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APPLICATION OF GAMMA IRRADIATION FOR INCORPORATION OF RUBBER POWDER IN THE FORMULATIONS

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ABSTRACT

The aim of this paper was to study the behavior of rubber recycle, in powder form of rubber industry. It was used EPDM rubber powder. The rubber powder was irradiated and used directly in classical formulations of rubber vulcanizate. The master-batch processed material was irradiated at doses of 50, 100 and 150kGy in ^{60}Co source at 5kGy s^{-1} rate, at room temperature. Gamma radiation created active sites devulcanization for further integration of the material (rubber powder) with facilities in formulations of commercial use. The processes were compared and their products were characterized by analytical methods of the physical properties such as tensile strength, elongation, hardness, rheology and abrasion tests.

1. INTRODUCTION

The interest in rubber and polymeric materials increases in parallel with the rapid industrialization and civilization. As polymeric materials do not decompose easily, the disposal of waste polymers is one of major environmental problems in the global approach. Recycling rubber waste is an economical alternative and environmentally recommended solution for polymers recovery of discarded materials by society [1].

The decomposition of rubber occurs rather slowly due to its vulcanized structures formed as highly crosslinked three-dimensional network. The hardening makes it less fused and insoluble material [2]. In addition, this three-dimensional structure brings about several problems for the recovery and reprocessing of the material.

Despite the various processes already developed and applied in the rubber claim processing, the practical applications of these processes still present several challenges. The scale and the quantities or the quality of the recovered material, regarding to the involvement of the main structure of the rubber are responsible for the physical-mechanical properties of the final items [3].

During their long period of service most polymers and derivatives gradually lose their functionality features as a result of polymer degradation. This is due to the action of stressors such as oxygen, humidity, light, heat and high energy radiation. The intensity of

effects induced by degrading agents depends mainly upon the chemical structure of polymer backbone.
Mechanical properties of polymers are changed considerably by bombed high energy radiation. This energetic modification may lead to crosslinking or scission. Material properties such as tensile strength and hardness are decreased as a result of chain scission. The effects of gamma radiation on polymeric materials and their blends have been reported in several papers [4].

EPDM has been selected for this study due to its excellent resistance to heat, oxidation, ozone and ageing properties. It shows appropriate electrical resistivity and no swelling in polar solvents such as water, acids, alkalies and alcohols is usually occurred [5]. The EPDM elastomer based compound behave satisfied well to the advanced loading various fillers and plasticizer [6].

The purpose of this work is to study the behavior of EPDM rubber powder used in rubber industry as classical formulations. The selected formulations were compared resulting samples that were characterized by physical methods as tensile strengh, elongation, rheology, abrasion and hardness.

2. MATERIALS AND METHODS

2.1. Material

In this work we used the EPDM rubber powder. The rubber powder was supplied by Rpolymer LTDA, in particle size from 30 mesh. It was incorporated in general accepted formulations of rubber with a loading proportion of 30 to 50 phr powder according to Table 1. The rubber Keltan 5470 was supplied by Lanxess.

The samples were prepared in open two-roll mixing mill (Semabor) with 5kg of capacity, at temperature between 50ºC and 60°C.

The concentration of components are expressed in parts per hundred rubber (phr) which describe the formulation of rubber compounds and refers to the amount of a particular compound in relation to the total amount of rubber used per 100 parts of rubber.

Table 1: Base formulation of EPDM

Rubber Formulation	Amounts in phr (formulation 1)	Amounts in phr (formulation 2)
Keltan 5470	100	100
EPDM master-batch	30	50
Activators	6	6
Carbon Black	40	40
Paraffin oil	10	10
vulcanization efficient acceleration	2 + 2	2 + 2

2.2. Irradiation

The master-batch (rubber mix with powder EPDM) was processed and irradiated. Specimens were irradiated at 50, 100 and 150 kGy exposed in a Cobalt-60 source, at a $5kGys^{-1}$ dose rate. The irradiation was accomplished by Embrarad /CBE in air atmosphere at room temperature.

2.3. Methods

The research was performed following the processing steps:

Step 1: Preparation of master-batch with rubber powder: mixed the rubber powder with raw rubber. The samples were prepared in open mixing drum (Semabor) with two rollers capacity of 5kg according to ASTM D-3182 at temperature range of 50°C to 60°C.

Step 2: Irradiation of master-batch parts with different doses. As nominated in section 2.2.

Step 3: Processing of selected formulations with different proportions of master-batch. The formulations were prepared in an open roll-mill, each roll of 5kg capacity. The samples were cured in an electrically heated HIDRAUL-MAQ, at 5MPa pressure and vulcanized at 170°C for 10 min.

Step 4: Mechanical properties tests were performed, abrasion tests and rheology, in the irradiated and non-irradiated samples.

2.4. Samples Characterization

2.4.1. Mechanical properties

The formulations were prepared according to ASTM standards (Annual Book of ASTM Standards) applied on rubber and they were analyzed as irradiated and non-irradiated materials. Rubber sheets were prepared with dimensions of 160 x 160 x 1.5mm, as ASTM D-3182-96 [7], in press Luxor with table size 300/350mm for tests tensile strengh and elongation. All formulations were vulcanized at 170°C for 10 min.

The formulations were tested for hardness (ASTM D-2240-96) [8] with Durometer - Digital Equipment Instrutherm model DP-200. Tensile strength and elongation were determined according to (ASTM D-412-96) [9] with Instron model 5567.

2.4.2. Abrasion tests

Resistance to wear is one of the most important properties of a rubber compound. Wear strength is usually considered in terms of abrasion, which is defined as the loss of material that results from mechanical action on rubber surface. The tests were repeated five times according to the standard DIN-53516 [10] was accomplished.

2.4.3. Rheology

The determination of vulcanization parameters in the oscillating disk rheometer, model 100 S (Monsanto) according to ASTM D-2084-96 [11]. The analyzed parameters were: TS1 - the time on minimum torque attendance presented for each formulation (lower point of the curve); TS2 - the pre-cure time; T90 - optimum time of vulcanization. The conditions used in the tests were: temperature of 170°C; arc of oscillation - 3 and time of 12 min. The curves were obtained by vulcanization torque (lbf.in) against time (min).

3. RESULTS AND DISCUSSIONS

The major changes in the properties of polymeric materials by exposure to ionizing radiation results are observed by two main processes occurring in the polymer bulk: the scission of the main links of the chains and crosslinking. Although these two processes occur simultaneously in all the polymers, the predominance of one or other effect depends primarily on the chemical structure of polymer and on irradiation conditions (dose, ambient radiation and dose rate) [12].

In fig. 1 shows the results of tensile strength and elongation for EPDM rubber. It is found that formulation 1 presents increased elongation at 50 kGy, while formulation 2 shows a slight decline, as mechanical answer for the same dose. This may indicate that there was more scission than crosslinking. It was observed that from formulation 2, the first 50 kGy, induced splitting of the EPDM chain. After the dose of 100 kGy it is observed that both formulations 1 and 2 exhibited a potential degradation of the material with the loss of their mechanical properties.

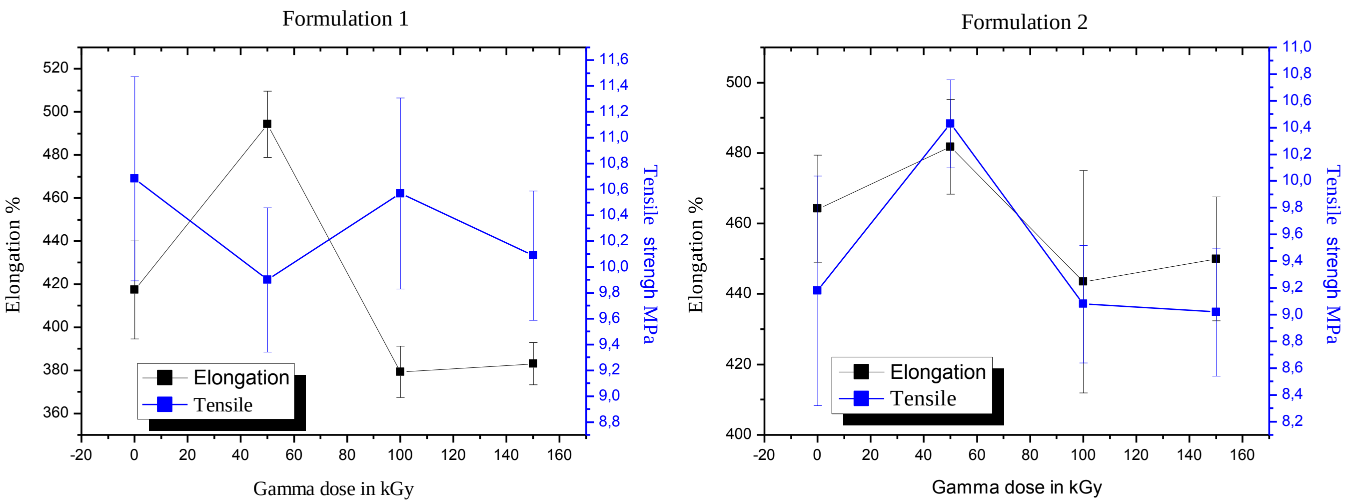

Figure 1: Variation of tensile strength and elongation for two studied EPDM formulations.

Figure 2 presents the results of hardness recorded on EPDM formulations. As we can see there was no significant change in hardness. This may indicate that for gamma radiation did not significantly induce the modification in the microstructure of samples.

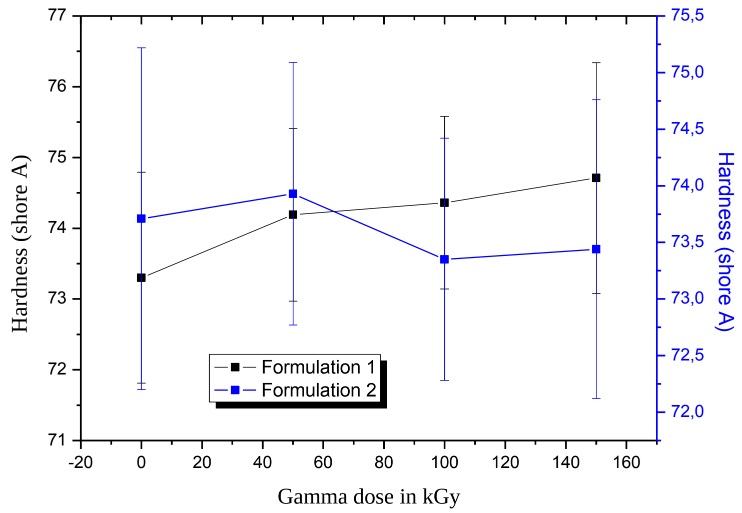

Figure 2: Graph of hardness testing of EPDM rubber.

In fig. 3 there are shown the abrasion result test performed on elastomer compositions formulations. It is shown that for both formulations there was a slight increase in abrasion up to the dose of 50 kGy. For the doses exceeding 50 kGy the decrease in the rate of abrasion was recorded. At a dose of 50 kGy it can notice the predominance of chain scission, like in the case of tensile strength. This can be assumed that the lower the dose, the higher the crosslink level meaning a proper wearing.

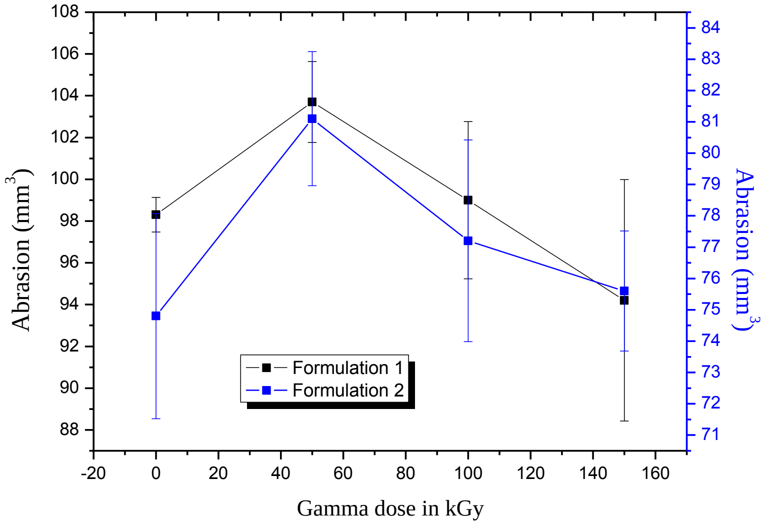

Figure 3: Graph of abrasion test for the formulation 1and 2.

Figure 4 are shown the results of rheological tests. As can be seen in the parameter T90 formulation 2 had a slight increase at dose of 100 kGy, which may indicate that the molecular scission occurred namely, devulcanization. In addition, in the formulation a slight diminution to a dose of 50 kGy was revealed, which may indicate a slight crosslinking. The difference between the two studied formulations may be explained by the difference in rubber loading. The formulation 2 has a larger amount of rubber powder indicating its possible devulcanization.

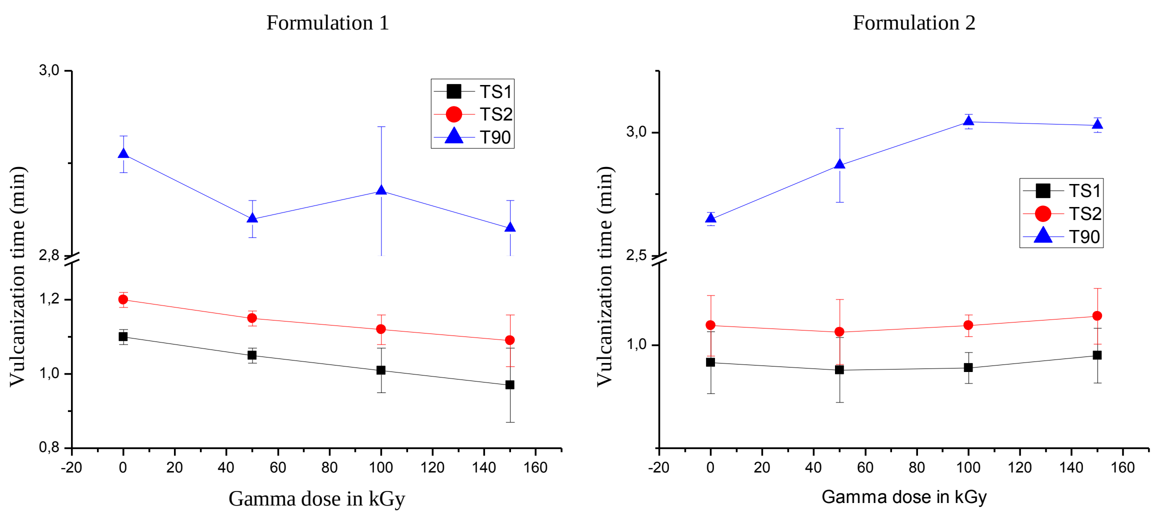

Figure 4: Variation in rheological behavior of formulations 1 and 2.

3. CONCLUSIONS

The mechanical testing suggests that the second formulation (with 50 phr of EPDM master-batch) presents a more satisfactory behavior. The competition occurred under irradiation, between crosslink and degradation maybe taken into account in the material qualification.

All of these analyzes were obtained performed with ionizing radiation, a proper agent for accelerated tests avoiding any chemical agent.

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