Analysis of Bamboo Fiber as Filler on the Mechanical Properties of Natural Rubber Compound

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Abstract

This research is based on the study of bamboo fiber as filler in natural rubber compound. The mechanical and sorption properties of bamboo fiber were analyzed to establish the possibility of using it as material for natural rubber article applications. The bamboo fiber was sourced locally, washed, dried, grinded and sieved and used as filler in natural rubber compounding. The bamboo fiber filler was used at different filler loadings of 0, 10, 20, 30 and 40g. The results of the tests indicated that tensile strength and flexural strength increases as filler loading increases from 10 – 30g. This was attributed to high surface area of the bamboo fiber which suggested better polymer interaction. However there was a decrease at filler loadings beyond 30g. The hardness result showed increase with increasing filler loading, thus filler loading at 40g gave the highest hardness of 25 IRHD. The sorption results for kerosene and diesel showed a decrease in sorption properties with increasing filler loading. This indicated that filler reinforcement prevented the rubber compound from solvent absorption.

***Keywords**: Natural rubber, Bamboo fiber, Sorption, Filler, Tensile Strength*

INTRODUCTION

Natural rubber (NR) is a known commodity polymer as well as a potential industrial elastomer because of its unique quality of phsico-mechanical properties. It has been compounded by other ingredients designed to be used for diverse applications such as fan belt, seal ring, conveyor belt, hand cover, power cable, air craft tyres, motor car tyres, brake linking, tractor, mudguard and clutch lining, etc. (Broutman et al., 2012). As mentioned, natural rubber has been compounded with other renewable resource materials as well as high durable materials by physical and chemical means, especially to impart and reinforce thermal stability, hardness and flame-retardant properties (Ghosh, 2013).

Natural rubber products are numerous in the society and they include automobile tyres, gasket, hoses, personal protective equipment etc. Hence, the demand for rubber based product is increasing with time which in turn leads to an increase in the price of natural rubber.

Fillers are incorporated in rubber composites to improve certain properties and reduce the materials cost. Fillers are one of the most important components and are added at the second highest portion in the products, whereas non-reinforcing fillers have little or no effect on the rubber properties. There are varieties of fillers available and used commercially in the rubber industry. The use of filler is necessary to achieve the level and range of properties that are required for technical reasons (Osabuohien, 2012).

Natural fibers are cheaper, pose no health hazards, and provide a solution to environmental pollution by finding new uses for waste materials. Moreover, natural fibers, being available in many developing countries, would allow these countries the opportunity to use their own natural resources in their composite processing industries (Hassan et. al., 2010).

In Myanmar, bamboo is one of the abundant natural resources and the most important non-wood low cost forest product, which has been extensively utilized in a wide diversity of applications. Bamboo is a rapid fibrous growing plant available in abundance on the earth and mainly consists of roots, culms and leaves. The bamboo fibers are naturally possessed with finer mechanical properties, but are brittle in nature as compared to other natural fibers due to the extra lignin content covering the bamboo fibers. Presently bamboo is considered important plant fiber and has a great potential to be used in polymer composite industry. It structural variation, mechanical properties, extraction of fibers, chemical modification, and thermal properties has made it versatile for use in composite industry (Dunkelberg, 2015).

Most of the bamboos are found in forestry and it is also widely spread outside forests usually farmlands, riverbanks, roadsides and rural areas. Bamboo is a long stick like non-wood forest product and sometimes used as wood substitute. They are used for housing, crafts, pulp, paper, panels, boards, veneer, flooring, roofing, fabrics and vegetable (the bamboo shoot). Products of bamboos are used everywhere and bamboo industries are now thriving in Asia and are quickly expanding across the continents to Africa and America (Bess, 2011).

The search for means and method of improving the properties and processing of rubber dates back to over a century ago. One way of achieving this extension of service life of rubber is the incorporation of additives into the polymer matrix. Additives are materials when incorporated into polymer base, help to ensure easy processing, reduced cost of production and enhanced service properties (Ski, 2014). The different type of additives used in the processing of rubber into product include, vulcanizing agent, accelerator, activator, anti degradant, fillers, softner, thickners, gel sanitizer, colorant e.t.c. (Okieimen et al., 2003).

Filler is one of the major additives used in natural rubber compound and has marked effect and influence on rubber materials. Filler functions to modify the physical and to some extent, the chemical properties of vulanizates (Drivers, 2012). The mechanism of reinforcement of elastomers by fillers has been reviewed by several workers (Brenan et al., 2013).

Economically, it is not possible to produce rubber product by using natural rubber only i.e. some materials are mixed with natural rubber to produce some better quality product to meet up the customer expectation. It’s now obvious at the point that filler will be added to improve the physical and mechanical properties of the vulcanizate.

Natural filler such as bamboo fiber, coconut fiber, rice husk, palm fruit fiber etc if not used are waste in landfills but can be chosen to reinforce natural rubber and increase its mechanical properties since they are also cheaper alternative as filler to process natural rubber.

The present work is concerned with the production of rubber compound from natural rubber and bamboo fiber as filler. This work indicates that it is feasible to utilize cost effective bamboo fiber and waste bamboo chopsticks as fillers to make eco-friendly composites materials.

MATERIALS AND METHODS

SAMPLE PREPARATION

Bamboo fiber was collected from, Colins Bamboo plantation, Agbor, Nigeria and then washed to remove any possible impurities and dirt particles, it was sun dried for two days to eliminate the moisture content. The dried bamboo fiber was then grinded and sieved to 0.250mm particle size.

Sources of other materials

The natural rubber (NSR - 10) used as the base polymer was purchased from Rubber Research Institute of Nigeria (RRIN), Iyanomo, Edo state. The remaining compounding additives such as zinc oxide, stearic acid, 1, 2-dihydro -2,2,4-Trimethy quinoline (TMQ), mercaptobenzothiazyl disulphide (MBTS), Tetramethly thiuram disulphide (TMTD), sulphur and processing oil were sourced commercially and used as supplied.

CHARACTERIZATION OF BAMBOO FIBRE

The pH of the bamboo fiber powder, moisture content and ash content were determined using standard methods according to ASTM D1512, ASTM D1509 and ASTM D2554 respectively.

PROCESSING OF THE NATURAL RUBBER COMPOUND

The formulation used for the compounding of natural rubber with bamboo fiber is given below;

Table 1: Formulation Table

Materials	**Formulation (pphr)**

Natural Rubber	100
Zinc oxide	5
Stearic Acid	2
Sulphur	1.5
MBTS	1.5
TMTD	1
TMQ	1.5
Processing Oil	5
Bamboo fiber	0, 10, 20, 30, 40

The rubber mixes were prepared on a laboratory size two-oil mill. The two roll mill was maintained at 70^{o}C to avoid premature vulcanization during mixing after which the rubber compound was stretched out. Mixing follows ASTM D3184 – 8 standards.

CURING OF THE NATURAL RUBBER COMPOUND

Curing of the vulcanizates was carried out at 120^{o}C for 12 minutes in the compression molding machine in order to get a three dimensional product. Compression moulding is a process of shaping and vulcanizing rubber by means of heat and pressure in a mould of appropriate design. The material softens and flows to take the shape of the mold.

ANALYSIS OF MECHANICAL PROPERTIES

Some mechanical properties tests were carried out on samples of the rubber compound to determine the effect of bamboo as filler on the properties of rubber compound:

TENSILE STRENGTH

The tensile properties were determined on a universal testing machine at a specified speed using a dumbbell test pieces of a specified dimension. The test sample was tested in the machine giving straight tensile pulling without any bending or twisting. The machine measures both the tensile stress and tensile strain. The tensile stress is the strength of pull in the area. The tensile strain is a measure of how the test sample has stretched in relation to the pull (Hebel et al., 2014).

FLEXTURAL STRENGTH

Flextural testing is performed in accordance with ASTM method D790 to measure the flextural modulus. The flextural test measures the force required to bend a beam at a specific rate. Flextural modulus is an indication of a material’s stiffness when bent on a three point apparatus. The three point bending fixture supports the specimen and the load is applied to the center by the loading nose producing three point bending at specified rate. The main parts of this test are specimen depth (thickness), the support pan, the speed of the loading, and their maximum deflection for the test. (Steven et al., 2017).

MODULUS

An elastic modulus, also known as modulus of elasticity is a quantity that measures an object or substance resistance to being deformed elastically when a stress is applied to it. The elastic modulus of an object is defined as the slope of its stress-strain curve in the elastic deformation region. A stiffer material will have a higher elastic modulus. An elastic modulus has the form;

$$\lambda = \frac{\text{Stress}}{\text{Strain}}$$

where 'stress' is the force causing the deformation divided by the area to which the force is applied and strain is the ratio of the change in some parameters caused by the deformation to the original value of the parameter (Askeland and Phule, 2006).

ELONGATION AT BREAK

Elongation at break is the ratio between increased length and initial length after breakage of the test specimen of a controlled temperature.

Elongation is a type of deformation. Deformation is simply a change in shape of anything that undergoes stress. When we're talking about tensile stress, the sample deforms by stretching and become longer. Usually we talk about percentage elongation which is just the length the polymer sample is, after it is stretched (L), divided by the original length of the sample (Lo), and then multiplied by 100.

$$\text{Elongation at Break} = \frac{L}{Lo} \times 100$$

HARDNESS

Hardness is the resistance to indentation. Hardness is tested by forcing an indenter into the material and measuring how far it goes in. It is important to note that hardness depend upon the size and shape of the test piece. Test result can be true or apparent and there can be difference between the two. True hardness is the result obtained when the test piece shape and thickness conform to test standard (Hoffman, 2013). Apparent hardness is the result obtained when the test piece shape and thickness do not conform to the standard.

DETERMINATION OF SORPTION PROPERTIES

The sorption properties of the natural rubber compound in solvents like kerosene and diesel were determined in accordance with ASTM D471.

RESULTS AND DISCUSSION

Table 2: Results of Filler Characterization

Parameters	Results
Particle size (mm)	0.250
pH	6.81
Ash content (%)	81.40
Moisture content (%)	2.09

The P^H of bamboo fiber filler presented in table 2 was 6.81. This shows that the bamboo fiber was acidic in nature. However, P^H at acidic level tends to decrease cure rate and increase the inter link within the polymer matrix.

Table 2 also showed the result of the moisture content characterization of bamboo fiber which was 2.09%. The moisture content of the filler often used to predict the degree of defects arising from shrinkages during molding and curing of polymer materials, particularly for product processed at elevated temperature.

The ash content was as a result of the moisture content lost in the sample. The particle size was 0.250mm. Thus, filler affect polymer matrix reinforcement during compounding and vulcanization of rubber. However, the smaller the particle size, the more reinforcing the filler in the matrix. Thus, it has higher degree of reinforcement.

Table 3: Results of Mechanical Properties

Mechanical Properties	Filler Loading (g)				
	0	10	20	30	40
Tensile Strength (Mpa)	0.76585	0.50640	0.51265	0.65444	0.60422
Flextural strength (Mpa)	0.26591	0.22279	0.23509	0.42844	0.22577
Modulus (Mpa)	0.123032	0.06392	0.11340	0.12067	0.13255
Elongation at Break (%)	805.27	605.69	575.50	526.17	506.99
Hardness (IRHD)	5	15	18	20	25

Tensile Strength

The tensile strength result in table 3 shows increase in tensile strength as filler loading increases from 10g - 30g. This may be attributed to high surface area of bamboo fiber, suggesting better polymer interaction and hence tensile properties. However, when compared to the control formulation (0 filler loading) the natural rubber filled bamboo fiber has low tensile properties. The factors that affect the reinforcing potential of filler include; filler dispersion, surface area, surface reactivity, bonding capacity and the particle size (Lunnace et al., 2001).

Flexural strength

Flex fatigue result in table 3 indicates an increase with increasing filler loading from 10g – 30g. Filler loading at 10g has the lowest flex fatigue and increases to the highest at 30g and beyond which there is a decrease in flex fatigue. This may be due to filler compatibility of the polymer matrix. Such degree of flex fatigue has been explained in terms of adherence of the filler to the polymer phase leading to the stiffening of the polymer chain and hence resistance to stretch when stress is applied.

Modulus

The result showed that modulus of filled composite depends on the level of filler dispersion in the polymer matrix. The reduction in the particle size account for the improved modulus, since fine particle size increases modulus. Filler loading at 40g which gave 0.13255 Mpa showed a higher modulus than the control sample suggesting that at 40g filler loading, the filler is properly dispersed in the polymer matrix and acts as semi reinforcement in the rubber compound.

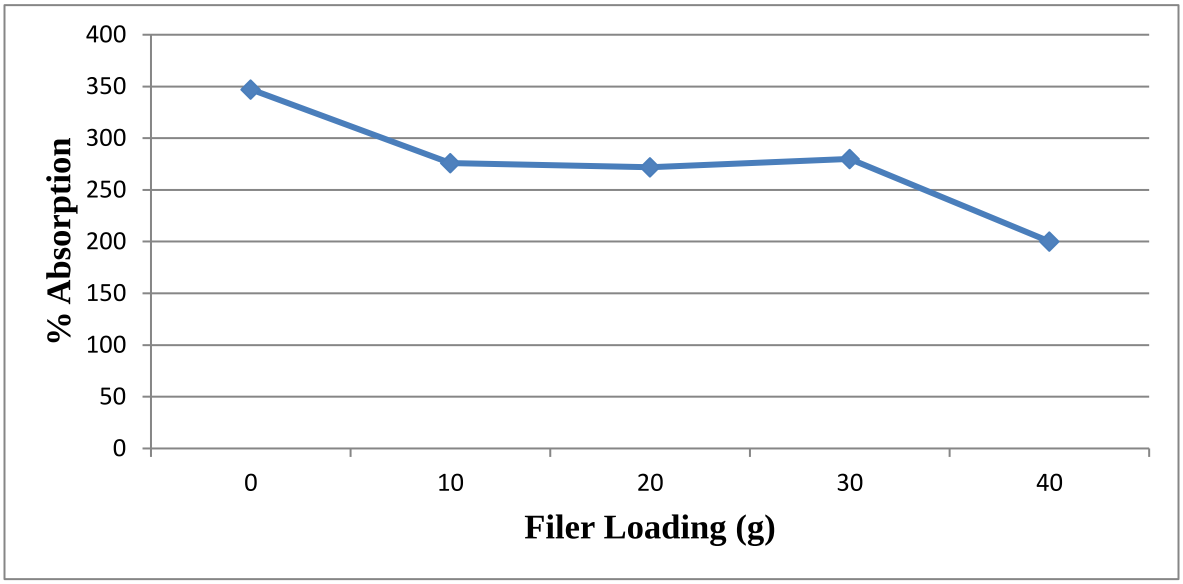
Elongation at break

The result in table 3 showed decrease in elongation at break with increasing filler loading in the polymer matrix. This result is expected because higher extension is obtained from lower filler loading. It can be seen that elongation at break for the compound without filler, that is the control formulation (0g filler) gave the highest elongation (805.27%) while at 40g filler loading, the elongation was 506.99%.

Hardness

The result showed that hardness increases with increase in filler loading. Since hardness measure small deformation at the surface of the polymer matrix and an approximately index of stiffness, longer shelf service life may be expected of service product. This result is expected because as more filler particle get into the matrix, the more the stiffness of the chain.

Sorption Results of Bamboo filled Natural rubber Compound



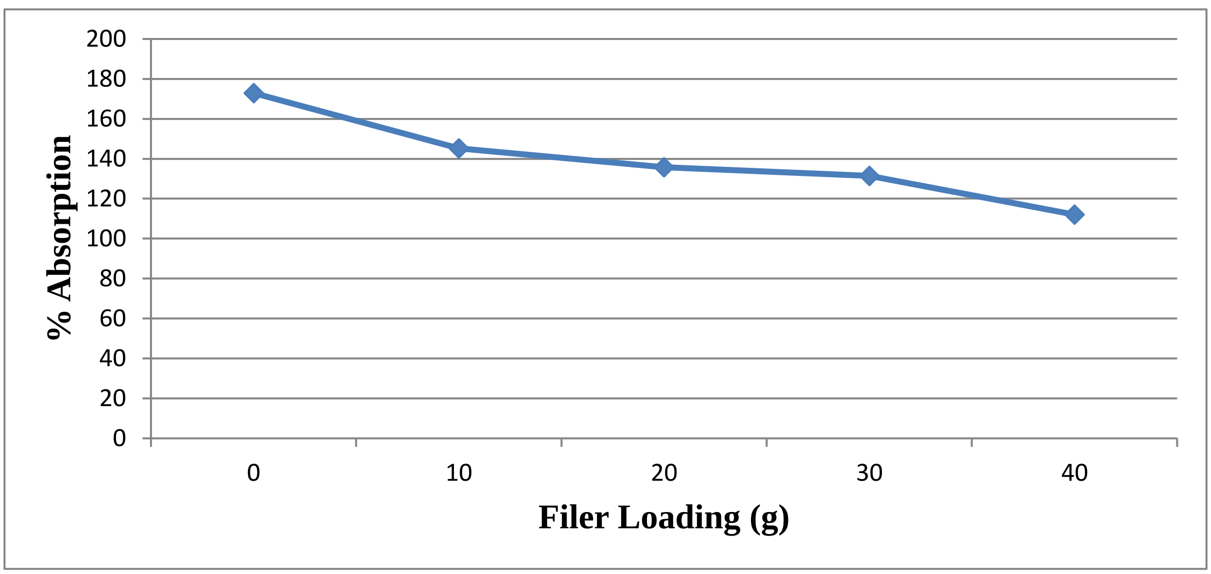


Fig 2: Absorption of Diesel by Bamboo filled Natural rubber compound

The sorption results for kerosene and diesel, Fig 1 and 2, showed a decrease in sorption property with increasing filler loading. The unfilled sample (control sample) tends to absorb more solvent than the filled samples. This indicates that bamboo filler reinforcement prevents the rubber compound from solvent absorption.

CONCLUSION

The aim of this work is to analyse the effect of bamboo fiber as filler on the mechanical properties of natural rubber compound. The mechanical properties of natural rubber filled with bamboo fiber filler was studied as a function of filler loading. The research showed that bamboo fiber exhibit semi reinforcing property as filler for natural rubber compounds. The result also showed that mechanical properties of the compounds are greatly influenced by filler loading and are therefore significant factors in determining the application in rubber compounding. The results also predict the potential applications of bamboo fiber as low cost filler in natural rubber products exhibiting semi reinforcing quality characteristics.

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