European Journal of Research Development and Sustainability (EJRDS)
Available Online at: https://www.scholarzest.com
Vol. 5 No 01, January 2024
ISSN: 2660-5570

EFFECT OF SOME FILLERS ON THE MECHANICAL PROPERTIES OF BUTYL RUBBER

Mustafa Ghanim Hameed
mat.mustafa.ghanim@uobabylon.edu.iq
Dhey Jawad Mohammed
dheyalhafagy@gmail.com
Ban Jawad Kadhim
banmaster28@gmail.com
Nabeel Hasan Al-Mutairi
mat.nabeeleng90@gmail.com
Polymers and Petrochemical Engineering Industries Department, College of Materials Engineering, University of Babylon, Al-Hilla, Iraq.

Article history:
Received 20th November 2023
Accepted: 11th December 2023
Published: 20th January 2024

Abstract:
The aim of this research is to study the effect of incorporating PVC and chopped glass fibers (CGF) on the mechanical properties of butyl rubber composites. In this study, PVC and CGF were employed as fillers in a rubber pastry formulation composed of 100% butyl rubber. To study the effect of incorporating these fillers on the mechanical properties of rubber, a series of tests were conducted, including tensile strength, hardness, and wear tests. The mechanical properties of the butyl rubber exhibit a notable increase in hardness and weight loss while experiencing a decrease in tensile strength due to the difference in the chemical structure between the added fillers (PVC and CGF) and the butyl rubber.

Keywords: Tensile strength; Butyl rubber; PVC, CGF; weight loss.

1.INTRODUCTION

Butyl rubber possesses exclusive elastomeric characteristic that render it very suitable for a diverse array of rubber-based applications. The material's low gas permeability and flexibility render it very suitable for applications such as tire internal tubes and high-pressure pipes. Additional uses encompass the utilization of elastomers in diaphragm, gasket, cables insulation, O-rings, seals, and bottle closures. Due to its minimal resilience, this material is well-suited for many applications such as shock absorption, vibration dampening, and insulation. Adhesives, hot melts, caulks, and sealants that are prone to stress employ lower molecular grades. Products made with butyl rubber exhibit enhanced chemical and heat resistant properties. In certain instances, butyl has comparable fluid resistance to EPDM elastomers, rendering it potentially suitable for analogous applications [1].
Elastomer blending is a method of reconfiguring materials to create a novel substance that can effectively manipulate specific characteristics in order to fulfill the necessary criteria for manufacturing automotive components. It is commonly employed in the rubber sector to achieve the optimal balance between the physical characteristics of the compound, its ability to be processed, and its cost [2]. Nevertheless, when two elastomers are blended together, they typically do not mix well, resulting in a lack of required qualities. To overcome this issue, a third component called a compatibilizer is necessary. The compatibilizer acts as a mediator, facilitating an attractive interaction between the different phases [3], [4]. Multiple experiments were conducted to reduce phase separation and enhance interfacial adhesion. The tests consisted of adding physical or chemical compatibilizers, such as a third homopolymer or graft or block copolymer, that created connections with both phases and introduced covalent bonds between the homopolymer phases. The compatibilizer also reduces the interfacial tension responsible for phase separation. Poly(vinyl chloride) (PVC) consists of an ethylene group as the main chain and a chlorine-containing vinyl group, enabling it to readily bond with different rubber kinds [5], [6]. Introducing glass fiber reinforcement is recognized to enhance the rigidity, durability, and heat resistance of polymeric materials [7], [8]. The mechanical characteristics of the resultant composite material, which is reinforced with glass fibers, are significantly influenced by the qualities of the interface between the fibers and the matrix. A well-designed interface usually leads to better overall characteristics, and several effective interfacial coupling agents have been discovered for polymer matrices composed of a single component. The investigation of interfacial chemistry in polymer matrices including many components has been greatly overlooked [9], [10].
This study aims to examine the effect of incorporating polyvinyl chloride (PVC) and chopped glass fibers (CGF) as fillers on the mechanical characteristics of butyl rubber. An investigation and discussion will be conducted on the

tensile strength, Shore A hardness, and wear rate of butyl rubber when combined with PVC and chopped glass fibers (CGF).

2. MATERIALS AND METHODS

2.1. MATERIALS

Butyl rubber was purchased from Babylon Tire Company, and the other additives were purchased from the rubber laboratory in the department of polymer and petrochemical industries. Table 1 shows the materials and their amounts for the prepared samples. Polyvinyl chloride (PVC), and chopped glass fibers (CGF) were purchased from China.

2.1. THE SAMPLE PREPARATION METHOD

The rubber dough was prepared as shown in Table 1 below, consisting of butyl rubber, zinc oxide, carbon black, castor oil, and sulfur, with the addition of vulcanizing aids. The ingredients were mixed using a laboratory mixer, after which the dough was divided into three parts. The first part was vulcanized without any addition, while the second part added polyvinyl chloride (PVC), and the third part added a chopped glass fiber (CGF). The vulcanization process was then carried out using a heat press at a temperature of 165°C and a pressure of 20 Pa for 5 minutes. The three prepared samples were left for 24 hours to complete the vulcanization process, after which they were cut into the required shapes to conduct laboratory tests on them.

Table 1: The compositions of rubber dough.

Ingredients	**Amounts (pphr)**		
	Butyl rubber **1**	Butyl rubber/PVC fibers **2**	Butyl rubber/Glass fibers **3**
Butyl rubber IIR	100	100	100
ZnO	5	5	5
Vulka-resin	10	10	10
Castor oil	5	5	5
HAF Black	60	60	60
Sulfur	1.5	1.5	1.5
PVC	--	5	--
Chopped Glass fibers (CGF)	--	--	5

2.2. CHARACTERIZATION

Multiple experiments have been carried out to examine the effect of PVC and chopped glass fibers (CGF) on the mechanical characteristics of butyl rubber. The rubber samples underwent a tensile test using the 5KN universal testing machine. The test was performed in accordance with ASTM-D13192. A hardness test was performed using a Shore A equipment in accordance with ASTM-2240. Multiple readings, ranging from three to five, were conducted for each sample, and the resulting average was calculated. The wear test was performed with the pin-on-disk apparatus in accordance with ASTM G99 standards. For each test, three samples were collected and their mean was used as the final result for the discussion [11], [12].

3.RESULTS AND DISCUSSIONS

1-TENSILE TEST RESULTS

The tensile strength of butyl rubber and it is composites with PVC and glass fibers CGF are shown in figure 1. It is found that the addition of PVC and glass fibers CGF reduced it is tensile strength. From figure 1, it is found that butyl rubber has a tensile strength of 3.21 MPa which is reduced to 2.42 MPa and 1.34 MPa for PVC and glass fibers CGF respectively. This reduction in tensile strength attributed to the absence of interaction between matrix (butyl rubber) and the other two materials (PVC and CGF). According to several studies [13]–[15], the addition of a second material causes a reduction in the elasticity and thus will reduce the tensile strength when there is no interaction between the two materials, there is a difference in the polarity of the two materials (matrix and fillers) and thus weaken the tensile properties.

3.2 HARDNESS TEST RESULTS

The hardness of a material can be defined as the resistance of its surface to penetration. Figure 2 shows the shore A hardness for butyl rubber and it is composite with PVC and glass fiber. It is found that the shore A hardness improved with the addition of PVC and glass fiber. Results show that butyl rubber has a hardness of 66.2 Shore A; as PVC and glass fiber were added, the hardness increased to 69 and 69.4 Shore A, respectively. The hardness increased by 4.2% and 4.8% as the PVC and glass fiber were added. These results are due to the higher hardness of both PVC and glass fiber, which have better surface properties. In addition, the presence of PVC and glass fiber within the rubber matrix causes a reduction in flexibility (PVC and glass fiber fill the spaces between rubber chains), and thus the hardness is improved. These results are in good agreement with [16], [17].

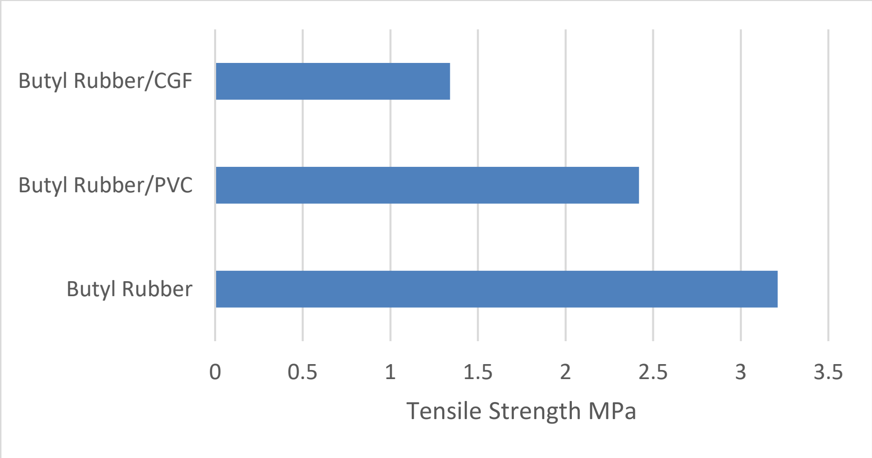

Figure 1: Tensile strength of Butyl rubber and it is composite with PVC and CGF.

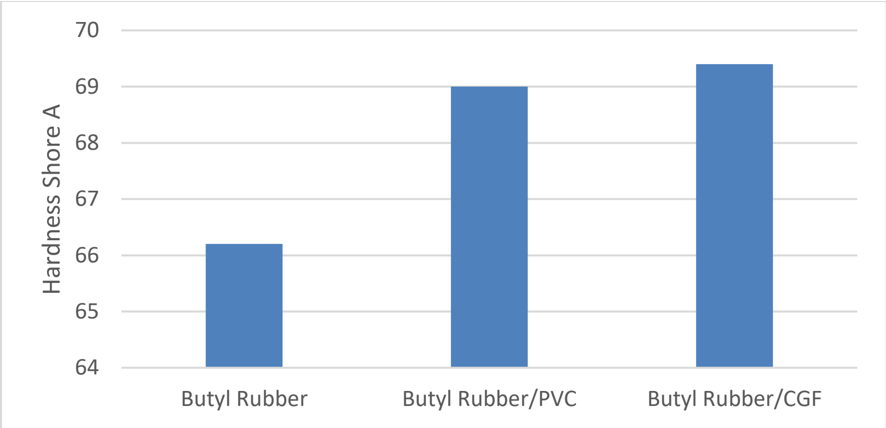

Figure 2: Hardness of Butyl rubber and it is composite with PVC and CGF.

3. 3 WEAR TEST RESULTS

Wera rate can be defined as the weight of material lost during a certain period of time at a defined load and distance. Figure 3 shows the amount of weight loss of the butyl rubber and it is composite with PVC and CGF. It is obvious from figure 3 that the weight loss amount increased as the two materials (PVC and CGF) were added to butyl rubber. From figure 3, it was found that butyl rubber has a weight loss of 1.65%, which increased to 2.31% and 2.45% as PVC and CGF were added, respectively. The amount of weight loss increased by 40% and 48.5%, respectively, as PVC and CGF were added. These results are due to the increased hardness of the two composites with PVA and CGF, which causes the removal of a higher amount of material also due to the absence of bonding between rubber and the aditives. This means that the addition of PVC and CGF has a negative effect on the wear properties. These results are in agreement with [18]–[20].

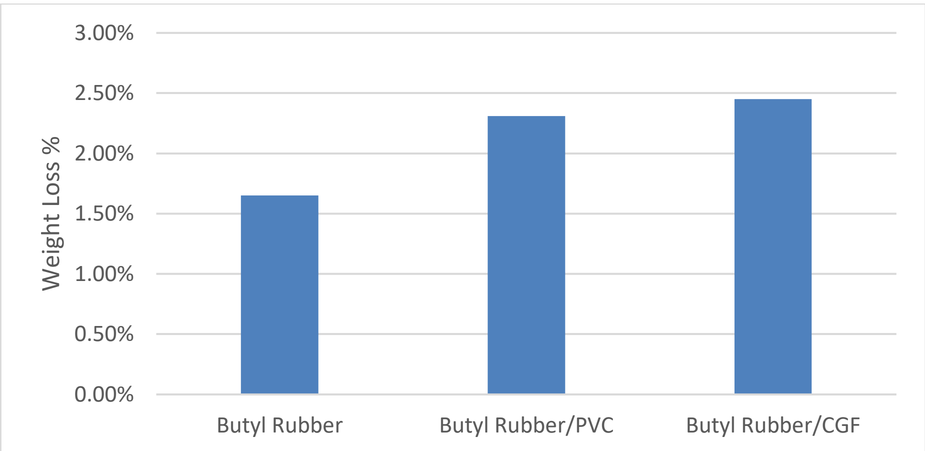

Figure 3: Weight loss of Butyl rubber and it is composite with PVC and CGF.

CONCLUSION

From the above results, it can be concluded that the addition of PVC and CGF causes a reduction in tensile properties due to the absence of compatibility between butyl rubber and the two material, while it is found that both shore A hardness and weight loss were increased due to the reduction in material elasticity and flexibility also due to the higher stiffness of the added materials (PVC, CGF).

REFERENCES

[1] A. Y. Coran, "Chemistry of the vulcanization and protection of elastomers: A review of the achievements," *J. Appl. Polym. Sci.*, vol. 87, no. 1, pp. 24–30, 2003.

[2] M. Phiriyawirut and S. Luamlam, "Influence of poly (vinyl chloride) on natural rubber/chlorosulfonated polyethylene blends," *Open J. Org. Polym. Mater.*, vol. 2013, 2013.

[3] D. J. Zanzig, F. L. Magnus, W. L. Hsu, A. F. Halasa, and M. E. Testa, "IBR block copolymers as compatibilizers in NR/BR blends," *Rubber Chem. Technol.*, vol. 66, no. 4, pp. 538–549, 1993.

[4] R. Holsti-Miettinen, J. Seppälä, and O. T. Ikkala, "Effects of compatibilizers on the properties of polyamide/polypropylene blends," *Polym. Eng. Sci.*, vol. 32, no. 13, pp. 868–877, 1992.

[5] A. P. Plochocki, S. S. Dagli, and R. D. Andrews, "The interface in binary mixtures of polymers containing a corresponding block copolymer: Effects of industrial mixing processes and of coalescence," *Polym. Eng. Sci.*, vol. 30, no. 12, pp. 741–752, 1990.

[6] H. Ismail and H. M. Hairunezam, "The effect of a compatibilizer on curing characteristics, mechanical properties and oil resistance of styrene butadiene rubber/epoxidized natural rubber blends," *Eur. Polym. J.*, vol. 37, no. 1, pp. 39–44, 2001.

[7] D. M. Laura, H. Keskkula, J. W. Barlow, and D. R. Paul, "Effect of glass fiber and maleated ethylene–propylene rubber content on the impact fracture parameters of nylon 6," *Polymer (Guildf).*, vol. 42, no. 14, pp. 6161–6172, 2001.

[8] D. M. Laura, H. Keskkula, J. W. Barlow, and D. R. Paul, "Effect of glass fiber and maleated ethylene–propylene rubber content on tensile and impact properties of Nylon 6," *Polymer (Guildf).*, vol. 41, no. 19, pp. 7165–7174, 2000.

[9] L. W. Jenneskens, H. E. C. Schuurs, D.-J. Simons, and L. Willems, "Molecular mechanisms of adhesion promotion by silane coupling agents in glass bead-reinforced polyamide-6 model composites," *Composites*, vol. 25, no. 7, pp. 504–511, 1994.

[10] J. Mahy, L. W. Jenneskens, and O. Grabandt, "The fibre/matrix interphase and the adhesion mechanism of surface-treated TwaronR aramid fibre," *Composites*, vol. 25, no. 7, pp. 653–660, 1994.

[11] W. S. Khudhir, "Experimental Investigation of Metal Removal and Micro-Hardness During MAF Process," *Al-Qadisiyah J. Eng. Sci.*, vol. 15, no. 2, 2022.

[12] A. Kuczkowski, "The electrical properties of polyester polymer-quinoline salt of tetracyanoquinodimethane composites," *Phys. status solidi*, vol. 105, no. 1, pp. K61–K65, 1988.

[13] J. Guo, X. Wang, Z. Jia, J. Wang, and C. Chen, "Nonlinear electrical properties and field dependency of BST and nano-ZnO-doped silicone rubber composites," *Molecules*, vol. 23, no. 12, p. 3153, 2018.

[14] A. I. Al-Mosawi, M. H. Al-Maamor, K. Marossy, H. A. Yasser, and S. A. Abdulsada, "Mechanical Properties of Acrylonitrile-Butadiene Rubber (NBR)/Poly (Vinyl Chloride) Resin Binary Blend," *Open Access Libr. J.*, vol. 6, no. 12, pp. 1–7, 2019.

[15] D. Dobrotă, V. Petrescu, C. S. Dimulescu, and M. Oleksik, "Preparation and characterization of composites materials with rubber matrix and with polyvinyl chloride Addition (PVC)," *Polymers (Basel).*, vol. 12, no. 9, p. 1978, 2020.

[16] J. K. Oleiwi, M. S. Hamza, and M. S. Abed, "A study of the hardness and wear rate of elastomer composites reinforced by Al2O3 and SiO2 particles," *Eng. Technol. J.*, vol. 27, no. 7, pp. 1423–1434, 2009.

[17] H. Norazlina, R. M. Firdaus, and W. M. Hafizuddin, "Enhanced properties from mixing natural rubber with recycled polyvinyl chloride by melt blending," *J. Mech. Eng. Sci.*, vol. 8, pp. 1440–1447, 2015.

[18] R. İlhan and E. Feyzullahoğlu, "Investigation of adhesive wear properties of glass fiber reinforced polyester composites having different chemical compositions," *Proc. Inst. Mech. Eng. part J J. Eng. Tribol.*, vol. 236, no. 1, pp. 156–173, 2022.

[19] S.-Y. Fu, B. Lauke, R. K. Y. Li, and Y.-W. Mai, "Effects of PA6, 6/PP ratio on the mechanical properties of short glass fiber reinforced and rubber-toughened polyamide 6, 6/polypropylene blends," *Compos. Part B Eng.*, vol. 37, no. 2–3, pp. 182–190, 2005.

[20] A. Güllü, A. Özdemir, and E. Özdemir, "Experimental investigation of the effect of glass fibres on the mechanical properties of polypropylene (PP) and polyamide 6 (PA6) plastics," *Mater. Des.*, vol. 27, no. 4, pp. 316–323, 2006.