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Enhancement of Mechanical Properties and Handling Characteristic of Tire Rubber Using Different Percentage of Nano Aluminum Oxide and Carbon Black

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ABSTRACT

Rubber based composites are widely used especially in transportation. The goal of the this paper is to study mechanical properties and handling characteristics of rubber based composites of carbon black and Nano Alumina additive (50 nm), then select an optimal composition, then study the effect of adding particle on the cornering stiffness. Carbon black increased mechanical properties and enhanced the handling characteristics as well as Nano Alumina. The wear rate decreased rapidly with increasing nano filler percentage. Post UV (345 nm) laser vulcanization shows improvement in mechanical properties. The optimum values for composite rubber were (2.5% Nano Al_2O_3 and 60 phr Carbon Black) which gave 800 %, decreasing in wear rate and slipping as well as an increasing about 22% in cornering stiffness of rubber composite, while slight increasing was carried out in hardness of the same composite rubber.

Keywords: Rubber Composites, Nano Composite, Cornering Stiffness.

1. INTRODUCTION

Rubber is used widely in many industrial and domestic applications such as road tires, belts, dash ports, etc. Rubber usually used in the form of composite materials. Many researchers work on rubber composite enhancements. Ling Yang *et al.* [1] combined PVC and silicone rubber with Nano $CaCO_3$ to improve its mechanical properties. Huang Ying *et al.* [2] studied the influence of adding nano-SiO_2 materials on the electrical and mechanical properties of rubber based composite for certain application. Ali Samadi [3] studied nano clay effect on mechanical and physical properties of rubber.

Bharat Bhushan [4]. They found that the addition of some particles of nano clay to 20 phr N550 carbon black increase tensile strength about 53%. Comparing between three different carbon black grades (N330, N550, and N660) the results show that the use of N550 provide the optimum nanocaly effects. Kaushik *et al.* [5] studied the effect of carbon black particles with different percentage on NR/BR/HSR rubbers. It is observed that the carbon black particles improve the abrasion resistance of the composite. On the other hand the results show that the size of carbon black particles has a major effect on strength, with the decreasing in particle size the strength of the composite increased. Ramin zafarmehrabian *et al.* [6] studied the effect of different percentage of

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silica/carbon black added to rubber on dynamic properties of track tires. The result shows a significant improvement in fatigue life and fatigue resistance as well as improvement in rolling resistance and decrease heat buildup. Meng-jiao Wang *et al.* [7] studies the effect of adding different weight ratio of silica particles to rubber such as S-SBR, BR and IR. The results show that the obtained rubber composites have better wear resistance. Goran S. Vorotovic *et al.* [8] made a mathematical model for a real vehicle in order to obtain the effect of slip angle on the cornering stiffness. The model shows that the decreasing in slip angle leads to increase in cornering stiffness.

Fillers contains such as for tires applications. Mostly filler used is in carbon black, with other aided contains. Carbon black gives generally good mechanical properties, as well as it is considerably cheap [9]. One of the most important factors that effected on tire properties was the particle size of carbon black, many research focused on the effect of nano particles used as a reinforcement material to tires in order to enhance the mechanical properties. Nanomaterials are more effective reinforce- ments because smaller fraction of nanomaterials causes a significant improvement of the matrix properties, leading to lightweight composites with lower cost and easy process ability, The load transfer from the matrix to the reinforcements is more efficient in case of nano-composites due to their increased surface area, assuming good adhesion at the interface, the crack propagation length at the interface becomes longer because of the size reduction of nano-materials, which improves both strength and toughness [10].

Nano-materials were used in the present work as additive to the rubber recipe, as well as enhancing the mechanical properties of the composite.

2. EXPERIMENTAL WORKS

2.1 Preparing Samples

The rubber compounds used in this work were prepared from natural rubber (SMR-20); The recipes with other compounding materials such as filler; vulcanizing agent (sulfur) and accelerator were prepared with the compound formulations as shown in table (1).

Table 1 Recipe of rubber composite

Material	phr
SMR 20	100
Zinc oxide	5
Stearic acid	2
Paraffin wax	1
Process oil	8
Carbon black	20 , 40 & 60
Sulphur	2.2

The standard vulcanization process for all samples implied that the vulcanization press was primarily heated by using electrical source between (30 to 200±1oC); mold brought to handling temperature within (±1°C) in the closed press, The un-vulcanized pieces were inserted after holding mold at least 20 min at these temperature [11]. To verify the mold temperature; a thermocouple was used for this purpose by insert it in one of the overflow grooves to ensure contact with the mold, after that the press should be opened and the uncured rubber composite insert inside the mold and then necessary to close the press very fast, in minimum time possible and insuring moderate time of temperature loss [12].

The experimental samples categorized into three groups, first one is a rubber composite of the different carbon black phr (20, 40, and 60). The second group of nano rubber composite of different Nano alumina (50 nm) of wetting percentage (1%, 1.5%, 2%, and 2.5%) respectively. The third group represents the optimal combination of the previous two classes with different energy irradiance of dispersed ultraviolet laser after vulcanization process. The third harmonic generation of Nd-YAG laser, of 1064 nm. To scan large areas by pulsed laser beam, the partial overlapping method can be used. The overlapping percentage can be calculated according to the relation [13, 14].

$$\%\,Overlap = \left(1 - {d_c}/{2r_f}\right) * 100\% \quad (1)$$

where (*rf*) is radius of the spot, (*dc*) center to center spacing; The overlapping percent has been used in this work 25%. The energy of the third harmonic pulsed laser (345 *nm*) was 30 mJ of 30μs plus duration. Spot size was 3.5 mm. The entire area was pulsed (0, 1, 2, 3, 4) times.

2.2 Mechanical Tests

2.2.1 Hardness and Adhesion Test

In this work the hardness is performed by using two different measurements shore (A) according to ASTM D 2240. Five measurements of hardness were made at different positions on the specimens, let H_1, H_2 … , H_5 be the values of the measured hardness arranged in increasing order of magnitude. The mean hardness value of the five measurements H is defined as follows:

$$H = \frac{1}{5}\sum_{i=1}^{5} H_i \quad (2)$$

The specimen thickness most be more than 6 mm, and the measurement should be done on a flat surface, and specimen lateral dimension should be suitable to permit measurements as passable about 12 mm from the edges.

2.2.2 Abrasion Wear Resistance: Wear and slipping Test

A compatible ASTM apparatus was used to measure weight method wear. Wear specimen was ASTM G99. Wear rate was calculated using weighting method.

3. RESULTS

3.1 Hardness and Adhesion Tests

Hardness and adhesion results of rubber composite with various phr of carbon black and for rubber composite with nano Al2O3, and Nano filler laser aided volcanized rubber composites of various laser pulse are shown in the figures (1), (2) and (3) respectively.

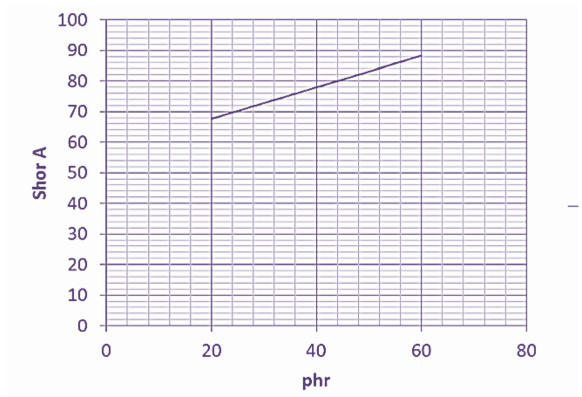

Figure 1. Shor a hardness and adhesion for carbon black rubber composite.

Fig.(1) shows increasing in hardness by about 52% due to additive 60 phr carbon black only to rubber paste which is improved this property compared with rubber only.

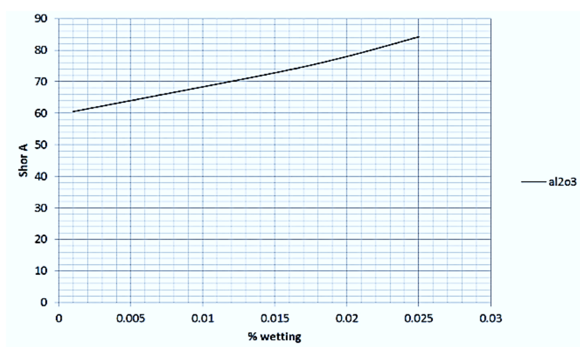

Figure 2. Shor A hardness and adhesion of rubber composite for Nano Al_2O_3.

It can be observed from Figure (2), that enhancement in hardness of rubber tire was 44%due to mixing 2.5% of nano Al_2O_3.

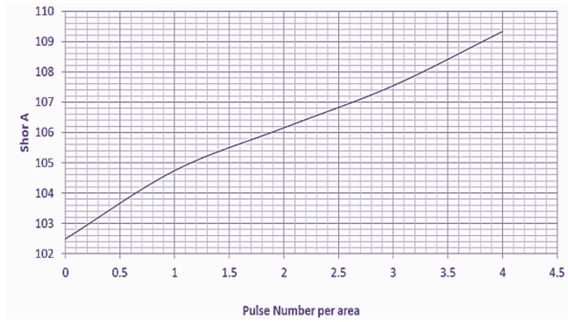

Figure 3. Shor A hardness and adhesion of rubber composite with road for Nano Al_2O_3 (2.5%) carbon black (60 phr) of various laser pulse exposures.

The results show that the hardness enhanced with increasing filler percentage. The optimum values for composite rubber are about (2.5% Nano Al_2O_3 and 60 phr Carbon Black). Figure (3) shows when two materials (Al_2O_3 and carbon black) are added to rubber paste, it is clear from figure that an enhancement achieved in wear resistance about (77% - 88%) due to pulse per unit area (0-4) respectively compared with rubber without any reinforcement.

3.2 Wear and Slipping Test

Wear and slipping tests results of rubber composite with various phr of carbon black and for of rubber composite of Nano filler volcanized rubber composites and for rubber with road of Nano filler laser aided volcanized rubber composites of various laser pulse shown in figures (4), (5) and (6) respectively.

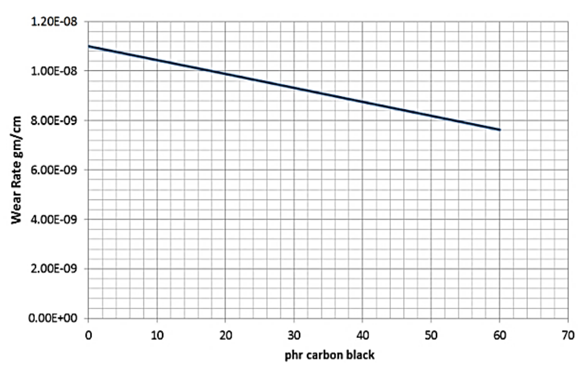

Figure 4. Wear and slipping of rubber composite tests of Carbon black.

Figure (4) displays a decreasing 41% in wear rate due to mixing 60 phr carbon black compared with rubber without any composite material, which enhancement in wear resistance of the tire.

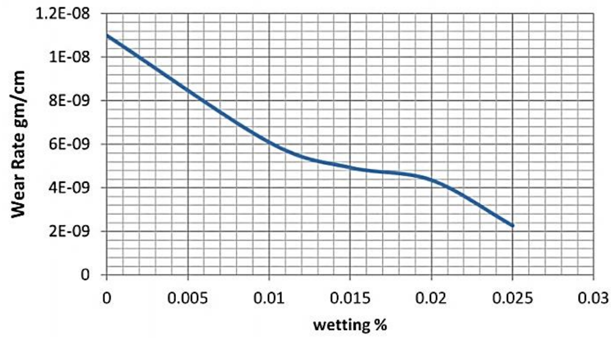

Figure 5. Wear and slipping of rubber composite tests of Nano Al_2O_3.

It is clear from Figure (5) that an enhancement in wear rate was (378%) due to addition 2.5% nano Al_2O_3 only.

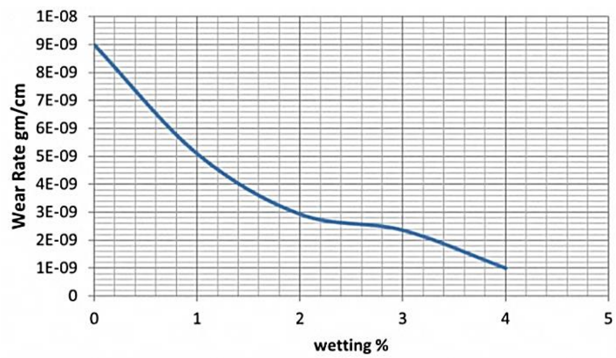

Figure 6. Wear rate and slipping of rubber composite tests of Nano Al_2O_3 (2.5%) carbon black (60 phr) of various laser pulse exposures.

While fig.(6) illustrates that the wear rate decrease with the increasing in reinforcement materials of the rubber composite due to the addition of 2.5% Nano Al_2O_3 and 60 phr Carbon Black which leads to enhance the wear resistance by 800% as shown in Figure (6).

3.3 Cornering Stiffness Test

Figure (7) indicates the relationship between the applied load (N) and the slip angle (α) in degree.

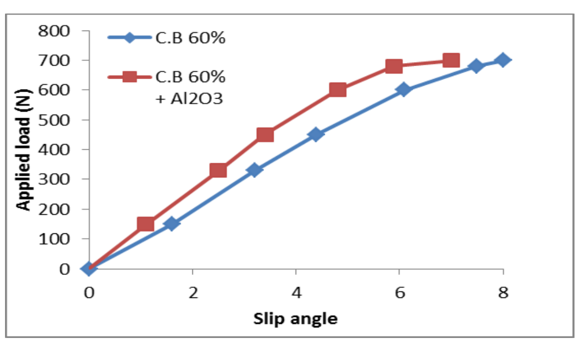

Figure 7. The relationship between the applied load (N) and the slip angle (α) in degree.

Form figure (7) it can be observed that the addition of (2.5 %) nano Al_2O_3 with carbon black (60 phr) leads to increase the cornering stiffness of tire by 22% in comparison with carbon black (60 phr) only due to decreasing in slip angle (α). A similar behavior was seen by Goran S. Vorotovic *et al.*. **[8]**, a linear relationship appeared between the applied load and slip angle when the slip angle less than 8º.

The enhancements have been achieved in hardness, wear rate and cornering stiffness due to the high strength of new composite materials (Al_2O_3 and carbon black), it is clear that nano filler have a greater effect when mixed with carbon black with rubber paste.

4. CONCLUSIONS

From the above results it can be concluded that:

i. Adding carbon black only with rubber leads to the enhancement in hardness a little more than the addition of Al_2O_3 nano metal.
ii. When the two materials (carbon black and Al_2O_3 nano metal) are added together to the rubber paste lead to an improvement in hardness higher approximately two times comparison with addition each of the materials alone to rubber paste.
iii. The addition of Al_2O_3 nano metal alone to rubber paste leads to an improvement in the wear resistance up to nine times more compared to the addition of carbon black alone to the rubber paste.
iv. The amount of enhancement in wear resistance is about 19.5 times higher due to the addition of two materials (carbon black and Al_2O_3 nano metal) than the addition carbon black only to rubber paste.
v. the cornering stiffness of tire increased with the addition of nano Al_2O_3 with carbon black (60 phr).

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