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(RESEARCH ARTICLE)

Strength improvement on production of oil and gas product system using *Musa paradisiaca* fibre

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Abstract

The aim of this research is to development of *Musa paradisiaca* fibre for strength & hardness in production of oil and gas facilities. *Musa paraisiaca* fibre is a natural fibre with their long history of serving mankind are very important in a wide range of applications, and they compete and co-exist in the twenty-first century with man-made fibres, especially as far as quality, sustainability and economy of production are concerned. The matured fibre was cut, gathered, extracted, retted, dried, treated and modified. The fibres were thoroughly washed to neutrality and oven dried at various temperatures at different fibre length for the modified fibre. The tensile strength result of alkalization treatment conducted using 10% NaOH concentrations of the solution at different oven temperature of 30, 50, 70 ℃ using 50 mm, 60mm and 70 mm length of fibre. Based on the experimental results, oven temperature of 70 ℃ at 80mm fibre length gave the highest strength of 706Mpa for mercerization treated fibre. At 50 ℃ oven drying temperature gave 689Mpa using 50mm fibre length. At temperature of 30 ℃ gave 682Mpa using 80mm fibre length. The mercerization modified fibre on 10% NaOH concentration at temperature of 70 ℃ gave the optimum highest strength of 706Mpa at 80mm fibre length. Therefore, from the results the 70 ℃ oven bath temperature is therefore adopted and accepted as the benchmark for developing the fibre while the developed fibre can be reinforced with HDPE for the production of oil and gas, offshore, onshore facilities like pipes and piping system etc.

Keywords: *Musa Paraisiaca*; Concentration; Alkalization; Oven; Drying; Temperature

1. Introduction

Natural fibers are simply defined as fibers that are not synthetic or manmade but from plants and animals. Natural fibres are gaining increasing attention as alternative to synthetic fibres because they are renewable, abundantly available and environmentally friendly. Composite materials, plastics and ceramics have been the dominant emerging materials over the last thirty years. Composite materials have grown steadily, penetrating and conquering new markets relentlessly in numerous volume and number of applications (Mwaikambo and Ansell, 2002). Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. current challenge is to make them cost effective, while composites have already proven their worth as weight-saving materials (Bledzki and Gassan, 1999). The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle especially for composites. For composites to become competitive with metals it is essential that there we be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management (Li et al., 2007). Due to the sheer size of transportation industry, the composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector. In recent years the shift of composite applications from aircraft to other commercial uses has become prominent (Ruys et al., 2002). The penetration of these advanced materials has witnessed a steady expansion in uses and volume has increased the introduction of newer polymer resin matrix materials and high-performance reinforcement fibers of

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glass, carbon and aramid. Volume increase has resulted in an expected reduction in costs (Anon, 2002; Saheb and Jog, 1999). As composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers, high performance FRP can now be found in such diverse applications. The use of composites rather than metals has in fact resulted in savings of both cost and weight for certain applications (Mishra et al., 2002). Some examples of FRP are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc. Additionally, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock and vibration through tailored microstructures (Kandachar and Brouwer, 2002). For rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic Activity composites are now extensively being used. Under the control of the designer, composite properties (e.g., stiffness, thermal expansion etc.) can be varied continuously over a broad range of values (Mohanty et al., 2001). To be tailored to almost any specific engineering requirement, careful selection of reinforcement type enables finished product characteristics. In many instances the use of composites will be a clear choice, material selection in others will depend on factors such as working lifetime requirements, number of items to be produced (run length), possible savings in assembly costs, complexity of product shape and on the experience and skills for the designer in tapping the optimum potential of composites (Wang and Huang, 2008). In some instances, best results may be achieved through the use of composites in conjunction with traditional materials.

1.1. Design of Oil and Gas System

Oil and gas facilities can be design and developed by using standard equations (1) to (7). The product system from oil and gas contain fluid which they will never absorb, there is need for permeability of the storage and pipeline material. The Crawford equation will be stated as permeability in relation to constant of permeation (Crawford, 2018)

$$K = \frac{Q}{Atp} \qquad \ldots\ldots\ldots \quad (1)$$

where

Q = Fluid volume passing through the plastic material, d = plastic thickness, A = area exposed, t = time, P = difference in pressure across surfaces of plastic material. Using plastic multi - layers, keeping permeation constant which can be written as

$$\frac{1}{k} = \frac{1}{d}\sum_{i=N}^{i=N} \frac{d_i}{k_i} \qquad (2)$$

By the relatively loose packing of the molecules means that gases and liquids can permeate through the plastics, the low density of plastics is an advantage in many situations. The yield strength of material, is another factor that is needed in the design of pipeline materials. Which is written using Barlow equation of pipeline material (Hopkins, 2005) as

$$\sigma_h = \frac{p^D code}{2t_{code}} \leq \emptyset_{code}\sigma_y \qquad (3)$$

σh = hoop stress, σy = yield stress (YS), $Dcode$ = pipe diameter, $\emptyset code$ = factor of design, p = internal pressure. Similarly, stress analysis equations for pipeline material are written using design code. The wall thickness determination is the first to be considered and can be written as

$$T_m = \frac{pD_O}{2(SE+py)} + A \qquad (4)$$

T_m = thickness of the wall in mm, p = pressure of design in kPa, D_o = outside diameter of the pipe in mm, SE = allowable stress in kPa, y = 0.4, A = 3mm (where y - the corrosion and A - erosion allowance in the pipeline). For pressure containment in most cases, pipeline standards have wall thickness requirements - standards of design in wall thickness is important based on limiting the internal pressure of the pipe hoop stress due to an allowable stress equivalent to the YS (σy) x $\emptyset$-$code$. The maximum factors of design for numerous codes are expressed in (Hopkins, 2005). Based on international codes, the maximum allowable design factor varies from 0.72 to 0.80. The puncture resistance is necessary in the design of pipeline system which is written as

$$PR = [1.17\text{-}0.0029\ (D/t)] \times (L + W)\ (t \times \sigma_u) \qquad (5)$$

t = thickness of the pipe wall, D = outside diameter of the pipe, W and L = width and length of digger tooth, σu = ultimate tensile test. Similarly, impact strength of the pipeline or toughness is necessary in the selection of pipeline material. Several known methods are used to stipulate a Charpy toughness to stop occurring fractures. For pipeline material, classical equation for toughness is written as

$$C_v = 2.836 \times 10^5 \sigma_h{}^2 (D)^{1/3} (t)^{1/3} \quad (6)$$

Cv = V-notch charpy energy in Joules, σh= hoop stress in N/mm^2, D = diameter of pipe in mm, t = thickness of pipe wall in mm

From equation (3) it can be seen that diameter of pipe, thickness of wall and factor of design are the most important parameter in design of pipeline system. The factor of design can be written as

$$\text{Factor of design} = \frac{\text{hoop stress}}{\text{yield stress}} \quad (7)$$

Furthermore, for design of piping, pipeline and pressure vessels system classical equations are obtainable. The equations comprise materials limiting stresses and thickness of wall for pipes and storage pressure vessel as written in the following equations. Moreover, the classical equations for thin walls, thick walls design as connected to pipe and pressure vessels system design are available in standard text books.

1.1.1. Pressure Vessels Design

In the development of composite materials, the yield strength, Poisson's ratio and elastic limit are required during selection and designing a pressure vessels system to contain external and internal pressurization effects. Many standard researches have stated models to study the containers thickness for pressure vessels to comprehend the internal pressures. The design of pressure vessel as thin or thick-walled cylinder where circumferential (hoop) stresses and longitudinal stresses are developed based on internal pressurization. A vessel or cylinder is said to be thin walled if:

$$\frac{t}{d} \leq 0.1 \quad (8)$$

Whereas a vessel is said to be thick walled if:

$$\frac{t}{d} \geq 0.1 \quad (9)$$

2 Design of thin wall cylinders

Circumferential tensile (hoop) stress is written as

$$S_1 = \frac{t}{d} \quad (10)$$

The longitudinal tensile stress is written as

$$S_2 = \frac{t}{d} \quad (11)$$

Where S_1 = Circumferential stress, S_2 = longitudinal stress, P = internal pressure, d = internal diameter, t = thickness of the wall

1.1.2. Design of Thick-walled cylinders and Pressure Vessel System

When designing a thick-walled cylinder with closed ends subjected to internal pressure Pi, stresses are induced as shown in figure 1.

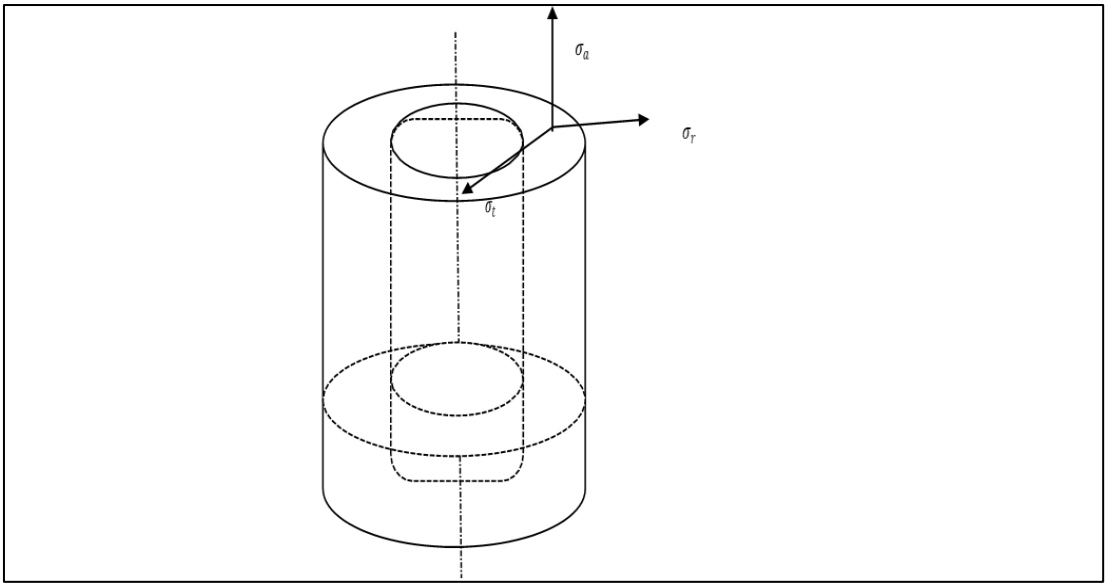

Figure 1 Principal stresses of pressurized cylindrical and pipe vessel (Ihueze et al., 2017)

To design a cylinder with thick wall subjected to internal pressure P_i, axial, radial and tangential stresses $\sigma_\alpha, \sigma_r, and\ \sigma_t$ are induced. The induced stresses are called principal stresses.

1.1.3. Lame's Equation

The principal stresses for internally and externally pressurized cylinders based on lame's classically equation of are written as

$$\sigma_r = \frac{P_i r_i^2 - P_o r_o^2}{r_o^2 - r_i^2} - \frac{(P_i - P_o) r_o^2 r_i^2}{r_o^2 - r_i^2} \frac{1}{r^2} \quad (12)$$

$$\sigma_t = \frac{P_i r_i^2 - P_o r_o^2}{r_o^2 - r_i^2} + \frac{(P_i - P_o)}{r_o^2 - r_i^2} \frac{r_o^2 r_i^2}{r^2} \quad (13)$$

where

r = radial distance of any point on cylinder, r_o = cylinder outside radius, r_i = cylinder inside radius.

The inside surfaces of the cylinder, stress analysis reveal that both induced radial and tangential stresses are higher. Let's assume that no external pressurization (12) and (13) will reduce to

$$S_t = \frac{P_i r_i^2}{r_o^2 - r_i^2} \left(1 + \frac{r_o^2}{r^2}\right) \quad (14)$$

$$S_r = \frac{P_i r_i^2}{r_o^2 - r_i^2} \left(1 - \frac{r_o^2}{r^2}\right) \quad (15)$$

For thick-walled cylinder axial stress with closed ends subjected to an internal pressure is written as

$$S_a = \frac{P_i r_i^2}{r_o^2 - r_i^2} \quad (16)$$

At the inside surface of the cylinder maximum tangential stress (due to internal pressure) will be

$$S_t(max) = \frac{P_i (r_o^2 + r_i^2)}{r_o^2 - r_i^2} \quad (17)$$

The radial maximum stress is written as

$$S(max) - P_i \tag{18}$$

1.1.4. Brittle Material Design and Stresses

Principal stress is equal to tangential stress and for the biaxial system, it is maximum in cylinder design of brittle material in agreement with the maximum-stress theory (MST) of failure, this should not exceed, or

$$S_t = S_t\,(max)\,\frac{P_i(r_o^2 + r_i^2)}{r_o^2 - r_i^2} \tag{19}$$

But $t = r_0 - r_i$ the cylinder thickness is made of material with brittle behaviour.

$$t_i = r_i\left(\sqrt{\frac{S_t' + P_i}{S_t' + P_i} - 1}\right) \tag{20}$$

$$= \square_{\square}$$

Equation (20) can be used to analyse open and closed cylinders system.

1.1.5. Determination of Thickness of Ductile Material

Failure is assumed to occur for ductile materials at the beginning of yielding maximum shear stress theory (MSST), at a particular point the maximum shear stress at any point in a stressed body is equal to one-half the algebraic difference of the maximum and minimum principal stresses. For a cylinder with thick-walled subjected to an internal pressure, the maximum shear stress occurs at a particular point on the inner surface (r-r_i). Therefore, the thickness can be written as

$$t = r_i\left(\sqrt{\frac{S'}{S_s' + P_i} - 1}\right) \tag{21}$$

$$S_s' = \frac{S_t'}{2} \tag{22}$$

Theory of maximum–strain

At the inner surface of a thick-walled cylinder, the maximum strain occurs and the thickness is expressed as

$$t = r_i\left(\sqrt{\frac{S_t' + (1-v)P_i}{S_t' - (1+v)P_i}} - 1\right) \tag{23}$$

Equation (23) is the Birnie's equation for cylinder with open end.

Recall that

$$t = r_i\left(\sqrt{\frac{S_t' + (1-2v)P_i}{S_t' - (1+v)P_i}} - 1\right) \tag{24}$$

Equation (24) is the Clavarino's equation for cylinders with closed-end

Finally, for ductile material equation

S_t' = allowable tensile, stress

= elastic limit / factor of safety or yield strength / factor of safety

The stresses acting in pressure vessels are markedly affected by the openings for manholes, hard-holes, nozzle attachments, and other connections and should be considered carefully especially when installing high pressure- high temperature materials.

2. Methodology

2.1. Materials

The *Musa paradisiaca* fibres were obtained from a plantation in Alakahia in River State. In this study, the following materials were used; they comprise of distilled water, weighing scale, oven, thermometer, pH meter and graduated cylinder, glass beaker, plastic container.

2.2. Methods

2.2.1. Fibre Extraction and Water Retting

The fibre was extracted and retted by retting method, which is a process of soaking the *Musa paradisiaca* in water. The remnants were soaked in water using about 2% detergent for three days until the fibres are distinct from pectin, hemicelluloses, oily substances, and other impurities. After that, the fibres were thoroughly washed and allowed to dry in the sun for two days.

Figure 2 *Musa paradisiaca* plantation in *Omuigwe Aluu*

Figure 3 Extraction of *Musa paradisiaca* fibres

Retting is a rotting process of the fibre in water. *Musa paradisiaca* fibre was soaked in water for days until the fibres are free from impurities. The fibre was retted for some days and were dried at varying oven temperatures for constant weight and subsequently, relevant physical and mechanical properties were determined before and after various modification treatments.

2.3. Chemical Treatment of *Musa paradisiaca*

The fibre was modified using (Aziz and Ansel, 2004) mercerization (alkalization) treatment techniques

2.3.1. Mercerization Treatment

After cleaning the fibres, it was soaked using 10% sodium hydroxide (NaOH) solution at a temperature of 30ºC for 60min. Later the fibres were removed from the NaOH solution and washed thoroughly using plentiful of distilled water to remove all the excess NaOH (or nonreacted alkali). After the treatment the tensile strength of the fibre were tested

2.3.2. Acetylation Treatment

After the fibre was dried, the mercerized fibre was further treated with acetic anhydride solution at 5% with soaking time of 60mins at varying temperatures at different fibre length. The fibres were thoroughly washed to neutrality and oven dried at various temperatures at different fibre length for the modified fibre. Hardness was determined after the treatment and results obtained on the hardness test were recorded and analysed.

2.3.3. Plantain Fibre Characterization

Tensile test was investigated for mercerization (alkalization) modified fibre using 10% concentration of NaOH to determine the soaking time in minutes for 60min, 120min, 180min and 240min at varying fibre length of 50mm, 60mm, 70mm and 80mm. The fibre was oven dried at varying temperature of 30 ºC, 50 ºC 70 ºC before further testing.

Hardness test was also investigated for the modified fibre using 5% concentration of acetic anhydride solution at three acetylation oven drying temperatures of 30 ºC, 50 ºC, and 70 ºC with varying fibre length of 50mm, 60mm, 70mm and 80mm.

2.4. Oven Drying

The fibre was oven dried to achieve 0% moisture content for the fibre. The drying process was carried out using an oven and an electronic weighing balance. These ovens are made by LABTECH India, S/No 01036 with heating capacity of 300°C. The electronic weighing balance is a Labtech brand, model BL7501 made by LAB-TECH India with maximum capacity of 750g and sensitivity of 0.1g. This oven was made available at Turret Engineering Services Limited Rumuosi, Port Harcourt, Rivers State.

2.5. Tensile Test

The fibres undergo a simple tensile test. The testing was carried out using Tensiometer, the tensile strength of the fibre was measured using the G99-046 Micro Fibre Test Jig. The fibre test specimen is glued at the top and bottom of a cardboard frame. Then the frame is gripped in the test machine. The lower grip is a basic manual vice grip.

2.6. Hardness Test

The resistance to permanent deformation, indentation or scratching is called hardness. The values of hardness of the fibre samples developed were measured using Rockwell Hardness Tester on MScale by ASTM D785. The results of the hardness test were also recorded.

3. Results and discussion

3.1. Oven Drying

It was observed that oven drying temperature suitable for development of the fibre, based on the results temperature of 70 ºC gave the highest maximum strength of 706Mpa at 80mm fibre length. Therefore, is adopted and accepted as the benchmark for developing the fibre.

3.2. Tensile strength

Table 1 to 3 shows results for tensile strength in alkali modified fibre with temperature of 30 ºC; 50 ºC and 70 ºC using 10% alkali concentration at varying fibre length were investigated and recorded.

Table 1 Tensile Strengths on 10% Alkali concentration at 30°C oven bath drying temperature

Fibre Replication	Tensile Strengths (MPa) @50mm	Tensile Strengths (MPa) @60mm	Tensile Strengths (MPa) @70mm	Tensile Strengths (MPa) @80mm
R1	593	480	586	488
R2	556	601	585	682
R3	553	414	452	481
R4	567	498	541	550
R5	520	408	518	508

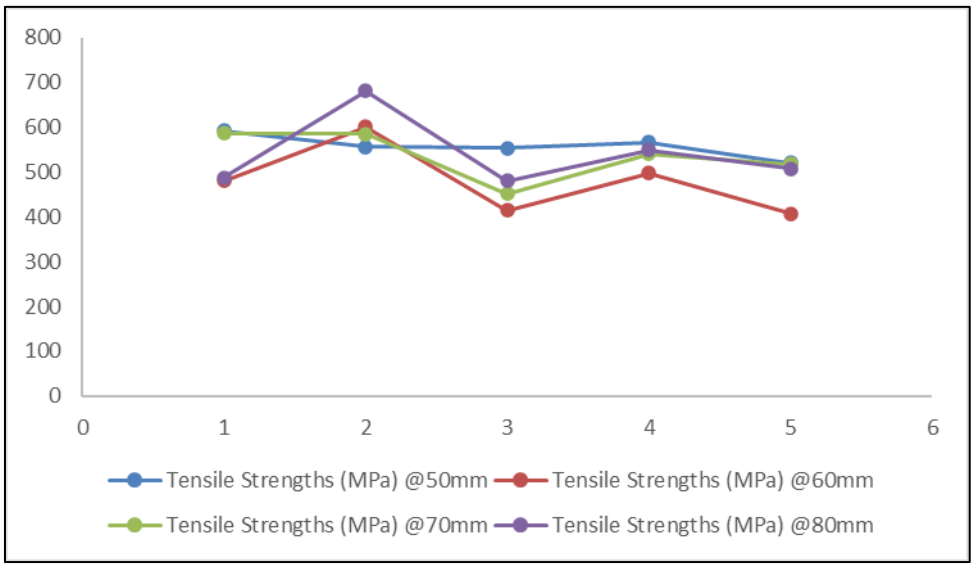

Figure 4 Graph of strengths for 10% Alkali concentration at temperature of 30 °C

Figure 4 illustrates the result of alkalization treatment conducted using 10% NaOH concentrations of the solution. The test conducted for strength on the mercerization treated fibres dried at oven temperature of 30°C using 50mm, 60mm and 70mm length of fibre. It was observed that the first replicate fibre R1 at 50mm, 60mm, 70mm and 80mm the tensile strength were 593MPa, 480MPa, 586MPa and 488MPa. For R2 at 50mm, 60mm, 70mm and 80mm the tensile strength was 556MPa, 601MPa, 585MPa and 682MPa. For R3 at 50mm, 60mm, 70mm and 80mm the tensile strength was 553MPa, 414MPa, 452MPa and 481MPa. For R4 at 50mm, 60mm, 70mm and 80mm the tensile strength was 567MPa, 498MPa, 541MPa and 550MPa. For R5 at 50mm, 60mm, 70mm and 80mm the tensile strength was 520MPa, 408MPa, 518MPa and 508MPa.

Table 2 Strengths for 10% Alkali concentration using 50 °C oven temperature

Fibre Replications	Tensile Strengths (MPa) @50mm	Tensile Strengths (MPa) @60mm	Tensile Strengths (MPa) @70mm	Tensile Strengths (MPa) @80mm
R1	689	382	419	523
R2	377	440	459	645
R3	656	389	585	419
R4	574	404	488	529
R5	360	430	550	620

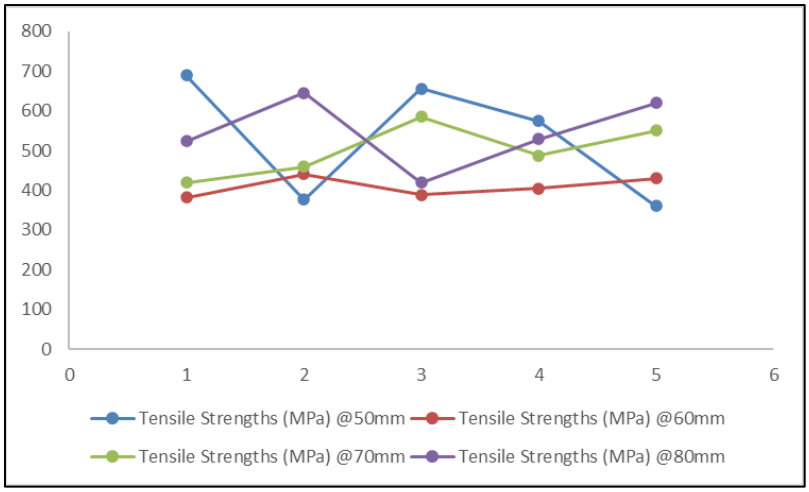

Figure 5 Graph of strengths for 10% Alkali concentration at temperature of 50°C

Figure 5 illustrates the result of alkalization treatment conducted using 10% NaOH concentrations of the solution. The test conducted for strength on the mercerization treated fibres dried at oven temperature of 30°C using 50mm, 60mm and 70mm length of fibre. It was observed that the first replicate fibre R1 at 50mm, 60mm, 70mm and 80mm the tensile strength were 689MPa, 382MPa, 419MPa and 523MPa. For R2 at 50mm, 60mm, 70mm and 80mm the tensile strength was 377MPa, 440MPa, 459MPa and 645MPa. For R3 at 50mm, 60mm, 70mm and 80mm the tensile strength was 656MPa, 389MPa, 585MPa and 419MPa. For R4 at 50mm, 60mm, 70mm and 80mm the tensile strength was 574MPa, 404MPa, 488MPa and 529MPa. For R5 at 50mm, 60mm, 70mm and 80mm the tensile strength was 360MPa, 430MPa, 550MPa and 620MPa.

Table 3 Tensile Strengths on 10% Alkali concentration at 70°C oven temperature

Fibre Replications	Tensile Strengths (MPa) @50mm	Tensile Strengths (MPa) @60mm	Tensile Strengths (MPa) @70mm	Tensile Strengths (MPa) @80mm
R1	458	487	380	706
R2	456	449	516	601
R3	499	571	560	527
R4	471	502	485	611
R5	409	490	510	625

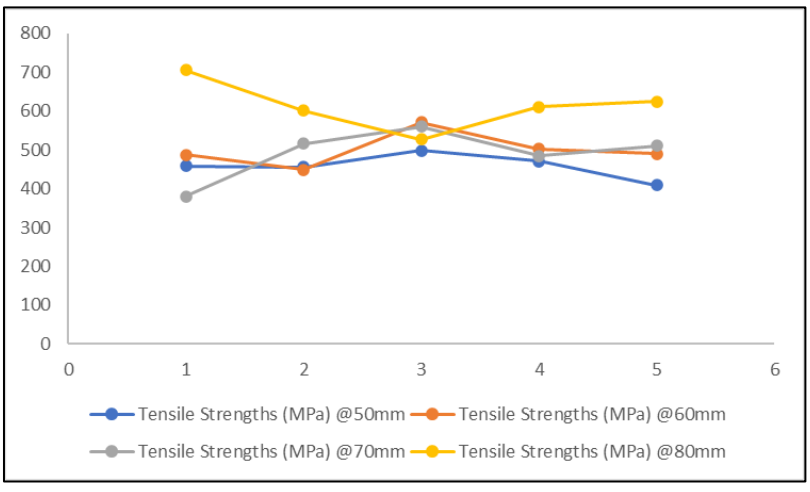

Figure 6 Graph of strengths for 10% Alkali concentration at temperature of 70 ºC

Figure 6 illustrates the result of alkalization treatment conducted using 10% NaOH concentrations of the solution. The test conducted for strength on the mercerization treated fibres dried at oven temperature of 30 ºC using 50 mm, 60mm and 70 mm length of fibre. It was observed that the first replicate fibre R1 at 50mm, 60mm, 70mm and 80mm the tensile strength were 458MPa, 487MPa, 380MPa and 706MPa. For R2 at 50mm, 60mm, 70mm and 80mm the tensile strength was 456MPa, 449MPa, 516MPa and 601MPa. For R3 at 50mm, 60mm, 70mm and 80mm the tensile strength was 499MPa, 571MPa, 560MPa and 527MPa. For R4 at 50mm, 60mm, 70mm and 80mm the tensile strength was 471MPa, 502MPa, 485MPa and 611MPa. For R5 at 50mm, 60mm, 70mm and 80mm the tensile strength was 409MPa, 490MPa, 510MPa and 625MPa.

3.3. Hardness Test

Table 4-6 illustrates the results of the hardness test conducted on 5% Acetic Anhydride concentration for oven drying temperature of 30 ºC, 50 ºC and 70 ºC at different length of 50mm, 60mm, 70mm and 80mm for modified fibre.

Table 4 Fibre hardness at 5% Acetic Anhydride concentration for oven drying temperature of 30 **ºC** at different length for modified fibre

Fibre Replication/Length	Hardness (HB) @50mm	Hardness (HB) @60mm	Hardness (HB) @70mm	Hardness (HB) @80mm
R1	133	124	130	120
R2	168	155	181	185
R3	152	132	177	104
R4	151	128	163	131
R5	146	142	155	172

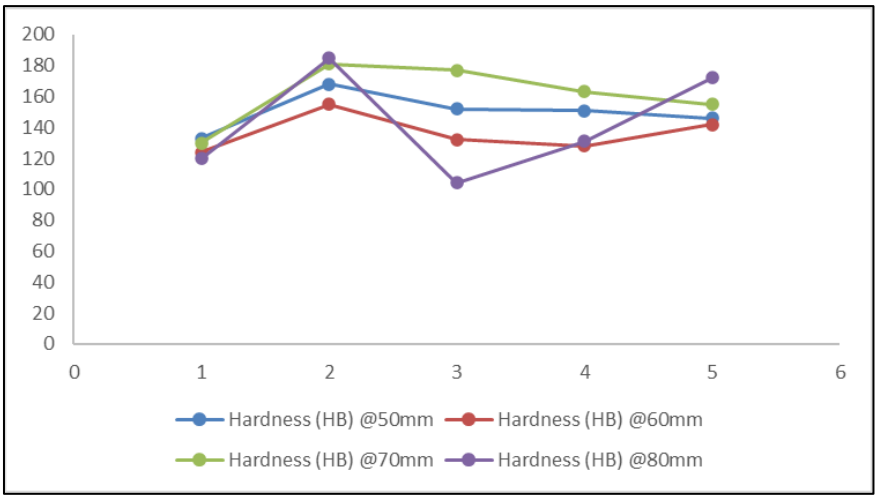

Figure 7 Graph of hardness at 5% Acetic Anhydride concentration for oven drying temperature of 30ºC using different fibre length for modified fibre

Figure 7 illustrates the result of acetylated treated fibre conducted using 5% anhydride concentrations of the solution. The test conducted for hardness on the treated fibres dried at oven temperature of 30 °C using 50 mm, 60mm and 70 mm length of fibre. It was observed that the first replicate fibre R1 at 50mm, 60mm, 70mm and 80mm the hardness were 133HB, 124HB, 130HB and 120HB. For R2 at 50mm, 60mm, 70mm and 80mm the hardness was 168HB, 155HB, 181HB and 185HB. For R3 at 50mm, 60mm, 70mm and 80mm the hardness was 152HB, 132HB, 177HB and 104HB. For R4 at 50mm, 60mm, 70mm and 80mm the hardness was 151HB, 128HB, 163HB and 131 HB. For R5 at 50mm, 60mm, 70mm and 80mm the hardness was 146HB, 142HB, 155HB and 172HB.

Table 5 Hardness at 5% Acetic Anhydride concentration for oven drying temperature of 50 **ºC** using different fibre length for modified fibre

Fibre Replication/Length	Hardness (HB) @50mm	Hardness (HB) @60mm	Hardness (HB) @70mm	Hardness (HB) @80mm
R1	153	157	155	158
R2	199	196	144	157
R3	145	370	153	300
R4	166	241	144	251
R5	145	182	135	145

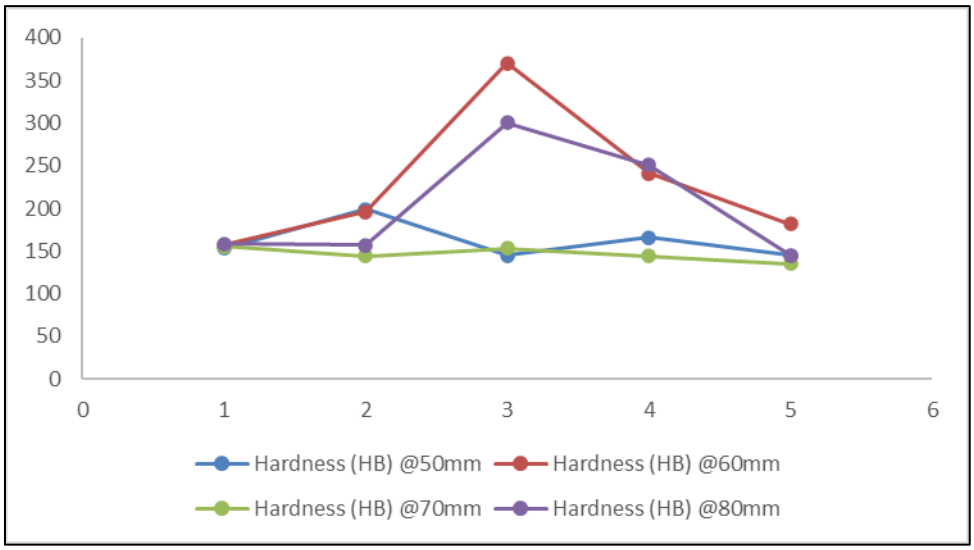

Figure 8 Graph of hardness at 5% Acetic Anhydride concentration for oven drying temperature of 50ºC using different fibre length for modified fibre

Figure 8 illustrates the result of acetylated treated fibre conducted using 5% anhydride concentrations of the solution. The test conducted for hardness on the treated fibres dried at oven temperature of 30 °C using 50 mm, 60mm and 70 mm length of fibre. It was observed that the first replicate fibre R1 at 50mm, 60mm, 70mm and 80mm the hardness were 153HB, 157HB, 155HB and 158HB. For R2 at 50mm, 60mm, 70mm and 80mm the hardness was 199HB, 196HB, 144HB and 157HB. For R3 at 50mm, 60mm, 70mm and 80mm the hardness was 145HB, 370HB, 153HB and 300HB. For R4 at 50mm, 60mm, 70mm and 80mm the hardness was 166HB, 241HB, 144HB and 251HB. For R5 at 50mm, 60mm, 70mm and 80mm the hardness was 145HB, 182HB, 135HB and 145HB.

Table 6 Hardness at 5% Acetic Anhydride concentration for oven drying temperature of 70ºC using different fibre length for modified fibre

Fibre Replication/Length	Hardness (HB) @50mm	Hardness (HB) @60mm	Hardness (HB) @70mm	Hardness (HB) @80mm
R1	155	166	155	185
R2	152	174	183	172
R3	172	277	163	161
R4	141	189	154	150
R5	145	210	174	148

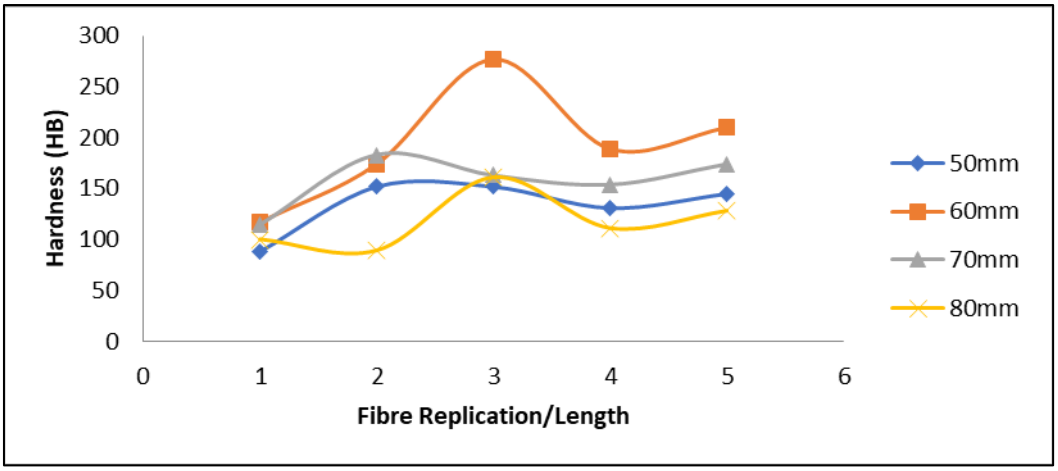

Figure 9 Graph of hardness at 5% Acetic Anhydride concentration for oven drying temperature of 70°C using different fibre length for modified fibre

Figure 9 illustrates the result of acetylated treated fibre conducted using 5% anhydride concentrations of the solution. The test conducted for hardness on the treated fibres dried at oven temperature of 30 °C using 50mm, 60mm and 70mm length of fibre. It was observed that the first replicate fibre R1 at 50mm, 60mm, 70mm and 80mm the hardness were 155HB, 166HB, 155HB and 185HB. For R2 at 50mm, 60mm, 70mm and 80mm the hardness was 152HB, 174HB, 183HB and 172HB. For R3 at 50mm, 60mm, 70mm and 80mm the hardness was 172HB, 277HB, 163HB and 161HB. For R4 at 50mm, 60mm, 70mm and 80mm the hardness was 141HB, 189HB, 154HB and 150HB. For R5 at 50mm, 60mm, 70mm and 80mm the hardness was 145HB, 210HB, 174HB and 148HB.

4. Conclusions

This study was aimed at the development of *Musa paradisiaca* fibre reinforced piping system for production of oil and gas facilities. It discussed and analyzed composites, classifications of composites and natural fibres, especially *Musa paradisiaca* which is the material fibre composite for the study. The fibre was collected from a *Musa paradisiaca* tree, retted, dried and then the fibres were extracted. The study thoroughly analysed composites which is central to the study of natural fibre in general, it gave a comprehensive analysis on the acetylation, mercerization and tensile strength as part of the process for the development of fibre reinforced piping systemfor oil and gas facilities. From the analysis, interpretation and discussion of findings carried out, it is obvious that the processes involved in the development of *Musa paradisiaca* fibre reinforced piping system starts at the most fundamental stage of collecting the material for production of the fibre to the apex which is the extrusion and moulding processes. This ingenious process is not only an essential piece of mechanical engineering but also an innovative process which is beneficial to the environment and ecosystem, hence it can be said to be a science that is a necessity.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflicts of interest and no financial or personal conflicts of interest."

Statement of ethical approval

ALL participants provided written informed consent prior to enrolment in the study. This research was conducted ethically in accordance with the Engineering standard.

Statement of informed consent

I have read and I understand the provided information which is correct and permitting you to publish the manuscript online.

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