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Effect of Sawdust as Filler on the Mechanical Properties of Natural Rubber Compound

[1]Okele, A.I, [2]Damburi, N. [3]Buba, M.A. [3]Garba, P., [1]Musa, E. and [3]Marut, A.J.
[1]*department of Polymer Technology,*
Nigerian Institute of Leather and Science Technology,
P.M.B 1034, Samaru Zaria, Kaduna State, Nigeria
[2]*department of Leather Technology,*
Nigerian Institute of Leather and Science Technology,
P.M.B 1034, Samaru Zaria, Kaduna State, Nigeria
[3]*department of Industrial and Chemical Process Technology,*
Nigerian Institute of Leather and Science Technology,
P.M.B 1034, Samaru Zaria, Kaduna State, Nigeria

Abstract: This project work focused on compounding and curing of natural rubber filled with sawdust as filler. The purpose of this research work was to investigate if the incorporation of sawdust in natural rubber compounding can enhance increase in tensile strength, water absorption resistance, abrasion resistance and hardness strength and also to determine their properties with different mixing ratios. Two roll mill was used in compounding the different ratio of filler in 0g, 10g, 20g, 30 and 40g into natural rubber and compressing (curing) was done using a hydraulic hot press at a temperature of 140°C. Afterward various tests were carried out on the vulcanizate which include hardness test, tensile strength, water absorption test and abrasion resistance. The following results were obtained for average hardness test 30.14, 34.71, 53.57, 57 and 64. For percentage abrasion resistance these results were obtained 2.9, 5.17, 11.7, 8.8 and 7.1. For percentage water absorption the following result were obtained 4.76, 4.16, 5.26, 3.57 and 6.06. It was observed here that the natural rubber with incorporated sawdust powder filler is good for application where hardness and water absorption is required.
Keywords: Sawdust, Filler, Tensile strength and Filler loading.

1.0 Introduction

Due to the vital role natural rubber plays in our economy from the19th century till date has prompted the study on improving its properties by the incorporation of additives.

Raw dry natural rubber is seldom, if ever used in its original state for any engineering application. Additives are foreign materials which are usually added to a base polymer in order to modify the polymer and to give an effect on the original base polymer, also to reduce cost of production and enhance service properties.

Natural rubber also called *caoutchouc* as initially produced consist of polymer of the organic compounds isoprene with minor impurities of other organic compounds plus water Natural rubber is used by many manufacturing companies for the production of rubber products; currently rubber is harvested mainly in the form of the latex from *para* rubber tree or others. The latex is sticky, milky colloid drawn off by making incision into the barks and collecting the fluid in vessels in a process called "*tapping*" the latex is then refined into rubber ready for commercial processing. The latex is allowed to coagulated lumps are collected and processed into dry form for marketing.

In recent years exhaustive research has been carried out on utilizing natural rubber as efficiently as possible to produce superior quality filler reinforced polymer composite for a wide range of application (Premlal et al, 2002, Sharma et al, 2001,Rahman et al, 2010, Yang et al, 2006).

The effect of sawdust content on the current characteristics and mechanical properties of EPDM composite was studied, it was found that sawdust content has no effect on the scorch time, the cure time, the minimum torque and maximum torque increased with increased sawdust content also increase in the hardness of the composite but tensile and elongation at break decreased, heat ageing resistance and ozone resistance slightly decreased. (Saramolee P and Saranyoo N, 2007)

Characteristics of wood sawdust and natural rubber composite processed by electronic beam and

radiation, physico-mechanical properties such as hardness, modulus at 100% elongation and tensile strength indicate a significant improvement as a result adding sawdust to blends. (Mara,2005).

The characterization of sawdust residues has been studied and evaluated to determine its potential utilization as a biomass fuel for cyclone gasifier. The raw sawdust was produces by cutter, sawing, sieving and sanding; the raw sawdust was pretreated throughout grinding process into smaller particles size and sieved. the sample of ground sawdust was analyze for it biomass fuel characteristic the result showed that the ground sawdust with a moisture content of 8.25% (wet basic) contained 14.04% fixed carbon, 76.23% of volatile matter and 1.49% of ash on dry basis. (Miskam et al, 2009).

The different types of additives used in rubber processing into fine products include, vulcanization agent, accelerators, anti-degradant, fillers, softeners, colorants etc. (Okieimen and Imanah, 2003).

Natural rubber is one of the most important elastomer and widely utilized to manufacture many rubber products such as sole of a shoe and floor mat. Natural rubber is usually reinforced by the incorporation of fillers to improve its mechanical properties such as modulus, hardness, tensile strength, abrasion resistance, tear resistance and compression resistance etc. Fillers are materials that are added to rubber compounds to modify its physical properties such as tensile strength, hardness, abrasion resistance etc. and also to facilitate processability, increase bulk and to reduce cost. In rubber industries Fillers that are commonly used are carbon black, China clay, and Calcium carbonate and Aluminumsulphate

Recently there has been a growing interest in the use of renewable resources such as limestone, eggshell, corn hob, kaolin, rubber seed shell, groundnut shell, coconut shell, and sawdust etc. as a result of its biodegradability but they are among them underutilized renewable resources in our society today which can be used directly or converted by simple processes to valuable material in polymer or related application (Osabohien et al 2004, Adeosun 2000, Ishak et al 1995, Oguniyi 1980, Jideonwo et al 2000, Imanah 2003 and Adewisi 1997).

However in this research work it was intended to work into the use of sawdust as an agricultural waste in natural rubber compounding for improved mechanical properties.

Materials and Methods

Materials

The materials that were used to carry out this research are as follows:
Natural rubber(NR), Sawdust, Zinc oxide(ZnO), Trimethylquinoline(TMQ), Mercapto benzoyl thiazole(MBT), Stearic acid, Processing oil and Sulphur

3.1 Equipment and Apparatus

The Equipment and Apparatus Used For This Work are Two roll mill, Hardness tester, Laboratory milling machine, Weighing balance, Hydraulic hot press, 450um sieve, Tensometer, Foil paper and mold, Shoe filling machine

The table below is a list of some equipment used for this research work and the various manufacturers' names as well as model number:

Table 1

S/N	Equipment	Manufacturer	Model no	Test location
1	Two roll mill	Reliable plastic and rubber company	5185	NILEST
2	Hardness tester	MuverDurometer	ShoreADurometer 5019	NILEST
3	Hydraulic hot press	Carver Inc. hydraulic press	60648	NILEST
4	Milling machine	Thomas-Wiley laboratory	4	NILEST
5	Tensometer	Monsanto Tensometer	9875	A.B.U
6	Shoe filling machine	Torielli service	730/M60	NILEST

Table 2
Formulation Table

S/N	Ingredients /Part per Hundred (g)		Sources
1	Natural Rubber	100	NILEST
2	Zinc Oxide	5.0	NILEST
3	Stearic Acid	2.0	NILEST
4	MBT	1.5	NILEST
5	TMQ	1.5	NILEST
6	Sawdust	Variable (0-40)	SABON GARI MARKET
7	Processing oil	3.0	NILEST
8	Sulphur	2.5	NILEST

Methodology

Filler Preparation

The sawdust used in this research work was obtained from the local sawmill at Sabon-Gari market in Zaria. After collection the sawdust was dried on a concrete slab for 3days and with the help of laboratory mill it was grounded into fine particulate powder and the resultant powder was sieved with a mesh size of 450um.

Compounding

The sawdust and the natural rubber was weighed according to the formulation table and was further compounded together using a two roll mill at a temperature of $70^{o}C \pm 5^{o}C$ into a homogenous mixture with appropriate addition of the additives in correct order in line with ASTM D 3182 method

Curing

The floor mat production was carried out on an electrically heated hydraulic hot press, a metallic mold was fitted with foil paper and processing oil was rubbed on the surface of the foil to avoid sticking of the compounded sample to the mold and to enhance easy removal of the sample after curing. The homogenous mixture was placed in the foil paper fitted metallic mold rubbed with processing oil and the mold was carefully closed and placed in between the platen of the hydraulic press at a temperature of $140^{o}C$, pressure and heat were applied and the sample was left to cure for 10minutes after which the sample was removed and placed in a cooler platen for 5minutes then it was removed from the mold and the foil removed from it surface.

Test Carried Out On the Samples

i. Hardness test
ii. Abrasion resistance test
iii. Water absorption Test
iv. Tensile strength

Hardness Test

This is the relative resistance of a sample to indentation by an indentor at a specific dimension under a specific load. This test was carried out using a hardness tester (Durometer) and the SI unit for measurement was the International Rubber Hardness Degree (IRHD) the ATSM D1415 (1983) was adopted
The sample was placed on the sample holder of the tester and the pins were allowed to penetrate the samples by moving the knob forward and then released when the pin had penetrated the sample. The procedure was repeated for seven indentations on the samples and the values were recorded and average taken.

Abrasion Resistance Test

This test was carried out by taking the initial weight of the sample; the sample was then subjected to rub by using a Shoe filling machine ensuring that equal and uniform pressure was applied for a period of 4minutes. After which the final weight of the sample was recorded.
The procedure was repeated for each percentage of the filler loading. The abrasion resistance was calculated using the below equation:

$$\%\text{abrasion resistance} = \frac{W_0 - W_1}{W_0} \times 100$$

3.4.3 Water Absorption Test

The water absorption was carried out according to the standard specified by BSEN ISO62:1999, the samples were cut into specified sizes and the mass noted (W_0). The samples were then immersed into a container filled with water and allowed to stay for 48hrs. After which they were removed, dried using a handkerchief and then reweighed (W_1). Themasses were noted and calculated using the below equation:

$$\%\text{absorption} = \frac{W_0 - W_1}{W_0} \times 100$$

Tensile Strength

The tensile strength was carried out using a tensometer, the sample of 50mm guage length was clamped on the jaws of hunsifiedtensometer and equal forces were applied in opposite direction until the sample failed. A graph of force against extension was obtained. The same procedures were repeated for all the samples and result obtained.

Results and Discussion

Results

Several physico-mechanical properties were carried out on the natal rubber and sawdust vulcanizate. Such test includes hardness, abrasion resistance, water absorption test and tensile strength test. The results obtained are illustrated in the tables below:

Table 3
Hardness Test Result

S/N	Samples loading (g)	Hardness Value
1	0	30.14
2	10	34.71
3	20	53.57
4	30	57
5	40	64

Table 4
Abrasion Resistance Result

Filler Loading (g)	% abrasion
Non-SD (0g)	2.9
10g	5.12
20g	11.7
30g	8.8
40g	7.1

Table 5
Water Absorption Result

Filler loading (g)	% water absorption
Non-SD (0g)	4.76
10g	4.16
20g	5.2
30g	3.57
40g	6.06

Table 6
Tensile Strength Result

Filler loading (g)	Stress(N/mm^2)	Strain	% elongation	Young Modulus (N/mm^2)
0g	0.933	5.58	558	0.167N/mm^2
10g	1.111	5.77	577	0.192N/mm^2
20g	2.77	5.15	515	0.537N/mm^2
30g	3.587	4.72	472	0.759N/mm^2
40g	2.39	4.38	438	0.545N/mm^2

Figure 1: A graphical illustration of hardness test result

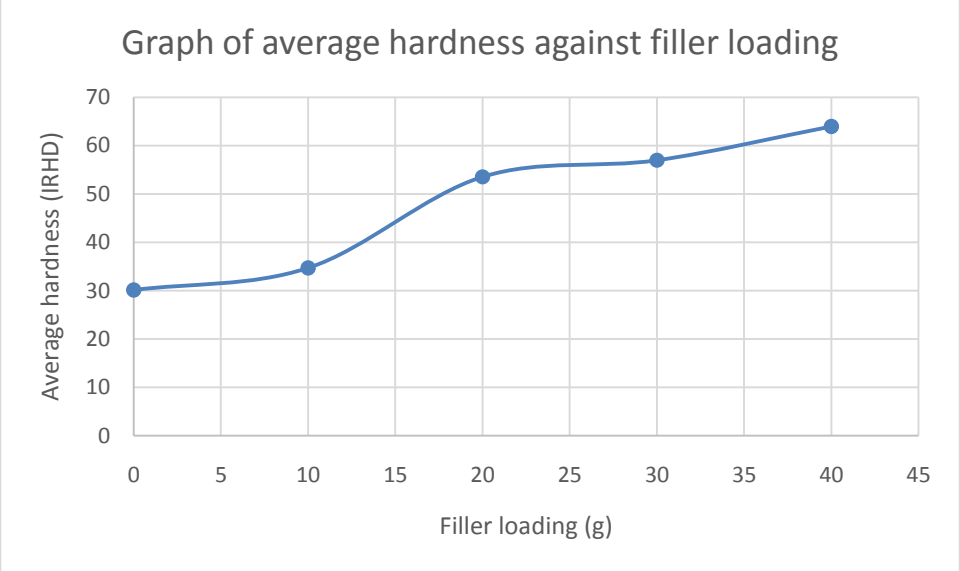


Figure 2: A graphical illustration for abrasion test result

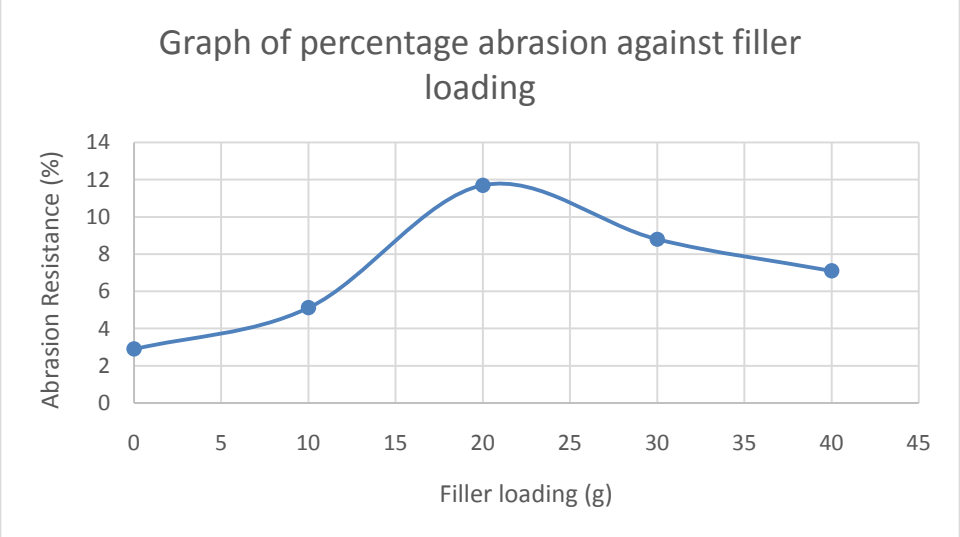


Figure 3: A graphical illustration for water absorption test result

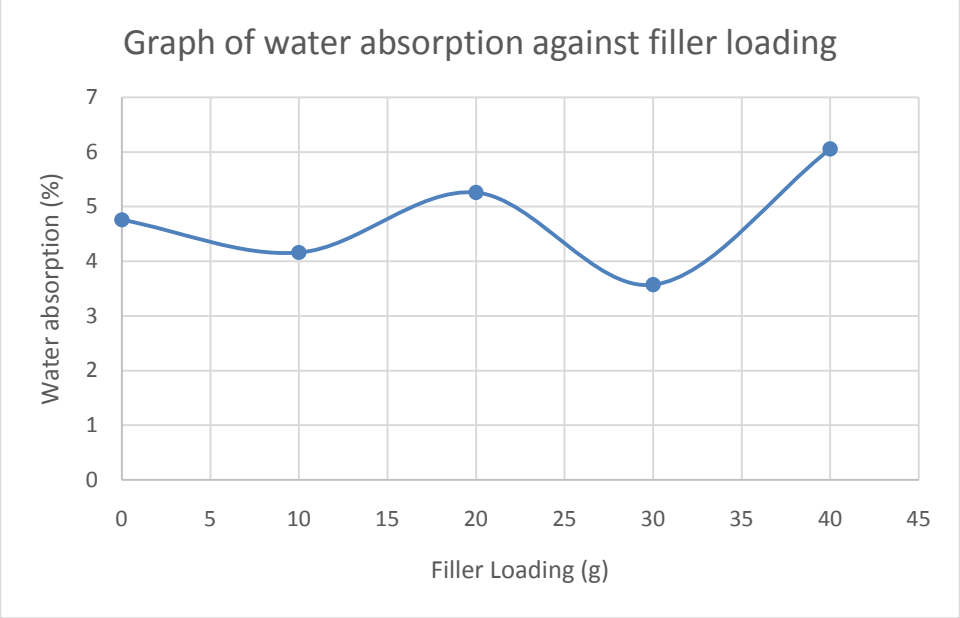


Figure 4: A graphical illustration of stress against filler loading

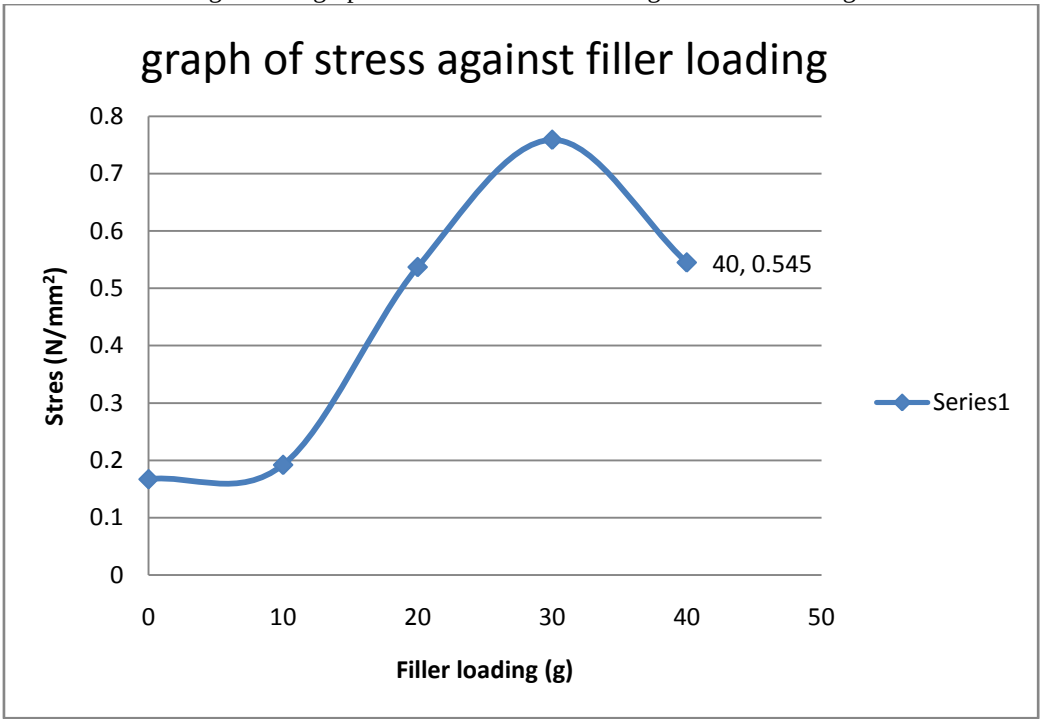


Figure 5: A graphical illustration of strain against filler loading

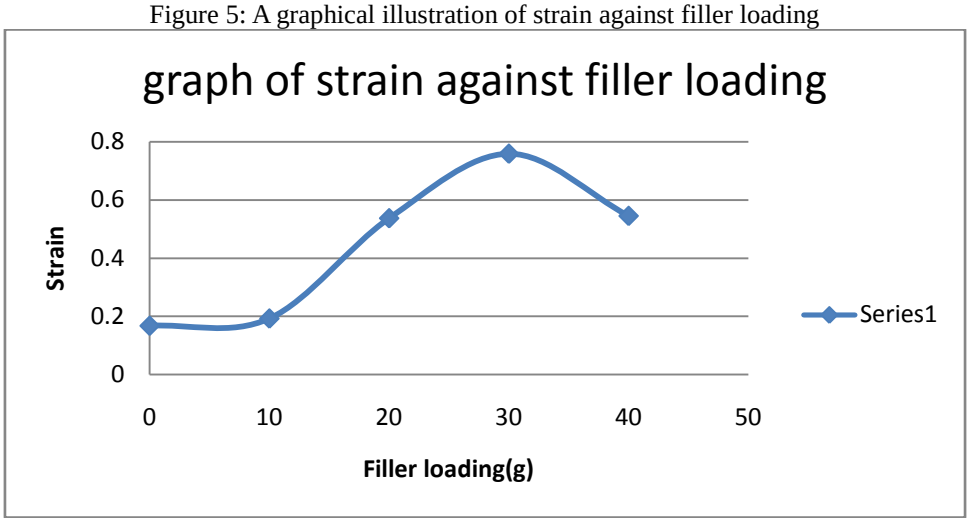
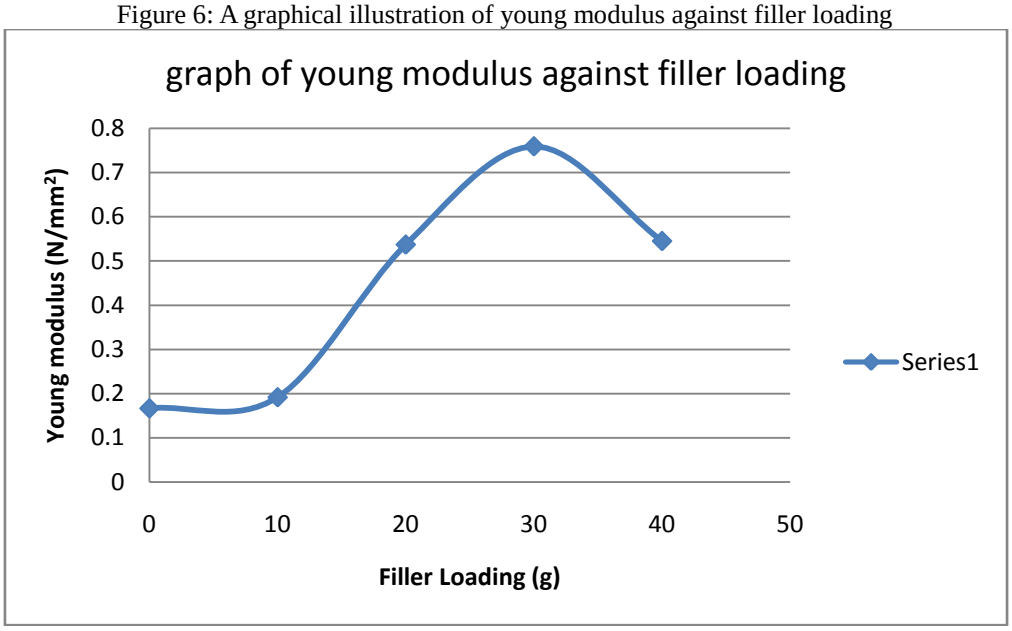


Figure 6: A graphical illustration of young modulus against filler loading



Discussion of Results

The result from the characterization of the filler shows that the filler is slightly alkaline in nature and suitable for compounding with accelerating the proper time of vulcanization.

Since acidic filler increase the time of proper vulcanization, alkaline fillers are needed in rubber compounding because they tend to reduce the time required for proper curing vulcanization which is very essential in any rubber compounding process short cycle time is required for a faster production.

Hardness as measured in this study is the relative resistance of the surface of samples to indentation by an indentor of specified dimension under a specified load. It is generally known that filler increases the hardness of a material. From figure 1, the result for hardness test was observed that the hardness of the vulcanizate tend to increase as the amount of filler loading increases. Although the vulcanizate without any amount of filler is hard but the hardness obtained is not as good as the hardness obtained from the vulcanizate with higher filler loading. Appendix A also gives the graphical effect of filler loading on the degree of hardness natural rubber filled with sawdust powder.

Gravan*et al*. (1969), defined abrasion as the unwanted progressive loss of substance from the surface of a body brought about by a mechanical action from the rubbing of one surface against another. The abrasion of

filled polymers depends on the relative size of the filler particle, the size of abrader, type of filler, and the nature of interface and strength of adhesion between the phases. Abrasion resistance is higher (low wear) when the filler particles are larger compared to the size of the abrasive particles, if the adhesion between the filler and the polymer matrix is good. Figure 2 shows the result of the vulcanizate to abrasion, from the result it was observed that the sample without filler loading is having a better abrasion than the vulcanizate with higher amount of filler loading. The result also shows a decreasing resistance to abrasion at increasing amount of filler loading. This is due to fact that the presence of filler tends to break the bond between the polymers thereby result in less abrasion resistance, but the decrease in resistance to abrasion stopped at 30g loadings were there was a further increase in resistance to abrasion from 40g – 50g

Figure 3 shows the result of the vulcanizate to water absorption it was observed that both the sample without filler and those with filler loading from the lowest to the greatest has high resistance to water absorption. This quality makes natural rubber and sawdust vulcanizate makes it very good for outdoor use as it has greater resistance to water absorption.

Figure 4 shows the result of the vulcanizate to tensile stress, it was observed that the vulcanizate with no filler loading exhibit high extension of 5.85mm while the sample with 10g of filler loading exhibit highest extension of 6.145, a noticeable decrease in the extension was consistence as filler loading increased from 20g, 30g and 40g for both two samples. The extension decreased from 5.85mm to 4.515mm. The decrease in the extension with increase in filler loading could be due to the fact that filler loading into polymer matrices disrupts polymer molecules from free mobility under stress as evident by Robert O. E, 2001.

Conclusion and Recommendations

Conclusion

Sawdust is an agricultural by product which was used in this project to substitute the role of the industrial fillers in natural rubber vulcanizate from the entire test carried out it was observed that the hardness increased with increase in filler loading.

The effect of sawdust on the mechanical properties of natural rubber was analysed and it revealed that the abrasion resistance of the vulcanizate and the tensile strength tends to be reducing with increase in filler loading and this is because of the space in between the molecules of the rubber which was created by the incorporation of the filler.The resistance to water absorption of the vulcanizate remains the same with that of no filler loading.

It can therefore be concluded from here that the natural rubber with incorporated sawdust powder filler is good for application where hardness and water absorption is required

Recommendations

From the results obtained in the course of this work the following recommendations were drawn: We recommend that further research should be carried out on this filler and also the micro structure should also be analyzed so as to discover other properties that this filler can induce in natural rubber.

The particle nature of sawdust as filer should be further reduced so to know how it can as well affect the mechanical properties of natural rubber compound.

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