Field Performance of Inlet Liner for Centrifugal Slurry Pump Manufactured by NR/PBR Nanocomposite

Puya Afsharjahanshahi, Seyed Yousef Ahmadi-Brooghani *, Mehdi Raghebi
Department of Mechanical Engineering,
University of Birjand, Iran
E-mail: M_afsharjahanshahi@birjand.ac.ir; Syahmadi@birjand.ac.ir, Raghebi@birjand.ac.ir
*Corresponding author

Mohammad Ali Karimi
Department of Chemistry,
Payame Noor University, Iran
E-mail: M_karimi@pnu.ac.ir

Received: 4 July 2018, Revised: 6 September 2018, Accepted: 6 December 2018

Abstract: Centrifugal slurry pumps are being used in many mineral companies to transport mineral materials. These materials are mainly abrasive and the liner of these pumps are eroded during their working life. Zinc oxide (ZnO) are usually used for enforcing rubber material but, the ZnO is harmful to the environment. Nano ZnO (n-ZnO) particles seem to purvey higher activity. In this work, the inlet liner of a centrifugal slurry pump was fabricated with n-ZnO that decreases environmental concerns and improves its wear life. The composite of inlet liner is made of Natural rubber (NR) and Polybutadiene rubber (PBR). For determining the optimal dosage of n-ZnO within the composite, mechanical properties for rubber compounds comprising 1-2 unit(s) n-ZnO, were investigated comparing to those of the compound with 5 units conventional ZnO (c-ZnO). It was found that optimal amount of n-ZnO was 1 unit which it was enough to give equivalent or better mechanical properties compared to one containing a higher amount of, namely 5 units, c-ZnO in the composite. In addition, field-emission scanning electron microscopy (FESEM) photo showed that n-ZnO particles were homogeneously dispersed in the composite. Finally, two inlet liners were manufactured, one of them was with 1 unit of n-ZnO (n-liner) and the other one with 5 units of c-ZnO (c-liner). These two liners were used in service in a plant. The field study showed that the life of n-liner was 1/3 unit more than the life of c-liner and n-liner face has been worn less than c-liner one.

Keywords: Field Performance, Inlet Liner of Centrifugal Slurry Pump, Nano Zinc Oxide, NR/PBR Composite

Reference: Afsharjahanshahi, P., Ahmadi-Brooghani, S.Y., Raghebi, M., and Karimi, M.A., "Field Performance of Inlet Liner for Centrifugal Slurry Pump Manufactured by NR/PBR Nanocomposite", Int J of Advanced Design and Manufacturing Technology, Vol. 11/No. 4, 2018, pp. 107–113.

Biographical notes: Puya Afsharjahanshahi is currently studying PhD in Mechanical Engineering at University of Birjand, Iran. His current research focus is nanocomposites. **Seyed Yousef Ahmadi-Brooghani** is Associate Professor of Mechanical engineering at the University of Birjand, Iran. **Mehdi Raghebi** is Assistant Professor of Mechanical engineering at the University of Birjand, Iran. **Mohammad Ali Karimi** is Professor of Chemistry engineering at Payame Noor University, Iran.

© 2018 IAU, Majlesi Branch

1 INTRODUCTION

Centrifugal slurry pumps transport slurry in mineral plants. Contacting-slurry components of a centrifugal slurry pump, including an impeller, inlet liner and outlet liner wear is mostly because of erosion [1-7]. The contacting-slurry components are usually made from rubber. These parts are in a different configuration and individually identified in "Fig. 1". Figure 2 shows the wear of rubber liner for VASA HD 455-100 pumps used in the magnetic plant of Golgohar mining & industrial Company. Wear affects the equipment performance and decreases its reliability, efficiency and operation life, and increases maintenance costs. The direct cost of slurry pump wear parts for the mining industry and the associated down-time and labor costs are important [3], [5], [8-12]. Also, ZnO is used as curing activator within rubber vulcanization. Excess ZnO may be released as a result of abrasion of rubber goods and during their production and leaching into the rainwater, so ZnO amount in rubber goods should be kept as low as possible for environmental reasons [13-15], especially components contacting slurry. The performance of ZnO within vulcanization can be added by the maximization of contact between the ZnO particles and the accelerators in the blend. The contact is dependent on the shape of the particles, their size, and their specific surface area. The use of n-ZnO particles seems to purvey higher activity, because they include ultra-small size and large surface area [16-17].

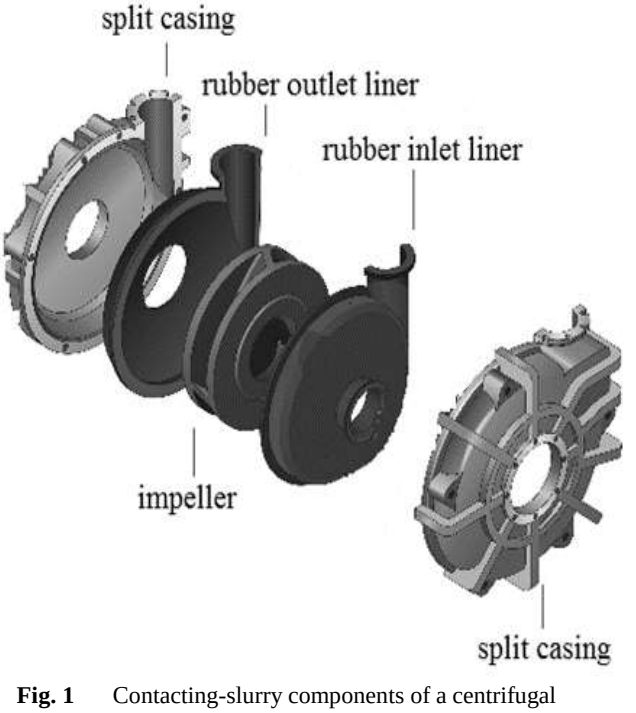

Fig. 1 Contacting-slurry components of a centrifugal slurry pump including the impeller, inlet and outlet liner.

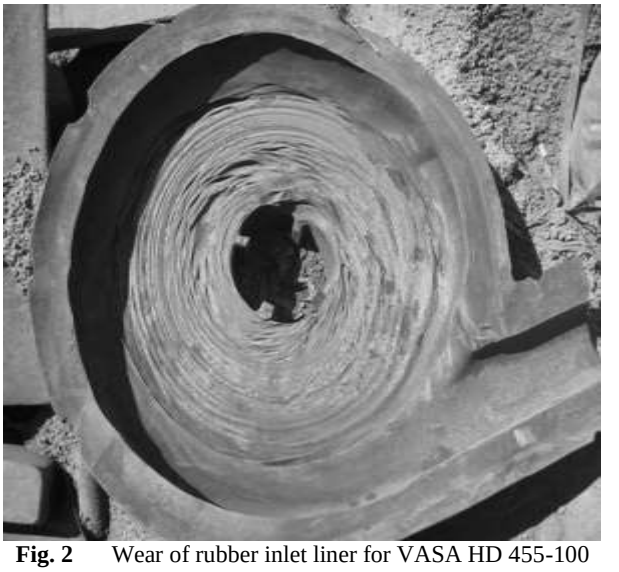

Fig. 2 Wear of rubber inlet liner for VASA HD 455-100 pumps used in Golgohar mining & industrial company.

The majority of liner wear has been attributed to the slurry leakage which occurs from the high pressure casing periphery back to the low pressure inlet (or eye), across the face of the impeller [4]. The results of investigations dealing with liner wear have confirmed that the wear pattern depends on the pump construction, solid particle size distribution, discharge flow rate, recirculation, mean concentration, rotational speed [10]. Also, The laboratory results of investigations dealing with the activation role of n-ZnO on EPDM rubber [17], NR [18], neoprene rubber [19], polybutadiene styrene [20], acrylonitrile butadiene rubber [21], NR/butadiene rubber (BR) (75/25) and NR/styrene–butadiene rubber (SBR) blends [22], and NR/BR/high-styrene resin (NR/BR/HSR) blend (20/70/10) [23] have acknowledged that low dosage of n-ZnO was enough to give equivalent curing and mechanical properties to rubber system compared to those comprising a higher dosage of c-ZnO particles.

In this work, the inlet liner of the centrifugal slurry pump was fabricated with n-ZnO to decrease environmental concerns and amend its wear resistance. The composite of inlet liner made of NR and PBR in 30/70 proportion, n-ZnO with this compound and proportion has been used for the first time, based on our limited literature knowledge. The optimal dosage of n-ZnO in the compound was determined from investigating mechanical properties such as tension properties, abrasion, tear strength and hardness for the samples comprising n-ZnO and c-ZnO contents; In addition, the morphological characterization of the nano sample was accomplished using FESEM (laboratory study). Finally, inlet liners made of n-ZnO and c-ZnO be separately serviced in a plant (field study, in addition to laboratory study).

© 2018 IAU, Majlesi Branch

2 MATERIAL AND METHODS

2.1. Materials

NR (SMR20, GM, Malaysia), PBR (Arak Petrochemical Company, Iran), c-ZnO (Sepid oxide zanjan, Iran) with mean particle size of 325 μm, n-ZnO (US Research Nanomaterials, US) with specific surface area of 20-60 m^2/g and mean particle size of 10–30 nm, black carbon (N330, doodeh sanati pars, Iran), stearic acid (IOI Pan-Century Oleochemicals Sdn. Bhd., Malaysia), sulfur (tesdak iran Co., Iran), oil (Behranoil, Iran), Dibenzothiazole disulfide (MBTS) and N-Cyclohexyl-2-benzothiazole sulfenamide (CZ) as the accelerators and 2 ,2 ,4- Trimethyl -1, 2-Dihydroquinoline Polymer (TMQ) as antioxidant (Hainan Huarong Chemical Co., Ltd, China), were used as received.

2.2. The Preparation of Samples

Different NR/PBR compounds with the details given in "Table 1" were prepared using a laboratory Banbury mixer and a two-roll mill. At the beginning for preparing each compound, NR and PBR were fed into the Banbury mixer for 1 min. Thereafter, black carbon and oil were added to the compound for 1 min. then, ZnO (nano or conventional, to study the effect of n-ZnO) together with stearic acid and antioxidant were added to the compound for 1 min. after that, the accelerators and sulfur were added to the compound for 45 s. then, the compound was fed into the two-roll mill and the milling process continued for 2 min.

The consequent compounds were vulcanized at 160 ◦C and pressure of 80 bars on an electrically heated hydraulic press. Finally, all the samples were rested for the following measurements.

Table 1 Compounding components of studied samples in parts per hundred (phr) of rubber

Sample	NR/PBR/ c-ZnO5	NR/PBR/n-ZnO1	NR/PBR/n-ZnO2
NR	30	30	30
PBR	70	70	70
TMQ	1	1	1
CZ	1	1	1
MBTS	0.7	0.7	0.7
BC	55	55	55
Stearic acid	3	3	3
Sulfur	1.5	1.5	1.5
Oil	25	25	25
c-ZnO	5	-	-
n-ZnO	-	1	2

2.3. Characterization Methods

Tensile properties such as tensile strength and elongation at break and also, tear strength were determined according to ASTM: D412 & D624, respectively at a uniform cross head speed 500 mm/min by HIWA tensile testing machine. Hardness (Shore A) of the vulcanizates was measured according to ASTM D2240 by a HIWA Hardness tester. The abrasion was measured according to ASTM D5963 using a HIWA Abrader.

2.4. Scanning Electron Microscopy

The rubbed surface of a nano sample was studied in FESEM by a TESCAN MIRA3 device equipped with an energy beam of 15 KV after coating the surface with sputtered gold.

2.5. Liner Model for Manufacturing

Many and various pumps were used to transport slurry in Golgohar Mining & Industrial Company. Their typical applications are primary mill discharge, cyclone feed and tailings disposal. Excess ZnO may be released as a result of wear of rubber contacting slurry components and causes environmental reasons including leaching into the rainwater. 350 rubber inlet liners of VASA HD 455-100 pump have been bought in Golgohar Mining & Industrial Co. for four years. Therefore, the inlet liner of this model was selected as the case to manufacture with n-ZnO.

2.6. Field Plant

PU302# pump, in the hematite plant of Golgohar mining & industrial company, was selected to assemble inlet liner. The pump operates in conditions such as solid content 47-55 w%, slurry density 1.4-1.8 g/cm^3, and solid size (d_{80}) 80-110 microns.

3 RESULTS AND DISCUSSION

3.1. Mechanical Properties

Mechanical characterizations are listed in "Table 2" for the entire samples. After comparing, NR/PBR/n-ZnO1 with 1 phr n-ZnO had better mechanical properties than NR/PBR/n-ZnO2 with 2 phr n-ZnO.

Table 2 The mechanical properties of the NR/PBR vulcanizates

Sample	NR/PBR/c-ZnO5	NR/PBR/n-ZnO1	NR/PBR/n-ZnO2
Abrasion (mm3)	87	87	87
Hardness (Shore A)	57	57	57
Elongation at break (%)	480	480	455
Tensile strength (MPa)	16.6	16.8	15.8
Tear strength (kN/m)	97.5	98	95

© 2018 IAU, Majlesi Branch

This may be owing to the formation of large size agglomerates in NR/PBR/n-ZnO2 [17]. Therefore, this shows that the amount of n-ZnO as the activator is optimized at 1 phr n-ZnO. Comparing the properties of NR/PBR/c-ZnO5 and NR/PBR/n-ZnO1, it is shown that the mechanical properties of NR/PBR/n-ZnO1 are equivalent or better than those of NR/PBR/c-ZnO5. This may be owing to the crosslinking in NR/PBR/n-ZnO1 being superior to NR/PBR/c-ZnO5 [19].

3.2. The Study of Microscopic Structure

Figures 3–5 illustrate the rubbed surface micrograph of the samples. The size and amount of agglomerates increased in the case of NR/PBR/c-ZnO5 while, ZnO nanoparticles were homogeneously dispersed in the NR/PBR/n-ZnO1 and NR/PBR/n-ZnO2 sample. ZnO nanoparticles due to the smaller size and higher surface area are easily dispersed within the matrix instead of forming agglomerates on the surface [21].

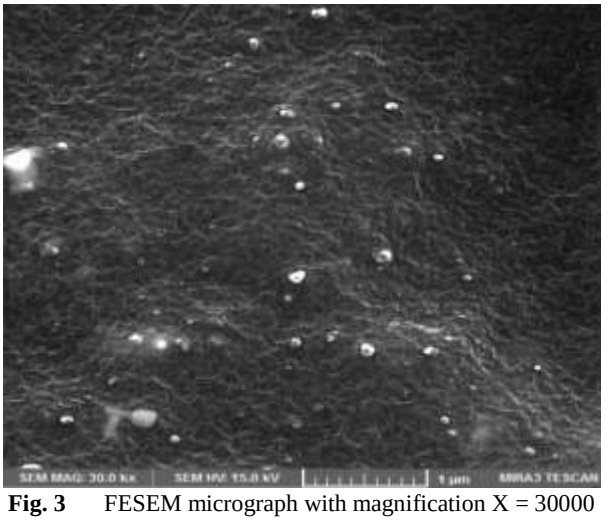

Fig. 3 FESEM micrograph with magnification X = 30000 of NR/PBR/c-ZnO5.

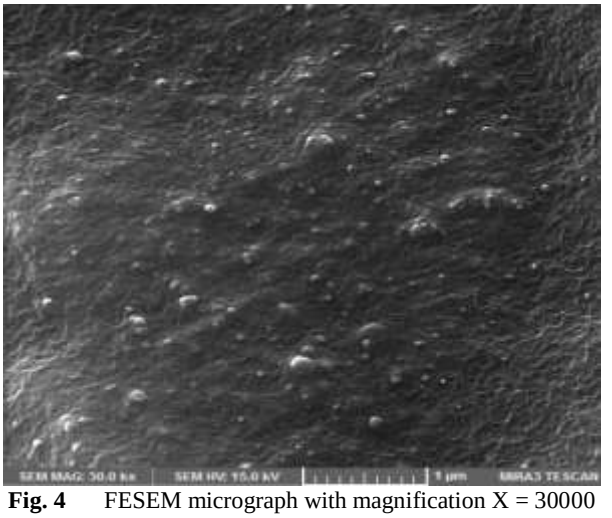

Fig. 4 FESEM micrograph with magnification X = 30000 of NR/PBR/n-ZnO1.

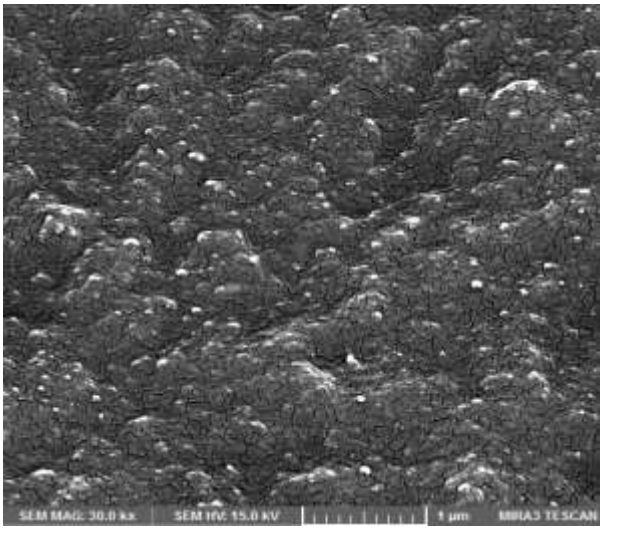

Fig. 5 FESEM micrograph with magnification X = 30000 of NR/PBR/n-ZnO2.

3.3. The Manufacture of Inlet Liner

The results showed that the optimal amount of n-ZnO in composite NR/PBR (30/70) was 1 phr, so, an inlet liner was made of NR/PBR/n-ZnO1 compound (n-liner). Also, in order to investigate the function of n-liner, another inlet liner was made of NR/PBR/c-ZnO5 compound (c-liner). For manufacturing, NR/PBR/n-ZnO1 or NR/PBR/c-ZnO5 blend was first placed in an open mould cavity ("Fig. 6 & Fig. 7"). Then, the mold was closed with a top plug member, the pressure was applied to force the compound into contact with all mold areas ("Fig. 8"), while heat (160 ◦C) and pressure (300 bars) were maintained until the blend has cured ("Fig. 9").

Fig. 6 Inlet liner mold for VASA HD 455-100 pump.

© 2018 IAU, Majlesi Branch

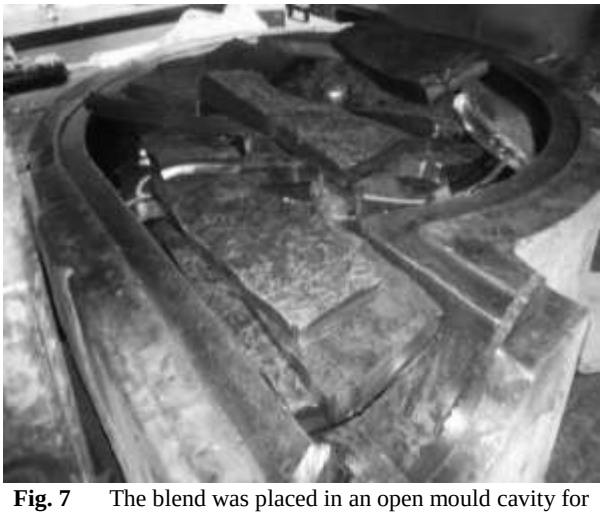

Fig. 7 The blend was placed in an open mould cavity for VASA HD 455-100 pump.

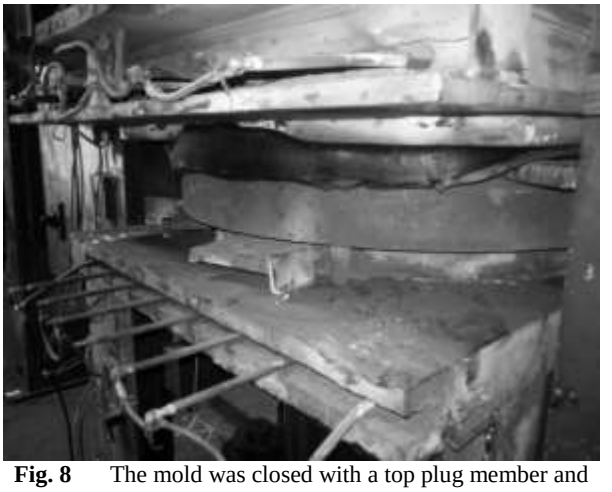

Fig. 8 The mold was closed with a top plug member and compressed in order to have the material contact at all areas of the mold, while heat and pressure were maintained.

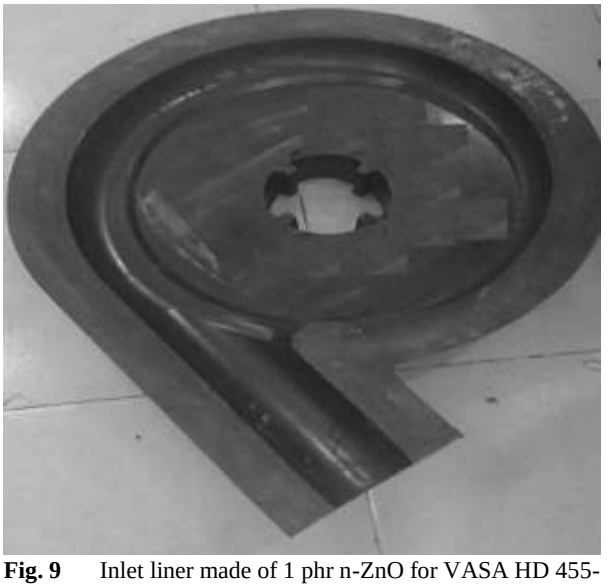

Fig. 9 Inlet liner made of 1 phr n-ZnO for VASA HD 455-100 pump.

3.4. Field Observations

Two inlet liner (n-liner and c-liner) were separately assembled in casing unit of PU302# pump to be serviced in the hematite plant of Golgohar mining & industrial company ("Fig. 10"). The inlet liner fails when it holes through and leaks slurry to the atmosphere. n-liner failed for 24 days, but c-liner failed for 18 days. Namely, the life of n-liner was 1/3 unit more than the life of c-liner. Also, comparison of n-liner ("Fig. 11") and c-liner ("Fig. 12") showed:

Fig. 10 Inlet liner was assembled in casing unit of PU302# pump for hematite plant of Golgohar mining & industrial company.

Fig. 11 Wear of n-liner (liner fabricated with n-ZnO) for VASA HD 455-100 pumps used in hematite plant in Golgohar mining & industrial company.

The main wear including hole occurred away from the eye namely, circle position of impeller outer diameter. Because the tangential velocity component of particles is greatest.

© 2018 IAU, Majlesi Branch

The n-liner face has been worn less than c-liner one. This may be owing to the crosslinking in n-liner is more than c-liner. So, use of n-ZnO in fabricating liner causes less consumption of ZnO dosage that decreases environmental concerns, in addition it increases liner life.

Fig. 12 Wear of c-liner (liner fabricated with c-ZnO) for VASA HD 455-100 pumps used in hematite plant in Golgohar mining & industrial company.

4 CONCLUSION

n-ZnO seems to have higher activity than c-ZnO. In order to reduce the dosage of ZnO in contacting-slurry rubber components because of environmental concerns and also better their life, Mechanical properties of a compound comprising 1-2 phr n-ZnO and 5 phr c-ZnO contents were investigated according to ASTM standards to determine the optimal dosage of n-ZnO in contacting-slurry rubber components of the centrifugal slurry pump. Compounds were made of NR and PBR in 30/70 proportion.

The compound comprising a lower amount (1 phr) of n-ZnO was figured out to have equivalent or better mechanical properties than compounds with 5 phr c-ZnO. Also, the FESEM picture showed that in n-ZnO containing systems, size and amount of agglomerates decreased and ZnO nanoparticles were homogeneously dispersed. Therefore, an inlet liner of VASA HD 455-100 pump was fabricated with 1 phr n-ZnO (n-liner) and another was fabricated with 5 phr c-ZnO (c-liner), finally n-liner and c-liner were serviced in hematite plant of Golgohar mining & industrial company.

Field observations showed that the life of n-liner was 33% more than the life of c-liner and n-liner face has been worn less than c-liner one. So, other contacting-slurry rubber components including impeller and outlet liner can be fabricated with a lower amount (1 phr) of n-ZnO to improve their wear life and detract environmental concerns.

REFERENCES

[1] Kumar, S., Gandhi, B. K., and Mohapatra, S. K., Performance Characteristics of Centrifugal Slurry Pump with Multi-Sized Particulate Bottom and Fly Ash Mixtures, Particulate Science and Technology, Vol. 32, No. 5, 2014, pp. 466-476.

[2] Gandhi, B. K., Singh, S. N., and Seshadri, V., Effect of Speed on the Performance Characteristics of a Centrifugal Slurry Pump, Journal of Hydraulic Engineering, Vol. 128, No. 2, 2002, pp. 225-233.

[3] Walker, C. I., Bodkin, G. C., Empirical Wear Relationships for Centrifugal Slurry Pumps Part 1: Side-Liners, Wear, Vol. 242, No. 1, 2000, pp. 140-146.

[4] Walker, C. I., Slurry Pump Side-liner Wear: Comparison of Some Laboratory and Field Results, Wear, Vol. 250, No. 1, 2001, pp. 81-87.

[5] Zengwen, H., Jinhai, C., Effect of Operating Conditions on the Wear of Wet Parts in Slurry Pumps, Wear, Vol. 162-164, 1993, pp. 1016-1021.

[6] Wang, D., Tse, P. W., Prognostics of Slurry Pumps Based on a Moving-average Wear Degradation Index and a General Sequential Monte Carlo Method, Mechanical Systems and Signal Processing, Vol. 56–57, 2015, pp. 213-229.

[7] Iwai, Y., Nambu, K., Slurry Wear Properties of Pump Lining Materials, Wear, Vol. 210, 1997, pp. 211-219.

[8] Roco, M. C., Addie, G. R., Erosion Wear in Slurry Pumps and Pipes, Powder Technology, Vol. 50, 1987, pp. 35-46.

[9] Bross, S., Addie, G., Prediction of Impeller Nose Wear Behaviour in Centrifugal Slurry Pumps, Experimental Thermal and Fluid Science, Vol. 26, 2002, pp. 841–849.

[10] Roco, M. C., Wear Mechanisms in Centrifugal Slurry Pumps, Corrosion Engineering, Vol. 46, 1990, pp. 424-431.

[11] Chandel, S., Singh, S. N., and Seshadri, V., Experimental Study of Erosion Wear in a Centrifugal Slurry Pump Using Coriolis Wear Test Rig, Particulate Science and Technology, Vol. 30, 2012, pp. 179–195.

[12] Xing, D., Hai-lu, Z., and Xin-yong, W., Finite Element Analysis of Wear for Centrifugal Slurry Pump, Procedia Earth and Planetary Science, Vol. 1, 2009, pp. 1532–1538.

[13] Boretti, L. G., Woolard, C. D., An Appropriate Model Compound for the Accelerated Sulfur Vulcanization of Polyisoprene: i. the Mechanism of Bisbenzothiazole-2, 2′-Disulfide Accelerated Vulcanization of Squalene in the Absence of ZnO, Rubber Chemistry and Technology, Vol. 79, No. 1, 2006, pp. 135-151.

© 2018 IAU, Majlesi Branch

[14] Heideman, G., Noordermeer, J. W. M., Datta, R. N., and Baarle, B. V., Multifunctional Additives as Zinc-free Curatives for Sulfur Vulcanization, Rubber Chemistry and Technology, Vol. 79, No. 4, 2006, pp. 561-588.

[15] Heideman, G., Noordermeer, J. W. M., Datta, R. N., and Baarle, B. V., Zinc Loaded Clay as Activator in Sulfur Vulcanization: a New Route for Zinc Oxide Reduction in Rubber Compounds, Rubber Chemistry and Technology, Vol. 77, No. 2, 2004, pp. 336-355.

[16] Przybyszewska, M., Zaborski, M., Effect of Ionic Liquids and Surfactants on Zinc Oxide Nanoparticle Activity in Crosslinking of Acrylonitrile Butadiene Elastomer, Journal of Applied Polymer Science, Vol. 116, No. 1, 2010, pp. 155-164.

[17] Akhlaghi, S., Kalaee, M., Mazinani, S., Jowdar, E., Nouri, A., Sharif, A., and Sedaghat, N., Effect of Zinc Oxide Nanoparticles on Isothermal Cure Kinetics, Morphology and Mechanical Properties of EPDM Rubber, Thermochimica Acta, Vol. 527, 2012, pp. 91-98.

[18] Sahoo, S., Maiti, M., Ganguly, A., George, J. J., and Bhowmick, A. K., Effect of Zinc Oxide Nanoparticles as Cure Activator on the Properties of Natural Rubber and Nitrile Rubber, Journal of Applied Polymer Science, Vol. 105, No. 4, 2007, pp. 2407-2415.

[19] Begum, P. M. S., Yusuff, K. K. M., and Joseph, R., Preparation and Use of Nano Zinc Oxide in Neoprene Rubber, International Journal of Polymeric Materials and Polymeric Biomaterials, Vol. 57, No. 12, 2008, pp. 1083-1094.

[20] Xiong, M., Gu, G., You, B., and Wu, L., Preparation and Characterization of Poly (Styrene Butylacrylate) Latex/Nano-ZnO Nanocomposites, Journal of Applied Polymer Science, Vol. 90, No. 7, 2003, pp. 1923-1931.

[21] Sahoo, S., Bhowmick, A. K., Influence of Zno Nanoparticles on the Cure Characteristics and Mechanical Properties of Carboxylated Nitrile Rubber, Journal of Applied Polymer Science, Vol. 106, No. 5, 2007, pp. 3077-3083.

[22] Mottaghi, M., Khorasani, S. N., Esfahany, M. N., Farzadfar, A., and Talakesh, M. M., Comparison of the Effect of Nano ZnO and Conventional Grade ZnO on the Cross-linking Densities of NR/BR and NR/SBR Blends, Journal of Elastomers & Plastics, Vol. 44, No. 5, 2014, pp. 443-451.

[23] Kim, I. J., Kim, W. S., Lee, D. H., Kim, W., and Bae, J. W., Effect of Nano Zinc Oxide on the Cure Characteristics and Mechanical Properties of the Silica-filled Natural Rubber/Butadiene Rubber Compounds, Journal of Applied Polymer Science, Vol. 117, No. 3, 2010, pp. 1535-1343.

© 2018 IAU, Majlesi Branch