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Development of Gasket Sheet From Groundnut Shell Composite For Medium Temperature Application

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Abstract
Converting groundnut shell into useful engineering materials has been investigated by many authors. In this research work, the possibility of using groundnut shell toproduce thermally stable gasket sheets for medium temperature application has been carried out. Groundnut shell particles of grain sizes 0.5m, 1mm and 1.mm were each blended with kaolin and top bond at a ratio of 30:10:60. This mixture was further blended with a mixture of epoxy resin + hardener at a ratio of 80:20. Gasket samples produced from each blend were coated with Thiokol. Mechanical and thermal properties of each sample were determined. Test results indicated that sample of grain size 0.5mm can withstand higher operating temperature of up to 400 ^{0}C, maximum tensile strength of 9.78MPa and a higher resistance to oil absorption of 4.97%. However, in terms of compressibility, gasket sample with grain size 1.5mm has the highest % compressibility of 22% and a lower % recovery of 10.13%*at maximum compression of 10MPa.*
Key word: *groundnut shell, Gasket sheet, Kaolin, Thermal stability*

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I. Introduction

Converting groundnut shell into useful applications has been extensively researched, with results from the outcome of these researches proving the viability of converting the shell into useful application such as corrosion control, production of roofing sheets, gasket sheets etc [1,2,3,4,5 and 6].

Results from a research conducted by this researcher titled **"Development of sump gasket sheet from groundnut shell composite**" and several other research works has proven the possibility of producing a qualitative and effective gasket sheet from groundnut shell composite. A sample of the gasket produced and tested was effective in terms of tensile strength, flexibility and compressibility and recovery. It was however, fairly effective in terms of resistance to fluid penetration and could only be recommended for low temperature application because of its poor heat resistance.

This research work is aimed at carrying out **further** investigation into improving heat resistance of gasket sheets produced from groundnut shell composite with the view of using it for medium temperature applications.

Gaskets are used to create a static seal between two stationary members of a mechanical assembly and to maintain that seal under operating conditions which may vary dependent upon changes in pressures and temperatures [7]. 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 [8].The effect of temperature in the efficiency of a good seal is often the most important consideration for seals (gasket) manufacturers; especially in temperature dependent application.Generally, the higher the application temperature, the lower the pressure a gasket can withstand and therefore the pressure/temperature graphs given for each material are best consulted for gasket material selection [9].Determining the temperature range of the application is essential in the proper selection of a gasket material and production process. Temperature is the starting point for determining which material is optimum for the application. Temperature can alter the characteristics of the gasket such as the sealing properties, compression set and maximum allowable stress even if all of the mechanical elements of the joint are properly installed. It is important to take into consideration both internal and external temperatures. Gaskets that are exposed to direct sunlight can see internal temperatures to over 60°C. Gaskets that are exposed to freezing temperatures can crack and become stiff or brittle. Gaskets that experience cycling for cold to warm will exhibit higher compression set. [10].

Gaskets are affected by temperature in three ways: gross physical characteristics, mechanical and chemical resistance properties. Gross physical characteristics of a gasket and/or its individual components include the material state, oxidation point and general resilience. Mechanical properties include creep relaxation (sometimes referred to as stress relaxation) and the resulting torque retention capabilities. Under ambient conditions, most gasket materials will not show any significant torque loss. As temperature rises, torque loss becomes a serious consideration and requires a gasket material which will be minimally affected by material degradation or creep relaxation[11]. If the gasket material is suitable for the temperature, re-torqueing at an ambient temperature may compensate for torque loss. At higher temperatures, the majority of applications lose the most torque within the first 24 hours of operation. Chemical resistance properties can be more difficult to assess on multi-component gasketing products. It is always important to consult with the manufacturer in order to gain specific information on their unique formulations as it pertains to the temperature requirements for a given application [12].

Sealing against high temperature medias such as steam and exhaust emissions require a rigid material impervious to thermal degradation over fluctuating conditions [13]. Manufacture of a range of high temperature gaskets from non-asbestos, fibre and materials that are in many cases reinforced with metal composites and coated with anti-corrosion and oxidation inhibitors is common amongst gasket manufacturing companies. Dobson gaskets [13] employ special materials in their gasket manufacturing process for application with continuous temperatures exceeding 500 ^{0}C. Common among these special materials is mica crystal; a naturally occurring silicate with excellent resistance to high temperature. The type of material used in the manufacture of gaskets used for high temperature plays the most important role in the sealing capacity of such gaskets [11]. High temperature resisting materials such as silicon, fluorocarbon, fluorosilicone and EPDM are considered high temperature rubber materials which are often available in sheet stock form [14]. Materials such as silicon unlike plastics can withstand an operating temperature as high as 1414 ^{o}C. At a high temperature up to 500 ^{o}C, silicon hardly loose its physical properties [15].Thermal stability is valuable information required to manufacture more thermally stable composites, possibly with good fire resistance.

Raju, Gaitondeand Kumarappa (2012) [16] investigated the optimization of thermal properties such as thermal conductivity, linear thermal expansion and specific heat of groundnut shell particles reinforced polymer composite materials. Applying the Taguchi *L9*orthogonal array, with results from ANOM (analysis of means) and AVON (analysis of variance); with particle size, % filler material and matrix material as the process parameters. The composite specimens were prepared with different weight % of randomly distributed groundnut shell particles in polymer matrix and the level of importance of each of the thermal properties of groundnut shell particles reinforced polymers composite was identified. Results obtained highlighted the effect of particle size and % loading level of the filler material on the parameters. Higher particle sizes and higher % loading levels of filler materials results in minimizing thermal conductivity and thermal expansion of the reinforced composite. However, the polyester resin is responsible for maximizing the specific of the composite.

Abik et al (2020) [17] investigated the failures of gaskets used in automobile to establish if the failure will be a cause or consequence of engine temperature. Their work involves analysing the thermal expansion of three different gasket materials viz Carbon steel (AISI 316L), Stainless steel (grade 321), Chromium(CR12) and finding the thermal stress and temperature deformation of this three gasket materials. Gasket models for each of the materials was designed using SOLIDWORKS whileFinite Element Method was applied in finding the cause of fracture by predicting the stress state of the gasket under (steady state) thermal effect loading. Results from the analysis shows that stainless steel material has a higher temperaturedistribution up to a maximum of 700^{0}C and maximum heat flux as high as 1.975 E^{5} W/m^{2} than the other materials.

In the quest for evaluating the technology of heat resistant gasket, Kumano, Hamada, Makawaand Oku (2021) [18] developed a new gasket evaluation method for the purpose of applying it to gaskets used under intermediate temperature environments, and various dominant factors which affect the gasket characteristics were evaluated. NSSC 302BN and NSSC S-4 (17Cr-15Mn-N) with high-temperature strength similar to that of conventional gasket materials and the NSSC ER-1 (19Cr-13Ni-3.3Si-Nb) with high-temperature oxidation resistance were selected as sample materials, while SUS301 used now as low-temperature gasket material and the NSSC 431DP-2 with softening resistance up to 500°C and like that of the SUS301 were used as control materials. To determine the effect of heat, of the materials were some gasket specimens were leak tested after heating at 700°C for 120 h by setting the heating temperature the upper limit (medium-temperature range). Results from the work indicates that materials with high room-temperature strength, high work hardening, and ultrafine-grained results in smaller residual bead height at 700 ^{0}C. It was also observed that leak amount decreases in materials with higher-temperature leak resistance. Consequently, it became evident that gas leakage amount used as an important indicator to understand the gasket characteristics was reduced by reducing the amount of high temperature degradation, and suppressing the deformation of the bead head, henceNSSC 302BN is recommended for medium-temperature range application.

Basmaet al (2017)[19]investigated the effect of kaolinite on the mechanical and thermal properties of poly (vinyl chloride) composite. Melt intercalation method was used in preparing PVC/Kaolinite composite. Four samples were prepared from a blend of PVC, stabilizers, lubricants, plasticizer and Kaolinite. However, all four samples were prepared with same percentage composition of each of the material with the exception of kaolinite. The kaolinite was added at a loading level of 0%, 3%, 7% and 12% respectively for each of the sample composite prepared. The samples prepared were tested for Tensile Strength, Hardness,Impact Strength, Water Absorption, Thermal Conductivity and Flammability. Results from tests carried out indicated a decrease in both tensile strength and elongation at breakwith increase in loading level of Kaolinite. Increase in kaolinite loading level increases hardness strength. In the case of fluid absorption, it was discovered that higher kaolinite loading level results in drop in the absorbability of the composite samples. This is attributed to the fact that the increase in kaolin content has the effect of filling the free interspaces between polymer chains which reduces the penetration of water particles through those chains. Test results also showed a shift to higher temperature stability corresponding to increase in Kaolinite loading level. The thermal conductivity values increase, while flammabilitydecreases with increase kaolinite loading level.

II. Materials and Method

2.1 Materials

The materials used in this research are:

- Groundnut shell
- Epoxy resin

Epoxy resin (Bisphenol-A-Co-Epicholorohydrine) and hardener (Tetraethylenepentamine)

- Top bond
- Kaolin

2.2Method

2.2.1 Preparation

Groundnut shells were procured from Dandume market in Katsina State, washed in distilled water to remove sand and other impurities and further leached using sodium hydroxide (NaOH)[Plate I] in order to further remove remnant impurities. The shell was then sun dried for 48 hours and then grounded using a grinding machine.The groundnut shell powder was sieved using BS sieves sizes 0.5mm, 1mm and 1.5mm [Plate III]. The sieved particle sizes where designated as SI, SII and SIII representing 0.5mm, 1mm and 1.5mm particle sizes respectively. The measureable 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 groundnut shell particle sizes.


Plate I: Groundnut shellPlate II: Leached groundnut shell

Plate III: Sieved Groundnut shell particlesPlate IV: Sieved Kaolin

2.3 Blending and compaction

The top bond adhesive, kaolin and each of the groundnut shell particles grain sizes SI, SII and SIII were measured at the ratio of 60:10:30 weights by volumerespectively[5]. Separately, the resin and the hardener were thoroughly mixed at the ratio of 10:1 for five minutes.The mixture of the resin and the hardenerrepresenting 20% by weight of the gasket sheet was first blended with the top bond adhesive and the kaolin. The blend was thoroughly mixed until a homogeneous blend was achieved. Each of the measured groundnut shell particle was further blended with the homogeneous blend of the resin, top bond and kaolin. The final blend was then poured unto a waxed mold and compressedfor ten minutes using a 5tonnes workshop press.


Plate V:Compressed Gasket sheet samplePlate VI:Uncured Gasket sheet sample

Plate VII: Cured Gasket sheet sample

Each gasket sheet sample removed from the mold was coated with Thiokol andplaced in a desiccator to effectively dry for 24hrs.The samples were further heat treated in an oven at 28 ^{0}C for twelve (12) hoursallowed to cool for one hour in a desiccator containing anhydrous calcium chloride.

Table 1: Composition for gasket paper samples

No.	Material	% by volume SI	SII	SIII
1	Groundnut shell particles	30	30	30
2	Top bond	60	60	60
3	Kaolin	10	10	10
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 + Kaolin	80	80	80

* S = Sample

III. Tests

3.1 Heat Resistance Test

This test was carried out in accordance with International standard method for determining loss in ignition ASTM F-495. Each test piece of approximately 2g wasconditioned, weight measured and recorded as W_1. The test pieces were then placed in an oven at 50°C for 2hours and then cooled to room temperature in a desiccator and weighed accurately as W_2. The test was repeated with new samples at temperatures of, 100°C, 150°C, 200°C, 250°C, 300°C, 350°C, 400°C and 450°C. Any sample that shows a decrease in weight at a particular temperature range, no further test was carried on it. The temperature at which weight loss starts is also recorded for the particular sample.

3.2 Tensile Strength Test

This test was carried out in accordance with International Standard method of determining tensile strength ASTM F-152.

Plate VIII: Samples used for Tensile test

Three tests were carried out on each of the test pieces of sample SI, SII and SIII and an average results adopted. Each test piece was 120 mm long, 20 mm wide and 3mm thick[20]. The test pieces were ensured to have clean and uniform cut edges. Samples with dents, uneven cut and any other deformity were discarded.

The test pieces were conditioned**.** Immediately on removal from the desiccator, the thickness of each piece was measured with a Vernier-caliper in about four places within 50 mm on both sides of the center. The smallest dimension was taken as the thickness. After measurement each test piece was gripped between the jaws of a suitable tensile testing machine, the distance between the jaws being not less than 100 mm. The rate of transverse of the moving jaw was 3 ± 1 mm per minute [21]. In cases where the test piece breaks at the jaws, the reading was not taken into consideration.

The tensile strength is determined as: $= \frac{\text{Breaking load}}{\text{Crossectional Area of test piece}}$

3.3Compressibility and Recovery Test

This test was carried out according to international standard for compressibility and recovery ASTM F-36. The size of each test piece was 50 mm **x** 50 mm and conditioned. After stabilizing, the thickness of each test piece (T) was measured. The test piece placed between the indenter and the bottom platen and loaded initially to 1.44 kN.This preload was maintained for 2mins and the average reading on the indicator was noted to obtain the thickness under preload (T_1). The load was raised to18.75 kN and maintained for a further 2mins and the average reading on the indicator was noted to obtain the thickness under the major load (T_2). The major load was removed and the sample allowed to recover for 2mins in a free state. The preload of 1.44 kN was re-applied and maintained for 30secs and the reading of the indicator (T_3) noted. The test was repeated by exerting loads equivalent to compression pressures of 8.0Mpa, 9Mpa and 10Mpa and all readings for thickness recorded.

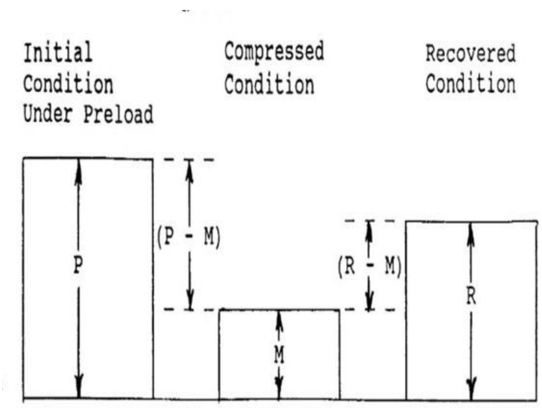


Fig 1: % compressibility/recovery [11]Plate VIII: Compressibility & recovery test

Compressibility was calculated as follows:

$$\text{Compressibility (\%)} = \frac{T1-T2}{T1} \; X\; 100$$

$$\text{Recovery (compression set) (\%)} = \frac{T3-T2}{T1-T2} \; X\; 100$$

3.4Oil Absorption Test

This test was carried out in accordance with International standard method of determining the oil absorption of gasket materials ASTM F-146. Thetest was carried out on three test pieces which were immersed in engine oil. The test pieces were cleanly cut to size 50 mm x 50 mm and conditioned. Each test piece is weighed in air to the nearest milligram (W_1). The three test pieces were placed in a container, containing the test fluid (engine oil) for 2 hours at l10 ± 2^0C. The test pieces were removed and transferred to a cool, clean portion of the same test fluid for another 3 hours.The samples were removed and quickly placed in acetone, and then cleaned lightly with filter paper free from lint and other foreign materials.Each of the specimens were weighed and its mass recorded as (W_2). The percentage increase in mass was computed to determine the rate of oil absorption of each of the gasket papers.

Plate IX: Oil absorption test

Percentage increase in Weight = $\frac{W2-W1}{W1}$ X 100

IV. Results and Discussion

4.1 Analysis on Heat Resistance

The result from heat resistance test is presented in figure 4.1.

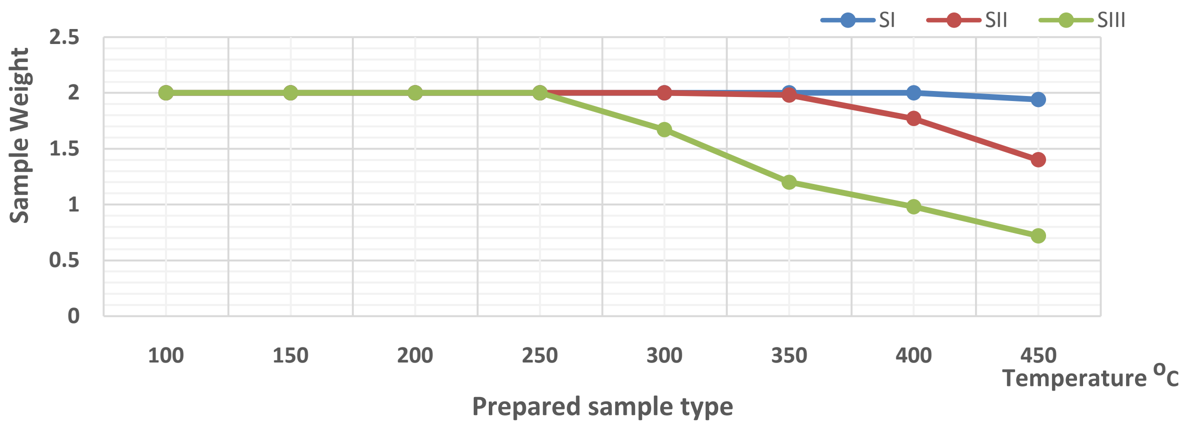


Fig. 4.1: Weight loss for gasket sample at different temperatures

Results from figure 4.1 shows gasket samples weight loss under increasing temperatures. Samples SI (particle size 0.5mm) and SII (1mm) could withstand temperatures up to 350 ^{0}C. At heating temperature of 400 ^{0}C, weight loss was observed in sample SII. Sample SIII (1.5), however could only effectively operates under a temperature range between 100-200 ^{0}C. It was observed that there is a sharp increase in temperature resistance of all gasket sheet samples tested owing to the heat resistance of kaolin addition in the sample blend.The fact that fillers fill the gaps or spaces between the groundnut shell fiber chain, they restrict the chains movement and improve their plastic properties;as observed by [19].Test results also indicates the measurable effect of grain size on most mechanical properties of Engineering materials. It therefore indicates that thegasket sample with smaller grain size has better thermal stability than samples with bigger grain size. In terms of thermal stability, gasket sample SI (0.5mm particle size)is better choice of the samples produced as it can effectively operate up to a temperature of 400 ^{0}C.

4.2 Analysis on Tensile Strength

Results from Tensile strength tests are presented in figure 4.2A and B.

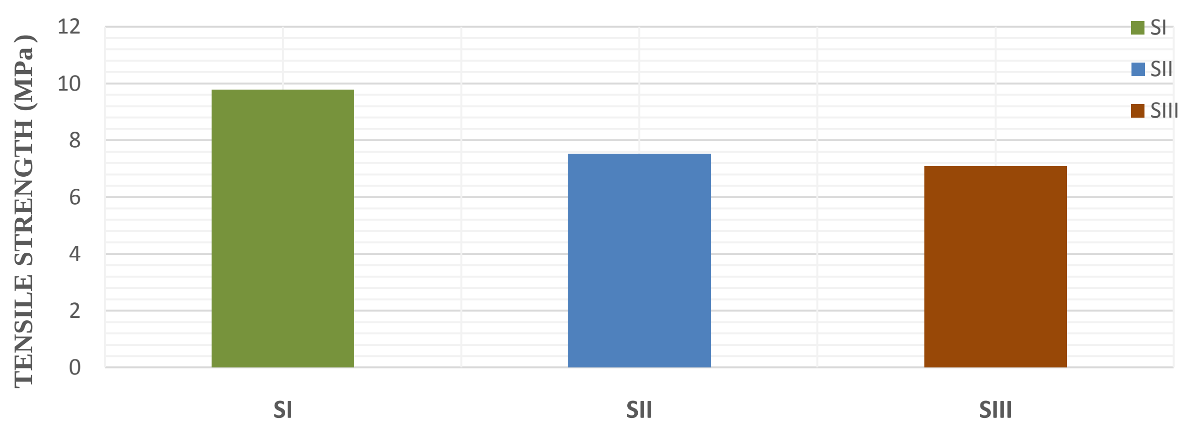


Fig. 4.2A: Tensile Strength for gasket samples from blend of groundnut shell particles, epoxy resin, top bond and kaolin

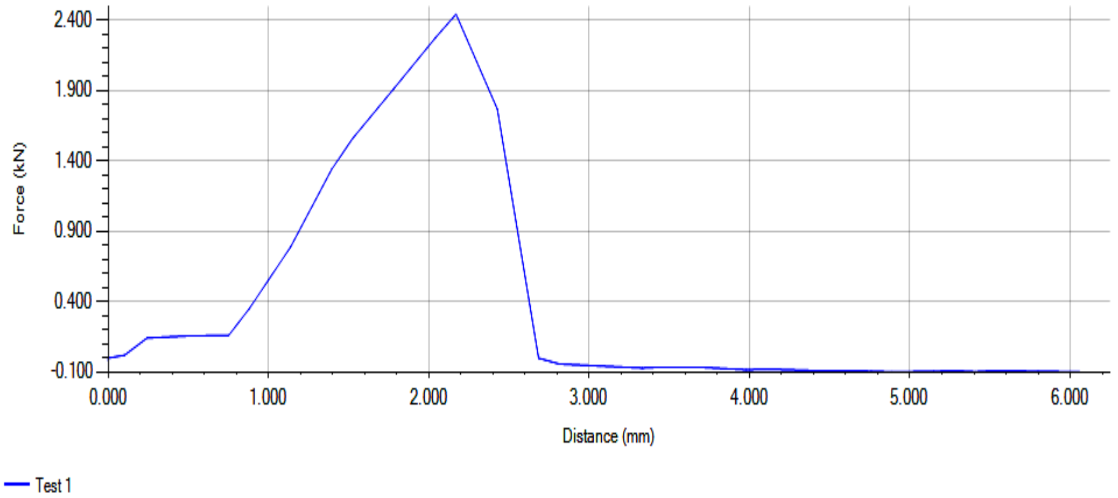


Fig 4.2B: Elongation at break for gasket sample SIII

Tensile test was carried out to determine the behavior of the gasket samples material upon application of force under tension. 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 occur upon elongation of the material [22]. Figure 4.2A highlights the tensile strength of all three gasket samples, while fig 4.2b shows the elongation at point of break for gasket sample SIII. Gasket sample SI(0.5mm) has the highest tensile strength of 9.78MPa while gasket sample SIII(1.5mm) has the least tensile strength at 7.03MPa. The effect on grain size of materials indicates a significant relationship between the effect of grain size and the tensile strength of the gasket materials. Adecrease in elongation at break for all the gasket samples tested was noticed. This may not be unconnected with the fact that the molecules of the fillers can distribute in the inter-aggregate space by an inter-structural process. The effect of kaolin addition plays an important role in tensile strength of materials. A high loading level results in decrease in tensile strength of materials due todecrease in the interfacial forces between PVC crosslinks across the interface and the filler particles [19].

4.3 Analysis on Compressibility and Recovery.

The results obtained from these tests serves as a guide in determining the maximum load(s) to be applied on the gasket. Fig 4.3A and fig 4.4A shows graphical representation of test results carried out on Gasket sheet samples from composition of groundnut shell fibre, epoxy resin, top-bond and kaolin, the percentage compressibility and recovery at maximum compression of 10Mpa was computed at 22% and 10.13% respectively for sample SIII (particlesize 1.5mm). Hence, even though the gasket sample has relatively higher percentage compressibility; its corresponding percentage recovery is poor when compared with other gasket samples tested at same maximum compression pressure.

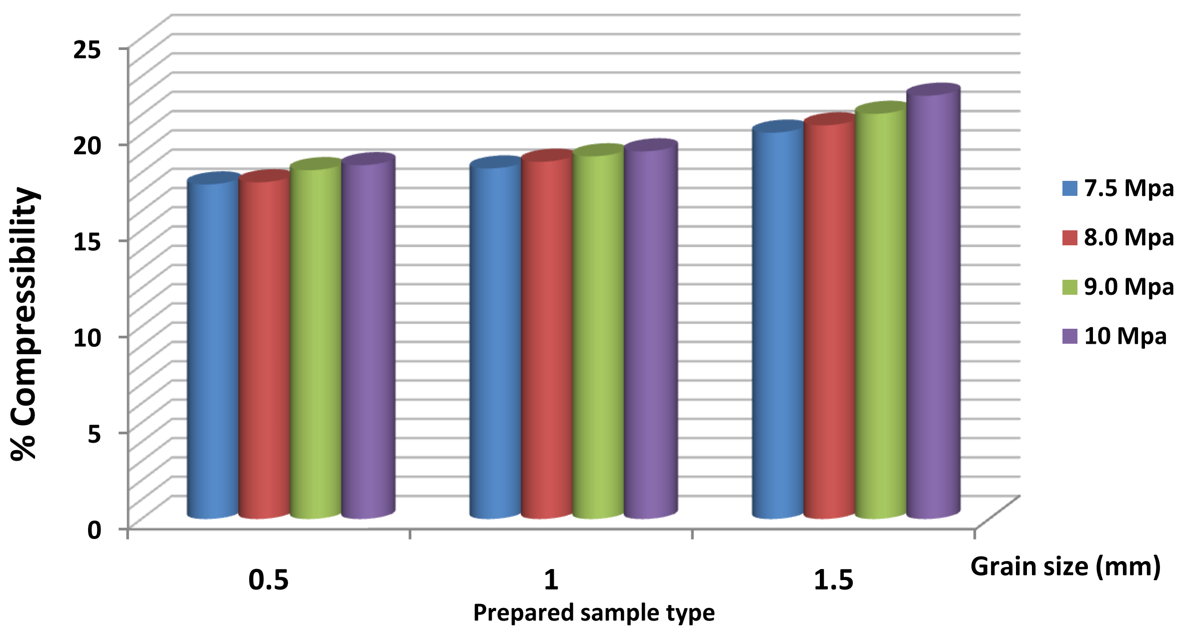
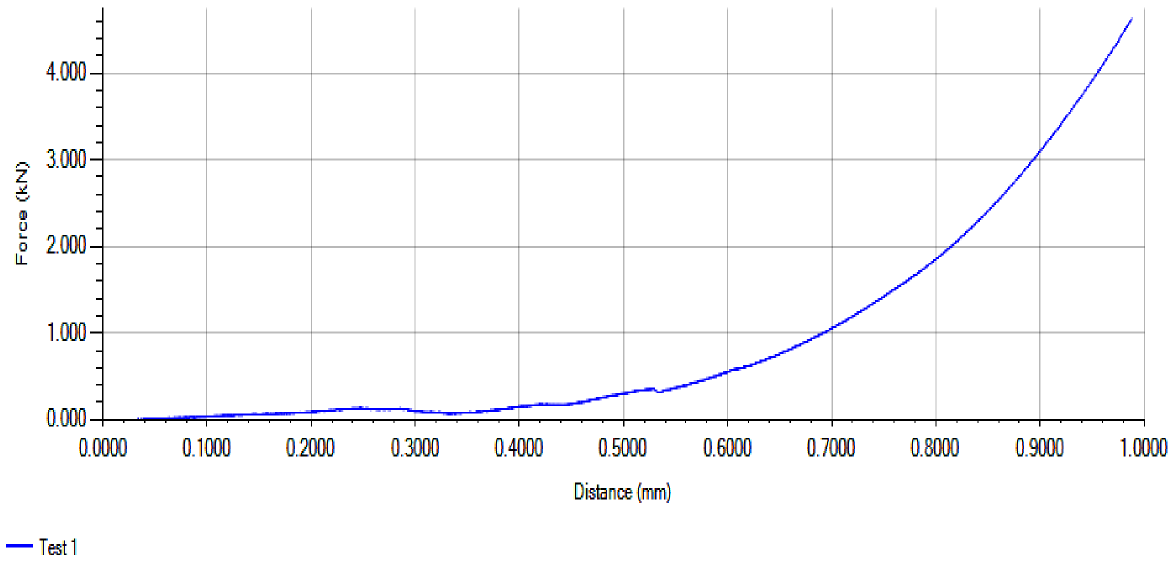


Fig. 4.3: percentage Compressibility for gasket samples from blend of groundnut shell particles, epoxy resin, top bond and Kaolin



4.3B: Result from application of major load for basic compression test on sample SI

Gasket sample SII (1mm) with a maximum percentage compressibility of 19.11% has a fairly poor percentage recovery at 12.91%. Sample SI (0.5mm) have the least maximum % compressibility of 18.39% and a corresponding lower percentage recovery.

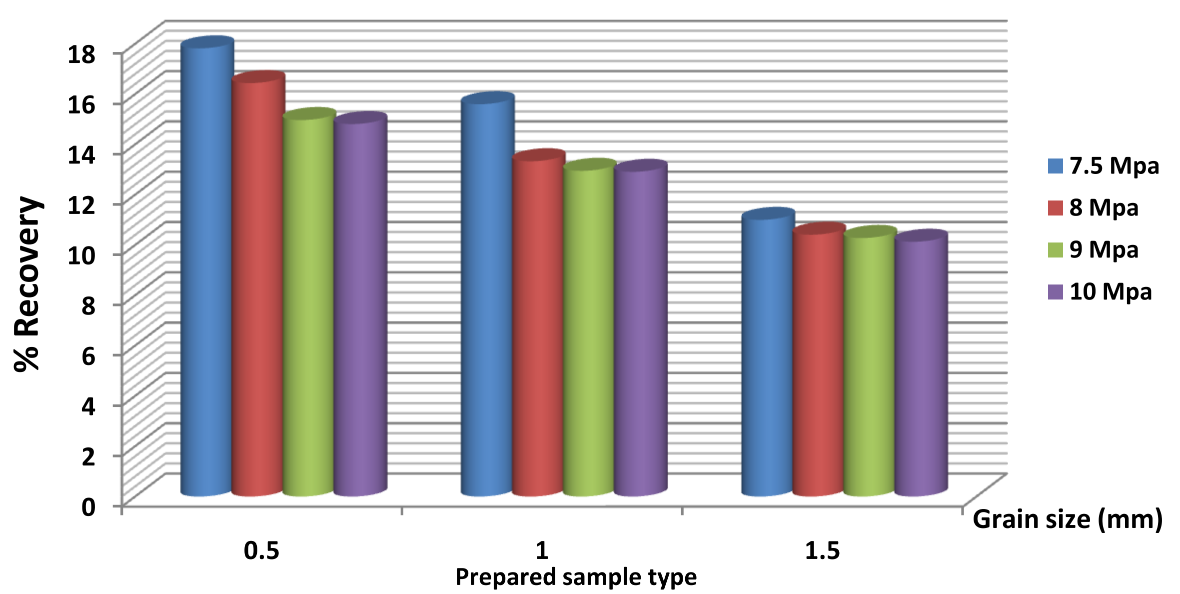
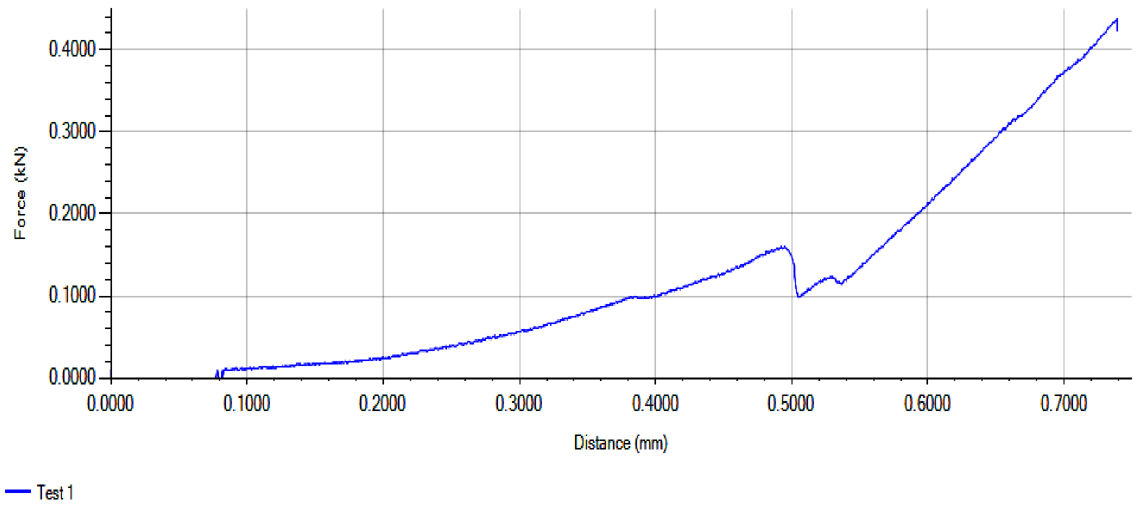


Fig. 4.4: percentage Recovery for gasket paper samples from blend of groundnut shell particles, epoxy resin and kaolin.



Result from application of second pre-load for basic compression test on sample SI

The effect of addition of kaolin in the blend for the gasket sheet samples may have a positive effect in the thermal stability of the gasket samples while having an opposite effect on other mechanical properties such as the harness and impact strength [19]. The noticeable low % compressibility and recovery of all gasket samples tested indicates the impact of kaolin loading level on the hardness and impact strength on the gasket samples tested.

4.4 Analysis on 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 large extent its ability to be used as a sealing material [22]. For an effective joint seal, gaskets must have considerable permissible percentage oil absorption.Figure 4.4 shows a representation of % oil absorption.

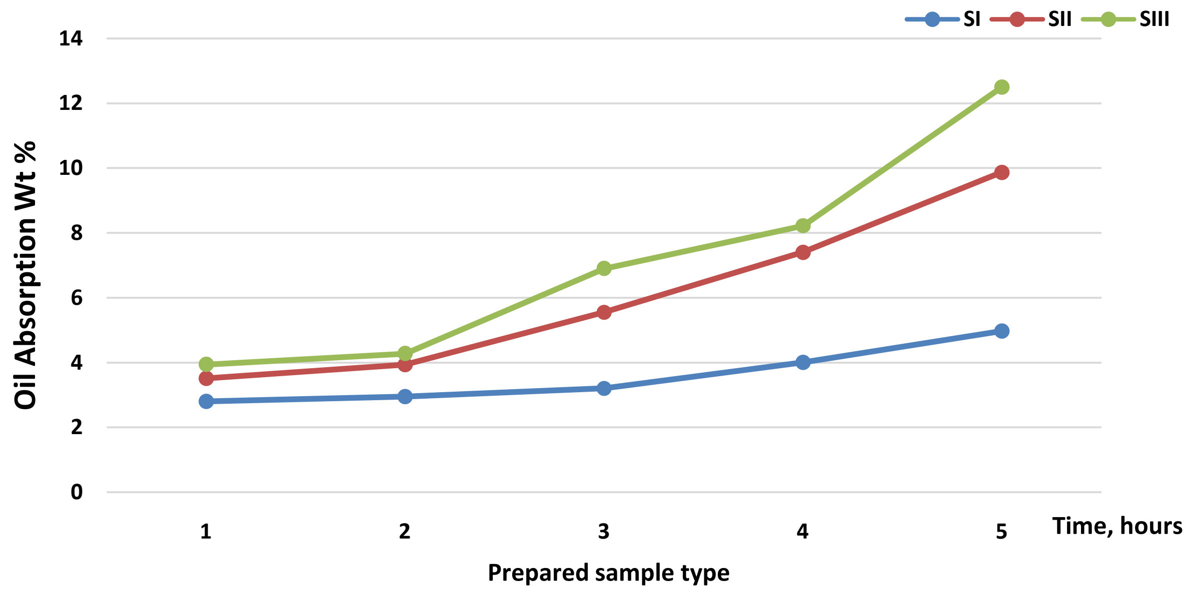


Fig. 4.5: percentage oil absorption for gasket paper samples from blend of groundnut shell particles, epoxy resin and kaolin.

The least percentage oil absorption after 5hrs immersion in hot engine oil was noticed in gasket sample SI (0.5mm particle size) at 4.97%, while sample SIII (1.5mm) has the highest oil absorption at 12.5%. These are considerable permissible percentage oil absorption rates for gasket sheet operation's especially for medium and low temperature applications.Fluid absorptions are often due to the presence of void spaces in the matrix which could have been formed during compounding of composites. The void spaces in the matrix accommodates the fluid absorbed [19]. These low percentages of oil absorption behavior might be attributed to the fact that kaolin content have the effect of filling the free interspaces between the groundnut shell fiber chains which reduces the penetration of oil particles through those chains. A higher kaolin loading level may further decrease the percentage oil absorption, but may however impact negatively on other mechanical properties of the gasket sheet samples.

V. Conclusion

Analysis from tests conducted and result outcomes from this research work, the following conclusions can be drawn:

1. Gasket sheet composite from groundnut shell with reasonable thermal stability could be produced.
2. Results from heat resistance test of gasket sheet samples produced indicated that kaolin when blended with gasket fiber materials at the right loading level, results in significant improvement inthermal stability of the gasket sheet sample.
3. Gasket samples SI (0.5mm) andSII (1mm) can withstand operating temperature of up to 350 ^{0}C, hence could be utilized for medium temperature applications. however, gasket sample SIII could only effectively operates under a temperature range between 100-200 ^{0}C, hence could only be recommended for lower temperature applications.It was observed that there is a sharp increase in temperature resistance of all gasket sheet samples tested owing to the heat resistance of kaolin addition in the sample blend. The fact that fillers fill the gaps or spaces between the groundnut shell fiber chain, they restrict the chains movement and improve their plastic properties. This is in agreement with [19].
4. Even though the application of kaolin at higher loading levels often decreases tensile strength, all gasket samples produced demonstrated good tensile strength. The effect of the kaolin filler was however observed as there was decrease in elongation at break in all samples tested.
5. All the gasket sheets produced demonstrated acceptably lower percentage compressibility and recovery. This behavior may be due to an increase in hardness of the gasket sheet samples; owing to the kaolin filler, as well as the effect of samples grain size.
6. All gasket sheets demonstrated considerably lower % increase in weight from oil absorption test. This good resistance to oil penetration may be attributed to the fact that kaolin content has the effect of filling the free interspaces between the groundnut shell fiber chains which reduces the penetration of oil particles through those chains.

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