

Hardness and compression resistance of natural rubber and synthetic rubber mixtures

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Abstract: This project aims to mechanically characterize through compression resistance and shore hardness tests, the mixture of hevea brasiliensis natural rubber with butadiene synthetic rubber (BR), styrene-butadiene rubber (SBR) and ethylene-propylene-diene monomer rubber (EPDM). For each of the studied mixtures were performed 10 tests, each of which increased by 10% the content of synthetic rubber in the mixture; each test consisted of carrying out five tests of compression resistance and five tests of shore hardness. The specimens were vulcanized on a temperature of 160°C, during an approximate time of 15 minutes, and the equipment used in the performance of the mechanical tests were a Shimadzu universal machine and a digital durometer. The results show that the A shore hardness increases directly proportional, with a linear trend, with the content of synthetic BR, SBR or EPDM rubber present in the mixture, being the EPDM the most influential. With respect to the compression resistance is observed that the content of BR or SBR increase this property directly proportional through a linear trend; while the EPDM content also increases but with a polynomial trend.

1. Introduction

Polymers have had a quick expansion in recent years, which has happened at the expense of traditional materials in already established applications, also the emergence of new applications and markets. This boom is due to the great versatility of properties that present these materials, among which highlights its low weight, corrosion resistance, ease of processing and economy, among others.

The natural and synthetic polymers known as elastomers have as main characteristic its ability to present a fully recoverable and unlimited instant elasticity to high deformations; due to this characteristic are widely used in the manufacture of elastic bands, tires, seals, hoses, etc.

Due to the large amount of elastomers available in the market and to the variation in mechanical properties that each of these materials presents, this project aims to mechanically characterize, through compression resistance and shore hardness tests, the mixture of hevea brasiliensis with BR, SBR and EPDM; to determine how vary these properties as a function of the amount of synthetic rubber present in the sample.

2. Conceptual framework

2.1. Elastomers

Elastomers are materials which characteristic property is the deployment of a large amount of deformation, generally greater than 200%, when a force is applied to them [1]. These materials have high molecular weights and flexibility. Rubbers are classified according to their origin in natural and synthetic. Natural rubber is obtained from a white liquid called latex, which is found in many plants,



being the most representative the tree of the specie *Hevea Brasiliensis*; synthetic rubbers are prepared from saturated hydrocarbons through chemical reactions and there is a wide variety of these rubbers, some of which have better mechanical properties than natural rubber.

The tire manufacturing industry is the largest consumer of natural and synthetic rubber [2-4] being the most commonly used natural rubber, styrene butadiene rubber, butadiene rubber and the rubber ethylene propylene diene monomer [5,6].

2.2. *Vulcanization*

The rubbers are polymers derived from dienes and as a result they possess double bonds in the main chains. The existence of these is used to insert in a controlled manner the clips between the chains through a process known as vulcanization. Through this process, the polymer that has very poor properties is transformed into a tough, tenacious and elastic rubber. The degree of vulcanization affects significantly these properties. The vulcanization, which uses sulphur atoms, is a common method of forming these cross-links; this process was accidentally invented by Charles Goodyear [7,8].

2.3. *Mechanical Properties of rubbers*

The stress-deformation curve for an elastomer shows that virtually all the curve represents elastic deformation; therefore, elastomers show a nonlinear elastic behaviour. At the beginning the elasticity modulus (E) is reduced due to the unwinding of the chains. However, once extended the chains, any additional elastic deformation happens thanks to the stretch of the links, which generates a high E.

The number of cross links determines the elasticity of the rubber or the quantity of Sulphur added to the material. Low Sulphur additions leave a soft and flexible rubber; while percentage increase, this restrict the unrolling of the chains and the rubber is made harder, more rigid and fragile. Many more efficient vulcanization systems that do not have sulphur have been developed in recent years [9].

A rubber hardness is an indication of its rigidity against moderate stress, as those that often has to bear in service. The most popular method of rubbers hardness is the shore A in which is performed the measurement with an instrument called a durometer, based on the penetration of a frusto-conical tip against a calibrated metal spring reaction.

3. Methodology

3.1. *Used materials*

The raw material used for the preparation of the different specimens were: natural rubber *Hevea Brasiliensis*, BR, SBR and EPDM. The accelerators added during the mixing process were the 2-mercapto benzothiazole (MBT), which helps the vulcanized process and curing of the rubber; and Thiuram, which is a secondary accelerator that is used to give consistency to the mixture in the vulcanization and supports the MBT.

Other used materials were sulphur, since being mixed with the raw rubber improve its hardness and resistance and is compatible with the selected accelerators, has low cost and present a high efficiency in the vulcanization process; and the black smoke, which has carbon particles that are mixed with the rubber and other components that allow a better mixture and composition in the vulcanization.

3.2. *Preparation of the mixtures*

For the manufacture of the specimens was used the same amount of additives in the mixing of all the specimens in order to not add additional variables that prevent analyse the relationship between the percentage of used rubber and the mechanical properties of hardness and compression resistance. In Table 1 are related the percentages of used materials in each of the tests performed, and were defined according to the permissible ranges found in the bibliographic information collected, and that correspond to: accelerators (0.2-0.8%), sulphur (0.5-3%) and black smoke (20-40%). For each specimen a total weight of 800 grams of rubber was taken as a reference.

Table 1. Amount of each material used in the rubber mixtures.

Test	Natural Rubber		Synthetic Rubber		Black Smoke		Sulphur		MBT		Thiuram	
	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)	%	Weight (g)
1	0	0	100	800	20	160	1	8	0.75	6	0.25	2
2	10	80	90	720	20	160	1	8	0.75	6	0.25	2
3	20	160	80	640	20	160	1	8	0.75	6	0.25	2
4	30	240	70	560	20	160	1	8	0.75	6	0.25	2
5	40	320	60	480	20	160	1	8	0.75	6	0.25	2
6	50	400	50	400	20	160	1	8	0.75	6	0.25	2
7	60	480	40	320	20	160	1	8	0.75	6	0.25	2
8	70	560	30	240	20	160	1	8	0.75	6	0.25	2
9	80	640	20	160	20	160	1	8	0.75	6	0.25	2
10	90	720	10	80	20	160	1	8	0.75	6	0.25	2

The time used to homogenize the mixture was between 50 and 60min. The mixing process was carried out in the following way: initially are laminated independently for 2min the synthetic rubber and natural rubber for 7min; subsequently two rubbers are mixed by an approximate time of 8min. Then is added the MBT accelerator and laminated the mixture for 5min; and for last is added the Thiuram and mixed for 5min; and finally is added the black smoke and laminated the mixture for 10min, time in which you get a homogeneous mixture and compact mixture, as you can see in Figure 1.

**Figure 1.** Lamination process of components that conforms the rubber mixtures.

3.3. Vulcanization process of the specimens

For the process of vulcanization was used a total weight of the mixture between 650 and 700 grams, in order to avoid excess material in moulds; the temperature and pressure used were 160°C and 90kPa, respectively. The processing time was 15min.

3.4. Tests performed

Specimens were subjected to hardness shore A, and to compression resistance of 25% deformation; the equipment used was a digital durometer and a Shimadzu universal machine. In total 8 hardness tests and 14 tests of compression for each test were performed.

4. Obtained results

The results of the average values of hardness and resistance to compression, for each of the mixtures of rubbers are listed in Figures 2 and 3 respectively.

Figures 2 and 3 allow to observe that both the Shore A hardness, as the resistance to compression (25%) increase when the natural rubber Hevea Brasiliensis is mixed with synthetic rubbers, being the

most influential the EPDM. The tendency of these properties is directly proportional to the content of synthetic rubber in the mixture and they usually have a linear behaviour.

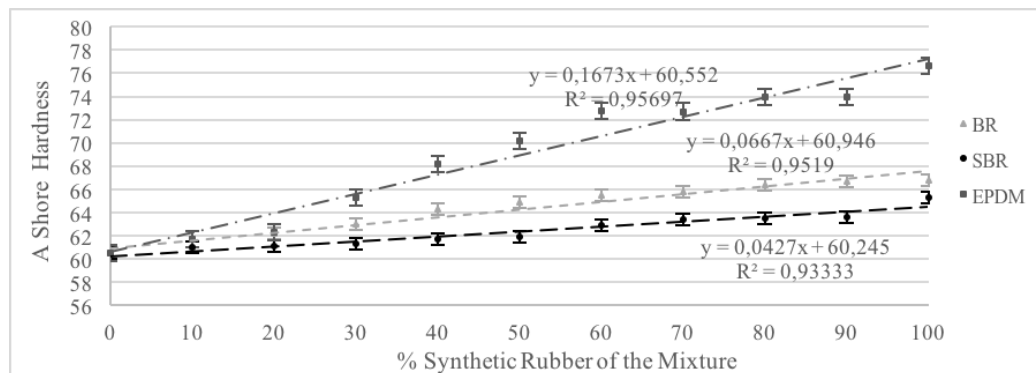


Figure 2. Variation of Shore A Hardness in Hevea Brasiliensis natural rubber and Synthetic rubber.

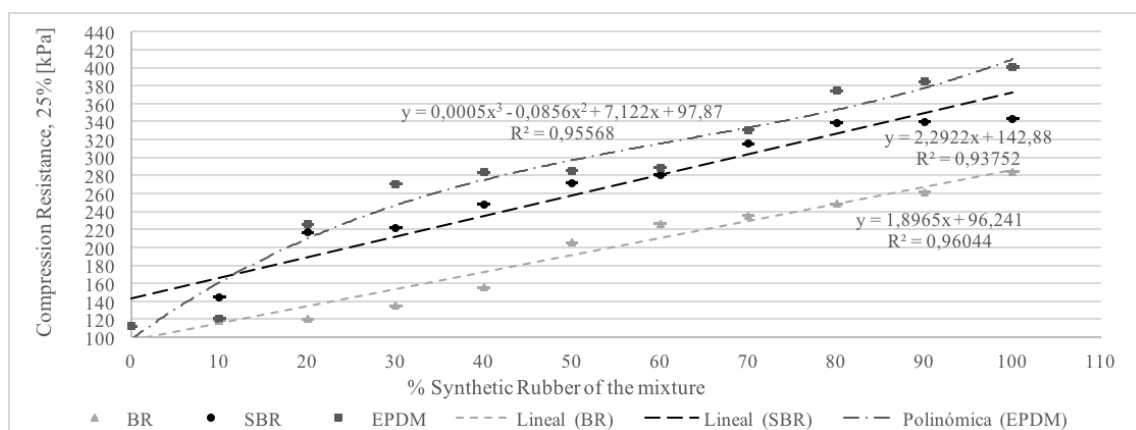


Figure 3. Variation of Compression Resistance at 25% in Hevea Brasiliensis natural Rubber and Synthetic rubber.

5. Conclusions

Shore A hardness in the mixtures present a directly proportional behaviour with a linear tendency, in function of the content of BR, SBR and EPDM present, being the EPDM the more influential.

The compression resistance at 25% is increased in a directly proportional way through a linear tendency with the content of synthetic rubber BR and SBR; while with the content of EPDM also is increased but with a polynomial tendency of third order.

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