Investigation of the physical abrasion of ternary polymer reinforced with nanoparticles used in medical applications

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Abstract: Nanocomposites are one of the most important polymeric materials that exhibit excellent biological, physical, chemical and thermal properties. Rubber based nanocomposites is one of the mast interesting field in the literatures and material science. The abrasion properties of ternary nanocomposites based on Styrene Butadiene rubber have been investigated with presence of nano aluminum oxide. The nanocomposites have been prepared by mechanical blending using two roll mills. Nano Aluminum oxide particles have been added to Styrene Butadiene rubber / Phenolic Resin binder and the abrasion properties have been surveyed. Results showed that the nano Aluminum oxide particles could enhance the abrasion resistance of matrix due to abrasive properties of nano Aluminum oxide particles. In order to better understanding the behavior of the material, optical microscopic observation and scanning electron microscopic pictures hve been conducted in this investigation that the obtained results revealed the presence of this phenomenon in abrasion properties of the ternary nanocomposite polymeric samples.

[Maryam K Hafshejani, Mehdi Khazaei and Ameneh Langari. **Investigation of the physical abrasion of ternary polymer reinforced with nanoparticles used in medical applications**. *Life Sci J* 2013;10(4):3601-3605]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 481

Keywords: Polymer matrix nanocomposites; nano-scale material; Abrasion characteristics; Butadiene rubber; phenolic, Reinforcement.

1. Introduction

With recent development in health science and medical developments, need for new materials with high reliability and performance is increased. New development in manufacturing health and medical devices require new materials. Polymeric materials such as rubbers and elastomers are used as common constructive materials in many health applications i.e. manufacturing medical equipment etc.. Specially, polymers are used as the composite matrix in composite materials. Composite materials are one of the main branches of science that nearly started at about half century ago. In these high performance materials, a combination of some reinforcement parts and matrix part forms a new composite material with excellent new physical and mechanical properties [1-6].

The commercial importance of polymers has been driving intense applications in the form of composites in various fields. In these materials, based on the size of fillers, there are some categories of these composites. If the size of fillers to the polymeric based composites is less than 100 nm, this category of composites named nanocomposites. It is well established that the nanocomposites based on polymeric materials have been attracted in recent years [7-11].

Nanostructured materials gained great importance in the past decade on account of their wide range of potential applications in many areas. Polymer nanocomposites represent an alternative to macroscopically filled polymers. Because of their nanometer size of particles, the nanocomposites exhibit markedly improved properties when compared with the pure polymers or conventional composites. These include increased modulus and strength, decreased gas permeability, increased solvent and heat resistance. In addition to their potential applications, polymer based nanocomposites are also unique model systems to study the structure and dynamic behaviors of polymer materials in confined environments [12-16].

In the composite materials, combination of the properties of each ingredient caused the good performance of the final composed material. Moreover, for enhancing composite properties, reinforcing fillers can be added to composites. Among the reinforcing fillers, nano materials have been attended in recent years [17-19].

Nano materials are special effects on the composite materials due to their nano size. Nano size of these reinforcing fillers cause more surface area. Effective surface area of filler leads to good interactions with matrix. Therefore nanomaterials are used as the reinforcement in many researches by the previous investigators [20, 21].

Acrylonitrile butadiene rubber (NBR) is one of the most applicant rubbers that could be used in the industrial and laboratory applications. Acrylonitrile butadiene rubber could be used as the main matrix for composites materials. It should be noted that NBR is attended for their good physical and mechanical properties like proper processing conditions, good flexibility and suitable damping properties.

Combination of two polymers as the matrix is one of the subject that attracted in recent years. In literature, the two parts matrix composing thermoplastic or thermoset have been used. Among two parts matrix, rubber and resin combination matrix is prepared in some works for their expletive properties. Bonnia and his coworkers prepared the Natural rubber / polyester nanocomposites with nanoclay [22]. In the other work, Boukerrou and his coworkers worked on the rubbery epoxy resin with organoclay [23]. They reported morphological, mechanical and viscoelastic properties of this ternary nanocomposite and showed that the good dispersion of nanoclay particles in the rubbery epoxy resin matrix.

Moreover improvement of mechanical properties with addition of nanoclay has been reported by previous researchers. Zhao and et. al. investigated on the hindered phenol and acrylonitrile butadiene rubber compounds [24]. They reported that this combination could be used as a high performance damping material.

In this work, we investigated on the abrasion properties of two parts matrix nanocomposites composed of styrene butadiene rubber (SBR) and Phenolic resin (PR) in the presence of nano aluminum oxides. In the literature investigation on the wear properties of two parts matrix have been confined. Yu and coworkers prepared the nanorubber particles for improving the wear properties of epoxy resin [25]. They mixed ingredients by mechanical mixing and reported the sliding wear properties by block-on-wheel friction and wear tester. These researchers have reported that the specific wear rate of epoxy have been decreased with addition of nano-sized rubber particles.

But please note that in our work, the influence of nano particles of nano aluminum oxide have been investigated on the abrasion content of Styrene Butadiene rubber / Phenolic Resin compounds. For more investigation on the wear properties of these composite samples, the optical microscopic images and the scanning electron microscopic (SEM) pictures are used.

2. Experiments

Materials

Styrene Butadiene Rubber (SBR) has been used as main part of matrix of nanocomposites is Styrene Butadiene rubber with 1502 code which produced by Jilin Rubber Co. Ltd. China. Styrene content is 22.5% and Rubber Mooney viscosity ML (1+4)100°C.

The phenolic resin was a typical novolac phenolic resin (Bakelite, originally developed by Bakelite Inc.). The resin is cured by HMTA (Hexamethylenetetramine).

Sulfur, ZnO, stearic acid and N-cyclohexyl-2-benzothiazyl sulphenamide (CBS) is composing the curing system. Sulfur and Zinc Oxide is the main part of curing system.

Two other parts are comprised stearic acid as activator and CBS as accelerator. The curing system was prepared by local company.

Nano aluminum oxide was with mean particle size of 30 nm and specific surface area 38 m2/g. The shape of nano oxide particles is spherical and their density and purity is 5.2 g/cm3 and 99% respectively.

Sample preparation

Sample preparation was done by two roll mills method. In the first stage, styrene butadiene rubber passes through two roll mills for some minutes which named mastication.

Mastication process is diminishing the viscosity of rubbers like styrene butadiene rubber which caused better condition for dispersion of particles. The mastication stage has been last for 5 minutes. After mastication stage, Phenolic Resin (PR) powders have been added to styrene butadiene rubber paste gradually. It lasted for about 2 minutes for get good combination of Styrene Butadiene rubber with phenolic resin. After that, nano Aluminum oxide were gradually incorporated to SBR / PR compound. Then curing system well mixed with each other except sulfur and added to SBR / PR paste. Sulfur is added to paste as the last ingredient for inhibiting the occurrence of soon cross linking reaction. After finishing the incorporation stage, the paste is passed thought the two roll mills for better distribution of nano aluminum oxide at styrene butadiene rubber / Phenolic resin matrix.

The resultant sample was prepared for curing stage. The paste was cured for 40 minutes at 140°C. After curing, compounds were post cured for about 4 hours. The formulation of compounds is shown in table 1 based on one hundred parts of SBR. The Phenolic resin has been added constant in 10 phr.

Table 1: Formulation of compounds based on phr of SBR.

Sample code	SBR	PR	Nano-filler	Sulfur	ZnO	Stearic acid	CBS
SR	100	10	0	2	4	2	1
SR-0.25C	100	10	0.25	2	4	2	1
SR-0.5C	100	10	0.5	2	4	2	1
SR-0.75C	100	10	0.75	2	4	2	1

Characterization

In the characterization section, abrasion test and microscopic observations have been used. The abrasion test was done with the DIN abrader according to DIN 53516. The cylindrical sample, 16 mm in diameter and 10 mm in height, was contacted with the abrasive surface of a rotating drum under 1 N load. The direction of abrasion changed continuously through the rotation of the specimen on its own axis while it underwent abrasion. After finishing abrasion path, sample was weighted by 0.001 balance tools. The abrasion was defined as a volumetric loss of a cylindrical nanocomposite sample. For better understanding the results of abrasion test, Optical observations have been used to survey the abraded surfaces. The optical microscope that used is Olympus bx51m which was produced by Japan. The microscope is connected to computer for saving the pictures. Moreover, scanning electron microscope or SEM pictures were captured from abraded surfaces. Field emission SEM is used that captured better pictures from abraded surface. SEM tool that used is TESCAN MIRA LM by USA. The picture was photograph at 15 KV.

3. Results and discussion

In table 2, abrasion test results of SBR/PR/Al2O3 nanocomposites have been shown. The densities of compounds have been measured by weighting of samples in air and in water. The density is defined by difference of these two weight to weight in air of samples. As it could be seen, with addition of nano Aluminum oxide to styrene butadiene rubber / phenolic resin compounds, the sample densities has been increased. With addition of 0.75 phr of nano aluminum oxide particles to Styrene Butadiene rubber / Phenolic resin compounds, about four percent increase in density have been shown compare to Styrene Butadiene rubber / phenolic resin base sample (SR) density.

This addition in density is duo to nano aluminum oxide particles' densities which is greater than density of both Styrene Butadiene rubber and Phenolic resin. Abrasion results show that the content of abrasion of Styrene Butadiene rubber / Phenolic resin base sample (SR) is equivalent. This content of abrasion of base sample is lower that styrene butadiene rubber sample abrasion which reported in the literature [26]. This increase in abrasion content in base styrene butadiene rubber / phenolic resin is duo to the presence of the phenolic resin.

Phenolic resin has low abrasion resistance comparing to styrene butadiene rubber and caused to decrease abrasion content of base sample (SR) in comparison with Styrene butadiene rubber based compound. Although in the literatures, there is no a research paper about abrasion properties of Styrene Butadiene rubber / Phenolic resin compounds for comparison. Moreover, with addition of nano Aluminum oxide particles, abrasion content of compound have been decreased. As it could be seen in table 2, with addition of just 0.25 phr nano Aluminum oxide to styrene Butadiene rubber / Phenolic resin compound, the abrasion content decreases. Most decrease in the measured abrasion content of the samples could be seen in SR-0.75C with 0.75 phr nano Aluminum oxide that is measured as about 360 mm3. In this sample decrease in abrasion content is about 13% comparing to base sample SR. this decrease in abrasion with presence of nano Aluminum oxide may be duo to good interaction between nano Aluminum oxide and the matrix of nanocomposites.

Nano Aluminum oxide as stiff particles caused better physical and mechanical properties of Styrene Butadiene rubber or Phenolic resin. This improvement could causes good homogeneity of rubber / resin matrix and leads to small particles in abrasion surface. For better understanding the reason of decrease in abrasion content of Styrene Butadiene rubber / Phenolic resin with presence of nano Aluminum oxide, scanning electron microscopic picture have been captured from abraded surface.

In figure 1, the SEM image of abraded surface of base sample (SR) and SR-0.75C compound which has 0.75 phr nano Aluminum oxide has been observed. As it could be seen there are more cavities on the abrasion surface of base sample in comparison with SR-0.75C compounds. Moreover the rougher surface could be seen in abraded surface of Styrene Butadiene rubber base sample. This observation is in agreement with the abrasion test results.

Table 2. Densities and Abrasion contents of SBR/PR/Al2O3 nanocomposites.

Sample	Δm (mg)	Δv (mm^3)
SR	402	400
SR-0.25C	398	381
SR-0.5C	380	374
SR-0.75C	365	342

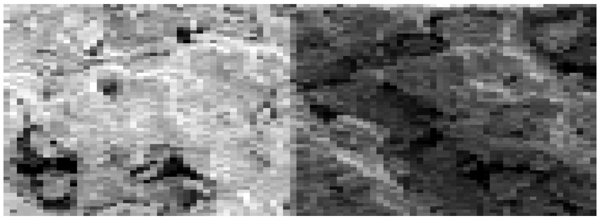

Fig. 1. SEM image from abraded surface of base sample SR (left picture) and SR-0.75C (right picture).

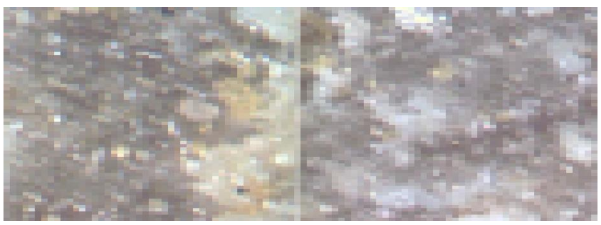

Fig. 2. Optical microscopic pictures from abraded surface of base sample SR (left) and SR-0. 5C (right).

Beside the SEM image from abraded surface of nanocomposites, the optical microscopic pictures have been captured from abrasion surface of rubber/resin/nano Aluminum oxide nanocomposites. In figure 2, optical graph from abraded surface of base sample Styrene Butadiene rubber / Phenolic resin Compound (SR) and SR-0.5C compound which has 0.5 phr nano aluminum oxide have been brought.

Similar to SEM image, there is rough surface on the abrasion surface of Styrene Butadiene rubber base sample. Meanwhile, in SR-0.5C, the abraded surface is softer that the abraded surface of base sample. It supports the abrasion results of SR based nanocomposites.

4. Conclusions

Styrene Butadiene rubber based compounds with and without nano aluminum oxides particles have been prepared successfully. For preparation of rubber / resin based nanocomposites, mechanical blending using two roll mills method has been selected. For abrasion results DIN abrader machine have been used. The abrasion content is higher than abrasion content of Styrene Butadiene rubber base compound. It showed that Phenolic resin caused to increase of abrasion content of Styrene Butadiene rubber samples. Moreover, with addition of nano aluminum oxides to Styrene Butadiene rubber / Phenolic resin sample, abrasion content of samples decreased. The lowest abrasion content was observed in SR-0.75C compounds which have 0.75 phr nano particles. It may be duo to good influence of nano Aluminum oxide on the mechanical and physical properties of Styrene Butadiene rubber and Phenolic resin simultaneously. SEM and optical graph observations is in accordance with abrasion results. In SR/C nanocomposite compounds more soft particles or smaller debris observed in the abraded surface.

Acknowledgments

Authors thank Mr Ovji for his useful suggestions.

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12/12/2013