ACADEMY JOURNAL OF SCIENCE AND ENGINEERING
Available online @
www.academyjsekad.edu.ng
AJSE 18 (1) 2024
Original Research

ASSESSMENT OF EXHAUST PIPE SUSPENDER PRODUCED FROM BLEND OF NATURAL RUBBER AND STYRENE BUTADIENE RUBBER REINFORCED WITH RICE HUSK ASH AND PERIWINKLE SHELL

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Abstract

The assessment of an exhaust pipe suspender made of a blend of natural rubber (NR) and styrene butadiene rubber (SBR) filled with rice husk ash (RHA) and periwinkle shell (PS) was investigated. The samples were compounded using a two-roll mill at various filler loadings of 0, 10, 20, 30, 40, and 50 phr with an 80/20 NR/SBR blend ratio. The mechanical characteristics of the compounded samples, including tensile strength, tensile modulus, elongation at break, hardness, abrasion resistance, compression set, and flex fatigue, were determined and compared. The results showed that the incorporation of rice husk ash (RHA) and periwinkle shell (PS) into the NR/SBR blend increased the tensile strength (13.0562 N/mm^2–27.5106 N/mm^2 for RHA-filled NR/SBR blend composites and 13.0562 N/mm^2–23.0007 N/mm^2 for PS-filled NR/SBR blend composites), tensile modulus (4.2435 N/mm^2–12.5200 N/mm^2 for RHA-filled NR/SBR blend composites and 4.2435 N/mm^2–9.5845 N/mm^2 for PS-filled NR/SBR blend composites), hardness (28.1668 IRHD–68.4603 IRHD for RHA-filled NR/SBR blend composites and 28.1668 IRHD–64.3209 IRHD for PS-filled NR/SBR blend composites) and abrasion resistance (20.0043 mm^3/rev.–35.007 mm^3/rev. for RHA-filled NR/SBR blend composites and 20.0043 mm^3/rev–29.3068 mm^3/rev for PS-filled NR/SBR blend composites) whereas the elongation at break, compression set and flex fatigue of composites decreased. The NR/SBR blend's tensile strength and tensile modulus have improved with the addition of either RHA or PS, but they appeared to have degraded at 50 phr. Additionally, the hardness, elongation at break, compression set, and flex fatigue (0-50 phr) all improved.

Keywords: Blend, Composites, Compounding, Hardness, Tensile Strength

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1.0 INTRODUCTION

Agro-wastes are by-products of agricultural produce, they can be husk, straw, cobs or fiber (Abubakar and Ahmad, 2010). But for multipurpose applications, agro-waste polymer composites combine agro-waste with recycled or virgin polymer to create a material with better qualities than each material alone. (Ayfer et al., 2011). Academicians and industrialists have given the research on agro-waste and natural filler composites sufficient importance because of their outstanding features, such as improved mechanical strength, water and oxygen barrier, dimensional stability, thermal resistance, chemical resistance, etc (Ates et al., 2008). In practical applications, low-cost reinforced polymer composites made from agricultural waste are growing increasingly important in the building and automotive industries, among other consumer applications (Dominique et al., 2012). Furthermore, agro-waste plastic composites can be used in a range of practical applications because of their inherent quality outputs, which include lower cost, renewability, biodegradability, low specific gravity, availability, high strength, and non-abrasiveness. (Albano et al., 2005).

Natural rubber (NR) possesses several advantageous qualities, including exceptional durability, high elongation, and tensile strength, making it a sustainable and renewable material suitable for a wide range of uses (Chanin et al, 2014). Its capacity to undergo strain crystallisation allows it to display greater tensile and tear strength than synthetic rubbers. (Williams et al, 2022; Boonmahitthisud and Chuayjuljit, 2012; Vu et al, 2015; Chuayjuljit et al, 2015). Styrene-butadiene rubber (SBR), nonpolar synthetic rubber, describes families of synthetic rubbers derived from styrene and butadiene. Its thermal ageing characteristics and abrasion resistance are good (Goyanes et al., 2008). It is generally used in wear applications. Thus, SBR has been used in a wide range of products such as side walls of tires, belts, hoses, foot wears, foamed products, etc (Williams et al, 2022; Findik et al, 2004; Tangudom et al, 2004).

The blending of two or more polymers either by physical or chemical means, tends to improve a variety of physical and chemical properties of the individual polymers (Jovanovic et al., 2013; Chanin et al., 2014). To produce a new product with better qualities, a universal technique known as polymer blending was often used. The physical qualities of the finished vulcanized product are improved in large part by the blending of the rubbers. In order to achieve the optimal balance of compound characteristics, processability, and cost, the rubber industry regularly uses rubber blends.
Therefore, to enhance its physical characteristics, thermal stability, and end-use performances, NR is typically modified by simply combining it with rubbers and/or fillers that are readily accessible in the market (Vu et al, 2015; Phiriyawirut and Luamlam, 2013; Boonmahitthisud et al, 2017). In comparison to NR, SBR is more resistant to fracture initiation, wet grip, abrasion, and ageing stability, while NR is more resilient and performs better at low temperatures (Boonmahitthisud and Chuayjuljit, 2012). For this reason, NR and SBR have been combined to improve SBR's oxidative stability, thermal stability, and abrasion resistance. (Boonmahitthisud et al, 2017).

Williams et al, (2022) investigated the assessment of the mechanical properties of NR/SBR blend reinforced with egg shell and carbon black. The results obtained for tensile strength, modulus, hardness and abrasion resistance showed an increasing trend as the filler loadings increased from 0-40 phr indicating improved mechanical properties and decreased at filler loading of 50 phr. The results for elongation at break, compression set and flex fatigue showed a falling trend as filler loading were increased.

Jawad et al, (2013) studied the effect of carbon black particles on the mechanical properties of SBR/NR blends used in passenger tire treads. The mechanical properties such as tensile strength, tensile modulus at 100% elongation, elongation at break, hardness, wear and resilience were studied. The results showed that the tensile modulus at 100% elongation (MOD 100) and ultimate tensile strength increase with increasing of carbon black loading level and maximum value was achieved at 60 phr (carbon black), while elongation at break decreased with increasing of carbon black loading for all recipes.

In rubber compounding, fillers are among the most crucial components. Rubber formulations are optimized with the addition of fillers to provide the necessary qualities for service application (Ahmad et al, 2004., Igwe et al., 2001, Osabohien et al., 2007, Suwatthana et al., 2010). Filler-reinforced rubber vulcanizates offer better mechanical qualities (such as hardness and tensile properties) and processing economy in addition to design flexibility (Ahmad et al, 2004; Amoke et, al., 2017).

Different filler materials, such as carbon black (CB) and silica (Si), are commonly used to improve the mechanical properties of rubber composites (Park et al., 2005; Choi and Ha, 2009). Petroleum is a non-renewable resource that is the main source of carbon black, which is imported and highly valued in the rubber industry. Industry concerns are also being raised by the volatility of crude oil and its derivatives pricing, which has led to a quest for other sources of filler (Osarenmwinda and Abode, 2010). There have been efforts to identify environmentally friendly substitute fillers that perform as well as their synthetic counterparts. Because of stringent environmental laws around the world and growing interest in the sustainable use of agricultural waste materials (Egwaikhide et al., 2007; Amoke et, al., 2017). Renewable natural resources are outstanding, and biodegradable substitutes for the most widely used synthetic fillers (carbon black) because of their low cost, easy availability, ease of chemical and mechanical modification, and high specific mechanical qualities. (Lovely et al., 2006).

This research work is aimed at studying exhaust pipe suspender produced from blend of NR and SBR reinforced with rice husk ash and periwinkle shell. Also, to investigate the mechanical properties of a blend of natural rubber and styrene butadiene rubber reinforced with rice husk ash and periwinkle shell.

2.0 MATERIALS AND METHOD

2.1 Materials

The natural rubber (NSR-10) and styrene butadiene rubber (SBR) used for the research work were obtained from Rubber Research Institute of Nigeria (RRIN), Iyanomoh Benin-City. Rice husk ash and periwinkle shells were obtained from Auchi Metropolis. The rubber compounding chemicals such as processing oil, tetramethylthiuram disulphate (TMTD), 2,2,4-Trimethyl-1,2-Dihydroquinoline (TMQ), zinc oxide, sulphur and stearic acid produced by British Drug House (BDH), England were obtained from Rovet Chemicals, Benin City, Edo State, Nigeria.

2.1.1 Equipment and Machines

The equipment used during this study includes;

i. Universal Tensile Tester, Manufactured by British Company Limited, England was used for tensile tests properties.
ii. Wallace Hardness Tester, Elektron Technology Series, UK was used for hardness test.
iii. Taber Oscillating Abrasion Tester, Model: 6160-F735, manufactured by Taber Co. Ltd, Canada was used for the Abrasion Properties.

iv. Flex meter Manufactured by British Company Limited, England was used for flex fatigue test.
v. Two Roll Mill, Manufactured by British Company Limited, England mills were used in mixing the rubber composite.
vi. Hydraulic press, Elektron Technology Series, UK was used for curing the rubber composite.
vii. CTM-2P-200-2000KN (200Tons), Manufactured by Interlaken Technologies Co. Ltd Thailand was used for the Compression Set.

2.2 Preparation of fillers and composites

The rice husk was burnt in an open environment to obtained ash content while periwinkle shell was ground with an automated grounding machine. The particle size of the rick husk ash and periwinkle shell was 75 µm. The rubber was masticated and mixed with additives using the two-roll mill and adopting the standard method specified in the ASTM-D 3184-80 for all the composites. The filler loadings were varied at 0, 10, 20, 30 40 and 50 phr. Table 1 shows the formulations for the natural rubber composites. The rubber mixes were prepared on a laboratory-size two-roll mill. It was maintained at 80^{0}C to avoid cross-linking during mixing after which the rubber composite was stretched out. Mixing follows (ASTMD 3184–80, 1983).

Table 1: Formulations for Reinforced Natural Rubber Composites.

Ingredients	Part per Hundred of Rubber (phr)
NR	80
SBR	20
Zinc oxide	5.0
Stearic acid	2.5
TMQ	1.5
TMTD	1.5
(Rice Husk Ash and Periwinkle Shell)	0, 10, 20, 30, 40, 50
Sulfur	2.5
Processing oil	5.0

2.4 Mechanical Properties of the Composites

2.4.1 Tensile Properties

The tensile properties determination was carried out in accordance with ASTMD 412-87 method. The test specimens were cut from the moulded dump-bell rubber sheets along the grain direction. The thickness and width of each test piece at the middle were maintained at 2.5 and 6 mm respectively. Each test piece was clamped into the grips of the tensometer. The stress applied, the load, and elongation at break was recorded. The test samples were tested in the machine giving straight tensile pull, without any bending or twisting. The machine measures both the tensile stress and the tensile strain.

2.4.2 Hardness Test

Hardness Test was done in accordance with ASTMD 785. Test pieces from the moulded spherical rubber pieces were clamped onto a durometer (Instrol Wilson) and the penetration of the indenter was measured. The standard dead method of measurement covers rubber in the range of 30 to 85 International rubbers hardness degrees (IRHD).

2.4.3 Compression Set Test

ASTMD 385 method was used for compression set determination. The compression set is the difference between the original thickness of the sample and the thickness after the test expressed as a percentage of the original thickness. Compression set evaluates the extent to which the specimen fails to return to its original thickness when subjected to standard compression load for a given period at a given temperature. A stress of 2.8MP was used and allowed for 24 hours at 70^{o}C for 30mins.

2.4.4 Abrasion Resistance Test

Wallace Akron abrasion tester was used in accordance to BS903 method. The angle between the test sample and the wheel was adjusted to an angle of 15^{o}. The abrasion was carried out for 100 revolutions and the material loss for each run was noted. The specimen was re-reweighed between each test run.

2.4.5 Flex Fatigue Test

The measurement was carried out by the procedure described in ASTMD 430 using the Flex machine, which functions by inducing surface cracking on the rubber vulcanizates sample.

3.0 RESULTS

3.1 Mechanical Properties

Table 2: Mechanical Properties of Rice Husk Ash and Periwinkle Shell filled NR/SBR Blend Composites

Properties	**Filler Loadings (phr)**					
	0	10	20	30	40	50
Tensile Strength (N/mm^2)	13.0562	(24.8892) [18.3524]	(26.1153) [22.0886]	(28.5030) [24.0770]	(28.7815) [24.6045]	(27.5106) [23.0007]
Tensile Modulus (N/mm^2)	4.2435	(10.4315) [7.9352]	(11.2341) [9.8672]	(13.5032) [10.8875]	(13.6320) [10.9903]	(12.5200) [9.5845]
Elongation at Break (%)	721.5002	(687.7862) [593.5624]	(668.3717) [588.5769]	(657.1873) [585.2350]	(625.4631) [576.6238]	(585.2554) [515.2008]
Hardness (IRHD)	28.1668	(52.8878) [50.0255]	(57.0355) [56.0060]	(61.5330) [56.0060]	(64.3033) [61.2004]	(68.4603) [64.3209]
Abrasion Resistance (Mm^3/rev.)	20.0043	(26.4406) [23.3210]	(32.0024) [29.0885]	(37.2400) [29.0885]	(38.4009) [33.2325]	(35.0077) [29.3068]
Compression Set (%)	56.0116	(53.0550)) [43.5160]	(51.4520) [40.0617]	(50.1255) [39.1206]	(40.3008) [36.0076]	(35.5218) [28.8095]
Flex Fatigue (%)	11.0001	(10.7153) [8.4352]	(9.8965) [7.9806]	(9.7500) [7.7521]	(8.0550) [6.8250]	(6.2880) [4.7550]

Key: ( ) = Rice Husk Ash (RHA) [ ] = Periwinkle Shell (PS)

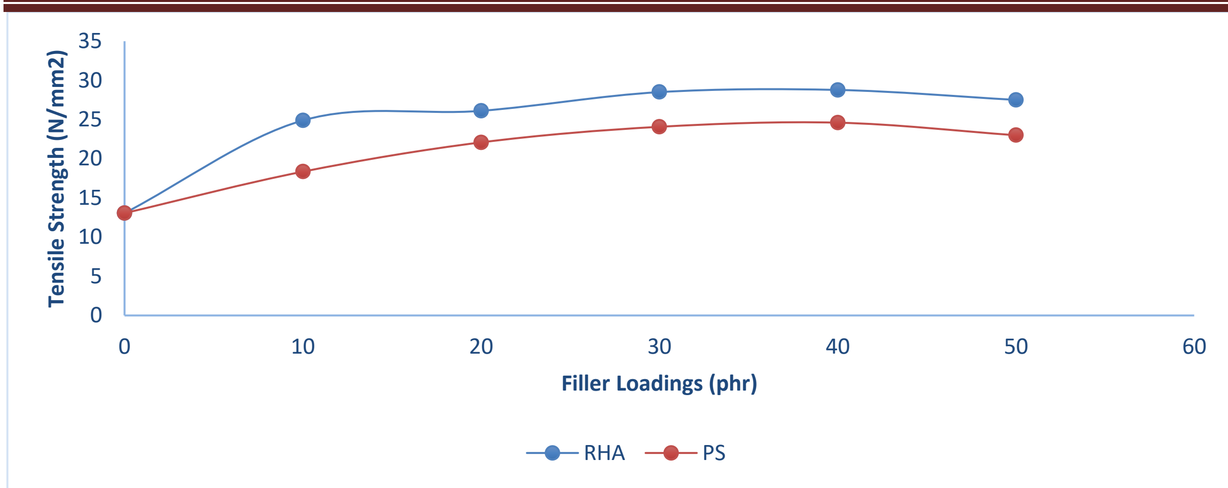

Figure 1: Effect on Tensile Strength of NR/SBR Blend Composites

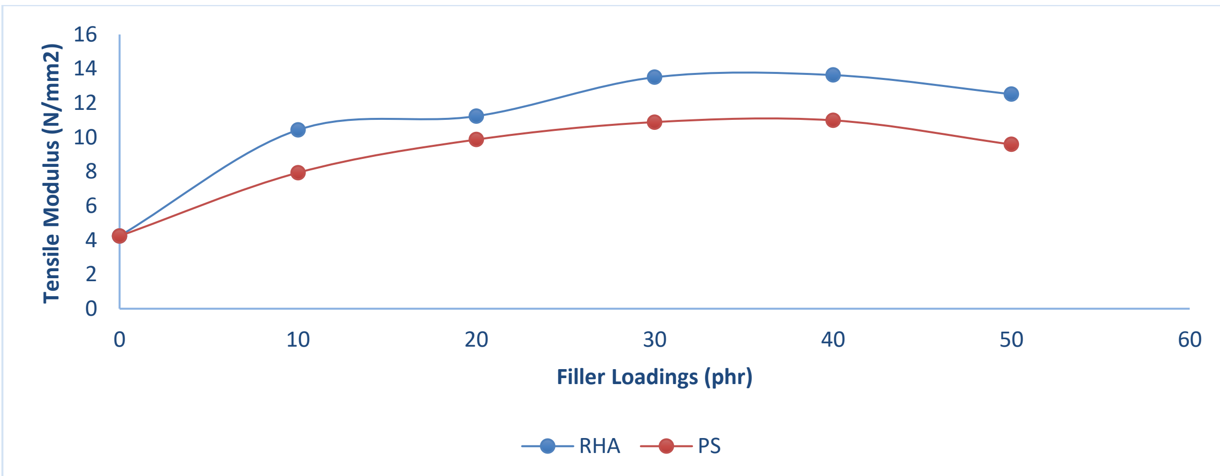

Figure 2: Effect on Tensile Modulus of NR/SBR Blend Composites

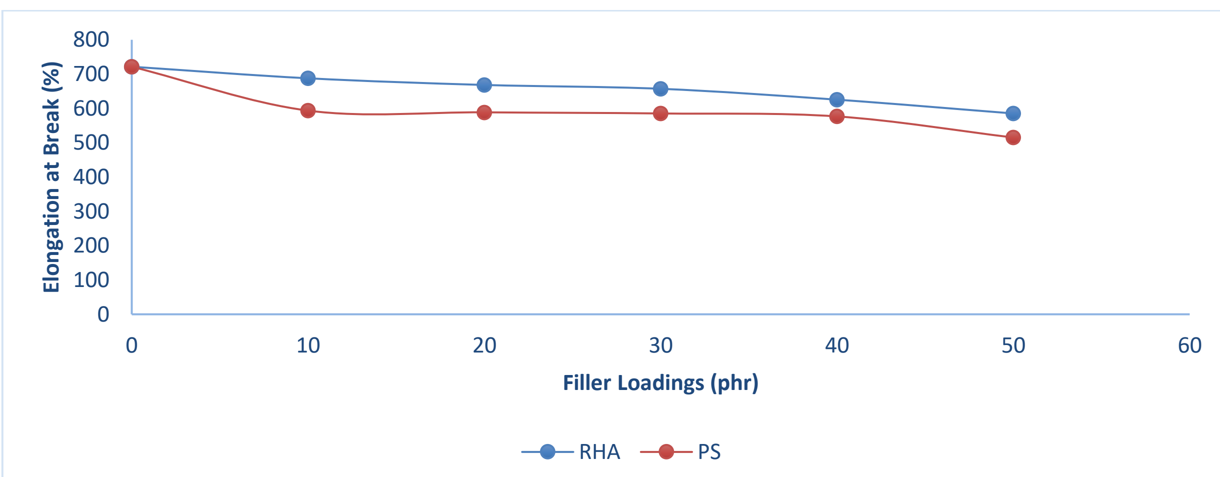

Figure 3: Effect on Elongation at Break of NR/SBR Blend Composites

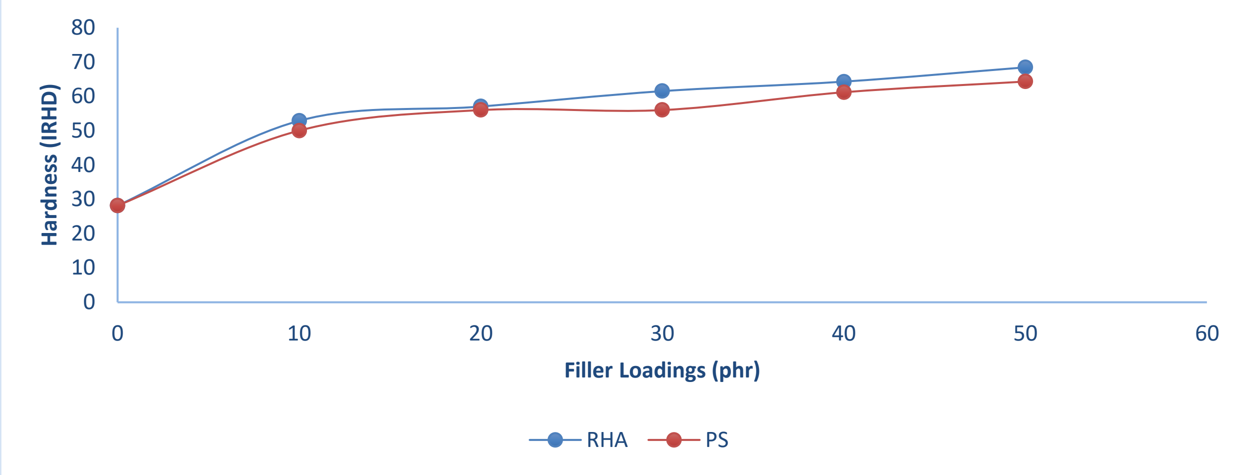

Figure 4: Effect on Hardness of NR/SBR Blend Composites

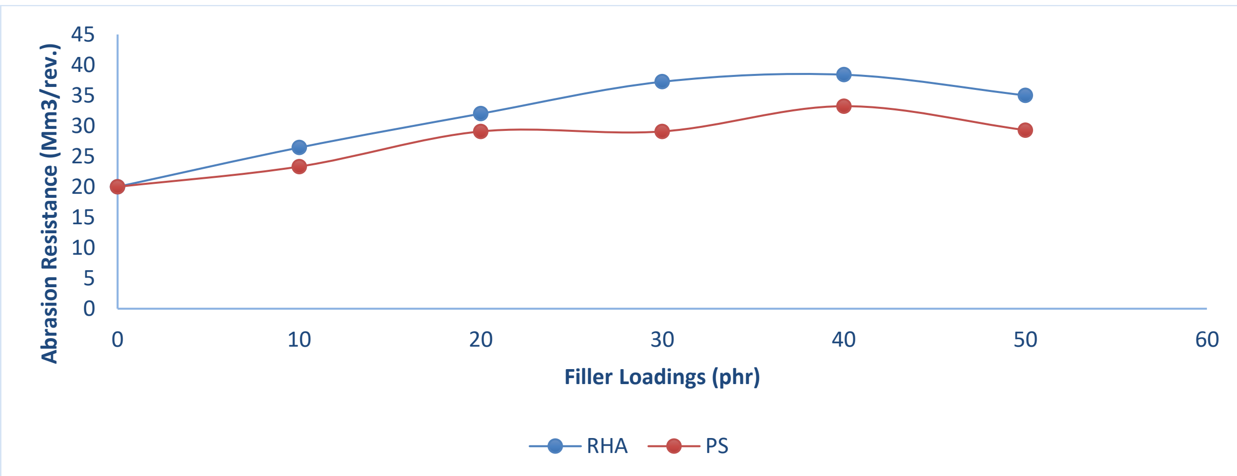

Figure 5: Effect on Abrasion Resistance of NR/SBR Blend Composites

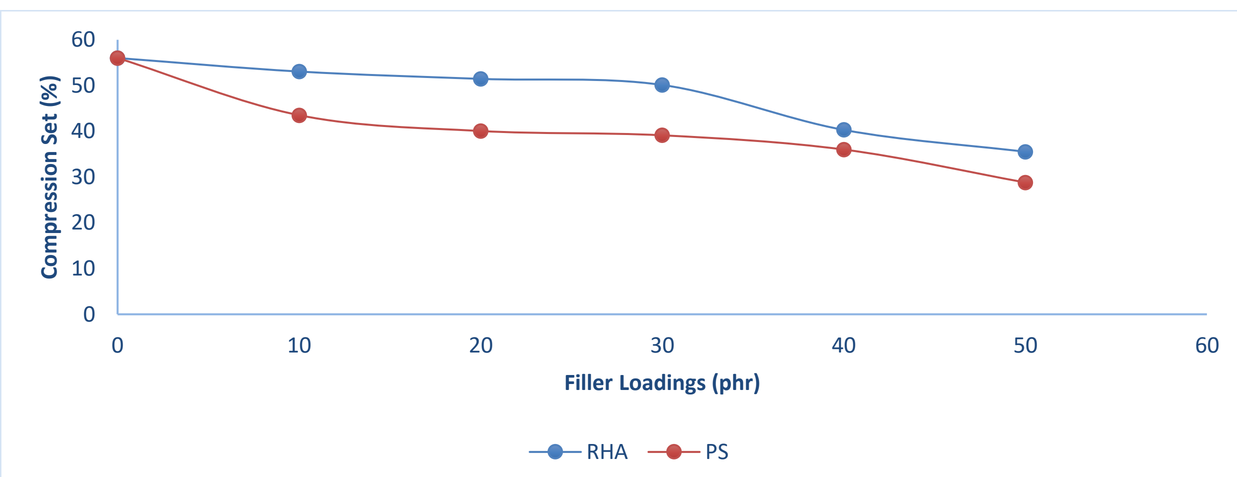

Figure 6: Effect on Compression Set of NR/SBR Blend Composites

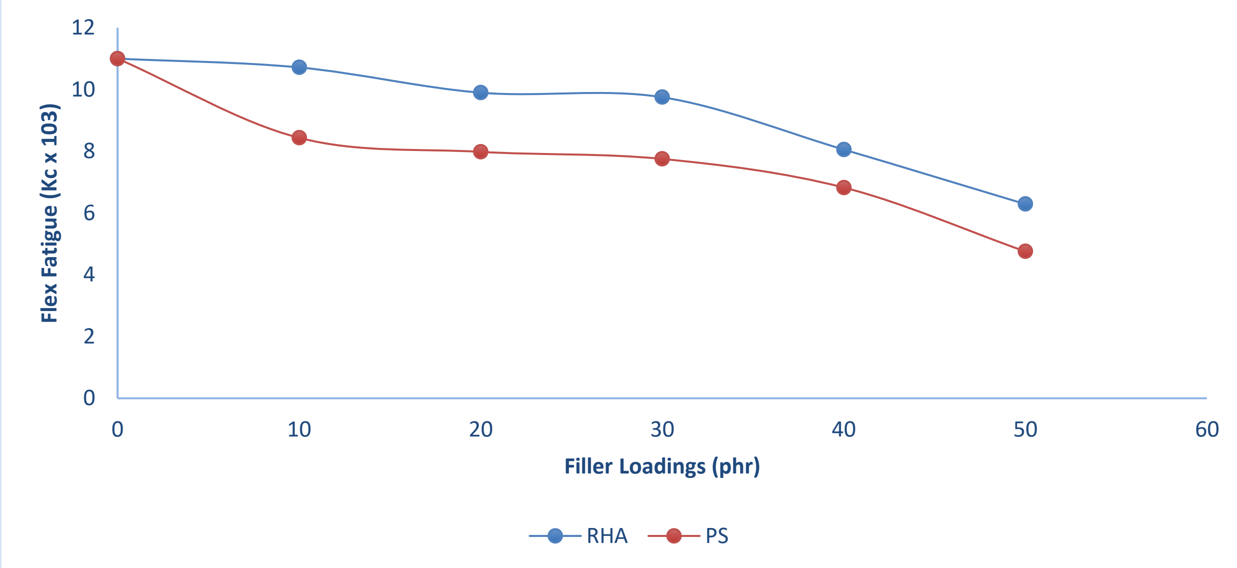

Figure 7: Effect on Flex Fatigue of NR/SBR Blend Composites

4.0 DISCUSSION

The experimental data relating to the mechanical properties of the 80/20 NR/SBR blend and its composites filled with (0-50 phr) of the respective particle fillers: rice husk ash (RHA) and periwinkle shell (PS) are shown in Table 2 and Figure 1-7. These mechanical properties include tensile strength, elongation at break, hardness, abrasion resistance, compression set, and fatigue resistance.

The percentage of filler materials in the compound, particle size, interaction of filler materials with the compound, cross-links, and production methods are all factors that affect tensile strength. (Savran, 2001; Akcakale, 2008). As RHA and PS filler loading increased, it was shown in Tables 2 and Figure 1 that the tensile strength improved for all of the composites. This might be a result of the RHA and PS's ability to act as reinforcement due to the binding force created at the filler-rubber matrix contact. The unfilled NR/SBR blend had the lowest tensile strength, 13.0562 N/mm^2, according to the test results. The tensile strength increased to the greatest values (28.7815 N/mm^2) and (24.6045 N/mm^2) at 40 phr for the NR/SBR blend composites with RHA and PS loadings, respectively. The RHA and PS fillers were evenly distributed within the rubber matrix, increasing the tensile strength, and the stress was highly transferred across the filler-to-NR/SBR matrix interactions. At 50 phr, the tensile strengths of the RHA-filled and PS-filled NR/SBR blend composites were 27.5106 N/mm^2 and 23.0007 N/mm^2, respectively. This decline might be explained by the self-agglomeration of PS and RHA fillers at high loadings, which reduced the filler rubber interaction. (Anyaporn et al, 2017). In all filler loadings, RHA-filled NR/SBR blend composites outperformed PS-filled NR/SBR blend composites in terms of tensile strength, indicating that RHA particles are more reinforcing than PS particles due to better RHA-rubber interaction than PS-rubber interaction.

As shown in Table 2 and Figure 2, the tensile modulus increased in proportion to the filler loadings of RHA and PS. The tensile modulus that was lowest (4.2435 N/mm^2) corresponded to the unfilled NR/SBR blend. At 40 phr, the RHA-filled and PS-filled NR/SBR blend composites' tensile modulus gained their highest value, respectively, of 13.6320 N/mm^2 and 10.9903 N/mm^2. This shows that adding these fillers can effectively decrease rubber chains' mobility while also increasing the stiffness of the composite blends that result (Anyaporn et al, 2017). NR/SBR blend composites filled with RHA (12.5200 N/mm^2) and PS (9.5845 N/mm^2) both saw a reduction in tensile modulus at filler loading of 50 phr. Due to the RHA and PS being agricultural waste, it's possible that they self-agglomerated within the rubber matrix, which may have caused the tensile modulus to decrease. Compared to NR/SBR blend composites filled with PS, the tensile moduli of RHA-filled composites are significantly greater.

With increased filler loadings of RHA and PS particles, Table 2 and Figure 3 showed a decrease in the elongation at break of the 80/20 NR/SBR blend. The elongation at break was reduced from 721.5002% of the unfilled NR/SBR to 585.2554% and 515.2008% for RHA and PS, respectively, at 50 phr. The observation is expected given that the stiff particles would serve as restriction sites for rubber chain movement during the application of strain and would therefore tend to lessen the elongation at break of the blend composites. However, the unloading of the fillers within the rubber matrix causes the elongation at the break of the unfilled NR/SBR blend to mostly be retained. At all filler loadings, the PS-filled NR/SBR blend composites showed higher values of elongation at break than the RHA-filled blend composites.

In comparison to the unfilled 80/20 NR/SBR blend, the NR/SBR blend composites showed enhanced hardness in all filler loadings (10–50 phr), as shown in Table 2 and Figure 4. Due to the restriction of segmental motion of the rubber chain, the hardness increased with increasing filler loading of RHA and PS particles as expected, creating more stiffen vulcanizates and the resilience decreased. At 50 phr of RHA and PS, the hardness increased from 28.1668 IRHD of the unfilled NR/SBR blend to 68.4603 IRHD and 64.3209 IRHD, respectively. Due to the finely dispersed RHA particles inside the rubber matrix producing a strong link between the RHA and the rubber matrix as compared to PS-filled NR/SBR blend composites, the RHA-filled NR/SBR blend composites showed greater values of hardness than the PS-filled NR/SBR blend composites.

The abrasion resistance presented in Table 2 and Figure 5 showed a regular pattern of increase with filler loading of RHA and PS particles. The unfilled NR/SBR blend had the lowest value of hardness (20.0043%) while the RHA-filled NR/SBR blend composites had higher values of abrasion resistance as compared to PS-filled NR/SBR blend composites. This indicates that filler loading is a function of the measured parameter attributed to the degree of dispersion of the fillers (Asore, 2000). The observation may therefore be attributed to the degree of dispersion of RHA and PS particles in the rubber matrix, where the filler-rubber interaction is poor the abrasion tends to be high.

As the filler loading of RHA and PS increased in the NR/SBR blend, Table 2 and Figure 6 showed a decline in the compression set. The decline is expected because there are fewer voids in the matrix as filler loading concentration in the rubber matrix increases, which leads to a decrease in percentage compression (Abode, 2010; Amoke et al, 2017). The maximum value of compression set (56.0116%) was for the unfilled NR/SBR blend, and the lowest values were 35.5218% and 28.8075% for the composites with RHA and PS fillers, respectively. The compression set values for the PS-filled NR/SBR blend composites were lower than those for the RHA-filled NR/SBR blend composites, proving that they had a higher compression set than the unfilled and RHA-filled blend composites.

The data in Table 2 and Figure 7 showed that while the flex fatigue of the NR/SBR blend composites decreased, the filler loading of RHA and PS increased. The stiffening of the polymer chain caused by the filler's adhesion to the polymer phase and subsequent resistance to stretching under strain can be used to explain a decrease in flex fatigue (Tenebe et al, 2013). It is conceivable that as filler loading increases, more filler aggregates and particles won't be effectively distributed and wettable by the rubber matrix (Sukru et al, 2008).

5.0 CONCLUSION

The assessment of exhaust pipe suspender from a blend of natural rubber (NR) and styrene butadiene rubber (SBR) filled with rice husk ash and periwinkle shells has been studied. These fillers have proven they can potentially act as reinforcement in NR/SBR blends. In comparison to PS-filled NR/SBR blend composites, the RHA-filled NR/SBR blend composites showed enhanced mechanical properties. The filler loading has a considerable impact on the mechanical properties, which is an important consideration when choosing where to use such polymer products. At filler loading 10–40 phr, the NR/SBR blend composites filled with RHA had higher tensile strength (24.889–28.7815 N/mm^2) and tensile modulus (10.4315–13.6320 N/mm^2) than those filled with PS, which had tensile strength (18.3524–24.6045 N/mm^2) and tensile modulus (7.9352–10.9903 N/mm^2). At filler loadings of 10 to 50 phr, the hardness of NR/SBR blend composites filled with RHA increased from 52.8878 to 68.4603 IRHD while that of NR/SBR blend composites filled with PS increased from 50.0255 to 64.3209 IRHD. In all filler loadings, the RHA-filled NR/SBR blend composites demonstrated higher abrasion resistance values than the PS-filled NR/SBR blend composites. Exception for unfilled, which exhibited the lowest value of abrasion resistance, the abrasion resistance increased as the filler loadings increased. When filler loadings are increased for RHA-filled NR/SBR blend composites and PS-filled NR/BSR blend composites, the compression set and flex fatigue decrease. In comparison to the RHA-filled NR/SBR blend composites, the PS-filled NR/SBR blend composites had lower values for compression set and flex fatigue, showing that PS-filled NR/SBR blend composites had better compression set and flex fatigue. It can be observed that the RHA-filled NR/SBR blend composites are more beneficial for manufacturing items with greater mechanical properties such as exhaust pipe suspender, foot mat, and shoe sole while the PS-filled NR/SBR blend composites are more useful for producing products with lower mechanical properties.

5.1 RECOMMENDATION

In order to modify this research work in future, the following recommendations are projected:

i. The influence of fillers, which are agricultural wastes, on the mechanical properties of polymer blend composites should be studied in relation to their nanoparticles.

ii. To improve the adherence of the fillers to the rubber blend matrix, further research should be done on the use of coupling agents.

iii. Rice husk and periwinkle shell should be carbonized, and its reinforcing potentials on the blend of natural and styrene-butadiene rubber should be similarly studied.

iv. Analyses on the reinforcing potentials of RHA and PS on the blend of natural rubber and styrene-butadiene rubber should be conducted using comparable ratios of the NR and SBR blends.

REFERENCES

Abode, S.I. (2010): An Investigation into the use of carbonized bagasse filler in rubber products. Postgraduate Diploma in Production Engineering Thesis. University of Benin.

Abubakar, M. S. and Ahmad, D. (2010): "Pattern of Energy Consumption in Millet Production for Selected Farms in Jigawa, Nigeria," Australia Journal of Applied Sciences, Vol. 4, No. 4, pp. 665-672.

Ahmad A, Mohd D.H, and Abdullah I, (2004,): Mechanical Properties of Filled NR/LLDPE Blends, Iranian Polymer Journal, 13(3), 173-178.

Albano, C, Karam, A, Dominguez, N., Sanchez, Y., Gonzalez, J., Aguirre, O. and Catano, L. (2005): "Thermal, Mechanical, Morphological, Thermogravimetric, Rheological and Toxicological Behavior of HDPE/Seaweed Residues Composites," Journal of Composite Structures, Vol. 71, No. 3-4, pp. 282-288.

Anyaporn Boonmahitthisud, Peeraphong Pokphat, Phasawat Chaiwutthinan and Saowaroj Chuayjuljit (2017): Nanocomposites of NR/SBR Blend Prepared by Latex Casting Method: Effects of Nano-TiO_2 and Polystyrene-Encapsulated Nano-TiO_2 on the Cure Characteristics, Physical Properties, and Morphology Hindawi Journal of Nanomaterials Volume 2017, Article ID 7676158, 11 pages

Amoke, A., Ogbobe. O., Tenebe, G.O., Ichetaonye, S.I. and Ayo. M.D (2017): Physico-Mechanical Properties and Water Absorption Behaviour of Natural Rubber Vulcanizates Filled with Sawdust. Research and Reviews in Polymers.8 (1):108.

Asore, E.J., Imanah, J.E. and Idiaghe, J.A. (2010): Principle and Techniques of Polymer Blends and Composites, Ribway Printers and Publishers Limited, Benin City, Nigeria, Vol. 1, 23 – 30

ASTM-D 412-87 (1983): American Standard Testing Method for Tensile Strength for Compounded Rubber

ASTM-D 385 (1983): American Standard Testing Method for Compression Set for Compounded Rubber

ASTM-D 430 (1983): American Testing Method for Flex Fatigue of Compounded Rubber

ASTM-D 785 (1983): American Testing Method for Hardness of Compounded Rubber

Ates, S, Ni, Y. and Tozluoglu, A. (2008): "Characterization and Evaluation of Paulownia Elongata as a Raw Material for Paper Production," African Journal of Biotechnology, Vol. 7, No. 22, pp. 4153-4158.

Ayfer, D. C., Hulya, K. and Fatih, M. (2011): "Tea Mill Waste Fibers Filled Thermoplastic Composites: The Effects of Plastic Type and Fiber Loading," Journal of Reinforced Plastics and Composites, Vol. 30, No. 10, p. 833.

Boonmahitthisud, A., Pokphat, P., Chaiwutthinan, P and Chuayjuljit, S. (2017): Nanocomposites of NR/SBR Blend Prepared by Latex Casting Method: Effects of Nano-TiO_2 and Polystyrene-Encapsulated Nano-TiO_2 on the Cure Characteristics, Physical Properties, and Morphology Hindawi Journal of Nanomaterials Volume 2017, Pp. 1-11

Boonmahitthisud A and Chuayjuljit, S (2012): "Effects of nanosized polystyrene and polystyrene encapsulated nanosilica on physical properties of natural rubber/styrene butadiene rubber nanocomposites," Polymer-Plastics

Technology and Engineering, vol. 51, no. 3, pp. 311–316.

Choi S. S, and Ha S. H (2009): Journal of Industrial and Engineering Chemistry, 15, 167-170.

Chuayjuljit, S, Nutchapong, T., Saravari, O and Boonmahitthisud, A. (2015): "Preparation and characterization of epoxidized natural rubber and epoxidized natural rubber/carboxylated styrene butadiene rubber blends," Journal of Metals, Materials and Minerals, vol. 25, no. 1, pp. 27-36.

Dominique, M. R., Georget, D. M. R., Elmoneim, O. Abd, Elkhalifa, A. E. O., and Beltom, P. S. (2012): "Structural Changes in Kafirin Extracted from a White Type II Tannin Sorghum," Journal of Cereal Science, Vol. 57, No. 48, pp. 106-111.

Egwaikhide P.A., Akporhonor E.E., and Okieimen F.E, (2007): Effect of Coconut Fibre Filler on the Cure Characteristics, Physico- mechanical and Swelling Properties of Natural Rubber Vulcanizates, International Journal of Physical Sciences, 2(2), 39-46.

Findik F, Yilmaz R, and Koksal T. (2004): Investigation of mechanical and physical properties of several industrial rubbers. Material Design.25:269-276.

Goyanes, S., C.C. Lopez, G.H. Rubiolo, F. Quasso, and A.J. Marzocca. (2008): Thermal properties in cured natural rubber/styrene butadiene rubber blends. European Polymer Journal, 44(5), 1525-1534.

Igwe I.O. and Ejim A.A., (2011,): Studies on Mechanical and End-use Properties of Natural Rubber Filled with Snail Shell Powder, Materials Sciences and Application, 2, 802-810.

Jawad K. O., Mohammed S.H., and Nassier A.N (2013): Studies of the Effect of Carbon Black Particles on the Mechanical Properties of SBR/NR Blends Used in Passenger Tire Treads. The Iraqi Journal for Mechanical and Material Engineering Special Issue, 77-82

Jovanovic, V., S. S. Jovanovic, J. B. Simendic, G. Markovic, and M. M. Cincovic. (2013). Composites based on carbon black reinforced NBR/EPDM rubber blends. Composites Part B: Engineering, 45(1), 333–340.

Lovely M., Joseph K.U, and Joseph R., (2006): Swelling Behavior of Isora/Natural Rubber Composites in Oils used in Automobiles, bull. Mater. Sci., 29(1) 91-99.

Osabohien E. and Egbo S.H.O., (2007): Cure Characteristics and Physico-mechanical Properties of Natural Rubber Filled with the Seed Shells of Cherry (chrysophyllum albidum), J. Appl. Sci. Environ. Manage, 11(2), 43-48.

Osarenmwinda, J. and Abode, S. (2010): Potential of Carbonized Bagasse Filler in Rubber Products. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 1 (2): 157-160

Park S. J, Seo M. K and Nah C. (2005): Journal of Colloid and Interface Science, 291, 229-235.

Phiriyawirut, M. and Luamlam, S. (2013): "Improved automotive fuel resistance of natural rubber/chlorosulfonated polyethylene blends by blending epoxidized natural polymer," Open Journal of Organic Polymer Materials, vol.3, no.4, pp. 104–109.

Savran, O. H. (2001): Elastomer technology 2, basic elastomers, Publications of Rubber Society, Ýstanbul

Sukru YO, Zlem C, and Ahmet C (2008): The effects of fibre contents on the mechanical properties of adobes. Construction and Building Materials 6:22.

Suwatthana P. and Cattaleeya P., (2010): Compatibility Improvement of Rice

Husk and Bagasse Ashes with Natural Rubber by Molten State Maleation, European Journal of Scientific Research, 43(3), 411-416.

Tangudom P, Thongsang S, and Sombatsompop N. (2014): Cure and mechanical properties and abrasive wear behavior of natural rubber, styrene-butadiene rubber and their blends reinforced with silica hybrid fillers. Material Design. 53, 856-864.

Tenebe O.G, Ayo M.D, Ichetaonye SI, et al. (2013): Effect of filler loading on the mechanical properties of natural rubber filled with guinea corn husk (Holus sorghum) as filler. International Journal of Life Science;2(4):156-16.

Vu, C.M, Vu, H.T and Choi, H.J (2015): "Fabrication of natural rubber/ epoxidized natural rubber/nanosilica nanocomposites and their physical characteristics "Macromolecular Research, vol. 23, no. 3, pp. 284-290.

Williams, A.O; Amoke, A and Ayo, M.D (2022): Assessment of the Mechanical Properties of NR/SBR Blend Reinforced with Egg Shell and Carbon Black. International Journal of Innovations in Engineering Research and Technology (IJIERT), Volume 9, ISSN: 2394 3696, Pp 53-63