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Study on the Effect of Recycled Tyre Rubber Powder on the Mechanical Properties of Carbon Black filled NBR Composites

T.Prabahar[1]
Lecturer, Department of Mechanical Engineering (R&A/C), Valivalam Desikar Polytechnic College (Government Aided), Nagapattinam, Tamilnadu, India.[1]

Abstract: In this work NBR composites reinforced with CB and NBR composites reinforced with both CB and ground tyre rubber (GTR) powder were developed by melt-mixing on a two roll mill. These composites were investigated for their mechanical properties. Results revealed that tensile strength, elongation at break, compression set and abrasion loss of NBR composites were decreased by with the incorporation of GTR powder due to poor NBR-GTR interaction. On the other hand 100% modulus and hardness were improved.
Keywords: NBR, Carbon black, Ground tyre rubber powder, Hardness, Tensile strength and Abrasion loss.

I. Introduction

The environment forms the background and support system on which all life forms sprout and grow. Until recently what affected environment were exclusively the natural phenomena, the complex seasonal changes together with some short-term natural upheavals like cyclones, earthquakes, floods and the like. In recent times, with advances in science and technology, man-made newer and highly versatile materials with attractive properties and almost infinite stability. Synthetic polymers are a class fall under this category. In a very short time, proliferation of these materials into the various aspects of the human life has reached to such an extent that these form one of the biggest threat to environment, as the nature meet its limited resources failed to absorb the accumulated waste from these materials. Discarded and scrap tyres and other rubber products prepared from different elastomers contribute one of the larger source of pollution and calls for urgent remedial action. According to recent estimates the world's rubber scrap amount to 10 million tons. Among the scrap rubber, used and scraped tyres form a major chunk. Disposal of rubber wastes is a worldwide problem.

A potential solution of this disposal problem is recycling of the waste and reusing it in rubber formulations.

Although thermoplastic wastes can be recycled easily, recycling of waste rubbers is not so easy, as they are cross-linked and not biodegradable. The main source of rubber waste is worn tires. To eliminate or reduce waste rubber from the environment and to reduce costs of some rubber goods, attempts are being made to reuse waste rubber. There are two main ways to reuse or to consume waste rubber namely e incineration or pyrolytic degradation of waste rubber to basic chemicals and grinding the waste rubber to form a granulate or regenerate, both of which are used in the production of technically less demanding rubber goods by mixing the rubber powder with a new rubber[1–5]. Worn tires can be shredded and transformed into powder of desired particle size by different techniques.[6–8].The rubber powder (RP) can be used as either asphalt modifier [9] toughening agent in thermoplastics and thermosets [10–12] or as extender/filler in rubber compounds[13–17]. The aim of this paper was to determine the reinforcing effect of Ground tyre rubber powder on the mechanical properties of carbon black filled nitrile rubber compounds.

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II. EXPERIMENTAL

Materials

NBR with Mooney viscosity (ML (1+4) at 100°C) of 60 Mooney unit supplied by Ramcharan rubber chemical, India is used as the matrix. Carbon black, Zinc oxide, Stearic acid, Sulphur, Paraffin oil, Tetramethylthiuram disulphide and 2-Mercapto benzathiazole of industrial grade are supplied by Ramcharan chemicals, Chennai, India and used as received.

Preparation of NBR composites

The NBR compounds were prepared by melt-mixing on a laboratory sized open two roll mill (160 mm X 320 mm) at room temperature and at a speed ratio of 1:1.4 as per ASTM D3182. The compound recipe for NBR composites is given in Table 1. Processing aids and rubber are first blended. Then GTR, CB and curatives are added orderly. The samples are then cured at 160° C in an electrically heated hydraulic press for their respective cure times (t_{90}) determined from oscillatory disk rheometer measurements.

Mechanical properties

A. Tensile properties

Dumbbell shaped samples are cut from compression moulded sheets according to ASTM D412 for tensile testing. The tests were conducted according to ASTM D-624. on a universal testing machine (Dak system Inc.,7200) at a crosshead speed of 500mm/min. Five samples are taken for each compound and their averages were reported.

B. Compression set

Evaluation of compression set is technically useful for a vulcanised rubber. The compression set at constant strain was determined by compressing to a fixed percentage of the original thickness by clamping the test specimen in between rigid parallel plates using standard spacers. Compression set at constant strain was measured according to ASTM D395-86 method B. Samples with 6.25 mm thickness and 18mm diameter were compressed to constant strain (25%) and kept for 22 hours in an air oven at 70°C. At the end of the test period, the test specimens were taken out, cooled to room temperature and the final thickness was measured. The compression set in percentage was calculated as follows.

$$\text{Compression set} = \frac{Ti - Tf}{Ti - Ts} \times 100$$

T_i and T_f are the initial and final thickness of the specimen and Ts is the thickness of the spacer used.

C. Hardness

Hardness is determined using shore. A hardness durometer according to ASTM D2240.

D. Abrasion loss

Abrasion resistance of the samples were measured using a DIN abrader based on DIN 53516. Samples having a diameter of 12 ± 0.2 mm and a thickness of 16-20 mm were placed on a rotating holder and a load of ION was applied. A pre run was given for conditioning the sample and the sample weight was taken. Weight after the test was also noted. The difference in weight is the weight loss of the test piece after it has travelled through 40 m on a standard abrasive surface. The results were expressed as volume loss per hour. The abrasion loss was calculated as follows.

$$V = \frac{\Delta M}{\rho} \times 27.27$$

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Where ΔM = mass loss, ρ = density of the sample and V = abrasion loss in cm^3/hr.

III. Results And Discussion

Table 1. Formulation of NBR composites (Phr).

Ingredients (Phr)	NBR-CB	NBR-CB-GTR
NBR	100	100
GTR	0	20
CB	30	30
ZnO	5	5
Stearic acid	1	1
DOP	6	6
Sulphur	1.5	1.5
MBTS	0.15	0.15
TMTD	0.15	0.15

A. Tensile properties

Figure.1. Tensile strength of NBR composites.

The tensile properties of NBR-CB and NBR-CB-GTR composites are shown in figure. Examination of data presented in Figure 1, it is apparent the tensile strength decrease by % 31.53 with the addition of GTR powder in the NBR matrix. This reduction in tensile strength is attributed to (i) poor CB-NBR interactions and (ii) poor NBR-GTR interactions.

Figure.2. Elongation at break of NBR composites.

Further it is evident from Figure 2, elongation at break of NBR-CB-GTR composites decreases by 8.30 % with the incorporation of GTR powder in comparison to CB filled NBR composites..This is attributed to poor interfacial adhesion between the NBR matrix and the GTR powder.

Figure 3. 100% modulus of NBR composites.

Fig 3 presents the 100 % modulus loading of NBR-CB and NBR-CB-GTR composites. From the Fig it is evident that 100% modulus of the NBR-CB-GTR composites is 4.65% high compared to the NBR-CB composites. This is due to the presence of (about 30 %)

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carbon black in the GTR. CB which is produced largely from oil, consists of irregular, branched aggregates of firmly fused nodular subunits. The dispersed carbon black agglomerates form a network themselves in the polymeric media. With increasing GTR content, CB content available in the matrix also increase. As a result, the network chains become shorter and the number of entanglements between two crosslinks decreases. Single molecules are likely to adsorb on several carbon black surface sites, so the bound rubber is essentially immobile .Hence a higher strength will be needed to deform compounds filled with CB which resulting in higher tensile modulus.

B. Compression set

Figure 4. Compression set of NBR composites.

Compression set of NBR composites increases with the incorporation of the GTR loading in NBR as shown in Fig 4. This marked increase in the compression set value may be the resulting from the combined effect of filler, plasticizer and elevated temperature, all of which reduce the elasticity of the matrix. Low elastic matrices facilitate irreversible flow under stress, resulting in higher set values [18].

C. Hardness

Figure 5. Hardness (Shore A) of NBR composites.

Hardness of NBR composites are presented in Fig. 5. Hardness of the NBR composites increase with the addition of GTR loading in NBR matrix Such an improvement in hardness due to the presence of cross linked precursors and fillers in the GTR.

D. Abrasion loss

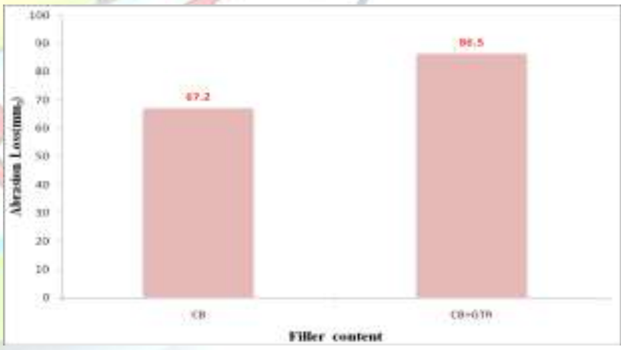

Figure 6. Abrasion loss of NBR composites.

Figure 6 displays the abrasion loss of NBR–CB and NBR-CB-GTR composites. Abrasion loss of NBR-CB composite is 67.2 mm $^{3.}$ This abrasion loss increases to 86.5 mm^3 for the NBR-CB-GTR composite. This is attributed to the poor strength and low molecular weight of GTR. . Consequently abrasion loss of NBR-CB-GTR compounds increase reflecting poor abrasion resistance [18].

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IV. Conclusion

The following conclusions are derived based on the experimental works carried on NBR-CB-GTR composites.

1. Tensile strength of NBR composites decreases by 31.53% with the incorporation of GTR powder in NBR matrix.
2. The elongation at break of NBR composites decreases by 8.30% with the inclusion of GTR powder in NBR matrix.
3. 100% modulus of NBR composites decreases by 4.65% with the inclusion of GTR powder in NBR matrix.
4. Abrasion loss of NBR composites is worsened by 28.72% % with the inclusion of GTR powder in NBR matrix.
5. Hardness of NBR composites is increased and % compression set is decreased with the inclusion of GTR powder in NBR matrix.

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