Development of Polymer-matrix Composite Material Using Banana Stem Fibre and Bagasse Particles for Production of Automobile Brake Pad

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Abstract: In this research, high quality asbestos free brake pads were produced from Banana Pseudo-Stem Fibre (BSF) and Sugarcane-Bagasse particles (BP) as reinforcement material and fillers respectively, epoxy resin as binder material, graphite as lubricant and Iron Oxide as the abrasives. A commercial brake pad was used as control sample of these constituent. Five different samples were produced by varying compositions based on loading levels, 2%, 4%, 24%, 27%, 30%, and 40% by weight of Banana Pseudo Stem and Sugarcane (Bagasse) to matrix. The Binder, lubricant and abrasive composition were kept constant. The method of production used in the work was the simple hand lay-up technique which was followed by hot compression allowing for post-production curing. The physical, mechanical, thermal, morphology and tribological properties of the composite were investigated to obtain the density, water absorption, tensile strength, flexural strength, macrostructural, thermal stability, hardness, friction and wear rate in order to determine the optimum composition. The experiments showed that the best sample was S22 with 27% wt of BSF as reinforcement, 27% wt of BP as filler, 40% wt of Epoxy as binder, 4% wt of Iron oxide as abrasive and 2% wt. of graphite as lubricant and result was compared with control sample. Sample S22 competed comparatively with the commercial brake pad. The optimized sample S22 has hardness property of 7.3HRF, tensile strength of 17.32N/mm^2, Flexural Strength of 36.80N/mm^2, it has a decomposition temperature of 300^{o}C, Coefficient of friction of 0.1400, wear rate of 0.0045mg/sec, water absorption (%) of 24.21 and a density of 1.36g/cm^3. The properties of control samples are hardness property of 7.7HRF, Flexural Strength of 23.3N/mm^2, it has a decomposition temperature of 200^{o}C, Coefficient of friction of 0.288, wear rate of 0.1727mg/sec, and a density of 2.70g/cm^3. The properties obtained compared favorably with the workable commercial brake pads. The brake pad was produced using the optimum formulation.

Keywords: Banana Pseudo-Stem Fibre (BSF), Banana Pseudo-Stem Particulates (BSP), Sugarcane-Bagasse particles (BP), Reinforcements, composite material, natural fibers.

1. Introduction

The benefits associated with the use of local materials in production of mechanical components like automobile parts cannot be overemphasized, stemming from its availability, flexibility, affordability and overall usability. Local materials do not require costly processing which consumes energy, other resources and can be used in their raw form. The merits arising from the use of local materials are; they are renewable, abundant and their production have low impact on the environment. In addition, they are naturally non-polluting, emitting no harmful vapours, particles or toxins into the environments. Besides being produced or harvested under good working conditions and fair means as well as has low waste and capable of being reused and recycled [1]. Local materials available in Nigeria are periwinkle shells, coconuts, bamboos, grasses, timbers, palms, sugarcanes and bananas. These materials exhibit high physical, chemical and mechanical properties, if worked upon can be used in production of machine components. These materials can largely be processed into composite materials.

Composite materials consist of two or more constituents with physically separable phases [2, 3]. However, only when the composite phase materials have visibly distinct physical properties, then it is categorized as being a composite material. Composite are materials that consist of a strong load carrying material, referred to as reinforcement, imbedded in a weaker material called matrix. Reinforcements give strength, rigidity and supports structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Obviously, constituents of the composite retain their individual physical and chemical properties, still together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibres and are usually added to improve mechanical properties, such as stiffness, strength and toughness of the matrix material.

In most applications, the use of composite rather than metals have in fact shown to be cost effective and more efficient in terms of frictional materials. As replacement for conventional synthetic fibres, natural fibres are increasingly used for reinforcement in polymer due to their low density, good thermal insulation, mechanical properties, reduced tool wear, unlimited availability, low price and minimal problem of disposal [2].

In recent years, many studies have been dedicated to utilize lignocellulosic biomass such as coconut shell, sugarcanes, wood, pineapple leaf, palm kernel shell, bananas etc., as fillers through the utilization of natural fillers or reinforcements in thermoplastic and thermoset polymer composites in an attempt to minimize the cost, increase productivity and enhance mechanical properties of product [4].

Banana and sugarcane are cultivated in a wide variety of environments. These Plants produce fruits year round and can produce for up to one hundred years and are suitable for multiple cropping. Bananas are grown in nearly 130 countries. Uganda is the largest producer of banana and sugarcane in sub-Saharan Africa (SSA), followed by Rwanda, Ghana, Nigeria, and Cameroon.

Brake systems are vital components of an automobile; they help in the prevention of accidents by their applications, as kinetic energy is converted to useful heat energy. Automotive friction materials must satisfy requirements of good wear resistance for prolonged wear life, low noise, stable braking friction force over a wide range of operating speeds, pressures, temperatures, high durability, ease of manufacture and cost; Asbestos has been used as base material in the manufacture of brake pads and lining materials for close to 100 years [5]. Due to its physical and chemical properties that remain stable over the temperature range experienced by frictional materials. Recent research has shown that asbestos poses serious health risks and diseases associated with asbestos include; asbestosis, mesothelioma, lung cancer and cost of importation is high which an ordinary man cannot afford. These myriad of problems therefore necessitated this research work, “Development of Polymer-Matrix Composite Material for Production of Automobile Brake Pad”. These material are available in our locality and can perform as well as asbestos that poses little or no health risk, with low cost of production, good friction properties, adequate heat resistance, low specific gravity etc, as replacement to the already existing asbestos based brake components [6,7].

2. Review of Related Works

Nagesh in 2014, studied the characterization of brake pads by variation in composition of friction materials. The brake pads were manufactured using powdered metallurgy technique and were tested for coefficient of friction, wear, shear strength, hardness and micro structural analysis. The various results were compared with the existing brake pad composition and sample S2 and S4 showed results which are equivalent to the existing brake pad [8].

Darlington in 2015, studied the production of eco-friendly brake pad using raw materials such as palm kernel shell and coconut shell powder sourced locally in Nsukka, Nigeria as base material and compared with commercially bought brake pad. By varying mass compositions of palm kernel shell and coconut shell at constant pressure of 16.75kN/m^2 and particle size of 0.63um. All the samples were tested under the same conditions. Sample C has a promising potential since it had a moderate water absorption, wear rate and hardness but had the least coefficient of friction [9].

Adeyemi in 2016, researched on the development and assessment of composite brake pad using pulverized cocoa beans shells (CBS) filler. The produced brake pad samples were analyzed by evaluating their mechanical, physical, and tribological properties. Based on the investigated properties of the developed brake pad, reducing the filler content increased the wear rate, tensile strength, compressive strength, while hardness, density, water absorption, oil absorption and thermal conductivity varied differently. Coefficient of friction increased with increase in the filler wt. %. The results showed that CBS particles could be effectively used as replacement for asbestos in automotive brake pad manufacture [10].

Edokpai et al in 2016, studied how the properties of eco-friendly (biodegradable) brake pad using egg shell (ES) particles and Gum Arabic (GA). The brake pad formulation was produced by varying the Gum Arabic from 3 to 18 wt%. The results obtained at 18 wt% of GA in ES particles formulation compared favourably with the commercial brake pads [11].

Onyeneke et al in 2014, investigated the production and testing of motor vehicle brake pad using locally available raw materials (Periwinkle and Coconut Shell). The disc brake friction lining with the geometrical specifications of Audi 90 model was produced using palm kernel and coconut shell powder as base materials. The commercial asbestos brake pad produced by Ibeto group of Companies served as control. Test results revealed that second major group composition with grit/particle size of 0.25 and 0.35 gave the best result in the test instruments used and in proof test on Audi 90 model [12].

Felix et al in 2015, studied the fabrication and characterization of brake pad using pineapple leaf fiber (PALF). In this project brake pads were fabricated using pineapple leaf fiber as a reinforcement/filler. The material used for brake lining is PALF. Thus the bled of matrix is created by hand lay-up process. The result obtained in the work is compared with asbestos brake pad [13].

Natsa et al in 2015, produced military helmet using coconut fibre reinforced polymer matrix. Specimen helmets were formed from blanks that were produced by the simple hand lay-up technique, adopting the formulation with the most acceptable combination of mechanical properties. Specimen “E” with a fibre content of 70% in 28% resin, 2% hardener, offered a remarkable combination of properties; impact strength of 8.733J/mm^2, hardness strength of 30.63HRF, tensile strength of 13.81N/mm^2 and a flexural strength of 31.88N/mm^2 were obtained [14].

Akindapo et al in 2017, researched on production of a safety helmet using palm kernel fiber (PRF) and shell particulates. Specimen “D” (10% PKF) with the highest impact strength of 6.62 J/mm^2, hardness of 6.9 HRF, tensile strength of 26.75 N/mm^2 and flexural strength of 31.02 N/mm^2 was selected and reproduced with PKS particulates as filler. All the mechanical tests (Impact, hardness, tensile and flexural strength) were evaluated for the hybrid samples. Specimen D6 (6% PKF –4% PKS) offered the most acceptable combination of mechanical properties [15].

From literature reviewed so far, the hybrid of Banana Stem Fibre (BSF) and sugarcane (bagasse) as raw material for brake pad production has not been reported.

3. Materials, Equipment and Methods

3.1 Materials

The following materials were used for the research work;

Banana Pseudo Stem Fibre and Sugarcane (Bagasse) Fibre as reinforcement and fillers respectively, Epoxy Resin (Bisphenol-A-glycidyl), Sodium Hydroxide (NAOH) and distilled water, Hardener (Tetraethylenepentamine) was used as matrix, Graphite and Metal Chips (Iron Oxide) were used as frictional addictive.

Plate I: Treated Banana Pseudo-stem Fibre and Bagasse Fibre.

3.2 Equipment

The equipment used in this research are; Glass and Metal Moulds, Digital Weighing Balance ,Rockwell Hardness Testing Machine, Universal Materials Testing Machine, Tensometer, Ball-On-Disc Wear Testing Machine, Metallurgical microscope, Grain milling machine, Grain Sieve Compression moulding machine, Thermogravimetric Analyzer. All the equipment are available at Polymer Science Department, Leather Research Institute, Zaria and Mechanical Engineering Department of Ahmadu Bello University Zaria, Kaduna, Nigeria.

3.3 Methods

3.3.1 Processing of Banana and Sugarcane Fibres

The natural fibre were manually extracted by scrubbing with a metal comb and chemical treatment using coupling treatment method. Accordingly, Banana stem and Sugarcane (bagasse) fibres were chopped off to an average length of 10mm short staple fibres before treated in sodium hydroxide solution (NaOH) for 60 minutes at a liquor ratio of 1:15 after which they were thoroughly rinsed with distilled water before sun drying for two (2) weeks in accordance with ASTM D2172 standard. Then a portion of fibres were milled and sieved into particle size of 0.50um as shown in Plate II.

Plate II: Banana Stem and Bagasse Particles

3.3.2 Fabrication of Composites

The formulations comprises of hybrid BSF as reinforcement, BSP and BP as fillers respectively varied in their appropriate proportions while the Epoxy served as the matrix, Graphite as lubricant and iron (II) oxide as abrasives which were kept constant during the formulations. The formulation were varied from 2%, 4%, 24%, 27%, 30%, 40% accordingly and were thoroughly mixed manually in order to achieve a homogenous mixture before compression as shown in Plate III. The composition of the constituents by percentage weight is given in Table 1.
The mould was filled with the homogeneous materials in such a way that after hot compression the composite will be reduced to the exact initial volume of the mould to ensure excellent compaction.

Table 1: Formulation of Hybrid Composite

Samples	Banana Stem Fibre (BSF)		Bagasse Particulates (BP)		2% wt. GRAPHITE (g)	4% wt. FeO_3 (g)	40% wt. Epoxy (g)
	%	Wt. (g)	%	Wt. (g)			
S11	30	58.32	24	17.97	6.53	30.19	74.88
S22 (27%BSF /27%BP)	27	52.49	27	20.22	6.53	30.19	74.88
S33	24	46.66	30	22.46	6.53	30.19	74.88
	Banana Stem Fibre (BSF)		**Banana Stem Particulates (BSP)**				
	%	Wt. (g)	%	Wt. (g)			
S44	30	58.32	24	46.66	6.53	30.19	74.88
S55 (27%BSF /27%BSP)	27	52.49	27	52.49	6.53	30.19	74.88

Plate III: Homogenous Mixture of BSF Composite for Compaction

3.3.3 Compression Moulding Process

This was carried out with carver-3851 compression machine. Each sample was pressed at a temperature of

150^{o}c and a compression pressure of 25 MPa for 10mins, samples are shown in Plate IV.

Plate IV: Composite Slabs for Characterization.

3.4 Experimentation

The following tests and examinations were conducted on the specimen using various international standard procedures; Tensile Test (ASTM D638)**,** Hardness Test (ASTM 2240) Friction and Wear Test (ASTM: G99), Density (ASTM D792), Scanning Electron Microscopy, Thermal test (ASTM C518).

3.5 Brake Pad Fabrication

The blanks used in the research were fabricated by machining in accordance to ASTM D562 standard. The brakepad mould was made from low carbon steel, lined with aradite to serve as glue between the steel back and the frictional lining. A release gel was sprayed in the mould to avoid sticking of the polymer to the surface. Reinforcement in the form of chopped strands was placed at the surface. The resin, having been mixed in suitable proportion with the tetraethylene pentamine (harder) was poured onto the surface of the BSF with the BF particles in the specified proportion. The resin was uniformly spread and thoroughly mixed to achieve a homogenous mixture with the help of a brush. Subsequent reinforcements, filler and friction modifiers were added until the required thickness was obtained and then the compression machine was moved over the composite with pressure to remove any air trapped, close compaction as well as distribute the resin uniformly. The composite was cured in open air for about 48 hours. Thereafter, the brakepad was removed from the mould and trimmed at the edges to give the final shape. The schematic showing the brakepad production from start to finish and a prototype of BSF brake pad are as shown in Figure 1 and Plate V respectively.

(i)

(ii)

Plate V: Prototype of Brake pad Produced

4. Results and Discussion

4.1 Discussion of Results of Experiments

4.1.1 Tensile Test

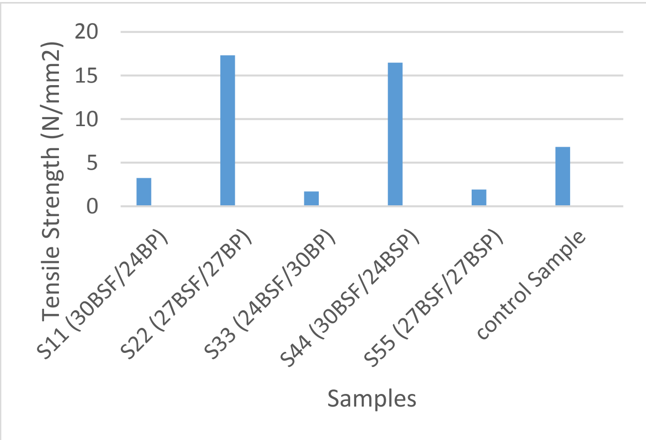

Figure 2: Tensile Test Chart

The sample S22 is a combination of BSF and BP which has the highest tensile strength of 17.34N/mm^2. The Sharp rise and fall in tensile strength as the fibre load decreases can be attributed to the increasing surface area, pores and compatibility due to increasing %wt, of the BSF and BP in the resin [16]. Hence, the highest tensile strength value was attained at equal fibre and particle.

4.1.2 Hardness Test

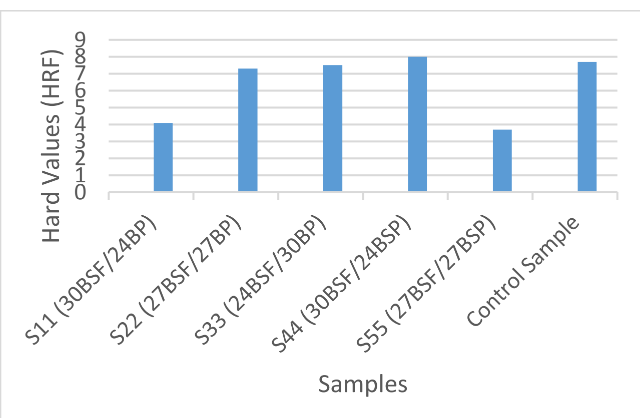

Figure 3: Rockwell Hardness Chart

The result above shows least hardness values for samples S11 and S55. This could be attributed to the fact that the composites had poor interaction between the reinforcement and matrix. However the results in Fig 3 also shows that as the weight percentage of fibre decreases, the hardness values of the samples increases between sample S22, S33 and S44. This may account for the good distribution and dispersion of the BSF and resin resulting in strong-fibre-resin interaction. Consequently, increases the ability of the brake pad formulation to resist gross deformation.

4.1.3 Density Test

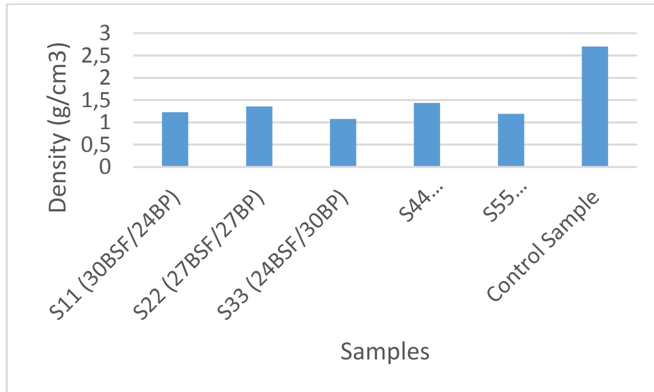

Figure 4: Density Test Chart

Figure 4 shows the result of the density with %wt of fibre and particulates addition. S44 with 30% wt of BSF and 24% wt of BSP gave a highest value of density. This is due to closer packing of BSF particles creating more homogeneity in the entire phase of the brake pad composite body. The levels of density obtained are within the recommended values for brake pad applications [16].

4.1.4 Wear Test

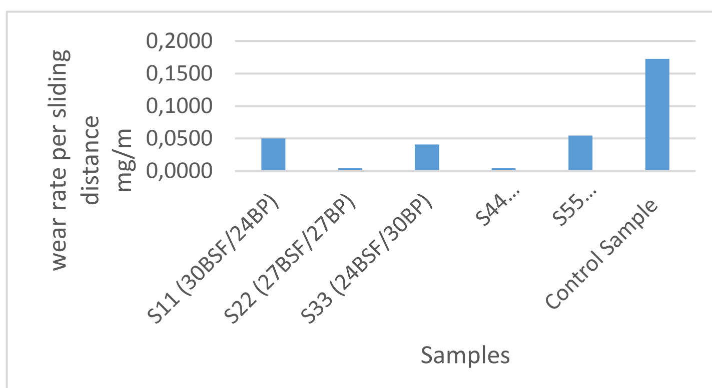

Figure 5: Wear Test Chart

The decrease in wear rate of the brake pad formulation for S22 and S44 can be attributed to higher load bearing capacity of the formulation and better interfacial bond between the fibre, particle and the resin reducing the possibility of fibres and particle pull out which may result in higher wear. The increase in wear rate of the formulation with S11, S33 and S55 may be attributed to low values of interfacial bonding strength obtained. The wear mechanism reported was adhesion and delamination [17]. The wear resistance of the brake pad formulation was improved by preventing direct contacts that induce subsurface deformation. The addition of Fe_2O_3 particles improves the resistance to seizure. The graphite particles allows considerable lubricant smoothing effects without having adverse effects on the wear behaviour [16]. The presence of epoxy resin provides a higher thermal stability, increased adhesion and sliding wear resistance is improved and delays the transition from mild to severe wear [16].

4.1.5 Coefficient of Friction Test

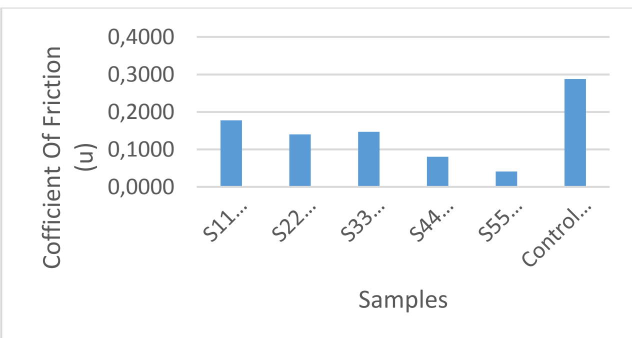

Figure 6: Coefficient of Friction Test Chart.

The co-efficient of friction of the samples decreases as the wt% of fibres increased in the formulation as shown in Fig. 6, again the effect of BSP shows a remarkable effect as lower friction was recorded for brake pad composites as the wt% of particles increased. Increases in friction coefficient does not tend to have higher wear rate, which is consistent with results reported by Aigbodion et al [17]. However, high values of coefficient of friction is good but not desirable in brake pad formulation as not to trade friction as against wear of the automobile rotor. Hence, the results of the work indicates that sample containing S22 (27% wt of BSF and 27%wt of BP) gave optimum properties than other samples tested. Though, the highest value of coefficient of friction was achieved at S11 (maximum load of BSF) in the composite.

4.1.6 Morphology Test

Macrostructural studies of the samples revealed a uniform distribution of BSF and BP as shown in plate VII, VIII and IX. The distribution of particles in the samples was influenced by good bonding of the BSF/BP, BSF/BSP and the resins in S22, S33 and S44 respectively. Again the good interfacial bonding was attributed to the increase in volume of particulates in the composite which is consistent with results reported by Idris and Aigbodion et al [16, 17].

Plate VI: Sample S11

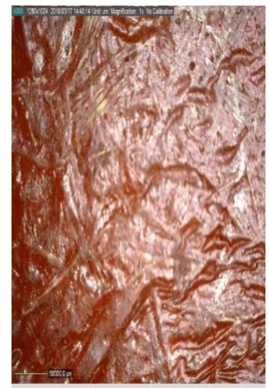

Plate VII: Sample S22

Plate VIII: Sample S33

Plate IX: Sample S44

Plate X: Sample S55

4.1.7 Thermo-Gravimetric Analysis/Differential Thermal Analysis (TGA/DTA)

The thermal test (DTA and TGA) for composite of BSF and BP for all samples were carried out in accordance with ASTM E1131. The blue curves represent the DTA while that of red curves represents the TGA of the composite. The TGA measures the change in weight of the samples in relation to change in controlled temperature. The curves showed the thermal scan between 29.54ºC and 720.2ºC. The onset temperature of decomposition (TGA) of the composite started at approximately 100ºC and continuously up to 300ºC with a corresponding mass depletion of 11%. The second stage of decomposition is 300-410ºC with a mass depletion of 60%. Total mass depletion from the thermal treatment is approximately 71% as shown in figure 7. The mass depletion is as result of further curing of the composite at elevated temperature thus causing reduction/loss in moisture content and evaporation of some oxides of the epoxy resins and natural particulate substance. The DTA curve showed percentage mass decomposition rate for the two respective stages of 120-220ºC and 220-380^{O}C mass depletion [18]. This was attributed to decomposition of the composite and oxidation of some impurities of the banana and Epoxy resin. The TGA/DTA curves simultaneously showed that the composite is thermally stable up to a temperature of 300^{O}C.

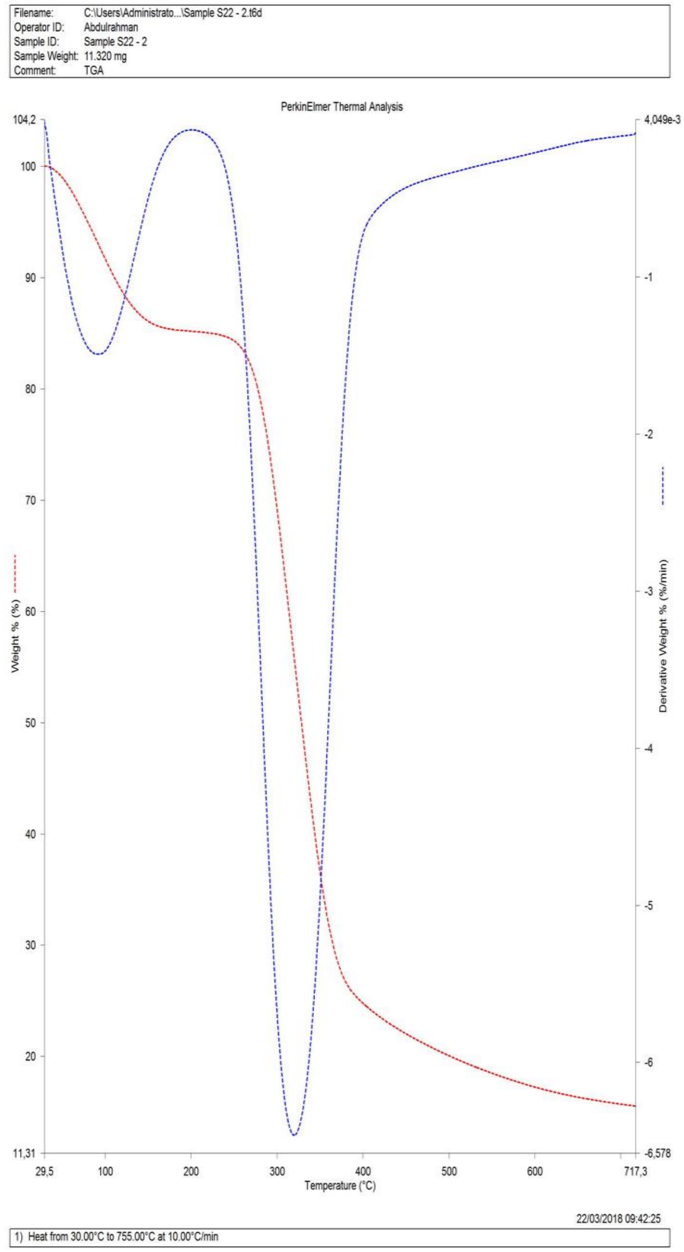

Figure 7: TGA/DTA Test results for Sample S22

4.2 Optimization of Results

From the behaviour of the composites under hardness, wear and temperature change due to wear, it was noticed that sample S22 has the best properties than other samples, although BSF has relative high amount of heat dissipation, this was taken care by the addition of the frictional addictives.

5. Conclusions

The properties and macrostructures of the samples were characterized and the following deductions were made:

i. Samples specimens of banana stem fibre (BSF) and bagasse reinforce epoxy base hybrid composite materials with different composition were produced.

ii. The mechanical properties of the samples shows that the hardness increased from 7.3HRF to 7.5HRF with decreased in BSF reinforcement compared to the commercial brake pad with hardness of 7.7HRF. Similar behavior was observed when samples were subjected to flexural and tensile strength tests. The result for tensile strength increased with addition of BP from 3.23 N/mm^2 to17.32 N/mm^2.

iii. The tribological characteristic shows that the addition of frictional additives improved the wear rate and coefficient of friction (Cof), the optimum sample shows a decrease in wear rate from 0.0053mg/sec to 0.0005mg/sec and a moderate decrease in cof from 0.1780 to 0.1400, with the best composition obtained at 27% wt. BF particulates and 27% wt. Banana stem fiber content. Hence wear rates are influenced by the applied normal load, sliding velocity which is a function of sliding distance and sliding time, and is preceded by friction which results to heat dissipation while the wear and cof result of the commercial break pad is 0.1727mg/sec and 0.288.

iv. The Thermal analysis (TGA/DTA curves) simultaneously showed that the composite is thermally stable up to a temperature of 300^{o}c of which exceeded the 100^{o}C braking temperature of a normal and balanced wheel vehicles. DTA curve showed that the composite has high glass transition temperature and good mechanical (stiffness) stability at higher temperature under dynamic load.

v. From the result of mechanical, thermal and tribological characteristic; Sample S22 gave the best properties. The composition was made of 27% wt., of banana stem fiber as reinforcement, 27 %wt., of Bagasse particles acting as fillers while graphite as frictional lubricant, iron oxide as abrasive, and epoxy as binder remained constant in these proportion (2%wt., 4%wt., 40% wt.,) respectively.

vi. The research work resulted in the successful production of a low cost and light-weight automobile brakepad using Banana pseudo-stem fibers as reinforcement and Sugarcane (Bagasse) particulates as filler in a polymer matrix composite by employing simple hand lay-up technique followed by hot compression moulding. The composite was tested for hardness, tensile, flexural, density, water absorption, wear, and coefficient of friction (Cof), thermo-gravimetric and macrostructural analyses.

6. Recommendations

The following recommendations are made for further studies:

i. The research of the performance of other low cost resin systems like Phenolic, blended with epoxy reinforced with BSF and BP as filler should be investigated.

ii. Engineering analyses methods such as finite element technique should be used to simulate the behaviour of the composite under variety of mass and speed in order to determine the kinetic energy required to be converted to useful heat energy.

iii. Statistical approach should be explored in the formulation of composite composition, to determine each percentage weight of composite constituent.

References

[1]. Department of Education, Curriculum Guides "What is Indigenous Materials" [online]. http://depedkto12.blogspot.com.ng/2012/12/what-is-indigenous-materials.html. Retrieved on April 2, 2017.

[2]. Mueller D. H and Krobilowski A, "A New Discovery in the Properties of Composites Reinforced with Natural Fibres", Journal of Industrial Textiles Vol 33, No 2, 2003, pp. 111-129.

[3]. Lilholt H and Lawther J. M, "Comprehensive Composite Materials", Elsevier Ltd, 2000.

[4]. Salmah H., Marliza M, Teh P. and Sinternat L, "Biofiber Reinforcements in Composite Materials", Journal of Engineering Technology, Vol 13, No 2, 2013, pp94.

[5]. Nice, Karim, "How Power Brakes Work". Howstuffworks.com. Retrieved 9 Feb., 2016

[6]. Dagwa I. M, and Ibhadode A.O.A, "Determination of optimum Manufacturing conditions for Asbestos-free Brake pads", Nigeria journal of Engineering Research and Development, 2006.

[7]. Smales, H, "Friction materials-Black art of science", Journal of Automobile Engineering. Vol. 209, 1995.

[8]. Nagesh S.N., Siddaraju C., Prakash S.V and Ramesh M.R, "Characterization of Brake Pads Variation in Composition of Friction Materials" International Conference in Advance Manufacturing and Material Engineering, 2014, Pp 295.

[9]. Darlington E., Chukwuaobi O., And Patrick O, "Production Of Eco-Friendly Brake Pad Using Raw Materials Sourced Locally In Nsukka". Journal Of Energy Technologies And Policy 2015, Pp.47.

[10]. Adeyemi I.O., Ademoh N.A., And Okwu M.O, "Development and Assessment Of Composite Brake Pad Using Pulverized Cocoa Beans Shells Filler" International Journal Of Materials Science And Applications, 2016, Pp. 66

[11]. Edopkpia R.O., Aigbodion V.S., Atuanya C.U., Agunsoye J.O., And Mu'azu K, "Experimental Study Of The Properties Of Brake Pad Using Egg Shell Particules Gum Arabi Composites". Journal Of The Chinese Advanced Materials Society. Vol 4, Issue 2, 2016, Pp 1.

[12]. Onyeneke F.N., Anaele J.U., and Ugwuegbu C.C, "Production of Motor Vehicle Brake Pad Using Local Materials (Periwinkle and Coconut Shell)" The International Journal of Engineering and Science (Ijes), 2014, Pp 17.

[13]. Felix V. And Prasanths, " Fabrication And Characterization Of Brake Pad Using Pineapple Leaf Fibre (Palf)" International Journal Of Research In Computer Applications And Robotics, 2015, Pp 107

[14]. Natsa Stephen, Akindapo J. O. And Garba D. K, "Development Of A Military Helmet Using Coconut Fibre Reinforced Polymer Matrix Composite", European Journal Of Engineering And Technology, Vol. 13, No 7, 2015, Pp 55-65.

[15]. Akindapo J.O., Orueri D.U., Garba D.K., and Ogabi R., "Production of a Safety Helmet Using Palm Kernel Fibre and Shell Particulates" International Journal of Engineering Science Invention, Vol 6, Issue 2, 2017, Pp 44-55.

[16]. Idris U.D., Aigbodion V.S., Abubakar I.J., and Nwoye C.I., "Eco-Friendly Asbestos Free Brake Pad; Using Banana Peels" Journal of King Saud University Engineering Sciences, 2013, Pp1.

[17]. Aigbodion V.S., Akadike U., Hassan SB., Asuke F., and Agunsoye J.O, "Development Of Asbestos-Free Brake Pad Using Bagasse" Tribology In Industry, Vol 32, No 1, 2010, Pp 12.

[18]. Bashar D, "Thermo-mechanical characterization of banana particulate reinforced PVC composite as piping material" Journal Of King Saud University Engineering Sciences, Vol 1, 2016, Pp 2-6.