Investigation of the physical abrasion of rubber polymer reinforced with nanoparticles used in fabrication of medical devices

Maryam K Hafshejani[1], Mehdi Khazaei[2], Ameneh Langari[3*]

[1] Shahrekord University of Medical Sciences, Shahrekord, Iran
[2] Bushehr University of Medical Sciences, Bushehr, Iran
[3] North Khorasan University of Medical Sciences, Bojnurd, Iran
Email: amenehlangari@yahoo.com

Abstract: With recent development in nanotechnology, nanocomposite materials have become of the most important polymeric materials which exhibit excellent biological, physical, chemical and thermal properties. Rubber based nanocomposites is one of the mast interesting field in the literatures and material science. In this paper preparation and characterization of rubber/ resin with nano iron oxide has been done. Two roll mills method have been used for mixing compounds. This route of mixing has been attracted in recent years especially for rubber and resin based nanocomposites. Effect of nano iron oxide on the abrasion properties of compounds has been investigated. The results show that with addition of nano iron oxide to acrylonitrile butadiene rubber / resin matrix, abrasion content of compounds has been decreased. Moreover the scanning electron microscopy and optical microscopy images have been used for better recognition of abrasion manner of compounds.
[Maryam K Hafshejani, Mehdi Khazaei and Ameneh Langari. **Investigation of the physical abrasion of rubber polymer reinforced with nanoparticles used in fabrication of medical devices**. *Life Sci J* 2013;10(4):3606-3610]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 482

Keywords: Natural butadiene rubber; Polymer matrix nanocomposites; Abrasion characteristics; Reinforcement; Nano-scale material.

1. Introduction

It is well established that fabrication and development of 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, medical and mechanical properties [1-6]. 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 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 [7-9].

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 [10,11].In middle of twenty century, composite materials have been attracted by researchers. Composite materials include two main part which named matrix and reinforcement. Micro composites materials were reinforced with micron-sized reinforcements. Recently, processing techniques have been developed to allow the size of inclusions to go down to nanoscale. For this work, the nano-sized inclusions are defined as those that have at least one dimension in the range 1–100 nm.

Experiments have shown that nanoscale reinforcement brings new phenomena, which contribute to material properties. When the diameters of particles are shrunk from micrometers to submicrons or nanometers, there appear several amazing characteristics such as very large surface area to volume ratio, flexibility in surface functionalities, superior mechanical performance, barrier properties and other one compared with any other known form of the polymeric material [12-17]. 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 dynamics of polymers in confined environments [18-22]. 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. In some works, mechanical and physical properties of two parts matrix nanocomposites have been investigated [23,24]. Acrylonitrile Butadiene rubber is one of the main rubber materials which have good properties. In literature, there are various works on the properties of Acrylonitrile Butadiene rubber based nanocomposites. Some researchers worked on the properties of Acrylonitrile Butadiene rubber / nanoclay nanocomposites [25]. They investigated on the mechanical and barrier properties of NBR/OC compounds. They reported that significant improvements in mechanical properties have been observed with the addition of organoclays at both room and elevated temperatures. Using of nano iron oxide in the Acrylonitrile Butadiene rubber based nanocomposites has been less considered in the literatures. In this paper, we investigate on the abrasion properties of Acrylonitrile Butadiene rubber/resin/nano iron oxide nanocomposites. For more survey, the optical and scanning electron microscopic images have been used.

2. Experiments

Materials

Acrylonitrile Butadiene Rubber (NBR) used is Europrene N 3345, acrylonitrile content of 33%, density of 0.98 g/cm3, Mooney viscosity ML(1 + 4) 100 °C of 45 produced by polimeri Europa company Italy. The resin was a typical novolac resin. The resin is cured by HMTA (Hexamethylenetetramine). For enhancement of Acrylonitrile Butadiene Rubber / resin based materials, the nano iron oxide (Fe_2O_3) has been used. Nano iron oxide with a mean size of 10–30 nm and specific area 35–40 m^2/g was procured from I-CanNano Company in India. Sulfur, ZnO, stearic acid and MBT is formed the curing system. In the curing system, Sulfur and Zinc Oxide is the main part. Two other parts are comprised stearic acid as activator and MBT as accelerator. The curing system was prepared by local company.

Sample preparation

For preparation rubber base nanocomposites, solution and mechanical blending method are two common routes. The Acrylonitrile Butadiene Rubber / resin / nano iron oxide nanocomposite have been prepared by mechanical blending. For this purpose, two roll mills method have been selected. Preparation of rubber based sample by two roll mills method is included three stages which named mastication, incorporation and dispersion. The first stage for preparation is mastication. In mastication stage, rubber is passed from two roll mills for some minutes. This process is caused decrease in rubber viscosity. This decrease in viscosity leads to better dispersion of ingredients in the rubber paste. So, first Acrylonitrile Butadiene Rubber was masticated by two roll mills. Mastication stage has been last for about 3 minutes. Mastication process caused stress on the Acrylonitrile Butadiene Rubber chains and leads to decreasing of molecular weight of NBR compounds. After mastication stage, nano iron oxide powders were gradually incorporated to Acrylonitrile Butadiene Rubber compound. After that curing system was added to compound. Before adding of curing system to rubber paste, the ingredients of curing system were mixed except of sulfur. Sulfur is added to paste as the last ingredient because of soon curing reaction. After finishing the incorporation stage, the paste is mixed for some minutes thought the two roll mills for better distribution of nano iron oxide at Acrylonitrile butadiene rubber / resin matrix. The resultant sample was prepared for curing stage. The cure temperature is 145°C. After curing the compound, post curing reaction was done. The formulation of compounds is shown in table 1.

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

Sample code	NBR	resin	Nano-iron oxide	Sulfur	ZnO	Stearic acid	MBT
NP	100	15	0	3	3	2	2
NP-1Fe	100	15	1	3	3	2	2
NP-1.5Fe	100	15	1.5	3	3	2	2
NP-2Fe	100	15	2	3	3	2	2

Characterization

In the characterization section, abrasion test and morphological observations have been selected.

For abrasion test, the cured Acrylonitrile Butadiene Rubber / nano iron oxide nanocomposites have been tested by abrader machine. The abrasion test of the nanocomposite samples was implemented 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 this pass, sample was separated from tools and weighted.

The mass loss of sample after finishing the abrasion test have been acquired in mg. for change the mass loss to volumetric loss of samples, the densities of compounds have been measured base on ASTM D6683. For better understanding the results of abrasion test, Optical observations have been used. The optical microscope that used is Olympus bx51m which product 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

Abrasion content of compounds has been done by abrader DIN machine. In table 1, abrasion content of Acrylonitrile Butadiene Rubber / resin / nano iron oxide nanocomposites have been shown. As it could be seen, with addition of nano iron oxide to Acrylonitrile Butadiene Rubber / resin matrix, the abrasion content has been decreased. The abrasion content of base sample (NP) is 163 mg. For getting the abrasion content in volumetric loss, the densities of Acrylonitrile Butadiene Rubber / resin / nano iron oxide nanocomposites have been done by weighting in air and in water based on ASTM D6683.

The results of density show that with addition of nano iron oxide to Acrylonitrile Butadiene Rubber samplers, the densities have been increased. This increase is due to presence of nano iron oxide particles and their greater densities compare to Acrylonitrile Butadiene Rubber / resin. With the addition of 2 phr nano iron oxide to Acrylonitrile Butadiene Rubber / resin compounds (NP-2Fe), the density is increase about 4 percent comparing to Acrylonitrile Butadiene Rubber / resin base composite sample (NP). With addition of 1 phr of nano iron oxide to Acrylonitrile Butadiene Rubber resin compounds, the abrasion content is decreased. This content of nano iron oxide (1 phr) leads to about 8 percent decrease in volumetric abrasion content. With addition of nano iron oxide to 2 phr (maximum content of nano iron oxide in this work for NP-2Fe composite compound), the abrasion content is decrease more. In the NP-2Fe compound with 2 phr nano iron oxide, there is about 30 percent decrease in abrasion content.

The most decrease in the abrasion content is observed in the NP-2Fe with the 2 phr nano iron oxide. The decrease in abrasion content with the presence of nano iron oxide in the Acrylonitrile Butadiene Rubber / resin samples is due to more abrasion resistance of these abrasive hard particles nano particles. This nano particles of iron oxide is strength the interaction between Acrylonitrile Butadiene Rubber and resin with each other and with nano iron oxide particles and leads to small particles in the abrasion surface.

Table 1. Abrasion content of NBR/PH/Fe nanocomposites.

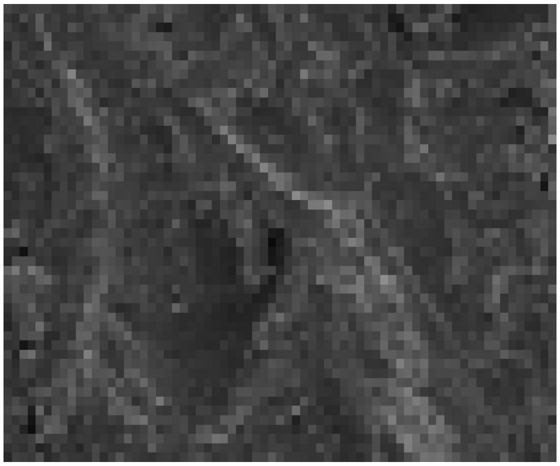
sample	Δm (mg)
NP	145
NP-1F	132
NP-1.5Fe	124
NP-2Fe	98

The morphological observation of abrasion surface of Acrylonitrile Butadiene Rubber / resin / nano iron oxide nanocomposites support the abrasion test results. For more investigation, scanning electron microscopic picture have been carried out from abraded surface.

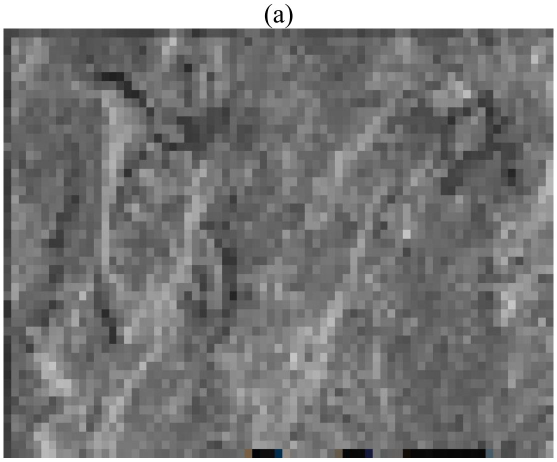
In figure 1, the SEM image of abraded surface of base sample (NP) and NP-2Fe sample has been brought. As it could be seen in this picture, the bigger debris consists on the abrasion surface of base sample compare to NP-2Fe sample. It seems that nano iron oxide leads to decrease the abrasive particles in the contact surface of the samples.

This observation is in accordance with abrasion results.In figure 2, optical microscopic picture from abraded surface of base sample have been shown. As it could be seen there is more sizable debris on the abrasion surface of base samples. It is in accordance with the abrasion results. These bigger debrides is caused to more rough surface in contact between sample and abrader machine and caused more abrasion content.

In figure 3, optical graph from abraded surface of NP-1.5Fe compound with 1.5 phr nano iron oxide have been seen. In optical graph of this sample is observed smooth surface in sample with nano iron oxide. This optical microscopic picture emphasizes the abrasion results. This accordance is also observed in scanning electron microscopic pictures.



(a)



(b)

Fig. 1. SEM image from abraded surface of base sample (NP) (a) and NP-2Fe (b).

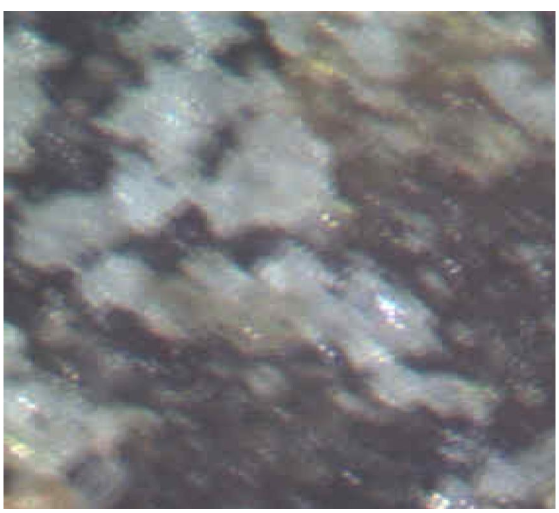


Fig. 2. Optical graph from abrasion surface of base sample (NP).

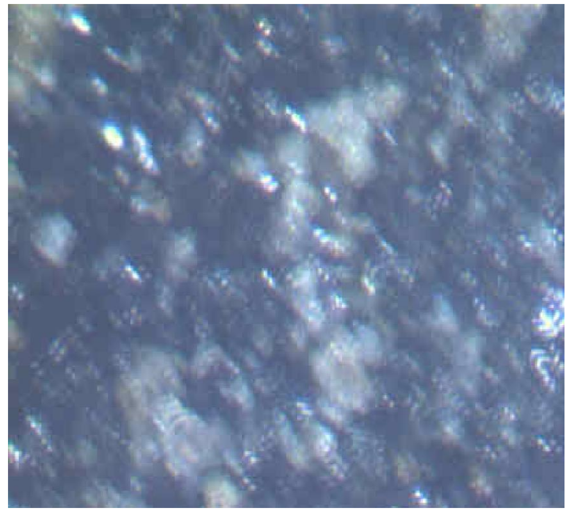


Fig. 3. Optical graph from abrasion surface of NP-1.5Fe compound (with 1.5 phr nano iron oxide).

4. Conclusions

In this paper, abrasion properties of two components matrix including rubber and resin investigated. Acrylonitrile Butadiene rubber / resin based compounds with and without nano iron oxide particles have been prepared by two rolls mills method. Abrasion results by DIN abrader machine have been done. Abrasion results showed that the volumetric mass loss content of Acrylonitrile Butadiene rubber / resin base sample is about 156.6 mm3. Moreover, with addition of nano iron oxides to NBR/PH sample, abrasion content decreased. The lowest abrasion content was observed in NP-2Fe compounds which have 2 phr nano iron oxide particles. The most decrease in abrasion content was observed in NP-2Fe sample with 2 phr nano iron oxide particles and decrease in abrasion is about 30 percent compare to base sample (NP). SEM and optical observations is in accordance with abrasion results. In NBR/PH/Fe nanocomposite compounds smaller particles or debris have been shown in the abraded surface. The optical microscopic and scanning electron microscopic pictures showed that with addition of nano iron oxide the more smooth abrasion surface have been observed.

Acknowledgments

Authors thank Mr Ovji for his useful suggestions.

Corresponding Author:
Ameneh Langari
North Khorasan University of Medical Sciences, Bojnurd, Iran
Email: amenehlangari@yahoo.com

References

1. Abadyan M, Khademi V, Bagheri R, Haddadpour H, Kouchakzadeh M A, Farsadi M. Use of Rubber Modification Technique to Improve Fracture-Resistance of Hoop Wound Composites. Materials and Design 2009; 30: 1976-1984.
2. Abadyan M, Bagheri R, Haddadpour H, Motamedi P. Investigation of the fracture resistance in hoop wound composites modified with two different reactive oligomers. Materials and Design 2009; 30(8):3048-3055.
3. Abadyan M, Bagheri R, Motamedi P, Kouchakzadeh M A, Haddadpour H. Loading rate-induced transition in toughening mechanism of rubber-modified epoxy. Journal of Macromolecular Science Part B 2010; 49:602–614.
4. Abadyan M, Bagheri R, Kouchakzadeh M A. Fracture toughness of a hybrid rubber modified epoxy: Part I. Synergistic toughening. Applied Polymer science 2012; 125(3):2467–2475.
5. Abadyan M, Bagheri R, Kouchakzadeh M A. Fracture toughness of a hybrid rubber modified epoxy: Part II. Effect of loading rate. Applied Polymer science 2012; 125(3):2476–2483.
6. Abadyan M, Bagheri R, Kouchakzadeh M A, Hosseini Kordkheili S A. Exploring the tensile strain energy absorption of hybrid modified epoxies containing soft particles. Materials and Design 2011; 32: 2900–2908.
7. Kazemi A S, Abadyan M, Ketabi S A. Controlled structural and optical properties of ZnO nano-particles. Physica Scripta 2010;82:035801 (9pp).
8. Kazemi A S, Ketabi S A, Bagheri-Mohagheghi M M, Abadyan M. The effect of the activity coefficient on growth control of ZnO nanoparticles. Physica Scripta 2011; 83:015801 (8pp)
9. Kazemi A S, Afzalzadeh R, Abadyan M. Zno nanoparticles as ethanol gas sensors and the effective parameters on their performance. Journal of Material Science and Technology 2013; 29(5): 393–400.
10. Salehi Vaziri H, Abadyan M, Nouri M, Amiri Omaraei I, Sadredini Z, Ebrahimnia M. Investigation of the fracture mechanism and mechanical properties of polystyrene/silica nanocomposite various silica contents. Journal of Materials Science 2011; 46(17):5628-5638.
11. Salehi Vaziri H, Amiri Omaraei I, Abadyan M, Mortezaei M, Yousefi N. Thermophysical and Rheological Behavior of Polystyrene/silica Nanocomposites: investigation of nanoparticle content. Materials and Design 2011; 32:4537–4542.
12. Shakir I, Shahid M, Cherevko S, Chung C H, Kang D J. Ultrahigh-energy and stable supercapacitors based on intertwined porous MoO3–MWCNT nanocomposites. Electrochimica Acta 2011; 58 (30):76-80.
13. Chen N, Wan C, Zhang Y, Zhang Y. Effect of nano-CaCO3 on mechanical properties of PVC and PVC/Blendex blend. Polymer Testing 2004; 23(2):169–174.
14. Huang Z M, Zhang Y Z, Kotaki M, Ramakrishna S. A review on polymer nanofibers by electrospinning and their applications in nanocomposites. Composites Science and Technology 2003; 63:2223–2253.
15. Asif A, Rao V L, Ninan K N. Preparation, characterization, thermo-mechanical, and barrier properties of exfoliated thermoplastic toughened epoxy clay ternary nanocomposites. Polymers for Advanced Technologies 2011; 22 (4):437-447.
16. Koo C M, Ham H T, Choi M H, Kim S O, Chung I J. Characteristics of polyvinylpyrrolidone-layered silicate nanocomposites prepared by attrition ball milling. Polymer 2002; 44(3): 681-689.
17. Njuguna J, Pielichowski K, Desai S. anofiller-reinforced polymer nanocomposites. Polymers for Advanced Technologies 2008; 19 (8):947-959.
18. Munusamy Y, Ismail H, Mariatti M, Ratnam C T. Effect of electron beam irradiation on the properties of ethylene-(vinyl acetate) copolymer/natural rubber/organoclay nanocomposites. Journal of Vinyl and Additive Technology 2009; 15(1): 39–46.
19. Tai Y, Miaoa J, Qian J, Xia R, Zhang Y, An effective way to stabilize silicon nitride nanoparticles dispersed in rubber matrix by a one-step process. Materials Chemistry and Physics 2008; 112(2):659–667.
20. Lai S M, Chen W C, Chen C M. Preparation, structure, and properties of styrene-ethylene-butylene-styrene block copolymer/clay nanocomposites: Part II fracture behaviors. European Polymer Journal 2008; 44(11):3535–3547.
21. Zhao S, Schadler L S, Duncan R, Hillborg H, Auletta T. Mechanisms leading to improved mechanical performance in nanoscale alumina filled epoxy. Composites Science and Technology 2008; 68(14): 2965–2975.
22. Liu X, Zhao S. Study on structure and properties of SSBR/SiO2 co-coagulated rubber and SSBR filled with nanosilica composites. Journal of Applied Polymer Science 2008; 109(6):3900–3907.
23. hao X Y, Xiang P, Tian M, Fong H, Jin R, Zhang L Q. Nitrile butadiene rubber/hindered phenol nanocomposites with improved strength and high damping performance. Polymer 2007; 48(20):6056–6063.
24. Bonnia N N, Ahmad S H, Surip S N, Nurul S S, Azlina H N, Anuar H. Mechanical Properties and Environmental Stress Cracking Resistance of Rubber Toughened Polyester/Clay Composite. Advanced Materials Research 2012; 576:318-321.
25. Cadambi R M, Ghassemieh E. Influence of nanoclays on mechanical and barrier properties of hydrogenated acrylonitrile butadiene rubber nanocomposites. Plastics, Rubber and Composites 2011; 40 (6):283-288.

12/12/2013