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Development of Sump Gasket Sheet from Groundnut Shell Composite

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ABSTRACT

The use of natural fibers as filler to produce polymer composite has been reported by many authorsand found out to have enormous potential for improving the mechanical properties of such polymer composites. In this research work, the possibility of using groundnut shells, which is generally regarded as Agricultural waste in most localities, to produce gasket sheets, has been carried out. A portion of the groundnut shell particles of grain sizes 0.5mm, 0.85mm and 1mm were blended with epoxy resin only at a loading level of 30:70 % for gasket sheet sample 1. Another portion was blended with top bond at a loading level of 40:60 % by weight and further blended with epoxy resin at a loading level of 80:20 % for gasket sheet sample 2. Six samples of gasket sheets were produced -three from each blend. Results of Mechanical properties of each sheet were determined and compared with BonTex 247(control) gasket paper in terms of compressibility and recovery, resistance to oil absorption, tensile strength, heat resistance, and flexibility according to ASTM F-36, F-146, F-152, F-495, and F-147 respectively. Test results indicated gasket sheet sample of grain size 0.5mm from a blend of groundnut shell particles, Epoxy resin, and top bond with compressibility-33%, recovery-35.35%, oil absorption of 10.78% increase in thickness, 14.55% increase in weight, Tensile strength-3.90N/mm^2, Maximum working temperature- 85 ^{0}C is the best of the lot.Samples from a combination of groundnut shell particles and Epoxy resin have poor heat resistance, flexibility, and recovery but good tensile strength and resistance to oil absorption.

Keywords*: Groundnut shell, Epoxy resin, Gasket Sheets*

I. INTRODUCTION

Loss of both fluid and pressure in hydraulic and pneumatic devices is prevented by proper design and use of seals, packing, and or gaskets. However, the definition of the words seal, packings, and gaskets are not exact. Generally speaking, any means to prevent leakage of fluid across a joint between adjacent members is referred to as a seal. If the seal is static, it is frequently called a gasket. Means through which leakages are prevented in dynamic seals are mostly identified as packings [1].

Because gaskets are generally low cost and appear to be simple, the criticality of their role in a device is often overlooked. They usually don't gain much attention until there is a problem with an application or if there are high maintenance costs to service the gasket. A gasket's main function is to provide a robust seal of a gas or a liquid throughout the life of the application. The gasket compensates for the imperfections between the mating surfaces to be sealed. This is done by utilizing external forces to compress the gasket material into the imperfections between the mating surfaces. If the perfect mating surfaces could be achieved and maintained through the life of the application, there would be no need for a gasket.

A gasket is a compressible material or combination of materials, which, when clamped between two stationary members, prevents the passage of a media across those members. Hence, the gasket material selected must be capable of sealing mating surfaces, resistant to the medium being sealed, and able to withstand the application temperatures and pressures [1].

Gaskets are installed in static clearances that normally exist between parallel flanges or concentric cylinders. For static seals, a flat rigid surface and a thin gasket are preferable, and a minimum amount of packing surface should be exposed to the fluid [1]. Gaskets are made from a variety of materials ranging from Metallic materials, Fibrous materials, Elastomeric materials,other materials such as Flexible graphite, Mica [3]. These materials must have some yield or compressibility properties in order to conform to the flange surface irregularities. In cases or situations such as automobile engines and air compressors where heat is present, the gasket must be able to withstand the highest temperature(s) to be encountered [4]. The rate of fluid absorption of gasket material is of paramount importance. Other considerations in gasket production/ selections are numerous; however, this research work would be limited to yield or compressibility of the gasket material, the range of temperatures for which the produced gasket paper is stable, and the rate of fluid absorption.

Groundnut, first grown in Brazil, was brought to Africa by the Portuguese [5].Nigeria is one of the large producers of groundnut in Africa, with an estimated production of 2.699 million metric tons in 2008 [6]. In Nigeria, the groundnut crop is almost entirely grown in the northern parts of the country. Hence groundnut shell is found in large quantities as agricultural farm wastes in parts such as Sokoto, Kebbi, Kaduna, Borno, and Yobe States [7]. It is grown as an annual crop in the tropical and subtropical regions and the warmer areas of the temperate regions of the world, principally for its edible oil and protein-rich kernels or seeds, borne in pods, which develop and mature below the soil surface [7]. Groundnut is also of value as a rotation crop. It improves soil nutrients due to the presence of atmospheric nitrogen-fixing bacteria in its root nodules [6]. Thus, all parts of the groundnut plant are fully useful. The matured fruit is an indehiscent pod containing 1-4 seeds having a fibrous pericarp [8]. The dry pericarp of the mature fruit or pod, known as the shell or husk, makes up about 20-30 percent of the whole nut and may be separated from the kernels [9]. The shell particles possess good physical strength properties and have great potential for commercial purposes. [9]. It may be used as fuel, soil conditioner, as filler in feeds and fertilizer as a source of furfural, processed as a substitute for cork or for hardboard.Increasing cost in imported products due to the rise in the foreign exchange rate is of great concern to Nigeria nowadays, hence the need for developing local production of such goods. Analysis from several research works carried out on the availability and uses of groundnut shells suggests that a high-quality gasket paper can be locally made from the shells. This will serve as a replacement or substitute for costly imported gasket paper. However, the scope of some of the research works carried out on the viability of using groundnut shell to produce gasket sheets were limited to a few test carried on the produced gasket sheets. This research work is aimed at carrying out further tests in heat resistance, flexibility, and oil resistance. Groundnut shells, which comprise 20-30 percent of the whole nut, are thrown away as waste after separation from the kernel. The discarded shells end up littering the environment. Nigeria, being a nation with relatively large groundnut production, could utilize research findings from the possibility of using groundnut shells to produce some of its basic needs; in this case, sump gasket, hence saving its foreign exchange and its environment.

II. Review of Previous Research Works on the use of Groundnut shells to produce Composites.

The concept of using natural fiber as a means of improving producing engineering materials with good mechanical properties is not new. For decades now, the use of natural fibers as a filler to produce composites has been increased. Many research works have been carried out on the use of natural fibers as reinforcing material for the preparation of composites. The extensive use of lignocellulose fibers and their composites is for the reason that they provide several advantages such as low densities, low cost, nonabrasive nature, high filler loading, low energy consumption, high specific properties, biodegradability, and safe working environment [23]. Investigations on the suitability of using natural fibers for gasket production has been covered in many research works. Oladele, I.O., and Adewuyi, B.O [26] investigated the suitability of natural fibers from bamboo, coconut husk, sponges, and wood for developing automobile gasket. The natural fibers were pulverized, sieved, and a homogeneous paste was formed by mixing with the top bond. They conducted fundamental tests in the study to determinethe material that has close properties to the commercially sourced gasket used as control. The tests included compatibility (hardness and creep) and suitability (water and oil) tests. Results from their investigation indicate that natural fibers havean appreciable hardness greater than 150 BHN at both ambient and elevated temperatures, good creep rate, and good density commonly associated with automobile gaskets. Naidu, A.L., Sudarshan, B., Krishna, K.H [17] investigated the mechanical properties of metal matrix composites based on groundnut fiber. The work describes the mechanical properties and development of a new set of natural fiber-based polymer composites consisting of groundnut coir as reinforcement and epoxy resin. They conducted the fundamental mechanical tests in the study to determine the effect of fiber length on the epoxy-based polymer composites, which included microhardness test, tensile strength test, flexural strength test, and impact strength test. They found that hardness decreases with an increase in fiber length up to 20mm. Further increase in fiber length increases microhardness value. Tensile strength, flexural strength, and resistance to impact loading of groundnut coir fiber reinforced epoxy composites increase with an increase in fiberlength.Akindapo, J.O., Binni, U.A., and Sanusi, O.M [6]investigated the properties of groundnut shell fiber composite in their quest to develop roofing sheet material using groundnut shell particles and epoxy resin as a composite material. They formed a homogeneous mixture of groundnut shell particles of sizes 0.5mm, 1mm, and 1.5mm with epoxy resin at a weight ratio of 30:70, respectively. The samples produced were tested for water absorptivity, flexural strength, tensile strength, and impact strength. Results from their findings show that the percentage of water absorption increases with an increase in particle size. Flexural strength test indicatesa sample with grain size 1mm shows greater flexural strength in terms of both deflection and bending. The tensile strength test results signify samples with particle size 1mm shows greater tensile strength. Results from impact strength show that the impact of energy absorption decreases with an increase in particle size. Their study shows that a sample with particle size 0.5mm is best suited and hence adopted for use as a commercial roofing sheet because of its excellent performance properties. G.U. Raju and S. Kumarappa [23] investigated the mechanical and thermal properties of epoxy composite filled with agricultural residue. Their research work is aimed at establishing the possibility of converting groundnut shell particles into a beneficial composite that would be a substitute for wood-based panels in many applications. They fabricated homogeneously mixed composite board samples with the different weight percentages of groundnut shells of particle sizes 0.5mm, 1mm, 2mm, 3mm, and epoxy resin. Three composite samples were produced from each groundnut shell particle size by mixing with the epoxy resin at the ratio of 50:50, 65:35, and 80:20. They conducted both mechanical and thermal tests, which include flexural, tension, impact, moisture absorption, thermal conductivity, and linear thermal expansion tests on each of the samples produced. Results from their investigations indicate the strength of the composite specimens decreased significantly with an increase in particle size and filler content. The strength properties were better in the 0.5mm sample at a filler loading level of 50%. The highest tensile, bending, and impact strengths were observed in 0.5mm particle size panel at filler loading of 50%. All the composite sample boards excluding boards of 3mm series satisfy the modulus of rupture (MOR) and modulus of elasticity (MOE) requirements. Tests conducted for moisture absorptions also indicate a percentage increase with an increase in both groundnut shell particle size and filler loading level. Results from thermal tests indicate composites samples of particle size 0.5mm, and a higher filler loading level of 80 % is beneficial for minimizing the thermal conductivity and thermal expansion of groundnut shell particles reinforced polymer composite materials. However, even though the composite samples exhibited low strength values compared to high-performance composites owing to high filler loading, their mechanical properties are better than areca fiber–urea-formaldehyde composites and coir-polyester composites.

Research gap

Innovative research works have been conducted, and rich literature has been written by a great number of scholars on the viability of using groundnut shell particles to produce composites. Some of the previous work findings consulted in the course of this research work strongly suggested the possibility of converting groundnut shell particles composite into gasket sheets. Tests conducted on composites developed from a homogeneous mixture of groundnut shell particle and Epoxy resin has shown relatively good mechanical and chemical properties similar to specifications required for gasket sheets. However, even though composites from a blend of groundnut particles and Epoxy resin may show some good properties required for a gasket sheet such as high tensile strength, Impact strength, appreciable creep, and hardness, they may be lacking in properties such as compressibility and recovery, flexibility and fluid penetration.

Research works conducted by Oladele et al. [26] and Akindapo et al. [6] were of great interest in the course of this research work. This research work targets the possibility of developing stronger, harder yet more flexible and compressible groundnut shell particle composite with the aim of using it as a sump gasket.

III. Materials, Equipment and Method, Testing

A. Materials selection

The following materials were carefully selected and obtained for the production of the gasket sheets:

a. Groundnut shell
b. Epoxy resin (Bisphenol-A-Co Epicholorohydrine) and hardener (Tetraethylenepentamine)
c. Top bond adhesive

The groundnut shell was purchased at the Dawanau grains market in Kano, while the top bond and Epoxy resin were purchased at the Sabon-gari market in Kano.

Plate I: Groundnut Shell Pyramids at Dawanau Grains Market, Kano

B. Equipment

The equipment used in the production of the gasket sheets are:

- The Mold (pattern)/ platen
- The Vat: a plastic container used for mixing the fiber with a blend of the resin/ hardener (binder).
- Standard metal sieve of aperture sizes of ISO 500 µm, 850µm, and 1.0mm sizes
- Grinding machine.
- Stirrer.

The equipment used in the testing of the gasket paper sheets are:

a) Universal Material Testing Machine manufactured by Cussons Technology Ltd, 102 Great Clowes Street, Manchester, M7 1RH, England
b) Digital balance- M6100 Mettler Digital balance Desiccator.
c) A Standard electric oven.
d) Universal Material Testing Machine manufactured by Magnus Worldwide Hydraulics International, Norwich. England.

C. Method

The methodology for this research is production and testing

a) The Mold (pattern)/ Platen

This is an essential tool (utensil) informing or producing hand-made paper. A rectangular wooden frame of size 41cm X 33.3cm covered at the bottom as well as an adjustable rectangular wooden cover (platen) for the top to be used in conjunction with the workshop press during compaction operation. The required gasket thickness of 3.5mm was, however, achieved through many pre-production trials by pouring a measured amount of blending gasket materials into the mold and a chosen amount of weight applied for compaction. This procedure was continuously repeated until the required quantity of material, as well as the required amount of weight to obtain a gasket thickness of 3.5mm, was achieved.

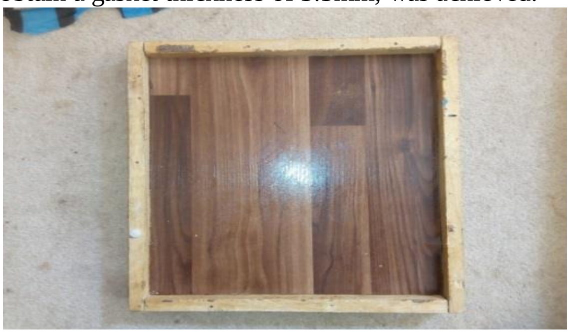

Plate II: Wooden Mold

Plate III: Mold and Platen

b) Preparation

The groundnut shells were sourced from the Dawanau grains market in Kano, as shown in appendix 2. The shells were first washed in distilled water to remove sand and other impurities. The washed groundnut shell was further leached using caustic soda in order to further remove remnant impurities. It was sun-dried for 48 hours and then ground in a grinding machine. The groundnut shell particles were then sieved using a standard metal sieve of aperture sizes of ISO 500 µm, 850µm, and 1.0mm sizes representing gasket paper samples SI, SII, and SIII respectively.

The measurable effects of grain size in terms of hardness, yield strength, tensile strength, fatigue strength, machinability at room temperatures were some of the considerations for the choice of grain sizes above. The effect of grain size is greatest on properties that are related to the early stages of deformation [24, 25]. Two sets of gasket paper samples were produced for each grain size. A sample from a blend of the groundnut fiber particles, top bond, and Epoxy resin, in this case, referred to as "Gasket 1," and a gasket sample from a blend of groundnut fiber particles and the epoxy resin referred to as "Gasket 2". Each of Gaskets 1 & 2 was tested for suitability as a replacement for the sump gasket.

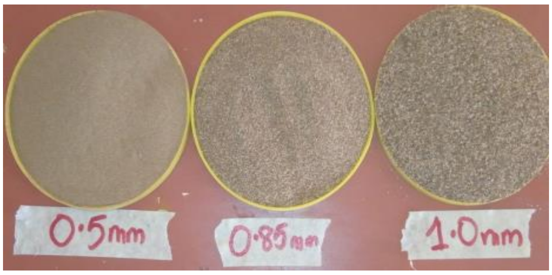

Plate IV: Groundnut shell fiber grain sizes

C. Blending

The top bond adhesive and each of the groundnut shell fiber grain sizes SI, SII, and SIII were measured at the ratio of 60:40 weights by volume [26]. The resin and the hardener were mixed at the ratio of 10:1 [6] for three minutes. It is very important to note that a relatively small amount of time is required for blending (mixing) the epoxy resin with the hardener. In this case, the blending was only done in four minutes. The amount of resin and hardener mixed represents 20% by weight of the combined weight of the top bond and the groundnut shell particles. The resin was thoroughly blended with the top bond by continuous mixing. The measured groundnut shell particle samples were thoroughly mixed with the blend of resin and top bond. Stirring was continued until a homogeneous blend was achieved. Each of the thoroughly mixed grain size samples was quickly but carefully poured into a mold to produce gasket sample 1, as shown in table 3.1. A second blend of the groundnut shell fiber grain sizes SI, SII, and SIII were thoroughly blended with only Epoxy resin without the top bond, as shown in table 3.2. Each of these was also poured into the mold and compacted/compressed to produce gasket samples 2. The mold was properly waxed to prevent the gasket from sticking on to the mold after compression/compaction. Waxing was done before the mixture/ blend was transferred into the mold. The mold was then mounted on a press for compression.

Table I: Composition for Gasket Sheet Sample 1

S/N	Material	% by volume		
		SI	SII	SIII
1	Groundnut shell particles	40	40	40
2	Top bond	60	60	60
A blend of the above mixture is further mixed with resin in the ratio below				
3	Epoxy resin + hardener (10:1)	20	20	20
4	Groundnut shell + Top bond	80	80	80

Table II: Composition for Gasket Sheet Sample 2

S/ N	Material	Composition by mass		
		SI	SII	SIII
1	Groundnut shell particles	30	30	30
2	Epoxy resin + hardener (10:1)	70	70	70

S = Samples representing grain sizes

d) Pressing and Compaction

After having been made to inter-woven matted fibers, the paper stock was pressed and compacted with a force of 50kg (0.055 tons) for 30 minutes using a workshop press. This was done to achieve stronger fiber to fiber bonding and to give a flat and smoothened surface. This was achieved using a workshop press, as shown below. However, care was taken in compaction to avoid entrapping of air in the mixture [6].

Plate V: Fresh gasket sheet sample

f) Drying

The next process was the conditioning of the compacted paper. The specimen was removed from the mold and conditioned in a desiccator for effective drying.

Plate VI: Cured sample of gasket sheet

D. Testing of the Gasket Sheets.

The tests carried out for all samples produced were in conformity with ASTM standard of testing and are as follows:

a. Compressibility and recovery
b. Tensile test
c. Oil absorption
d. Resistance to heat
e. Flexibility test

These tests were carried out in accordance with International standard procedures; Compressibility and recovery (ASTM F-36), Tensile Strength (ASTM F-152), Oil absorption (ASTM F-146), Resistance to heat(ASTM F-495), Flexibility (ASTM F-147).

Plate VII: Load Application for Tensile Strength

Plate VIII: Load Application for Compressibility&Recovery Test

PlateIX: Heating Samples with oil in an oven

Plate X: Samples in Fresh Oil after Heating

IV. RESULTS AND DISCUSSIONS

A. Results

a) Result for compressibility and recovery

The percentage Compressibility and recovery test results are presented in figures 1, 2, 3 and 4

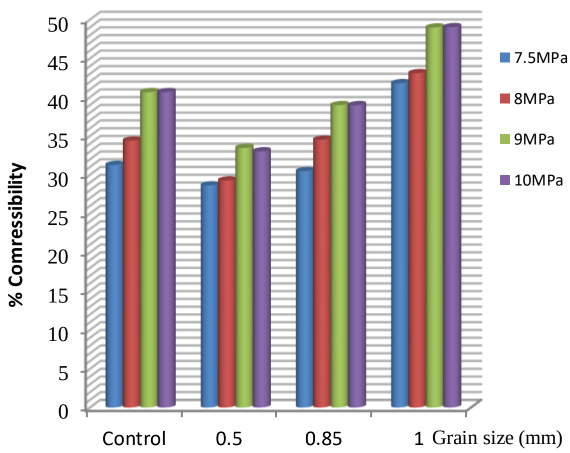

Fig 1: percentage Compressibility for gasket samples from blend of groundnut shell particles, epoxy resin and top bond

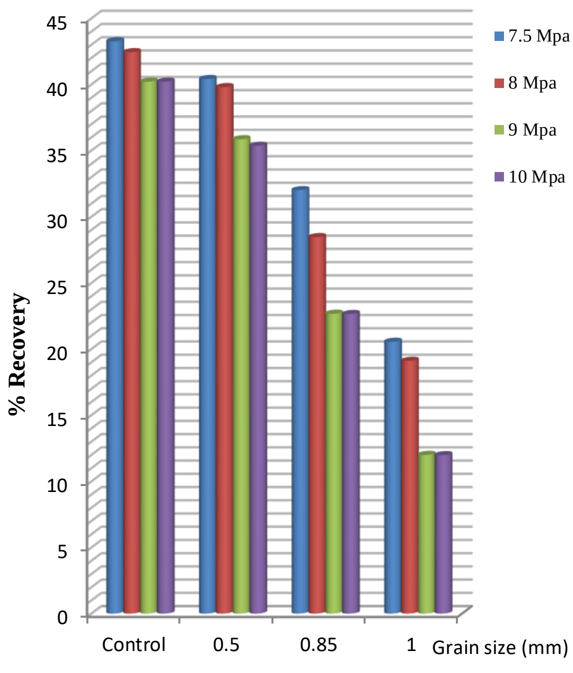

Fig 2: percentage Recovery for gasket samples from blend of groundnut shell particles, epoxy resin and top bond

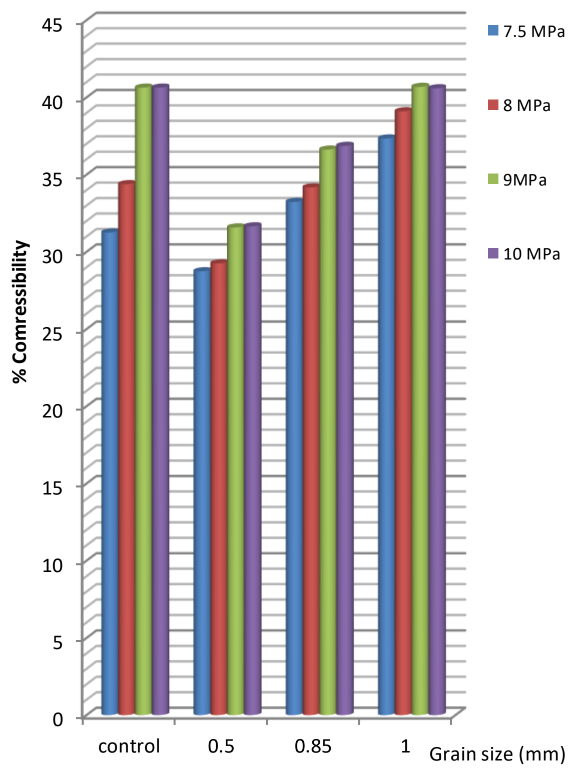

Fig 3: percentage Compressibility for gasket paper samples from blend of groundnut shell particles and epoxy resin only

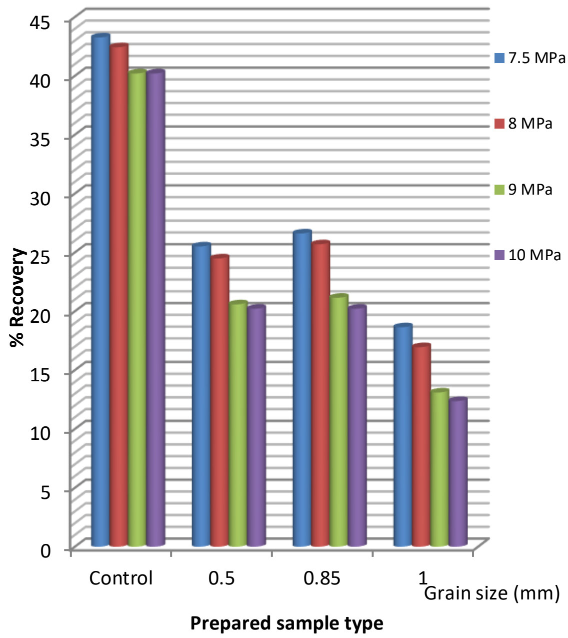

Fig 4: percentage Recovery for gasket paper samples from blend of groundnut shell particles and epoxy resin only

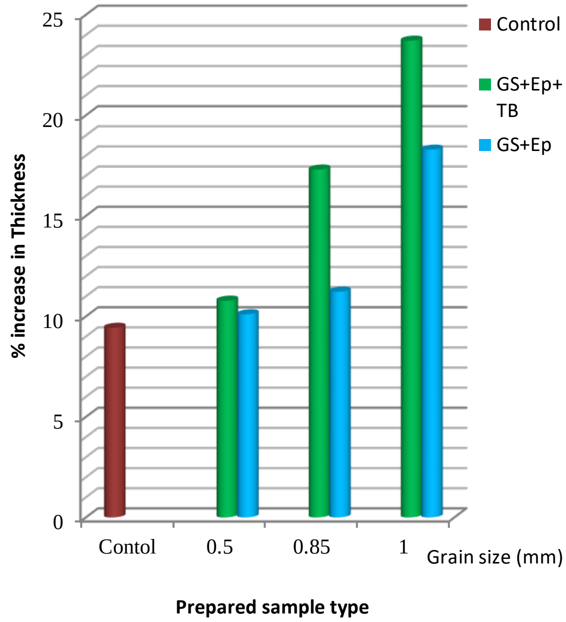

Fig 7: percentage increase in thickness for gasket paper samples from blend of groundnut shell particles, epoxy resin and top bond / groundnut shell particles and Epoxy resin only.

b) Tensile Strength Test

The result of tensile strength tests is represented in Figure 5.

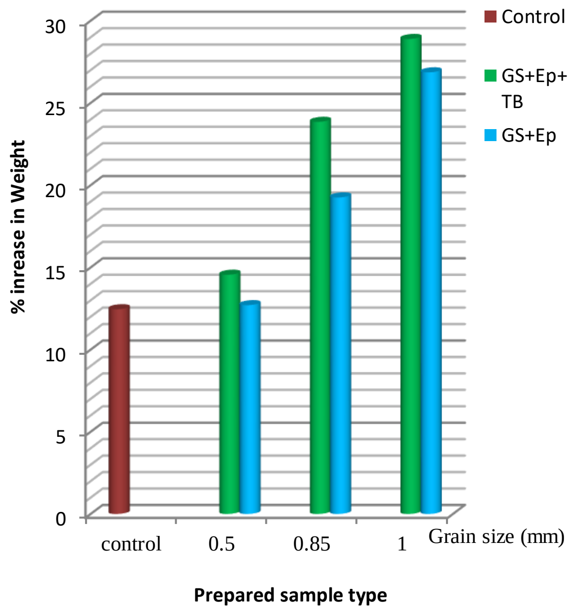

Fig 6: percentage increase in weight for gasket paper samples from blend of groundnut shell particles, epoxy resin and top bond / groundnut shell particles and Epoxy resin only.

c) Oil Absorption Test

The result for oil absorption tests are represented in Figures 6 and 7.

d) Heat Resistance: The result for heat resistance tests are represented in Figures 8, 9, 10, 11, 12, 13, 14

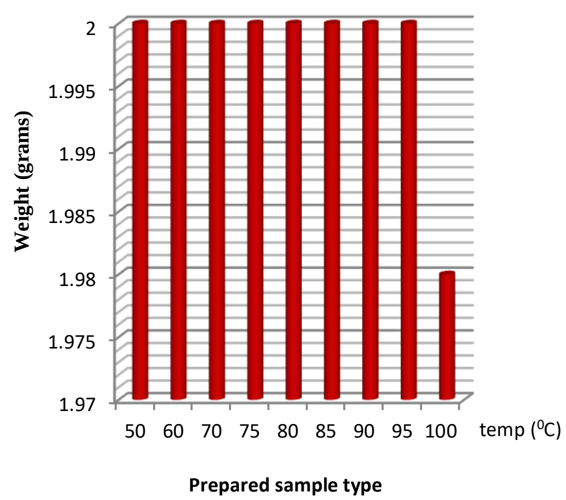

Fig 8: Weight loss for control gasket sample at different temperatures

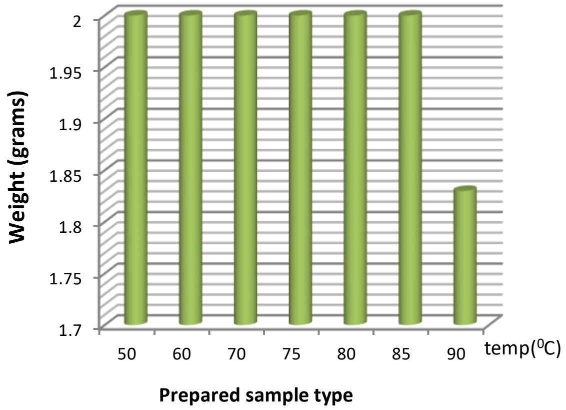

Fig 9: Weight loss for 0.5mm grain size gasket sample from blend of groundnut shell particles, epoxy resin and top bond at different temperatures

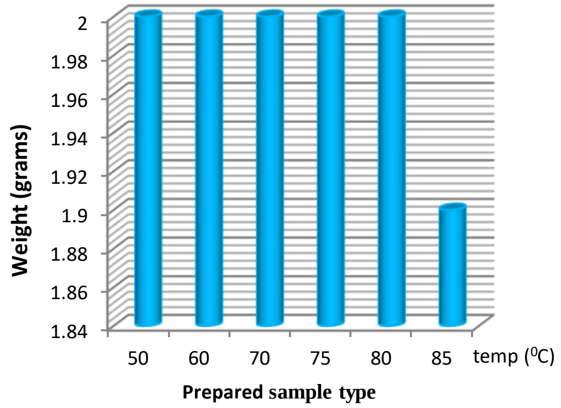

Fig 10: Weight loss for 0.85 mm grain size gasket sample from blend of groundnut shell particles, epoxy resin and top bond at different temperatures

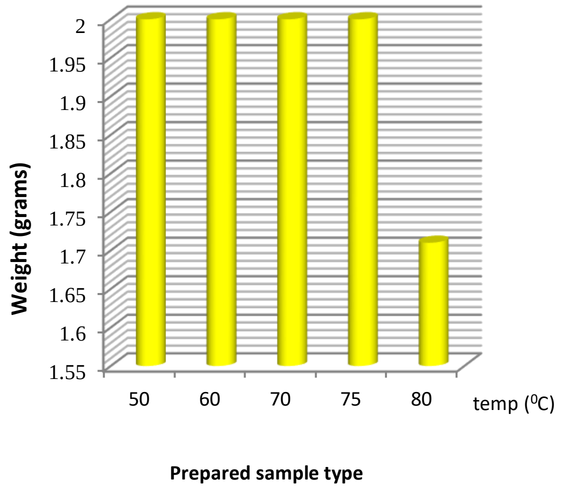

Fig 11: Weight loss for 1 mm grain size gasket sample from blend of groundnut shell particles, epoxy resin and top bond at different temperatures

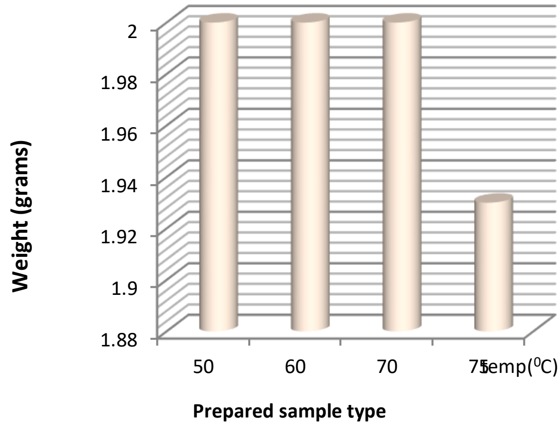

Fig 12: Weight loss for 0.5 mm grain size gasket sample from blend of groundnut shell particles and epoxy resin at different temperatures

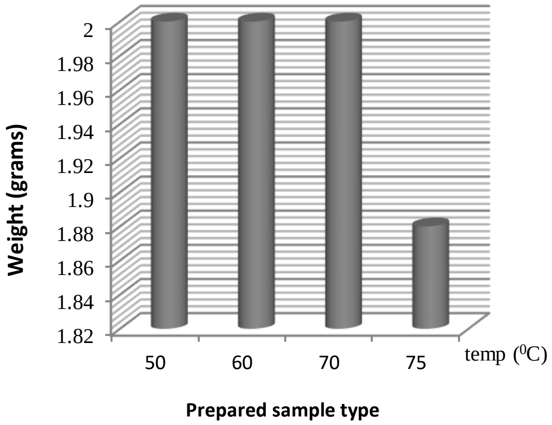

Fig. 13: Weight loss for 0.85 mm grain size gasket sample from blend of groundnut shell particles and epoxy resin at different temperatures

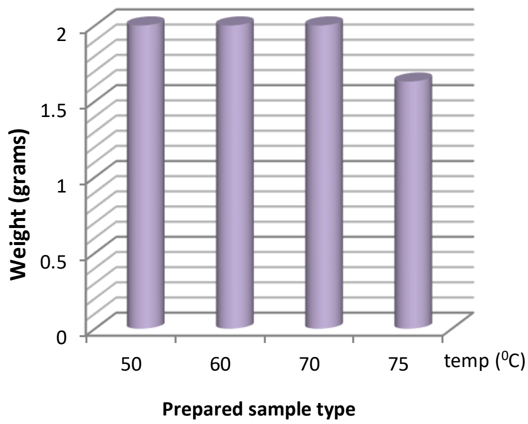

Fig 14: Weight loss for 1 mm grain size gasket sample from blend of groundnut shell particles and epoxy resin at different temperatures

e) Flexibility.

Table 3: Result for Flexibility Test

Sample	**Mandrel size (mm)**			
	7.0	10.5	14.0	17.5
Control	Passed	Passed	Passed	Passed
Composition of groundnut shell fiber, epoxy resin, and t				

bond				
All Sampl	Failed	Failed	Passed	Passed
Composition of groundnut shell fiber and epoxy resin				
All Sampl	Failed	Failed	Failed	Failed

B. Discussion

Results obtained from various tests carried out showed that:

a) Compressibility and Recovery

Compressibility and Recovery tests were carried out to determine the effect of compressive loads/ bolt load, hydrostatic force, and the internal pressure that the gasket samples produced can withstand; and the ability of the gasket to recover after bolt loading for effective sealing. The results obtained from these tests serve as a guide in determining the maximum load(s) to be applied to the gasket. Another purpose of this test is to determine how well the gasket is able to flow on the flanges (mating surfaces) such that most if not all flange irregularities are compensated for [12, 18, and 29]. Fig 1 and Fig 2 shows a graphical representation of test results carried out on samples from the composition of groundnut shell fiber, epoxy resin, and top-bond, the percentage compressibility and recovery at maximum compression of 10Mpa was computed as 33% and 33.5%, respectively for sample SI (grain size 0.5mm), sample SII (0.85 mm) with maximum percentage compressibility of 38.9% has a fairly poor percentage recovery. However, sample SIII (1mm), even though having higher maximum percentage compressibility of 49%, has a poor % recovery. For samples SII and SIII, even though having compressibility increases, their respective rate of recovery is poor when compared to

both sample SI and the commercial available BonTex type (control), indicating the effect of grain size on some of the properties of the material [24].

Figures 3 and Fig 4 are graphical representations of sample results from the composition of groundnut fiber and Epoxy resin only. At a maximum compression pressure of 10 MPa, all three samples show good maximum percentage compressibility but considerably poor corresponding percentage recoveries when compared to results from the control sample. It is imperative to note that for a vegetable fiber gasket (as in most gaskets), to produce an effective joint sealing in most situations, it must have considerable percentage compressibility and a corresponding % recovery upon loading. Hence, juxtaposing % compressibility and % recovery results with the results from commercial available BonTex 247 (control), gasket sample produced from the composition of groundnut shell fiber, epoxy resin, and top-bond with a grain size of 0.5mm (SI) is best suited as a replacement for proposed sump gasket at a maximum loading pressure of 10 MPa.

b) Tensile Strength Test.

A tensile test was carried out to determine the behavior/reaction of the gasket samples material upon application of force under tension, i.e., when it is being pulled apart. In other words, it is used to measure the amount of force required to elongate the gasket samples to a breaking point. Under compressive loads, the gasket material is expected to have a certain level of stretch without breakage, hence the need to determine the maximum force at which such breakage occurs upon elongation of the material. Fig 5 depicts a representation of the tensile strength of gasket sheets produced from the composition of groundnut shell fiber, epoxy resin, and top bond (GS+Ep+TB) and composition of groundnut shell fiber and epoxy resin only(GS+Ep). Gasket sheet sample SI (grain size 0.5mm) from composition

GS+Ep+TBis observed to have the highest tensile strength of 3.9 N/mm^2.Gasket sheet produced from composition GS+Ep, Sample SI (grain size of 0.5mm), is observed to have the highest tensile strength of 9.56 N/mm^2. Comparing the two results with the control (BonTex 247) with a tensile strength of 7.52 N/mm^2, gasket sheet sample SI (0.5 mm grain size) from the composition of groundnut shell fiber and epoxy resin only is best suited as replacement/ substitute for sump gasket in terms of tensile strength

c) Oil Absorption Test

This test was carried out to determine how the gasket will perform when exposed to oil or the maximum percentage of oil absorbed by the gasket samples produced. The rate at which a gasket absorbs the fluid it is designed to seal determines to a large extent its ability to be used as a sealing material. For an effective joint seal, a sump gasket must have considerable permissible percentage oil absorption in terms of an increase in both thickness and weight. Oil spills may result due to poor absorption rate (property) of gasket material.

Fig 6 and Fig 7 show a representation of the percentage oil absorption in terms of percentage increase in weight and in thickness, respectively; for gasket samples produced from the composition of groundnut shell fiber, Epoxy resin, and top-bond. The least oil absorption in terms of the percentage mass of oil absorbed was noticed in gasket sheet Sample SI (0.5mm) from the composition of groundnut shell fiber and Epoxy resin only at 12.70%. Sample SI (0.5mm grain size) from the composition of groundnut shell fiber, Epoxy resin, and top bond has a percentage oil absorption of 14.55% after immersion of all samples in both heated and fresh oil for four hours. Comparing these results with that of the control, samples with the grain size of 0.5mm produced from the composition of both groundnut shell fiber, Epoxy resin and groundnut shell fiber, Epoxy resin, and top-bond have the potential of being replacements or substitutes for Sump gasket in terms of the mass of oil absorbed. From fig 7, representing the percentage absorption of oil in terms of increase in thickness, Samples SI having a grain size of 0.5mm in gaskets produced from both compositions have the least oil absorptions in terms of percentage increase in thickness. The samples SI (0.5mm) produced from the composition of groundnut shell fiber, Epoxy resin, and top bond have a percentage increase in the thickness of 10.78%, while that produced from a composition of groundnut shell fiber and Epoxy resin is 10.1%.

Comparing the results from gaskets samples produced and that of the control, samples with 0.5mm grain size can serve as a replacement or substitute in sump gasketing.

d) Heat Resistance.

Temperature plays a vital, if not the most, role instability of gaskets for maintaining effective seals in automobiles. This test was carried out to determine the heat resistance of the gasket produced and to determine the maximum temperature at which the gasket will start to fail.

Figure 8 shows the reaction of the control specimen to the effect of different ranges of temperature. It shows stability up to a maximum temperature of 95^{o}C. Figures 9, 10, and 11 show a representation of the reaction of gasket specimens of grain sizes 0.5, 0.85, and 1mm from a composition of groundnut shell fiber, epoxy resin, and top bond to different temperatures. All gaskets samples from this composition were stable at a temperatures range of 50 ^{0}C – 75 ^{0}C. At 80 ^{0}C, gasket weight loss was noticed in gasket sample SIII (grain size 1mm). Weight loss was noticed at temperatures 85^{0}C and 90^{0}C in gasket samples SII (0.85mm) and SI (0.5mm), respectively. Therefore sample SI has thehighest resistance to heat, up to a maximum temperature of 85 ^{0}C. Figures 12, 13, and 14 show the reaction of gasket samples from the composition of groundnut shell fiber and epoxy resin only. All the samples were stable at temperatures below 70^{0}C. However, at 75^{0}C, all the samples began to lose weight. The maximum working temperature of these samples is 70^{0}C.The control can resist heat up to a temperature of 95 ^{0}C, hence comparing this with the results above; sample SI (0.5mm) from a composition of groundnut shell fiber, epoxy resin, and top bond is best suited for replacement as sump gasket.

e) Flexibility.

This test was carried out to determine the extent of flexibility of the gasket material. Flexibility is a vital characteristic of gasket material. Upon application of load(s), gaskets tend to bend and or twist. This effect of these turns and twists must be overcome by the gasket material, such that it does not crack or break. From the test carried out, all gasket samples from the composition of groundnut shell fiber, epoxy resin, and top bond were able to be bent to 180^0 without cracks or breakage using a mandrel with a thickness size four times (14mm) the thickness of the gasket samples. Using mandrel with lesser outer diameter results in failure. All samples from the composition of groundnut shell and epoxy cracks and or breaks even with a mandrel having an outer diameter five times the thickness of the gasket samples.

V. CONCLUSION

The aim of the research work is to convert groundnut shells into a gasket sheet with the view of using it as a sump gasket. Groundnut shells were processed to a hand-made gasket paper by employing the basic operations in the gasket making process. Six sheets of gasket were made from two different compositions. Three of the gasket sheets were produced from a composition of groundnut shell fiber, epoxy resin, and top bond, while the remaining three sheets were produced from a composition of groundnut shell fiber and epoxy resin only. Both compositions were graded by three groundnut fiber grain sizes of 0.5mm, 0.85mm, and 1mm. all paper samples were tested for compressibility and recovery, tensile strength, oil absorption, heat resistance, and flexibility, and the result compared with BonTex 247 paper (control).

The following conclusions were drawn from the work:

i. It was found out that the composition of groundnut shell and epoxy resin, despite showing high tensile strength and lower oil absorption, is not ideal for gasket production due to its inflexibility and brittleness.

ii. Gasket paper samples with the grain size of 0.5mm and a combination of groundnut shell fiber, epoxy resin, and top bond is the best of hand-made paper amongst the six paper samples produced, even though its mechanical properties come short of that of the control (BonTex 247).

iii. All the gasket papers produced work effectively up to maximum temperatures of 90^{0}C, with the sample SI (0.5mm) having the highest heat stability at 85^{0}C. This is, however, lower than the maximum temperature that the lubricating oil may reach. This is due to the inability of the type of fiber to resist higher temperatures as well as the heat resistance of the binding materials. Lack of sizing may also be a reason for the poor heat resistance.

iv. All the gasket papers produced can be said to have good compressibility. However, the samples produced from the composition of groundnut shell fiber and resin only show poor recovery tendency.

v. The control box 247 gasket paper has greater strength, higher flexibility, and less fluid absorption when compared to the gasket papers produced. This may be due to the variations in the type of fiber or pulp used, degree of composition or blending of the

vi. stock, formation conditions of the sheet, and the physical or chemical treatment applied to the paper after its formation.

VI. RECOMMENDATIONS

From the conclusion drawn above, further studies could be carried out on:

i. Possibility of replacing the Epoxy resin with other matrices such as polyester resin and vinyl ester.

ii. Proper and effective coating of the gasket sheetwith sizing agents with high heat resistance, such as Thiokol, may improve the heat resistance as well as the fluid absorption capacity of the gasket sheet.

iii. Possibility of using groundnut shell fiber in modifying the rheological properties and protective coatings in corrosion control.

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