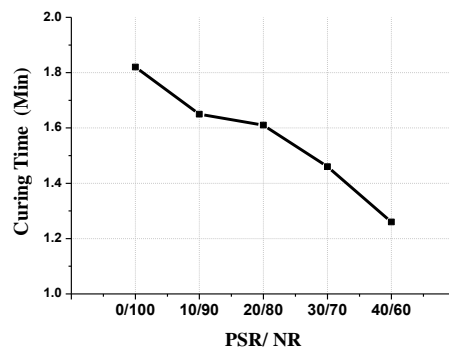


Figure 2 : The dependency of the Curing time on the PSR content

3.2. Hardness, elongation and tensile strength

Figure (3) shows 15% increasing hardness (shore A) with the increasing the percentage of PSR where the hardness increased from 57 for natural rubber to 67 for (40/60) rubber blend. This is due to increasing the cross linking density by the additional sulfur bridges arises from PSR source.

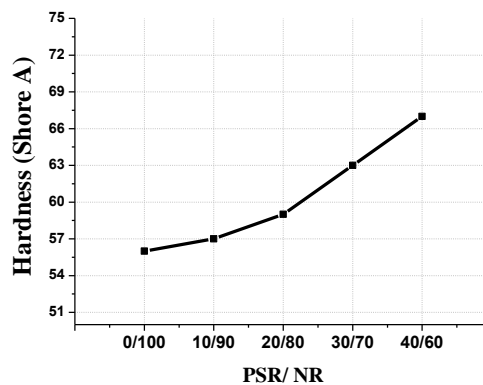


Figure 3: The dependency of the Hardness on the PSR content

Figure (4) shows the decreasing in the tensile strength and elongation at break with the increasing the weight percentage of the PSR by 27.6% and 31.4% respectively.

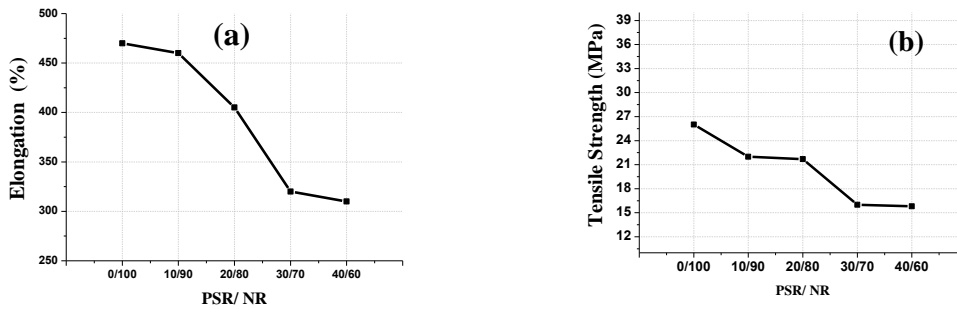


Figure 4: The dependency of the tensile strength and elongation at break on PSR content

It can be seen that the increase of crosslink density resulted in the linear decrease of the elongation at break (Figure 4a) due to the increasing restriction of the crosslink joints on the mobility of intercrosslink chains. The tensile strength also (Figure 4b) decreased because the length of intercrosslink chains will be short, which will consequently restrict the orientation of the stretched intercrosslink chains. The results agreed with the study of FEI ZHAO et al (Taylor, Zhao, Bi, & Zhao, n.d.).

3.3 Rebound Resilience

Resilience is the ratio of energy released by the recovery from deformation to that required to produce the deformation. Figure (5) shows decreasing the percent of rebound resilience with the increasing the weight percent of PSR. This is because the presence of PSR caused decreasing the flexibility of the molecular chain due to the cross-linking action. The resilience is related to the flexibility of the molecular chains, the more flexible the molecular chains, the better the resilience.

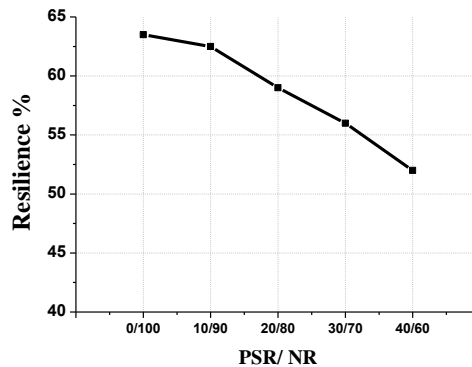


Figure 5: Rebounds resilience percent as a function of blend composition

3.4 Adhesive Strength

The presence of polysulfide caused to increase the adhesive of rubber composite with Nylon 66 cord by 29.4% (Figure 6). This significant increase in adhesion was obtained due to increasing cross linking density, and these results agreed with the study of H. Ou et al.,(Ou *et.al.*, 2014).

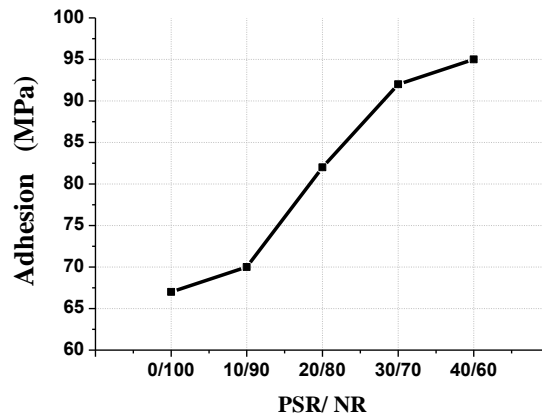


Figure 6 the dependency of adhesive strength on the PSR content

4. Conclusions

From the present study, the following conclusions could be drawn:

- 1- Presence of PSR in the blend PSR/ NR led to increasing the hardness and improving the adhesion strength of rubber with Nylon 66 cord.
- 2- Hardness (shore A) were increased with the increasing the percentage of PSR
- 3- Excessive amount of PSR can lowers the tensile strength and elongation at break.
- 4- Increasing the ratio of PSR caused decreasing the rebound resilience and curing time.

References

- Campion R. P., Ellul M. D., Finney R. H., Gent A. N., Hamed G. R., Hertz D. L., ... Yeoh O. H. , 2002, *Engineering with Rubber*. (A. N. Gent, Ed.) (2nd Editio). HanserGardner Publications Inc..
- Charef Harrats • Sabu Thomas Gabrie. ,2006, *Micro- and Nanostructured Multiphase Polymer Blend Systems*. (CRC Press).
- Khalaf A. I., Yehia A. A., Ismail M. N., & Al E. T. (2012). High Performance Oil Resistant Rubber, *2012*(October), 88–93.
- Ou H., Sahli M., Barrière T., & Gelin J. C. Adhesion strength study of silicone rubber compounds to nylon 66, *623* , 453 – 458. 2014 . <https://doi.org/10.4028/www.scientific.net/KEM.622-623.453>
- Puyvelde P. V.,Van, Moldenaers P., & Leuven K. U.,2005 . Rheology and morphology development in immiscible polymer blends, Peter Van Puyvelde , Paula Moldenaers, 101–145, *2005*.
- Ramazani, S., 2010, Effect of Moisture on Mechanical Properties and Adhesion Strength of Nylon 6 and 66 Cords/RFL/Rubber Systems. *Polymer Journal*, *19*(6), 427–436,.
- Taylor P., Zhao F., Bi W., & Zhao S. (n.d.),(August 2012), *Journal of Macromolecular Science , Part B: Physics Influence of Crosslink Density on Mechanical Properties of Natural Rubber Vulcanizates Influence of Crosslink Density on Mechanical Properties of Natural Rubber Vulcanizates*, , 37–41. <https://doi.org/10.1080/00222348.2010.507453>
- Tinker A. J., & Jones K. P. (n.d.). *Blends of Natural Rubber Novel Techniques for Blending with Speciality Polymers* Edited by Andrew J Tinker and Kevin P Jones Suported by the Common Fund for Commodities.
- Utracki, L. A. (Ed.) , 2002. *Polymer blends handbook* (Kluwer Aca).
- Wootton D. B. 2001, *The Application of Textiles in Rubber* (©, Rap, Vol. 44)