DEVELOPMENTOF COMPOSITE REINFORCEMENT FIBEREXTRACTOR MACHINE FOR BANANA PSEUDOSTEM

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MEng /SEET/2017/6901

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SEPTEMBER, 2021

ABSTRACT

The use of many products such as fibers from banana plant (pseudo stem) is becoming inevitable due to high demand for fiber in Nigeria. However, the means of extracting fiber and processing it is associated with various problems such as longer extracting time, poor production rate and treatment. Therefore, this study is targeted at overcoming the limitations associated with means of extracting the banana fiber and treatment that may be involved. In this work, two methods of banana fiber extraction were adopted: manual and mechanized method. Manual method involves the use of scrapper to force out the fibrous tissues in the pseudostem to extract the fiber while mechanical method involves the use of machine to extract the same fiber. In design and fabrication of banana fiber machine, various stages involved include selection of appropriate materials, design, fabrication and assembly of the various components of the machine parts. Two horse power(2 Hp)electric motor could be used to drive the machine effectively as it was achieved from machine design analysis. The total length of flat-belt to drive the pulley was 1.33m at an angle of lap on the smaller pulley of 2.58rad and velocity of4.46m/s. The resultant load of 292.2N act on a diameter shaft of 14mm with maximum bending moment of 17.946Nmand the torque required by rolling drum to pulp rib was 25.8Nm respectively. The machine was tested to ascertain the efficient of the device. At the design stage, the calculations of the length, width and thickness of the banana sliced stem were determined. The thicknesses of banana sliced stem used for this test was: 8.0 mm, 7.0 mm, 8.50 mm, 8.54 mm, 9.0 mm and 10.0 mm. The test was done on a steady voltage supply of 220 V single phase induction motor using a stop watch to determine the extraction time. The machine capacity was calculated to be 39.375 kg/h. From the test result obtained, the machine could extract a sliced stem of maximum width of 150 mm and thickness of 10 mm respectively, while the length varies. The alkaline treatment was done using 8% of sodium hydroxide (NaOH) solution to increase mechanical properties of fiber like strength and luster.

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ABBREVIATIONS, GLOSSARIES AND SYMBOLS

M = Mass (kg)

T = Torque (Nm)

P = Power, watt (w)

$\mathbf{r_1}$ = Radius of smaller Pulley (mm)

r_2 = Radius of larger Pulley (mm)

N_1 = Motor Pulley Speed (rpm)

N_2 = Driven Pulley Speed (rpm)

T_1 = Tension on tight side of belt on pulley (Nm)

T_2 = Tension on slack side of belt on pulley (Nm)

R = Radius of the pulley, (mm)

d_1 = Diameter of Small Pulley (mm)

d_2 = Diameter of Big Pulley (mm)

d_0 = Shaft Diameter (mm)

M_b = Bending Moment (Nm)

M_t = Torsional moment (Nm)

K_t= combined shock and fatigue factor applied to torsional moment

K_b = combined shock and fatigue factor applied to bending moment

L_B = Length of V-belt (cm)

χ = Distance between the centres of two pulleys (mm)

E = Modulus of elasticity, (N/m^2)

Te = the equivalent twisting moment (Nm)

M_e = the equivalent bending moment (Nm)

τ = the Shear stress induced due to twisting moment, (Nm)

σ_b = the Bending stress induced due to bending moment, (Nm)

V = Linear velocity of belt, (m/s)

σ = the Maximum safe stress in N/mm^2

b = the Width of the belt in mm,

t = the Thickness of the belt in mm

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Banana, from family of Musaceae called *Musa paradisiacal,* is a common fruit crop grown at tropical or sub-tropical areas of the country. It takes up to 8.8 million hectares of land to be grown according to (Mohapatra *et al*., 2010). Banana is one of the ancient crops ever cultivated according to (Kumar *et al*., 2012). Banana fruit is a major important source of carbohydrate and vitamin with about 67% calories in every 100g fruit. It is amongst the most commonly traded fruits crops all over the world (Emaga*et al*., 2008). Banana tree is one of the tallest herbaceous trees with a pseudostem, tough tree like pliable stem. It is made up of the twisting sheath leaf base, which contains fibers of maximum strengths to uphold its tree effectively. Banana plant scientifically called Musa Acuminata and plantain plant scientifically called Balbisiana hybrids does not only give delicious fruit, but also qualities of natural fibers. As a natural fiber, it has important advantages which are; appropriate stiffness, low density, and good mechanical properties with high disposability and renewability ratio, and there are biodegradable and recyclable in nature. Some research has been carried out based on natural fibers uses as reinforcement agent. Banana fiber, as lignocelluloses fiber is extracted from its pseudostem. Banana fiber from a group known as a bast fiber is called Musa Sepientum with high mechanical properties. Banana tree is a good perennial herb with leaf sheaths, which form pseudostem of height3.0 to 8.2 meters covered with, 8 to 12 wide leaves. The leaves are up to 2.7 m height and 0.61mwidth.

Banana farm is available in Thailand, Philippines, South East Asian, Uganda, India, China, Indonesia, Bangladesh, Malaysia, Hawaii and other Pacific islands.

In Africa countries today, Uganda stand as the largest banana producer country, followed by Burundi, Cameroon, Kenya, Egypt, Tanzania and Rwanda. Nigeria is among, though produced in little quantity compare to other countries above.

It is easily grown when spring out new shoots and normally found out in hot tropical climatic areas. All species or categories of banana trees contain fibers in high quantities and the fibers are always produced after the fruits bunch might have been harvested. Traditionally, immediately the fruit has been harvested, the trunk of banana plant is always dumping as a refuge on agricultural farm to some an extent.

These pseudostems been thrown away could be efficiently utilized in the production of good banana fibers. The pseudo-stem could be profitably utilized for many uses, suchlike:bags, baskets, ropes, foot wears, socks, decorative papers, floor mats, rugs, currency paper and home furnishings can be made with banana fibre according to (Mohiuddin*, et al*.,2014)

Nevertheless, the first people to discover the yield of banana fiber, properties and structures were (Kulkarn*iet al*., 1983). Additionally, the yield structured and properties of banana fibers were seen and the differences that existed in both the structure and fibers properties, along the length and its across-sectional thickness of the pseudo-stem. It was discovered that the variation in structural properties and strength among fibers, belong to different species and have shown that the matrix in which the cells are made up of has a function in determining the tensile strength of the fiber.

1.2 Statement of the Problem

After the fruit of the banana crop is harvested, greater part of banana plants will be left as wastage, therefore causing an environmental problem and making un-balanced ecosystem. Recently, billions tons of banana pseudostem were left in our nation as material wastage and many of the farmers are in-depth challenges in off-loading these abandoned banana pseudostem. For these reasons, the major economic way of solving this environmental hazards, is by the extraction of fibers for an important economical production of many essential industrial products, which is useful in various technical and agricultural applications, like: fertilizer, bio-chemicals, bags, baskets, ropes, socks, decorative papers, floor mats, currency paper, home furnishings and other compositesfrom banana waste (pseudo-stem) is necessary. (Mohiuddin *et al*.,2014).

The high cost of existing machinery, prevent banana farmers from transforming their stalks into more useful material that could improve their economic well-being. Therefore, the design and development of extracting fiber machine is hereby proposed as a part solution to the problems explained above.

1.3 Significance of the Study

The significance of the study is to unveil the benefits of banana fiber products and evaluate the factors influencing the production here in Nigeria. The research work would open the agricultural value chain, improve farmers' income and nation economy, reduce dependence on importation of fibers and help develop better understanding and further breakthrough in banana fiber Production Company.

It will improve standard of living to poor people in rural areas, thereby creating job opportunities in the fiber manufacturing industries as well as it has great importance in the economy of the country through foreign exchange earnings, by exporting the produced fiber to other countries in Africa, and beyond. The use of banana fiber to produce the product like absorber pads for menstruation, papers, cloths, bags and other composites, will reduce the cost of these productsfrom90% to 40% because of the banana fiber is the residue of banana tree. The main advantage of banana fibers, unlike any other natural fibers is that, banana fibers are always available in high quantities, very cheap, with good tensile strength. It will increase the economy of Nigeria towards economic self-reliance.

1.4 Justification of the Study

This study is necessary as regards to banana fiber production in the world today. Banana fiber production is one of the most income generations of people in different country of the world especially in India. Production of banana fiber serves as an avenue for job employment to millions of graduates and non-graduates living in rural area. The applications of the banana fiber in our home are too numerous to be mentioned. Today, Plaster of Paris (P O P)ceiling has begun in Nigeria and beyond, and had equally created employment opportunities for millions of adult and youth. Imagine what would happen when Nigerians start the production of the banana fiber and fabrication of the machine here in our nation, the unemployment among our youths would be drastically reduced and therefore increases our social and economic well being.

1.5 Aim and Objectives

The main aim of the study is to develop a composite reinforcement fiber extractor machine for banana pseudo-stem.

The objectives are to:

i. Produce banana fiber using banana stem (pseudo stem).
ii. Carry out a complete design work on each component partof the fiber extractor.
iii. Fabricate and develop a portable and affordable banana fiber extraction machine, possibly to do the work with little human effort.
iv. Evaluate the working performance of fiber extractor.
v. Achieve quality of fiber in Nigeria with minimum cost.

1.6 Scope of the Study

The scope of this study is to generate fiber for composites reinforcement, using banana stem (pseudo stem). To generate this fiber, there will be a detailed design and fabrication of all component parts and the assembly of banana fiber extraction machine, capable of extracting fiber with ease and without having any damage to the fiber. The machine will be powered by electricity supply, driving the electric motor. The machine does not incorporate features like cutting, peeling or slicing of pseudo stem. These would be done manually with aid of cutlass and/or knife or with some other working tools or machines.

CHAPTER TWO

2.0LITERATURE REVIEW

2.1Brief History of Banana plant

Banana plants are essentially found at hot climatic place. The origin or home is hot tropical forests of Asia. it also has economic importance as a source of fibers. It has an important role to play in our mythology. It happened to be Noah or Manu according to western tradition or Haz-rat Noah according to Muslims society. When he started implementing life new on this planet after the terrible flood, he seeks help from God for a multi-purpose plant that serve as food, fruit and food crop. It was discovered that God gave him banana plant which happen to solve most of our need today. Since then, fruits, flowers, vegetables and stems are cooked as food. Plant gives fiber for production of cloths while the leaves are used as plates in some places to serve food, and of course they are equally used for various medicinal values. When the plant sets young shoots from the ground it easily grows of its own.

In today, banana has good historical backgrounds. People talked about it in different languages like: Greek, Hindu, Roman and Chinese languages. It was also discovered, that the foremost history of banana was in Sanskrit as far back as 500 BC. Horticulturists discovered that bananas are one of the first fruit on earth. Banana is originated from South East Asia. It is found at the areas of Philippines, Indonesia and Malaysia, where so many types of species of wild bananas still grown at moment. Today, bananas had travelled to other country of the world through human population. The first people in Europe to know about bananas were Alexander de Great armies, when they were campaigning in India, during 327 BC. In Africa, it was brought by Arab. Bananas had been traded internationally since nineteenth century till date. But before that time, North Americans and Europeans countries could not enjoy them, because there was no adequate transportation of bananas to their country. The growth of railways and scientific advances in refrigeration and maritime transportation gives way to bananas, to becoming the most beneficial world international traded fruit. Bananas are from Musaceae family. They were considered to have been derived from the wild varieties. In the world today, there are about 1000 species of bananas which later sub-divided into 50 further groups. The world ever known variety of banana is commonly called Cavendish which is the one manufacture for local and international export markets of the world.

Banana is cultivated, in over 120 countries of the world. The ten largest banana producing countries in order of hierarchy are: India, Uganda, Ecuador, Brazil, Colombia, Philippines, China, Indonesia, Democratic republic of Congo, and Costa Rica. About 17% of bananas produced in the world are from India. Banana is a major rich source of carbohydrate, contains natural fibers in quantities, and the pseudo-stem can be efficiently utilized for different numerous applications.

According to the history in the world today, India has the largest producer of banana with an annual output of about 30 million tones which accounts for 22% of the global banana production. Whereas in Africa countries today, the largest producer of banana are Uganda, followed by Burundi, Cameroon, Kenya, Egypt, Tanzania, and Rwanda. Nigeria banana production is about 2.73 million tons per year. Nigeria is also one of the largest plantains productions in West Africa countries. It is generally produced in the Central and South regions of the country like; Oyo State, Edo State, Ondo State, Bayelsa State, Delta State, Akwa Ibom State, Rivers State, Ogun States, Cross River State, Ebonyi State, Abia State, Ekiti State, Imo State, Plateau State, Osun State, Kogi State, Anambra and Enugu state.

2.1.1Banana as a fruit crop

The main purpose of banana cultivation is mainly for its fruits, cooked vegetables, and fiber as it is found in India, Bangladesh and other country of the world. According to (Khanum *et al*., 2000), citrus was the first to be produced in the world, second by banana in largest quantity which contribute almost 16% of the total fruit of world's production according to FAO., (2009). Banana contains high nutritious elements, Sharrock and Lustry., (2000), and is digest easily than any other fruits including apple in human system. (Mohapatra *etal*., 2010). Banana plant is not a tree as the case may be, but herbs. The height is close to fifteenth (15) feet, it is a perennial crop that replicates itself. Banana plant grows from bulb or rhizome and not from the seed. The time between a banana planting and the harvest of the bunch of fruit is between nine to twelve months. The flower comes out in either six or seven (6 or 7) months. Bananas are always available at all time in a year.

The botanical name of banana is called Musa acuminate AA, and that of plantain is commonly called balbisiana hybrids BB, and both are perennial crops. There are from the family of genus called Musacea and looks alike in their appearances, but they have different features in between them FAO, (2007).

According to FAO in 2007, Uganda has the highest production of banana and plantain, in sub Saharan Africa (ASS) country, followed by Rwanda, Ghana, Nigeria, and Cameroon. The world largest production of bananas countries, according to the statistics in 2013, was

India, with around 30 million tons of production in a year. The largest banana producing countries in order of hierarchy are stated in the Table 2.1.

Table 2.1: World Largest Bananas Producing Countries, (Mohiuddin *et al*.,2014).

Rank	**Country**	**Production Qty (in tons)**	**Production Value**
1.	India	29666973	$8,355,139,000
2	Uganda	12000000	$3,107,962,000
3	China, Mainland	10400000	$2,928,962,000
4	Philippines	9165043	$2,323,044,000
5	Ecuador	7427776	$2,091,891,000
6	Brazil	7329471	$2,064,206,000
7	Indonesia	6132695	$1,727,157,000
8	United Republic of Tanzania	3143835	$885,401,000
9	Angola	2646073	$745,216,000
10	Guatemala	2679934	$726,589,000
11	Mexico	2138687	$602,320,000
12	Costa Rica	1937122	$531,472,000
13	Burundi	1848727	$520,658,000
14	Colombia	2042925	$517,685,000
15	Thailand	1600000	$450,609,000
16	Viet Nam	1523428	$429,044,000
17	Cameroon	1394675	$392,783,000
18	Kenya	1197988	$337,390,000
19	Egypt	1054243	$296,907,000
20	Papua New Guinea	1000000	$253,467,000
21	Dominican Republic	829827	$233,705,000

2.2 Applications of Banana Fiber

Some numerous of products which can be derived from banana herb includes the following: bags, baskets, floor-mats, home furnishings, according to (Mohiuddin *et al*.,2014).Production of fibres by mechanized means is of better advantage and is generally used for producing high special quality papers. In some of the countries like Germany, banana fibre is use for production of paper currency and for production of socks in many European countries and more especially in the whole world today as a reinforcement fibre. Numerous uses of banana fibres are summarized below;

i. Fibers from banana have been recognized for home furnishings and apparels.

ii. Poly-propylene reinforced with banana fiber is widely used by automobile industries for making under floor protection panels in luxurious cars like Mercedes.

iii. Banana fiber composites are used in building boards and fire resistance boards.

iv. Banana fiber is use in production of products like: filter paper, paper bags, pen stands, greeting cards, decorative papers and lamp stand (Mohiuddin *et al*.,2014).

v. The innermost part of the banana stem is medicinal and also use as food for man.

2.2.1 Types of banana fiber (textiles)

It is about fourteen to eighteen sheaths (14 to 18), available in a banana stem. The outermost part contains four to six (4 to 6) sheaths, of course fibers. The middle part contains 6 to 8 sheaths of lustrous soft fiber and the inner part excluding the core contains four to six (4 to 6) sheaths very soft yield fibers. In any given banana stem, there are three different layers of pseudostem. The outer layer includes the epidermis which contains the bundles of fibers dispersed in a soft tissue matrix. The middle layer consists of water transportation vascular tissue of fiber and the core or the innermost layer, consists of cellular soft tissues. The quantities and qualities of fiber in each sheath, is depend on its width and location in the trunk.

The quality of the fiber inside the banana stem (pseudo stem) varies:

I. Inner fibers (fine, smooth, and natural shine) - smoothest textiles like kimonos and saris.

II. Outer strands (coarse)-basket weaving and making handbags.

Plate I: Coarse Fiber(Manogna, 2017)

Plate II: Fine and smooth fiber (Ravi, *et al*., 2015)

2.2.2 Varieties of banana plant

All the species of banana trees contain fibers in quantum which falls in the categories of bast fibers. But their tensile strength varies according to Kiruthika and Veluraja, (2009) who studied the banana pseudo stem physical properties. They discovered that the strength of red banana fiber was higher compare to any other variety. This has been long stand as major source of good textiles in so many industrial parts of the world especially in Nepal and Japan. As a tropical fruit, bananas do not care for the chill of the refrigerator, so the best way to store them at room temperature where they will continue to ripen gradually. You can speed up the ripen process, depend on consumer's need by simply lapping the fruits in a paper bag and leave it for some days. The followings are some of the banana varieties traded within and outside our country Nigeria;

A) Cavendish Bananas: This is the most commonly varieties. They are long yellow in nature slightly bananas found in most country of the world. They go from under ripe green to perfectly ripe, and still firm mellow yellow. Some sizes of Cavendish specie include Giant Dwarf, which at times not easy to be found.

B) Blue Javaor Ice-Cream bananas: This could be called chubby bananas. It is about 7 inches long, blotchy skinny, silvery blue, and creamy white flesh. The flavour is some-what like rich ice cream.

C) Man-zano Bananas: It can be called banana apple or candy apple banana. They are grown in the rain tropical forests. They are small bananas chubby with a mild flavour reminiscent of apples and some straw-berries. When fully ripe, the skin turns black.

D) Red-Bananas: They are many types of red banana but all of them look supper cool, and tend to be on the sweeter side of the bananas flavour family. They can only be eaten when they are pure red. Its fiber is among the varieties that has the highest tensile strength (Kiruthika and Veluraja, 2009).

E) Ninoor Baby Bananas: These are small bananas called chubby, at times called Lady Finger bananas with average of 3 inches in length. The skin becomes yellow bright when ripe. They are creamy in nature and have sweet taste.

F) Burro Bananas: These kinds of bananas are slightly lemony and tangy. There are known by their squatty and slightly squares at all the edges. The fruit becomes soft and the skin yellow with black spots when ripe. They are also called Horse Hog or Orinoco bananas.

G) Pisanga Raja: This variety of banana is popular in Indonesia where they often used to make banana fritters. They are also known as Musa Belle banana.

H) Plantains (Musa balbisiana). Plantains and bananas belong to the same family of Musacea. They are known as cooking bananas, though they contain high starch. They can be roasted, steamed, fried into tasty chips and otherwise use like any starchy vegetable and can sold green. It has the same colour of banana when allowed to ripe, but won't be sweet as that of banana. Plantains are nutritious just like bananas. It contains vitamin B6, potassium, and vitamin C. Plantains has carotene, which is un-usual in a non-colorful fruit, with one and half cup cooked, containing enough to provide 5 % of the recommended dietary allowances (R.D.A) for vitamins A, compared with 1 % in the same number of raw bananas.

2.2.3 Characteristics of banana Fiber

Banana fibers, commonly called Musa sepientum, have good chemical and physical characteristics. Some other features that make it fine quality fibers are characterized with high tensile strength, less weight, good luster, small elongation, good moisture and quick absorption, good environmental protection and degradation. Banana fibers applications are as follows: in the production of bed sheet, towel, garment and curtain due to its features with good moisture content and luster. The main advantage of the banana fibers, unlike other natural fibers, is that banana fibers are always available in large quantities, very easy to obtain and have a conductive protection value, and other properties like:

i. The appearances are familiar to that of ramie and bamboo fiber, but banana fibers have good spin ability and fineness than others. They have shinning nature appearances, based upon the method of spinning and extraction processes. Rao and Mohana, (2007).
ii. The chemical composition contain by banana fibers are:(50 to 60%)cellulose,(25 to 30%)hemicelluloses, (3 to 5%) pectin,(12 to 18%)lignin,(2 to 3%)water soluble materials,(3 to 5%)fat and (1 to 1.5%)wax and ash.(Mukhopadhay*et al.*, 2008).
iii. It is of high stronger fiber than others.
iv. Its properties of elongation is smaller
v. It is lighter in weight than other types of fiber.
vi. It possesses stronger moisture absorption qualities, and also gives moisture easily.
vii. Its biodegradability has no effect on surroundings, that is to say, it is eco-friendly fiber(Mukhopadhay*et al.*, 2008)
viii. It possesses an average fineness of about 2400Nm.

ix. It could be spun through all the processes of spinning. Examples are spinning by ring, end-open spinning, bast fiber spinning, and semi worsted spinning.

2.2.4 Uses of products made from banana pseudo stem

Banana fibers are generally used materials for blending in textile companies of the world like: Philippines, Korea, Japan and Malaysia. Therefore, so many company products like yarn, ropes, geo textiles, gunny bags, tri-vialities, carrier luggage, door mats, carpets, decorative interior crafts papers, tissue and bag papers, could be produced from the fiber while a maximum strength is to be used. It has some other industrial applications like absorbent, base material for bioremediation, re-cycling and purifier of water. (Mohapatra *et al.*,2010). Some of other products obtain from banana fibers are:

a) Yarns: The process of making ropes from twisted banana fiber is called Banana fiber yarn. Production of ropes is of great skills in converting any material that is linear into a useful one. Manandhar, (2010). When the length of fibers are braided or twisted together, to increase the strength for pulling and connection of things together, r it is called rope. The tensile strength of rope is so much flexible, to give compressive strength. (Maleque*et al.*, 2007).

b) Apparel and fabric materials: The use of rope or yarn to produce cloths, are known as fabric whereas different kinds of dresses produce of cloths are regarded as apparel. Sapuan and Maleque,(2005). The processes of apparel and fabric extraction from banana fiber are the same as that of cotton textile.

c) Paper making: Paper industries are now using banana fiber as an alternative raw material in making different kind of papers like: writing paper, cheque paper, ant grease paper or hard-board papers. Cordeiro *et a*l.,2004 and (Mohapatra *et al*., 2010).

d) Handy-crafts: Banana fibers are use in preparing so many of handicraft items, Manandhar, (2010) and (Mohapatra *et al*., 2010). Some of these handicrafts include the followings: tablemat, pillow, decorative wall hangings, bags, coaster, sofa sets and dolls.

e) Ecobag: Degradable bag known as eco bag could be produced from banana fiber (Mohapatra *et al*.,2010). This ecobag is the combinations of banana fiber and cotton. It is sturdy, wrinkle with good absorbent resistant, compared to other bags with only cotton.

f) Micro-crystalline cellulose (MCC):This product is obtaining from banana fiber and can be used for several industrial purposes. It could be used in pharmaceutical companies, in bakery, beverages and even in animal health products (Oliveiro*et al*., 2007).

g) Central core based products: The central based core of banana tree is good edible for food as the innermost parts of the pseudo-stem. Such like, candy drinks, pickles are from banana stem (Aurore *et al*., 2009).

h) Vermin-compost: During banana fiber extraction, from pseudo-stem, the great quantities of scutcher, 30 to 35 tons are produced. The scutcher is now transformed to natural products such like vermin-compost by putting some important products in order (Oliveiro*et al.*,2007 and Phirke*et al.*, 2001).

i) Used as an organic fertilizer: Vermin-compost may be applying to some crops like banana, papaya, sugarcane and ginger as an organic manure (Phirke*et al.*, 2001).

j) Used as liquid fertilizer: The sap gotten from banana, during fiber extraction from the pseudo-stem, may be used as liquid manure for bananas, papaya, and sugarcane Patil and Kolambe,(2011).

2.2.5 Physical properties of fibers

Fibers are generally soft, flexible and capable of being transformed into desired shapes without resistance and are durable over a reasonable period of time. The yarn is formed, by twisting a bundle of fibers together. It is therefore obvious, that the properties of ultimate textile strength will depend very largely on the characteristic of the fibers from which they are made. Fibers have been defined by the textile institute as a unit of substance which is characterized by finesse, flexibility, and a high ratio of length to thickness, tensile strength, spinnability and luster Goswami (1977).

a) Fineness: Fibers, whether natural or synthetic come in various forms and cross-sectional shapes. Some are circular in section (wool, and synthetics) while others are irregular cross-sectional area, (cotton, silk and especially manmade synthetic fiber). The fineness or the coarseness of a fiber has been sometimes defined in terms of its diameter. This term can be used advantageously where a fiber has a cylindrical cross-sectional area, but it has no useful meaning when characterizing other shapes such as elliptic and also mass per unit length is the most commonly parameter used to characterize the fineness of fibers (Goswami 1977).

b) Fiber length: The length of fiber varies proportionately within any given staple. The variability may be as high as 40% for cotton, but manmade staple fibers are always the same, with variation of 10%. This variation is caused partly by fiber breakage that occurs during processing. If the length of fiber L, is increasing, the fiber reinforcement will become more effective (L>>Lc)reinforcement are termed continuous, fiber discontinuous or short fiber of length less than critical length (Lc). The matrix deforms around the fiber to extend that there is no virtuality stress occurring and little fiber reinforcement to affect a significant improvement in strength of the fiber, the fiber must be continuous.

c) Tensile-strength: The strength of the fibers is the most important fiber property. Since they contribute both the processing behavior and to the characteristics of the end product. The tensile-stress in the fiber increases, from zero at the end to a maximum value in the central region. Tensile-strength is the highest engineering tension, which may be stress without sustaining facture(William, 1997).

d) Spinnability: Fiber must have good spinnable qualities; spinnability may be defined as the ability of the fiber to cling together (cohesion). So that it can be made into another material such as yarn. This property depends on the surface and the internal structure of a fiber.

e) Flexibility: This may be defined as the property of a fiber that permits it to bend without breaking, not only once, but severally as the case may be.

f) Luster: It is the amount of light reflected from the surface of the fiber. It is measured by its degree of brightness or dullness. The natural fiber, silk, and mohair have high luster cotton and wool have low luster. Luster can be controlled in man-made fiber by adding pigment to make it; dull or by changing the shapes of the fiber to reflect more light from the fiber surface.

2.2.6 The chemical composition of banana fiber

The major constituent of bananas is sugars, which comprises of fructose, glucose and sucrose, and contains fiber in quantities. The major chemical elements in banana fiber are: cellulose, hemicelluloses, and lignin. They have different content in the pseudo stem of different banana. By elemental analysis of (Bilba *et al.*,2007),who discovered the chemical composition of banana pseudostem. It shows that;(31 - 35%) of cellulose, (14-17%) of hemicelluloses and (15-16%) of lignin were present.

The percentage of chemical compositions of banana fiber is stated in the Table 2.2.

Table 2.2: Chemical Composition of Banana Fiber (Mukhopadhay*et al.*, 2008)

Constituent elements	Percent (%)
Cellulose	50 - 60
Hemi cellulose	25 - 30
Lignin	12 -18
Pectin	3 - 5
Ash	1 - 1.5
Moisture	60 above
Wax	3-5

From the table above it shows that,the major constituent is cellulose, hemi-celluloses, lignin and pectin in respective other.

2.3 Banana Fiber Production

Banana fibers can be extracted through any of the following methods: mechanical, chemical, biological and manual (hand scrapping) techniques. Extraction of banana fibers by mechanical method, contain some adhering gums, which consist of hemicelluloses and pectin. Therefore, for this reason, it is necessary to degumming the fiber before applying it as a textiles material. In other to remove the gumming effect, fiber must undergo bleaching action inform of enzymatic treatment using hydrogen peroxide (Goswami *et al.*,2008). While extraction fiber by chemical process is costly and time consuming, and biologically or natural retting method has already been done by (Girisha*et al.,*(2012). According to them, natural fibers are normally obtained from plant trunk by microbial (organic) decomposition of pectin to binds up with woody inner core of the banana tree. The pseudo stem (banana stem) in general, contains only 11 exterior sheaths that could be used to extract its good fibers. The interior fibers sheaths, is not good enough due to its low strength. The peeling of these fibers is always hard due to its brittleness in nature and little strength. Thefour methods of banana fiber extraction are briefly discussed.

2.3.1 Manual method of fiber extraction

In this process, fiber could be produced from the stem, leaf or roots of banana tree respectively. Generally speaking, quantity of fiber could be produced, after the removal of the outer surface stem sheaths. It could be separated easily through ribbons of five to ten (5 to 10) cm strips wide and two to five (2 to 5) mm thick, across the length of the entire sheath. The removal process is called Tuxying, while theribbon is known as Tuxies.During manual extraction process, a skillful labourer can only produce 500 to 600g of dry fiber in 12 hours according to Sheikh S.A and Awata N.P., (2016).

Types of manual extraction processes are;

a). Bacnis-Process: This is stripping processes whereby stems are separated apart and sheaths are un-dressed. The fibers are produce by forcing out pulpy, and taking the ribbons (tuxy).

b). Loenit-Process: This involves the use of blunt metal or pointed sharp tool, to process ribbons. Ribbons could be achieve from one fiber sheath of 20 to 25 kgat a time and then are dried, cleaned and bundled, Sheikh and Awata , (2016).

2.3.2 Chemical method of banana fiber extraction

During the chemical method of banana fiber production, treatment of fiber with alkali solution NaOH, decreases fiber roughness and make it easily to obtain a good fiber quality. In other hand, hydrogen peroxide, sulfuric acid, pectinase, protease and sodium citrate could be also used, Sheikh and Awata, (2016).

$$\text{Fiber-OH} + NaOH \longleftrightarrow \text{Fiber-}O^{-}Na^{+} + H_2O$$

The disadvantage of using chemical process is longer time production always required. It was discovered by Sheikh and Awata, (2016). Therefore, to achieve qualities of fiber by chemical means, it takes like 35 to 40 days to be processed. Therefore, this process is said to be costly and time wastage.

2.3.3 Biological method of banana fiber extraction

Banana fibers extraction by biological or retting method has been done by (Girisha*et al.,*2012). Normally, natural fibers are obtained from either plant, animal or mineral by biological process which is by microbial (organic) decomposition of pectin to binds up with wood innermost core of the trunk. The biological technique is the combination of microbial action and water to separate the plant fiber. It gives high impact on fiber production output and qualities. Apart from varietal differences, the climatic conditions such like soil pH, water, ripen of plant material during harvest and method of harvesting play important roles for good management of banana fibers Indrani and Deka, (2016).

2.3.4 Mechanical method of fiber extraction

This involves the use of machine to splitting of pseudo-stem into two or four halves. Then from these halves, banana sheaths are being separated easily. This kind of cutting machine for separating pseudo-stem is good enough for processing sheaths required by four extractors, Patil and Kolambe, (2011). Mechanical extraction involves the use of machine which has one roller and rolls on permanent support. The roller is attached with short horizontal steel blades with blunt edges. Generally, up to 17 - 27 blades are normally used according to (Oreko*et al.*, 2018). The pseudo stems are cut from banana plant, and slice into different sections. The sliced pseudo-stems are feed into the extracting machine for fiber extraction, known as mechanical decorticator manually one after the other, and fibers are extracted freely. The extractor machine consists of a beater blade and pair of feeding rollers. (Mukhopadhay*et al.*,2008). When fibers are extracted through this technique, they are later dipped into bio enzymes to be cleaned and also to improve its qualities in form of tensile-strength, softness, length and colour, which finally makes the fiber shinnies Manandhar, (2010). Then, when fibers are dried, they are ready for knotting. A typical banana fiber extracting machine is shown in plate I11.

Plate I11: Banana Fiber Extracting Machine (Rahamaththulla*et al.,* 2018).

2.3.5 Alkali treatment of banana fiber

Sodium Hydroxide, (NaOH solution)is used to treat the banana fiber after the extraction and sun dried. The treatment of fiber with alkali helps to increase its surface roughness a lead good mechanical properties or bonding. The investigation of the effect of NaOH solution, on reinforced kenaf fiber composite polyester by (Mohd*et al.,*2011), shows that the mechanical properties of the composite will be increased with the increasing in the concentration of the alkali. This help to increase the possible reaction sides for better wetting of fibers. From his experiments, he ensured that the banana fibers were cleaned and insert in 6%of alkaline solution (NaOH), for about 2 hours at room temperature, to remove the impurities present in the raw fiber and washing them thoroughly using clean water, to ensure the removal of the non-reacted alkali. After this, fibers were filtered and then dried in sun light for 24 about hours. The chemical composition of banana pseudo-stem, such like cellulose, hemicelluloses, lignin, pectin, wax and cuticle layers, were removed from fiber surface during the treatment with alkali.(Aiswarya*et al.,*2017).

2.4 Fibers and Its Classifications

Fibers are in a category of materials that are either continuous or in discrete elongated filaments in Pieces form, similar to the length of thread. The importance of fiber cannot be over emphasized in more especially for holding of tissues together. The uses of fibers by human beings are in different ways. They could be formed into strings, filaments or ropes even as a component of composite materials formed into sheets to produce products like papers. Fibers could be used in the production of many materials. Synthetic fibers could be processed very easily and cheaply in huge amounts unlike natural fibers, though natural fiber has some beneficial effect over the manmade. The qualities of good finished textile are known by the length, the strength, and the nature of the fibers. The filaments fibers or staples are normally used for textiles. Filament is a long lengthen fiber while staples are short lengthen fibers, requiring actions of twisting them together to become usable. Bello, (2008).

Two types of textile fibers are natural and manmade fibers.

a) Natural fibers: These are naturally occurring fibers, which are grouped as vegetable fibers, mineral fibers and animal fibers respectively. They are biodegradable in nature. The entire natural fibers have a unit length attached with them, starting from (5 to 20)cm. This may be like the length of the sheep (wool) hair or the length filament of cotton in a cotton plant just to be woven into a fabric. These filaments are to be first put together into a continuous strand, called thread or yarn. Springing machine is used to accomplish the task. The filaments are held together by van Der Waal's forces. Normally, fibers obtained in the vegetative matter are called vegetable fibers which are cellulosic in compositions, whereas animal fibers which are proteinic in composition are produced by animals or insects. Mineral fiber is also achieving from mining certain types of rocks. Bello, (2008).

b) Manmade fibers: This type is further grouped into two, namely; regenerated and synthetic fibers. Manmade or synthetic fibers are normally process from synthetic material like petrochemicals. Some synthetic fibers manufactured from natural cellulose are nylon and modal. The textile fibers neither natural nor manmade are form from the compounds belonging to the group of high molecular compounds for instance, high polymers. The manmade fibers are polymer fibers and micro fibers.

2.4.1 Definitions of fiber

a) Botanical Definition: Fiber is defined botanically, as a dead hollow tapering cell, narrow at maturity thick cell wall form mostly of cellulose or lignin, rigid for giving supporting vascular tissue.

b) Commercial Definitions: Fiber is defined as a long thinning flexible material, which could be from animals such like hair wool, from Minerals example; asbestos or synthetic such as nylon, Dacron and plant.

c) Nutritional Definitions: Fiber is defined as a virtually indigestion material that is found mainly inthe skin layers of tree. Fiber is a special type of carbohydrate that passes through a human digestion and being broken down into nutrient. Bello, (2008).

Fiber was also defined by the textile institute as the unit of matter which is characterized by flexibility, finesse with high ratio of length to thickness, tensile strength, spinnability and luster". Goswami, (1977).

2.4.2 Plant fibers and its structure

Plant yielding fibers are most essential rudiments for life which are shelter, food and clothing which centered on plants. Plant fibers have more uses than silk, wool and other animal fibers. The uses of vegetable fibers have increased spontaneously and all fibers are similar in their sclerenchyma cell which acts as part of the plant skeleton. Fibers come in singly smaller in groups, but they composed sheets of tissue with the cells individual, over-lapping and inter-locking. Fibers occur, in every part of the plants like the stems, leaves, fruits and seeds Michael, (2002).

2.4.3 Economic classification of plant fibers

a) Textile-fibers: These are the most necessary types of fibers which are used for netting, fabrics and cordage. To produce nets and fabrics, flexible fibers will be twisted together in form of yarn or thread and then spun together, knitted woven are then utilized. These kinds of fibers must have a great tensile strength and cohesiveness with pliability. They will also possess fine uniform lustrous staples, durable and always available in quantity all the time. The main fibers as textile are classified into three major groups; surface-fibers such as cotton; soft bast fibers example; Hemp, Jute, flax and Ramie, and Hard fibers e.g. Abaca fiber, Agave fiber, bamboo fiber, Mauritius Hemp fiber, coir and carob fiber.(Das *etal*., 2008)

b) Stiff tough fibers (brush fibers): These include stems that are small and twinges which are utilized for producing brushes and brooms. Brooms, whisks and brushes are produced from different vegetable fibers. These kinds of fibers are elastic, stiff and very strong with a great flexibility in nature. Examples of Brush fibers are piassava fiber, broom corn, broom root, Palmyra fiber and kittle fiber .Rough weaving and plaiting fibers: There are flat and pliable fibrous strand which are interlaced to making baskets, hats, straw, seats sandals, and chairs. The high elastic strands will be woven together for matting and the thatched roofs of houses. Examples of these fibers are hat fiber, mats and matting, bamboo fibers Michael, (2002).

c) Filling fibers: Many plant fibers are now being used as fillers such as in cushions chairs, mattresses, furniture and stuff pillows. They could be used for caulking the vessel as producing of staff for buildings and stiffening the plaster, packing for bulk heads and machine bearings, and for the protection of objects that are delicate during shipment. Examples are kapok fiber, sisal fiber, white silk cotton tree and ponchos.

d) Natural fabrics: These categories are normally gotten from basts tree, which are produced from the sheets or layers, and pounded into rough substitutes either for cloth or lace. The examples are bast tree and tannery.

e) Fiber for paper manufacture: The manufacturing of papers requires the uses of cellulose, present in plant fiber. Trees cannot be limited absolutely one group, as much as some fibers could be used for many purposes. Examples of such fibers are wood fibers, textile fibers and which may be produced in raw state. (Das *etal*., 2008)

2.5 The Natural Fiber Composites (NFC)

Fibers which are neither man-made nor synthetic are referred to as natural fibers. They are naturally from animals and plants. The applications of natural fiber from plant and animal, renewable or non-renewable like palm tree, jute, sisal and flaxto manufacture composite materials. These have so far achieved proper attention in years ago. The plants that give cellulose fibers could be grouped as bast fibers. Examples are jute, kenaf, hemp, banana, flax and ramie. Seed fibers also includes: coir, cotton and kapok while leaf fibers are sisal, abaca and pineapple. Grass and reed fibers are wheat, rice and corn. Core fibers which are kenaf, jute and hemp as well as all other kinds like roots and wood fibers. Recent, scientists and engineers have put an interest over effectively usage of plant fibers as means of producing better qualities of fibers reinforced polymer composites for building, structural and other uses. Due to its availabilities, instead of conventional or manmade materials, it has brought the development of several alternative ones. In polymers uses, some investigated natural fibers are jute fiber (Mohanty et al.,2006) and Kamel, 2004, banana (Pothan *et al.,* 2003), sisal fiber (Joseph et al., 1999),pineapple fiber (Mishra et al.,(2001), kenaf fiber (Rowell et al.,(1999),wood fiber (Maldas et al., 1995).

2.5.1 Applications of natural fiber composites

Materials of natural fiber composite are of many applications as follows:

i. Building and construction industry: There are use for partitioning as panels, production of false ceilings, building walls, setting of door frames, windows, and house floors, roof tiles, prefabricated or mobile buildings, which may be used to prevent natural calamities like floods, cyclones and earth-quakes .Hull and Clyne, (1996).

ii. Storage devices: In building post office boxes, silos for storage of grain and biogas containers.

iii. Furniture: In building of tables, chairs, and bath units like showers.

iv. Electric devices: In making some electrical appliances and pipes.

v. Everyday applications: Widely used in lamp-shades, suit-cases and helmets.

vi. Transportation: It is use in automobile and rail-way coach-interior and boat.

The widely used of natural fibers in the automotive industrial applications is because of its favorable eco-balancing during vehicle operation due to its less weight, Kumar and Anbumalar, (2015).

2.5.2 Natural fiber reinforcement composites

Reinforcement is the support of strength of the material by the use fiber, either by physical or chemical binding of fibers or particles together. The type of fiber used depends upon the composite being intended to form. The structural properties from composite materials are derived mainly from fiber reinforcement. In composite materials, fibers contribute great strength; thereby improving component properties such like stiffness while the weight is being reduced. There are other different types of fiber that could be used to reinforce polymer matrix and also as an element of composite materials. They could be formed into sheets to produce products like papers or felt, Kumar and Anbumalar, (2015).They are from the following material fibers;

2.5.2.1 Vegetable fibers

These are fibers derived from ramie, jute, hemp, sisal, cotton and flax. These regarded as cellulose fibers which are used in the making of papers and cloths. They are classified as follows;

a. Seed fiber: These types of fiber are obtained from the seeds. Example is kapok and cotton.

b. Leaf fiber: These types of fiber are obtained from the leaves. Examples are agave and sisal.

c. Bast fiber (Stem fiber): These types are obtained either from the stem or skin of their parent plant. Examples are Flax, banana, jute, hemp, ramie, kenaf, rattan, Soya-bean fiber and vine fibers.

d. Fruit fiber: These types are obtained from the fruit of the parent plant. Example is coir fiber from coconut.

e. Stalk fiber: These types of fiber are obtained from the stalks of the parent plant. Examples are straws of wheat, bamboo, grass, rice, barley and tree wood.

The natural fibers that are generally used are hemp, sisal, cotton, flax, jute, kenaf and coconut (Kumar and Anbumalar, 2015).

2.5.2.2 Animal fibers

These types of fibers are obtained from silk, mo-hair, wool, angora and alpaca. They are classified as;

a. Animal hair: These are wool or fibers from hairy mammals or animals. Some examples are sheep's wool, goat hair (cash-mere, mo-hair), horse hair and alpaca hair.

b. Silk fiber: These are fibers obtained from insects or bugs saliva that are dried during the preparation of co-coons. Example is silk obtained from worm'ssilk.

a. Avian fiber: These are fibers obtained from birds, that is feather fiber, Kumar and Anbumalar, (2015).

2.5.2.3 Mineral fibers

These are fibers occurring naturally or slightly modified from mineral elements. There are grouped as follows;

b. Asbestos: These are the only naturally occurring mineral fibers. Variations are serpentine (chrysotile) and amphiboles (amosite, crocidolite, tremolite, actinolite, and anthophyllite).

c. Ceramic fibers: These are; Glass fibers which include glass wool and quartz, silicon carbide, aluminum oxide and boron carbide.

d. Metal fibers: These fibers are obtained from metal. Example is Aluminum fibers Kumar and Anbumalar, (2015).

2.6. Banana Fiber Composite

Composite can be defined as a system composed by mixing two, or more different materials together. It is the formation of two different materials to perform a function which they cannot do individually. In general, composite materials are said to be materials that have some properties that may not be found in each component.

According to (Pothan*et al.,*1997), who differentiated the mechanical properties of banana fibers reinforced polyester with sisal, coir and jute reinforced composites. The absorption of water shows that an increase in water up-take increases fiber content. At maximum tensile strength the fiber length of 30 mm was observed, while the impact strength at maximum was observed at 40 mm fiber length. The comparative analysis of banana fiber composites with other natural fibers shows that it has superior mechanical properties than other natural fibers.

The fabrication of a multipurpose table by (Sapuan, *et al.,*2007) using fabric reinforced composite material and banana stem fiber woven while (Barreto, *et al*., 2010) studied the effect of NaOH treatment on structure, biodegradability and dielectric of banana fiber. This study shows that NaOH solution increased the fraction crystalline of the banana fiber due to the gradual removal of the lignin. They investigated the effect of banana fiber alkali treatment and its poly-urethane reinforced composite. Their study included the banana fibers treatment with 10 % of NaOH, fiber tensile strength, prediction of critical fiber length and composite. The study also shows that treatment of fiber with alkali enhances the interfacial adhesion between fiber and matrix, which increases the tensile strength of the composite.

2.6.1 Advantages of natural fibers as reinforced material

Natural fiber to be used must possess the following properties as reinforced composites material, to assist in balancing ecological cycle. Natural fiber composite materials should be bio-degradable, exhibit less energy consumption during production and during degradation. The properties are as follows;

a) It has lower thermal conductivity: This helps in determining thermal insulation value in natural fiber. It is the ability of the material to transfer heat from one part to another. Natural fibers reduce heat in its surroundings. Hull and Clyne,(1996).

b) High flexural strength: Flexural strength is the determination of the bending limit of a given component. Natural fiber composite possesses good flexural strength as to avoid accidents, due to breakdown of the composites**.**

c) Resistant to Moisture changes: The change in atmospheric moisture is a natural process. The composites should be able to prevent any change in moisture. Moisture as vapour acts the same as any other gas. It mixes with other gases in the air, and yet maintains its own identity and characteristics. Natural fibers have affinity to retain moisture.

d) Lower density: The weight of the composites is determining by its density. The lower the density, the lower the weight and vice versa. The performances depend upon strength to weight ratio. The composite should possess lower density with higher strength to function effectively. The densities of natural fibers are in the range of 1.4 to 1.6 respectively.

e) Ease of work-ability: Natural fibers can be easily cut, shaped, or smoothed by hand or machines. The better the work-ability of the material, the quicker the work is done.

f) Good aesthetic and pleasant finish: The natural composites possess good aesthetic and pleasant finishing. The aesthetic properties play an important role in ergonomics. This can be considered as challenge while designing the natural fiber gypsum composites. Hull and Clyne, (1996), Michael, (2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Research Materials

The following materials and instruments were used during the machine fabrication and fiber extraction

- Cutlass: This was used to cut and slice the banana stem from the base after the fruit have been harvested.
- Kitchen Knife: This was used to separate the pseudo stem to the required measurement of length and width.
- Scrapper: This was used to force the non-fibrous or banana stem tissue out, there by retaining the fiber.
- Sodium Hydroxide Solution (NaOH): This is an alkaline reagent used to treat the fiber after production.
- Measurement Tape: This was used to determine the length and width of the banana sliced pseudo stem before fiber extractions.

- Sheet of Mild Steel: It is used in construction of the machine body (main frame).
- 2HP electric motor: It is used to drive the machine when powered with electricity.
- Inverter welding machine (IWM): It is used in welding or joining the body parts together.

- Drilling machine: It was used in drilling the major parts before the assemblage
- Cutting machine: it was used in cutting during measuring and welding parts.

3.2 Design Analysis

Banana pseudo stems were obtained from a village called Ado Kuchi, near Nyanya/Mararaba in Karu Local Government Area (L.G.A) Nassarawa State, Nigeria. Both manual and mechanized methods were employed to extract the fiber. These methods were considered necessary for this study because, the traditional retting technique of extracting banana fibers is faced with various problems like longer extraction time, high cost of locally fabricated machine and poor fiber production rate.

3.2.1 Manual method of fiber extraction

The matured pseudo stem of the banana trunk was used for the extraction of the fibers. Banana trees are usually cut down immediately the fruits are being harvested. Some harvested trunks were collected, peeled and sliced accordingly and the outermost green brown part was separated and the cleaner or white portion isolated and then separated manually from each other with the aid of cutlass and knife into 60cm length and 15cm width sheaths. These sheaths have different grade of fiber, as they from different layers of the pseudo-stem. Therefore, with the use of scrapper or blunt metal edge, the non-fibrous material, can be forced out, left with extracted fiber. Extracted fibers were sun-dried and later washed in the solution of clean water and detergent to whiten the fiber and free the knotted ones accordingly.

Manual extraction of banana fiber required proper care to prevent damages to the fiber. Hence, this method could not be recommended for industrial application since it will always give low output. The best method of extracting banana fibers is the mechanized method of which, it is the objective of this thesis work. A typical banana farm with bunch of fruits on its plant stem is shown in plate IV.

Plate IV: The Banana Plantations

3.2.2 Mechanical method of fiber extraction

This method involves the use of simple electrical machine, which consist of double rollers that will roll on permanent support to extract the fiber. The rollers are provided with rotating shaft, horizontal steel blunt metal blades with edges. From the designed calculation, the required power, to drive the extractor machine was 1.210 kW or 1.6hP. Therefore2 hP, electric motor will be selected as the standard electric motor available to drive the extractor machine.

3.3 Banana Fiber Machine Design Concept

The banana fiber extractor or the decorticator machine is a machine with multiple parts or components to perform different functions. The Figure 3.1 shows the proposed banana fiber extracting machine using solid works:

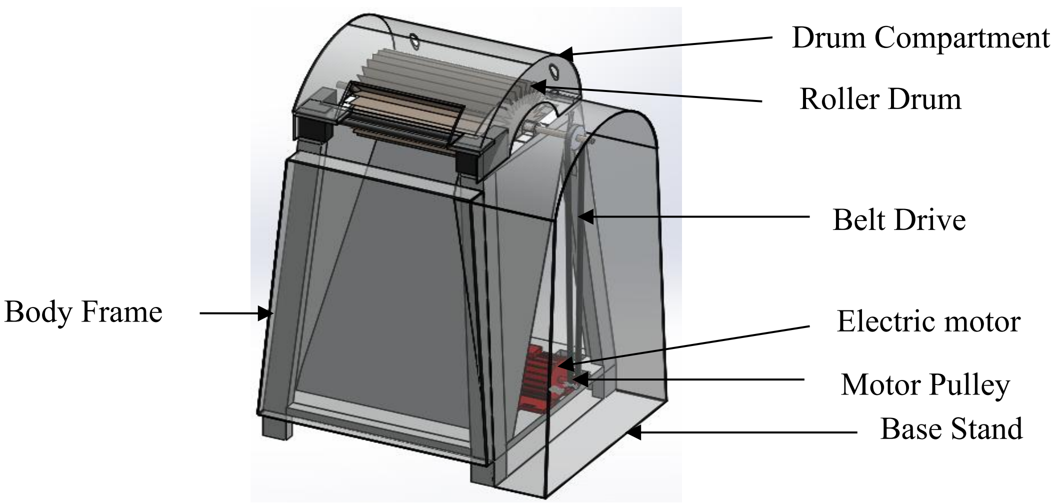


Figure 3.1: Proposed banana fiber machine to be fabricated

The component parts are as follows;

(1) Roller drum with beating blade and shaft (2) Inlet (3) Bearings (4) Frame (5) Belt Drive (6) Pulleys (7) Electric motor (8)Screw Guide (9) Drum Compartment (10) Belt cover.

Some of the following parts of the machine are being explained below and all the drawing of parts is shown in the appendix;

a) Main Frame: This includes Parts like square stand which acts as the chassis that supports the machine structural body. This would be made of2.5 mm mild steel (angle bar) materials due to its strength, machineability and reasonable corrosion resistance. The whole parts will be mounted on this frame structure with a suitable arrangement. Provisions are made to protect the bearings with carefully selected lubricant (grease). The following conditions were given attention during the selection of the flame;

i) Strength: The tensile strength to be able to carry the weight of the whole body.

ii) Weld-ability: The ability of the component parts to be welded.

iii) Vibrations: Ability of the machine to withstand vibration when it is in use.

b) Rotating Shaft: Shaft is a rotating part of a machine, usually of solid or hollow circular (cross section) materials. It transmits rotational power or motion from one machine member to another. The shaft revolves on rolling bearings or bush bearings. The dimension of shaft is strictly based on the design calculation of the machine shaft diameter. In construction of the shaft, mild steel was considered the best because of its reasonable corrosion resistance, rigidity, strength, and toughness.

c) Electric Motor: This work by electro-mechanical action, which means it converts electrical energy into mechanical energy which the extractor machine will use to extract the banana fiber. When the electric motor is powered, the drive mechanism is activated, which creates rotating force at the roller drum compartment with input voltage of 220V. The size of the electric motor used for this extractor was obtained from the calculation of the power required to affect the rotation of the roller drum, shaft and pulley speed. The calculated power was approximately 1.210 kW or 1.6hp, but I opted for 2hp which operate at 1420 rpm and 50 Hz because of its availability and reliability. This motor transmits power through flat rubber belt which in turn drives the roller drum.

d) Roller Drum: The roller with beating blade is the rotating component of the machine which strips the sliced banana stem (pseudo stem) into fiber strands. It isone of the most important elements in this machine. The number of blades in this design is 10 and each blade is 350mm long, 20mm wide, 2.5mm thick and it is separated at 70mm from each other. It is rotated by rubber belt that is driven by electric motor. It applies squeezing action or force that is necessary on pseudostem of banana to separate the pulp, from the fiber. There are also two fixed support rollers for feeding sliced pseudo stem to the extractor machine.

e) Pulleys: The pulley is a wheel like structure with groove and fixed belt that revolves along the grove. The pulley transfers motor speed to shaft assembly through the rubber belt attached with the electric motorto facilitate the rotational action of the rolling beating drum. Power is transfer from the single-phase motor to the system through the belt drive. The pulley will be selected based on the belt drive design calculation which will take into consideration of the following;

i. Shaft diameter and/or speed

ii. Proper centre distance and

iii. Acceptable belt drive.

f) Bearings: The two ball bearings were proposed tobe used in this fiber extractor machine. The bearings proposed to be used could be able to withstand both radial and thrust loads. In ball bearings, the load is transfer from the outer circumference race, to the inner ball and from the ball to the inner race to ensure frictionless rotation of the shaft as they will be attached to the shaft. Provided the ball is spherical in shape, it will only make contacts with the inner and outer race at a very small point which will help it spin very smoothly and if the bearing is overloaded the balls could deform or stop ruining the bearing.(Rahamaththulla*et al.,*2018).

g). Belt drive: Flat rubber belt will be chosen for transmission of mechanical power from electric motor to pulleys that drive the shaft. From design calculation, belt drive will transmit power of 1.210 kW with 1.33m length, 12.5mm wide and 5 mm thick will result to cross sectional area of 62.5mm^2. The centre distance between the motor pulley and driving pulley is 450mm.

3.3.1 Principle of the proposed banana fiber extraction machine

The fiber extractor machine will contain a rotating drum, with several blades on its circumference mounted on a shaft that will cause a beating action as the drum is rotating by an electric drive machine. As the drum is being rotated by electric drive, the pseudostem is being fed between the drum and permanent feeding rollers. This brings beating, pulling and crushing action which makes the pulpy material easily removed when it is half way through in the machine. The pseudostems are slowly pulled manually by hand from the drum and then the fibers are easily collected.

3.4 Design Considerations

Before the materials selection of the various parts of the banana fiber extraction machine for fabrication, the following considerations were given attention to;

a) Strength: Each component was selected based on its ability to withstand the loads/stresses, torques and frictional forces it would experience during pulp operation. Mild steel was one of the main materials selected.

b) Corrosion resistance: Since the pseudo stems from which fiber will be extracted were moist and wet, corrosion resistant materials were considered. Other important considerations such as wear resistance, use of standard part for ease of replacement, cost, and safety of operator were critically weighed and made.

c) Machine height from ground: Considering the ergonomics factors for operator, the machine height was properly given attention regarded the operator to be able to work for couple of hours without being tired. The machine will be considered to be higher slightly than the waist level; 3.5m high will be used with the clearance between the rollers set at 5 to 8mm, to permit enough clearance from ground level and to facilitate easy/prompt cleaning.

3.4.1 Design of machine component

The major components of the banana extractor machine such as the frame, pulley, shaft, roller drum, drum compartment, belt drive, electric motor and bearings were all designed to ensure efficiency. For instance, the motor shaft should be able to withstand the loading in motion. The frame which houses all other components should be able to with-stand vibration and loads on it. The mathematical analysis of the concepts used for developing the fiber extractor machine were all shown from equations (3.1 – 3.23)

3.4.2 Design of the machine shaft

The machine shaft design was made in order to safe-guard against torsional and bending stresses. From the equations given by (Khurmiand Gupta.,2013) and (Shigley and Mischke.,2001). The belt will be at an angle of 30 ^{o} inclination to the horizontal and the forces acting on the pulley will comprise of vertical and horizontal forces as follows;

(a) Forces exerted by Pulley

(i) Loads vertically acting on the position of shaft and pulleys,

$$F_{PV} = WP + (T_1 + T_2) \times \text{Sin } 30^o \qquad 3.1$$

Where; F_{PV}= Load vertically acting on the position of shaft and pulleys

W_P= Weight of pulley

T_1 = Tight side tension on belt drive

T_2 = Slack side tension on belt drive

(ii) Load horizontally acting on the position of shaft and pulleys

$$F_{PH} = (T_1 + T_2) \times \text{Sin } 30^o \qquad 3.2$$

Where F_{PH} =load horizontally acting on the position of shaft and pulleys

(b) Load vertically on shaft exerted by Roller drum assembly $F_{R,}$

$$F_R = W_R + F_{RT} \qquad 3.3$$

Where: W_R = Roller drum Weight.

F_{RT} = Tangential force exerted by roller drum as a result of rotation.

F_R = vertical load on shaft exerted, by Roller drum assembly

$$F_{RT} = \frac{T}{R} \qquad 3.4$$

Where; T = torque developed by the machine.

R = radius of roller drum.

Khurmi& Gupta (2013)

3.4.3 Diameter of the machine shaft

Applying equivalent twisting moment T_e, we have that

$T_e = \sqrt{(Kb \text{ x } Mb)^2 + (Kt \text{ x } T)^2} = \frac{\pi}{16} \text{ x } \tau \text{ x } d^3$ 3.5

Using equivalent bending moment, M_e, we have,

$M_e = ½ [K_b \text{ x } M_b + \sqrt{(Kb \text{ x } Mb)^2 + (Kt \text{ x } T)^2}$

$M_e = ½ [K_b \text{ x } M_b + T_e] = \frac{\pi}{32} \text{ x } \sigma_b \text{ x } d^3$ 3.6

Using ASME code equation; Hall et al. (2002)

$d^3 = \frac{16}{\pi Ss} \sqrt{(Kb \text{ x } Mb)^2 + (Kt \text{ x } T)^2}$ 3.7

Where: K_b =Combined fatigue and shock factor for bending stresses.

M_b = Bending moment, Nm

M_t= Torsional moment, Nm

T = Twisting moment or torque acting upon the shaft, N

Te=Twisting equivalent moment, Nm

τ = Induced shear stress due to twisting moment, Nm

πSs = Allowable stress without keyway, N/m^2

σ_b = Induced bending stress due to bending moment, Nm

d = Shaft diameter, mm

3.4.4 Length of open belt drive

From theory of machine by Khurmi and Gupta.,(2010) the open length belt drive expression is obtained as;

$L = \pi (r_1 + r_{2)} + 2\chi + \frac{(r1 + r2)2}{\chi}$ 3.8

Where; r_1=Larger pulley radius

r_2=Smaller pulley radius and

χ=Centre distance between the two pulleys.

3.4.5 Velocity ratio of the belt drive

The belt drive velocity ratio could be expressed as;

$$\frac{N2}{N1} = \frac{d1}{d2} \qquad 3.9$$

Where:

d_1 = Diameter of the driver.

d_2 = Diameter of the follower.

N_1 = Speed of the driver in rpm and

N_2 = Speed of the follower in revolution per minute (rpm)

Considering the thickness of the belt (t), the velocity ratio becomes;

$$\frac{N2}{N1} = \frac{d1+t}{d2+t} \qquad 3.10$$

3.4.6 Determination of angle of contact or lap

The angle of contact or lap, ϴ is expressed in radian (rad.)

$$\Theta = (180^{o} - 2\alpha)\frac{\pi}{180}(\text{rad.}) \qquad 3.11$$

And the centrifugal tension $T_{C,}$ becomes

$$T_C = MV^2 \qquad 3.12$$

Where, M = Mass of belt per unit length in kg

V = Linear velocity of belt

Khurmi and Gupta (2010)

3.4.7 Maximum tension on the belt

The maximum tension (T)on the belt is equal to the total tension (T_{t1})in the tight side of the belt.

Therefore: $T = \sigma.b.t$ 3.13

Where; σ= Safe stressat maximum in N/mm^2

b = Belt width in mm, and

t = Belt thickness in mm

T_t= Tight side tension.

$T = T_t + T_C$ 3.14

$T_t = T - T_C$ 3.15

Where, T=Maximum tension and Tc = Centrifugal tension. (Oreko *et al*. 2018)

3.4.8 The force or torque needed to pulp the banana rib

The young modulus of elasticity E, could be expressed as

$E = \frac{fl^3}{48yl}$ 3.16

Where: E =Young modulus of elasticity

y= Deflection in mm

f = Pulping force or load in N

I = moment of inertia and

L = length of material/ banana rib. (Oreko *et al*. 2018)

Rearranging the equation (3.16), we have

$EI = \frac{F}{48y} l^3$ 3.17

Where, EI is the flexural rigidity of the banana rib.

Also, $I = \frac{B}{12} H^3$ 3.18

Where: I = Inertia moment

B = Breadth of banana rib in mm

H = Thickness or height of banana rib in mm.

3.4.9 Torque needed to pulp the banana rib

The required torque to pulp the rib is expressed as

$$T = f \times r \quad 3.19$$

Where; f = force needed to pulp the banana rib

r = radius of the rolling drum

3.4.10 Power required to drive the drum

The required power to drive the rolling drum is given as:

$$P = \frac{2\pi TN}{60} \quad 3.20$$

Where; P =Transmitted power to the shaft

T =Required torque in Nm and

N= speed of the shaft in (rpm).

Khurmi and Gupta, (2010)

3.4.11 Power transmitted by belt drive

The transmitted power by a belt is given as;

$$P = (T_1 - T_2) V \text{ (Watts)} \quad 3.21$$

Where: T_1= Tension in the tight side of belt in Newton, (N)

T_2= Tension in the slack side of belt in Newton, (N) and

V = Velocity of the belt in metre per second, m/s.

The ratio of driving tensions for flat belt drive is given as;

$$2.3\log\left(\frac{T1}{T2}\right) = \mu.\Theta \qquad 3.22$$

The given expression above is the relationship between the tight side and the slack side tensions, in terms of coefficient of friction and an angle of contact.

Where: Θ = Angle of contact in radians and

μ= Coefficient of friction between the belt and pulley

Khurmi and Gupta, (2010)

3.4.12 Bearings selection

The selection of bearings was based on the shaft diameter, load carrying capacity and the working mechanism of the machine following the SKF general catalogue and selected bearings were pressed smoothly to fit into the shaft because if hammered, the bearings may develop cracks, (Hall, *et al.,*2002). The selected bearing number is 6206.

$$\text{Bearing Life} = \frac{60 \text{ x N x Operating Time}}{10^6} \qquad 3.23$$

Where: N = Number of revolutions.

(Oreko*, et al.,*2018)

3.5 Cost Considerations

The bill of materials costing to produce banana fiber extractor machine is summarized in the Table 3.1. The analysis of the cost of producing a unit set of banana fiber extractor machine comprises the cost of each component and material bought the cost of fabricating the machine parts and the machining cost and non-machining jobs done in the workshop.

Table 3.1: The Bill of Engineering Measurement and Evaluation (BEME) of a given unit banana fiber extractor machine.

S/N Components	Material	Specifications	Cost (₦)
1.Frame stand	Mild steel angle iron	600 x 50 x 50mm length	10,000.00
2. Frame body	Mild steel	10,000 x 50 x 50mm length	15, 500.00
3.Shaft	Solid iron shaft	14mm diameter and 600mm length	3,000.00
4.Pulley	Cast iron	180mm diameter	600.00
5.Roller drum	Mild steel	190mm diameter	7,000.00
6. Fixed roller	Carbon steel	2 x 600mm length	6,000.00
7.Beating blade	Mild steel plate	2.5 x 20 x 350mm	5,000.00
8. Belt drive	Rubber v-belt	A50, 1.33m length	1,000.00
9.Belt cover	Mild steel	200 x 80 x 80mm	4,000.00
10.Bearings	Ball bearings	NO: 6206	3,000.00
11.Motor	Single phase electric motor	M5 X 10, 2hp	18,000.00
12.Nuts, bolts and washer			300.00
13. Electrodes	Gauge 12 stainless		2,000.00
14. Paint	Blue emulsion paint	2 litres	4,000.00
15. Labour Cost			25,000.00
16. Miscellaneous expenditures			10,000.00
Grand Total			#115,400.00

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Calculated Design Results

Considering the following given technical assumptions for the design; Banana width =150mm maximum, Banana maximum thickness (sliced trunk thickness)=10mm, driving means is single phase induction motor (electric motor) with operating voltage 220-240 V maximum, feeding method is manual, coupling method is belt drive, belt type is V-Belt.

Number of blades for this design = 10, Distance between two blade, L = 70mm

Drum diameter = 180mm, Drum thickness = 4 mm

Blade length = distance between the rolling plates = 350mm.

Blade width = 20mm

The length of banana stem used = 600mm

Blade thickness = 2.5 mm flat bar plate

Belt drive material is rubber

Belt drive width b = 12.5mm

Belt drive thickness t = 5mm

Belt drive cross sectional area a = 62.5mm^2

4.2 Determination of Force or Torque Needed to Pulp the Banana Rib

The following banana rib parameters for ease of computation were adopted;

Area moment of inertial of stem, I = 450mm^2; breadth B = 110mm and Thickness H= 8 mm, deflection y = 4 mm

Using the Modulus of Elasticity Eb of banana fiber expressed by Indira et al., (2013) as,

Eb = 29GPa = 29 x 10^9 N /mm^2

From equation (3.17)

$I = \frac{B}{12}H^3 = \frac{110 \times 8^3}{12} = 4693mm^4$

From equation 3.15 and 3.17, we have Flexural Rigidity

EI = 29 x10^9 x 4693 = 136 x 10^{14}N/mm

Deflection, y = 4 mm. We have

$f = \frac{EI \times 48 \times y}{l^3} = \frac{136 \times 10^{14} \times 48 \times 4}{450^3} = 286.76N$

Therefore, the force required to pulp banana rib is 286.76N

4.3 Analysis of Thickness/Pulping Force

Combination of equation3.16 and 3.17 gives

$$f = \frac{48EByH^3}{12l^3} = \frac{4EByH^3}{l^3} \quad 4.1$$

Where, E, B, Y and L are constant for a given rib sample,

Therefore; $f = KH^3$ 4.2

$$K = \frac{4EBy}{l^3} \quad 4.3$$

$= \frac{4 \times 29 \times 10^9 \times 110 \times 4}{450^3} = 560 \times 10^3 N$

Therefore, K = 560 kN

Then; $f = 560 \times 10^3 H^3$ 4.4

Computing the force required to pulp the rib as 286.76N into equation 4.4,

$286.76 = 560 \times 10^3 H^3$

$$H^3 = \frac{286.76}{560 \times 10^3} = 8.0$$

Therefore, the thickness H is 8.0mm

Assume, force of 300N, 350N, 400N were used as a pulping force, the corresponding thickness of rib would become H ≃8.12mm, H ≃8.54mm, H ≃9.0mm, respectively.

4.4Torque Required by the Rolling Drum to Pulp Banana Rib

Torque = Radius x Force

That is; T = R x F 4.5

Where F = pulping force

R = radius of drum

When, F = 286.76N; r = 90mm = 0.09 m,

T = 286.76 x 0.09 = 25.8Nm

4.5 Velocity Ratio of Belt Drive

The following specifications were obtained from the selected belt base on the thickness, size and calculated length of belt drive;

$d_1 = 0.06$m, $d_2 = 0.19$m and $N_1 = 1420$rpm

Therefore, from equation (3.9) we have;

N_2 = 448rpm

We know that peripheral velocity of the belt on the driving pulley is

$$V_1 = \frac{\pi\, d1.N1}{60} \text{ (m/s)} \qquad 4.6$$

Also, the peripheral velocity of the belt on the driven or follower pulley is

$$V_2 = \frac{\pi\, d2.N2}{60} \text{ (m/s)} \qquad 4.7$$

The velocity ratio according to equation 4.6 – 4.7

Are; V_1 = 4.46m/s

V_2= 4.46m/s

When there is no slip, $V_1 = V_2$ = 4.46m/s

4.6 Power Required to Driving the Drum

The drum is driven by an electric motor, with motor power transmitted by belt. From equation (3.20), we have $P = \frac{2\pi\, TN}{60}$

Where; P = Required power in watts (W)

T = torque in Nm

N = Shaft speed in rpm.

Figure 4.1 shows the rotating drum with beating blade which will facilitate thepulping fiber from the sliced banana pseudo stem when it is power by the electrical motor drive.

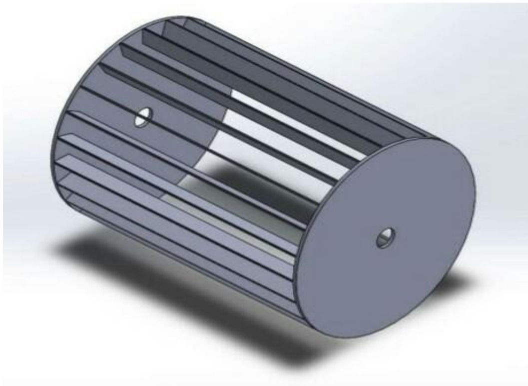


Figure 4.1; Rolling Drum with Beating Blade

Given that; T =25.8Nm and N = 448rpm. Substituting the values into (equation 3.21) above, gives $P = \frac{2\ x\ 3.142\ x\ 25.8\ x\ 448}{60}$ = 1210N

Therefore; power P = 1.210 kW

The power required in Horse power becomes;

1hp = 745.7W

Therefore 1.210 KW=$\frac{1210}{745.7}$ = 1.6hp

Hence, required motor rating selected to drive this machine is 2 hp because of its availability and reliability.

4.7 Tension Required on Belt

Let Tensions on the tight and slack side of the belt be given as T_1 and T_2in Newton (N) respectively, and that of the Radii of the driver and the follower be given asr_1 and r_2 in mm respectively.Therefore, the following design component will be calculated thus;

4.7.1 Design analysis of the belt drive

To determine the total length of the flat belt, L

Given that;

r_1 = 30mm =0.03m and r_2 = 95mm = 0.095m, $x = 450\ mm = 0.45\ m$

Where r_1 is the smaller pulley radius

r_2 is the larger pulley radius

x is the centre distance between the pulleys

Using equation (3.8), $L = \pi\ (r_1 + r_2) + 2\chi + \frac{(r1 + r2)2}{\chi}$ Khurmi and Gupta (2010)

$= 3.142(0.125) + 0.9 + \frac{(0.125)2}{0.45} = 1.327$

Therefore, the total length of the belt drive L, = 1.33m

4.7.2 Angle of lap on the smaller pulley

Given that the diameters of the pulleys are

d_1 = 0.06m, d_2 = 0.19m

$\sin\alpha = \frac{r1 + r2}{\chi} = 0.2778$

$\alpha = 16.128^0$

Therefore, angle of lap from equation (3.11) becomes Θ = 2.58rad

4.7.3 Mass of the belt per metre length

The density of V- belt selected was 1140kg/m^3

Where M = Length x Area x Density

Taking b = 12.5mm, t = 5mm, area a = 62.5mm^2, ρ = 1140kg/m^3

Therefore; mass M = 0.07127kg/m

4.7.4 Centrifugal tension on belt drive, T_C

$T_C = MV^2$(equation 3.12)

$T_C = 0.07127\ (4.46)^2$

$= 1.42N$

4.7.5 Maximum tension on belt drive,

$T = \sigma.b.t = T_t + T_C$(equation 3.13 and 3.14)

Where: σ = Safe stress at maximum in N/mm^2

b =Belt width in mm, and

t =Belt thickness in mm

T_t=Tight side tension.

T=Maximum tension and

Tc = Centrifugal tension

When T_t = 333.8N and Tc = 1.42N

Therefore, T = 333.8 + 1.42

= 335.2N

4.7.6Tension on tight side T_1, and on slack side T_2

According to Khurmi and Gupta,(2010),

Applying the coefficient of friction between the pulleys and the belt as 0.3,

Taking the angle of contact as 2.58 rads, from equations 3.22 and 3.23, solving them simultaneously, weobtainedT_1=333.8N

T_2 = 153.8N

Figure 4.2 shows the drive mechanism of belt on pulleys.

D_1 =Driver pulley diameter, D_2 = Driving pulley diameter

T_1 = Tight side tension on the belt drive, T_2 = Slack side tension of the belt drive.

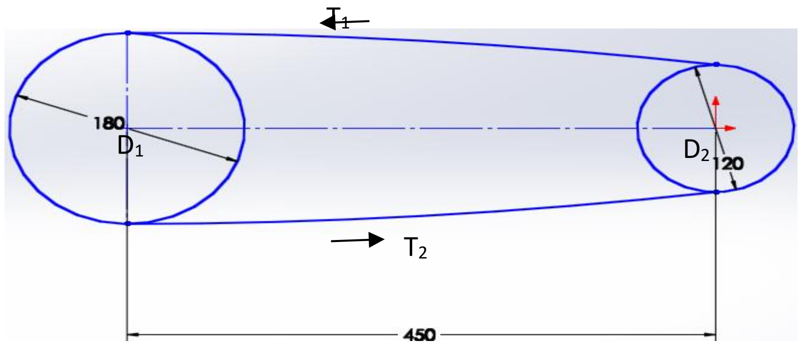


Figure 4.2: Belt Drive Mechanism on Shaft

4.7.7 Power transmitted by belt drive

From equation (3.21), the induced power by belt drive is given as;

$P = (T_1 - T_2)\,V$, in Watts

Then power, $p = (333.8 - 153.8)4.46 = 802.8$

Therefore, power = 802.8W

4.8Rolling or Pulping Drum Shaft Design

The main loads on the shaft were the bearing reactions, the weights of the pulley, belt tension, weight of gear, weight of roller assembly and tangential forces on the gears and roller assemblies as a result of torque, cutting drum and belt tensions. The shaft will be subjected to fluctuating torque and bending moment while combined shock and fatigue factors were taken into account. Since the feeding of the banana sliced pseudostem is steady and gradual, therefore taken k_b to be 1.5 and k_t to be 1.0 were applied.(Hall*et al.*, 2002). Where k_b and k_t are the combined shock and fatigue factors.

4.8.1 Loading on the shaft

Assuming that the weight of pulley W_{P}, is equal to 2kg

Therefore; $W_P = 2 \times 9.81$

$= 19.62N$

If we substitute T_1 and T_2 from equation 3.1 and 3.2, we obtained:

Vertical load acting on shaft at pulley position from equation (3.1) becomes $F_{PV} = 263.42N$

Horizontal load acting on shaft at pulley position from equation (3.2) becomes,

$F_{PH} = 243.8N$

Vertical load on shaft exerted by pulping drum assembly was obtained from equation 3.4.

When W_R is the total weight of shaft, pulping drum with beating blade and bearings= 92.2N, Torque,T = 25.8Nm and Radius of roller Drum = 90mm = 0.09m

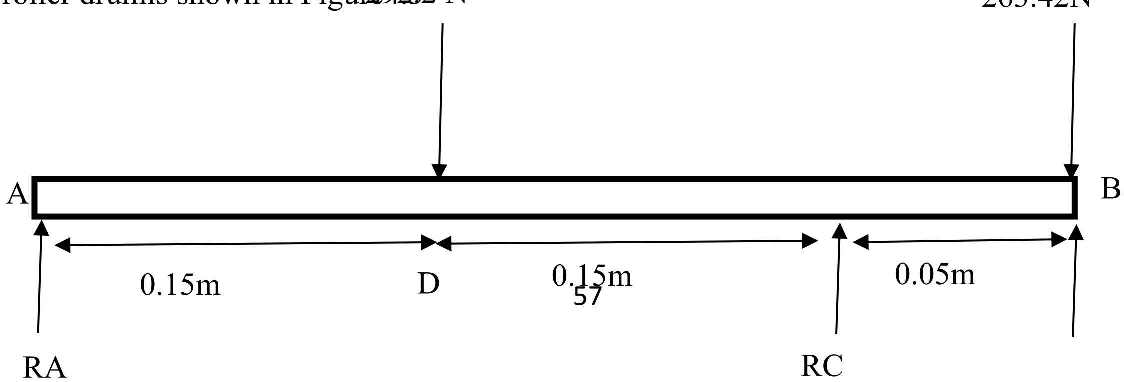
Therefore, from equation 3.4 and 3.3

$F_{RT} = 286.67N$ and

$F_R = 92.2 + 286.67 = 378.87N$

4.8.2 Shaft diameter design calculation

The schematic representation of the shaft loading in the vertical direction exerted by the roller drumis shown in Figure4.3



C

Figure 4.3: Shaft vertical loading by roller drum

Where RA and RC are the reaction forces at the support of A and C

Taking the moment at point R_A, in Figure 4.3

$\sum M_A = 0$

$R_A (0.35) + R_C (0.05) - 292.2(0.2) - 263.42(0) = 0$ 4.7

$R_A (0.3) + 263.42(0.05) – 292.2(0.15) = 0$ 4.8

From equation 4.8,

$0.3R_A + 13.171 – 43.83 = 0$

$R_A = 102.197N$

Adding all the vertical forces or computing the value of R_A into equation 4.7,

$R_C + R_A – 263.42 - 292.2 = 0$

Therefore, $R_C = 453.42N$

And the bending moment at A and B will be,

MA = MB = 0

Moments at C and D become;

$M_c = 263.42 \times 0.05$

$= 13.171Nm$

$M_D = 263.42(0.05+0.15) – 453.42(0.15)$

$= -15.329Nm$

The schematic representation of the shaft loading in the horizontal direction exerted by the roller drumis shown in Figure 4.4

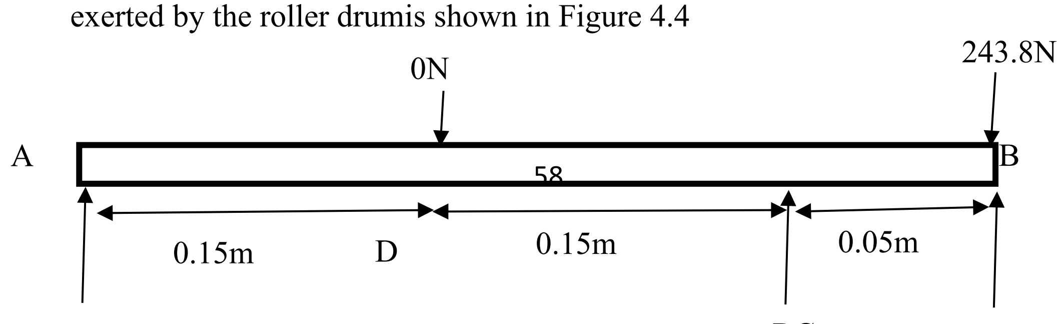


Figure 4.4: Shaft horizontal loading by roller drum

Taking moment about R_A

$\sum M_A = 0$

$R_A(0.35) + R_C(0.05) – 0(0.2) – 243.8(0) = 0$ 4.9

$R_A(0.3) + 243.8(0.05) – 0(0.15) = 0$ 4.10

From equation 4.10,

$0.3R_A + 12.19 = 0$

$R_A = -40.63N$

Adding all the horizontal forces or computing the value of R_A into equation 4.9,

$R_C + R_A – 243.8 - 0 = 0$

$R_C = 284.43N$

Therefore, the horizontal bending moment at A and B,

MA = MB = 0

Moment at C and D becomes;

Mc = 243.8 x 0.05 = 12.19Nm

$M_D = 243.8(0.05+0.15) – 284.43(0.15) = 6.0955Nm$

Resultant bending moment at C,

$$Mc = \sqrt{(\mathbf{13.171})^2 + (\mathbf{12.19})^2} = 17.946Nm$$

Resultant bending moment at D,

$M_D = \sqrt{(-15.329)^2 + (6.0955)^2} = 16.496Nm$

Using the ASME equation for standard solid shaft, equation 3.7

$$d^3 = \frac{16}{\pi Ss}\sqrt{(KbMb)^2 + (KtMt)^2}$$

But $M_t = \frac{kw \times 9550}{rev/min}$ (Hall *et al.*,2002)

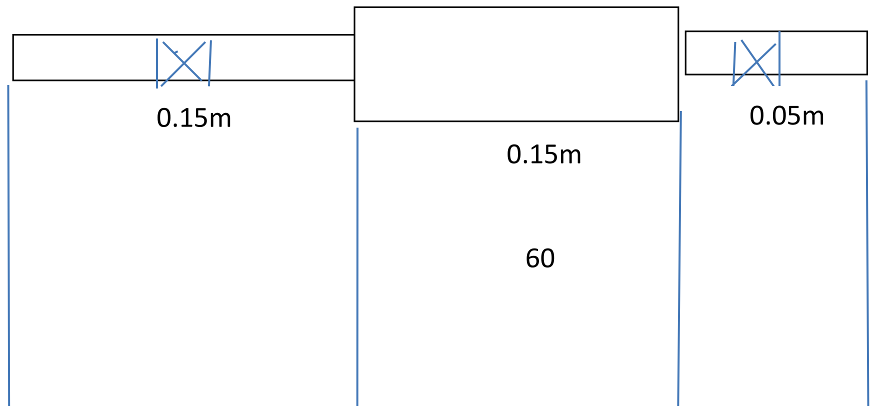
$$= \frac{1071 \times 9550}{1420} = 7.103Nms$$

Assuming the shaft is without keyway; $55MN/m^2$

$$d^3 = \frac{16}{\pi 55 \times 106}\sqrt{(1.5 \times 17.946)^2 + (1.0 \times 7.103)^2}$$

= 13.71mm = 14mm to the nearest standard size

The moment diagrams for vertical loadings, horizontal loadings and resultant bending diagramswith the reaction forces at the support of the machine shaft areas shown in Figure 4.5;



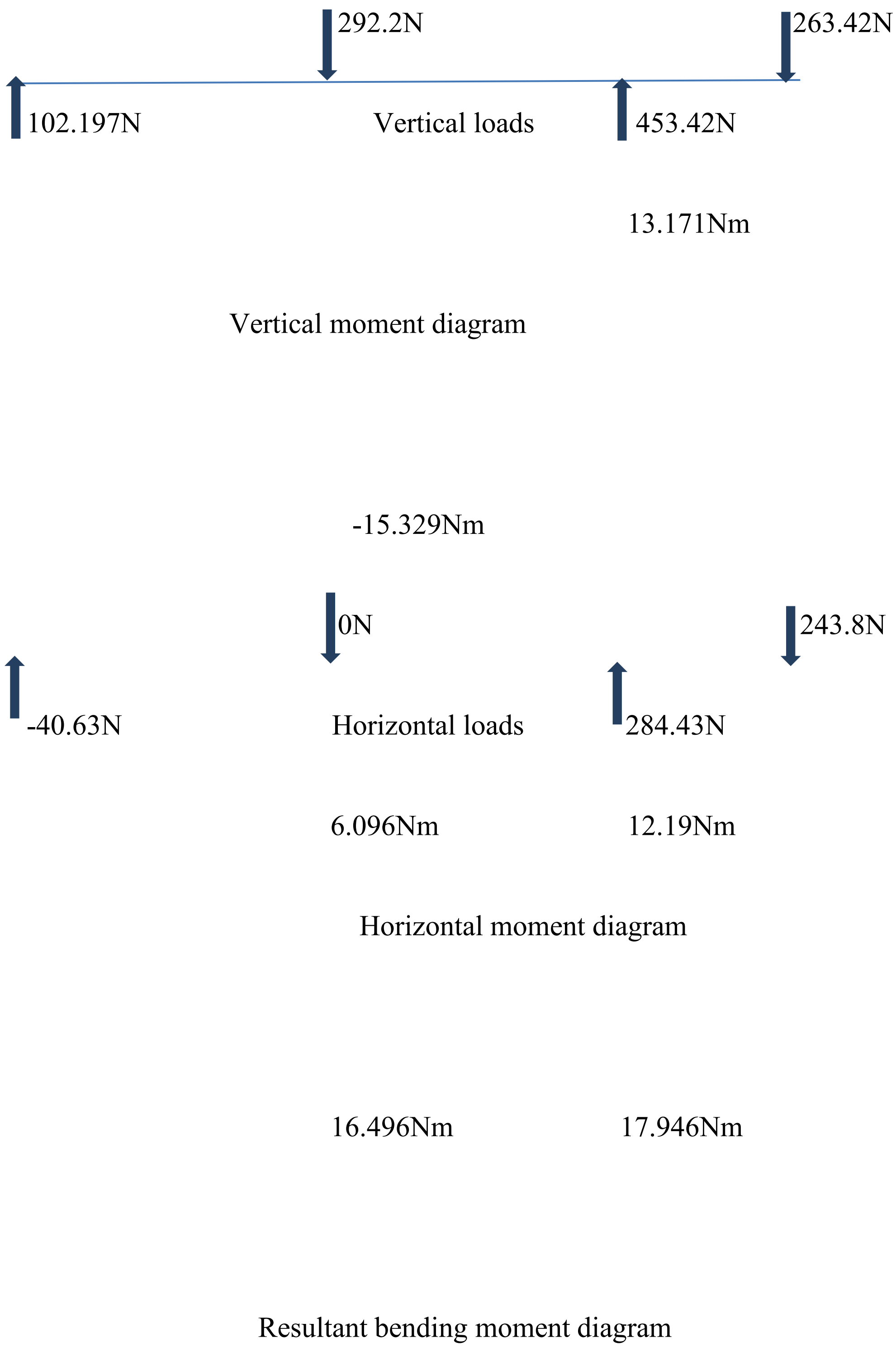


Figure 4.5: Bending Moment Diagrams

Applying the methods of twisting equivalent moment T_e andbending equivalent moment M_e to the shaft diameter, taking the larger value as the maximum shaft diameter.

Using equivalent twisting moment, in equation (3.5), we have;

$$T_e = \sqrt{(1.5 \text{ x } 17.946)^2 + (1.0 \text{ x } 18)^2} = \frac{\pi \text{ x } \tau}{16} \text{ x } d^3$$

T_e= 32.38Nm

Assume that; τ is constant = 56N/mm^{2}or 56Mpa and σb= 115Mpa

Therefore, d = 14.3mm or 14mm approximately.

Using equivalent bending moment, from equation (3.6)

$$M_e = \frac{1}{2}(1.5\, x\, 17.946 + 32.38) = \frac{\pi \text{ x } \sigma b}{32} \text{ x } d^3$$

M_e=29.65Nm

Hence; d = 13.79mm or

d = 14mm approximately.

So, considering the values of the shaft diameter, it gives approximately the same value no matter the method used. Therefore, the correct diameter of shaft to the nearest whole number is 14mm.

4.8.3 Resultant forces acting on frame structure

The frame structure that housed the various components should have the capacity to with-stand the forces acting on it to improve system stability. The following parameters were determined.

Mass of electric motor = 13.5kg

Weight of motor = mg = 9.81 x 13.5 = 132.435 N

The force pulling the electrical motor from slop =MgsinΘ

= 132.435sin30 = 66.218N

The force of the bolt holding motor =MgcosΘ

= 34.34cos30 = 114.695N

Therefore, the resultant force, $F_R = \sqrt{(66.218)^2 + (114.695)^2}$= 132.438N

Total Weight of shaft, pulping roller drum with beating blade and bearings =

6kg + 2kg +1.4kg = 9.4kg

9.4kg x 9.81 = 92.214N

4.9 Fabricated Fiber Machine and Assemblage

The designed and fabricated components of fiber extractor machine include; the frame stand that housed the other components, the pulleys, the roller drum, drum compartment, the guide, tissue scrubbing bar and shaft. The frame-stand is made of mild steel angle bar and squared pipe, cut to the required dimensions and assembled using inverter welding machine(IWM). The pulley, roller drum and shaft were also cut and machined to the required dimensions, sizes and shapes using the lathe machine. Each fabricated part was assembled to form the single unit (fiber extraction machine).

The standard methods were adopted and carefully used to fabricate each of the parts of the machine. The fabrication processes include the following; measuring and marking out, cutting, machining, drilling, joining, welding, fitting, test running and painting.

Some of the workshop tools and machines used are; measuring tape, centre punch, compass, hammer, scriber, and treadle operated guillotine for cutting and inverter welding machine for joining. The fabrication, construction and assembly of all the parts of the machine were carried out in the workshop of Engr. Abraham (Hamstring Engineering

Company) at Minna, technology incubation centre, Niger State. Some of the standard machine tools used are; drilling machine, inverter welding machine, cutting machine and other facilities available therein.

4.9.1 Working principles of the fiber extractor machine

When the tare is fixed to the frame stand by two end bearings, it runs freely according to the banana fiber speed of the extracting shaft. The banana fiber extracting shaft is rotated when the single-phase induction motor is switch on. The drive mechanism is activated to create rotating force at the roller drum compartment. The rolling drum is a rotating component of the machine that strips the sliced banana trunk (pseudo stem) into fiber strands. The rotating force pulps the banana ribs that were fed into the receptacle (inlet), to generate a torque greater than the banana rib tissue strength estimated with the expression in equation (3.16). The pulped banana rib is pressed against a scrapping bar which contains scrapping or beating blades surface to remove the crushed tissues. The pulping drum is fixed on two bearings to reduce power loss due to friction. Figure4.6 is a simplified block diagram showing the extraction of the banana fiber process.

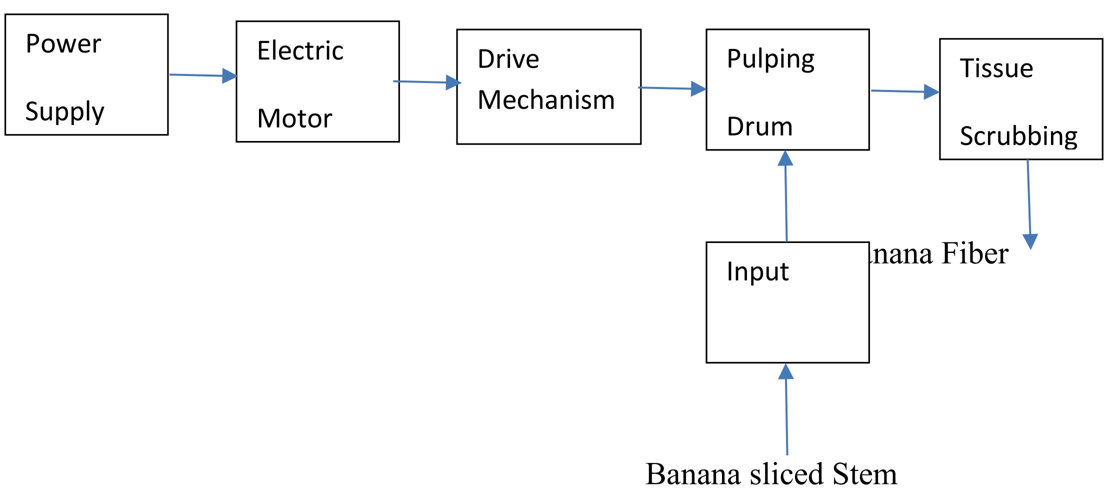


Figure4.6: Block Diagram of Fiber Extractor Machine

From the figure above the sliced pseudo stem sheaths was inserted one after the other into an extractor machine. The machine now removed the non-fibrous tissues and coherent materials known as scorcher from the fiber bundle present in the sheath and gave out the fine fiber as shown in Figure 4.6. After extraction, the extracted fiber is then sun dried for a day or more and packed for storage.

4.9.2 Summary of the results of sizing design analysis

The summaries of results gotten from calculated components of machine design are shown in Table 4.1;

Table 4.1: Results of sizing design analysis

S/N	Component Name	Measure Size	Values
1	Motor pulley	Diameter (d_1)	60mm
2	Driven pulley	Diameter (d_2)	90mm
3	Motor pulley	Speed (N_1)	1420rpm
4	Driven pulley	Speed (N_2)	448rpm
5	Belt drive	Velocity (V)	4.46m/s
6	Tight side of belt drive	Tension (T_1)	333.8N
7	Slack side of belt drive	Tension (T_2)	448N
8	Power require by machine	Power (P)	1.210 Kw
9	Torque develop by machine	Torque (T)	25.8N
10	Shaft diameter	Diameter (d)	14mm
11	Belt drive	Thickness	12mm
12	Power transmitted by motor	Power (P)	1.6 = 2hp
13	Force need to pulp the rib	Force (N)	286.76N
14	Weight of pulley	Weight (N)	19.62N
15	Centre of pulleys	Distance, x	450mm
16	Belt drive	Length (L)	1.33mm
17	Motor pulley	Angle of lap (ϴ)	2.58rad
18	Mass of the belt drive	Mass (M)	0.07127kg/m
19	Driving pulley	Radius (r_1)	30mm
20	Driver pulley	Radius (r_2)	95mm
21	Load on shaft	Vertical (F_{pv})	263.42N
22	Load on shaft	Horizontal (Fph)	243.8N
23	Bending moment	Resultant (RBM)	17.946Nm
24	Roller drum	Radius (r)	90mm
25	Roller drum	Weight (wt)	92.2N
26	Force pulling motor at slop	Force (N)	66.22N
27	Power transmitted by belt	Power (P)	802.8 W
28	Centrifugal tension on belt	Tension (T)	1.42N
29	Maximum tension on belt	Tension (T)	335.2N

When a force of 300N, 350N and 400N is applied the corresponding pulping thickness of banana ribs of approximately, 8.12mm, 8.5mm and 9.0mm, will be obtained respectively. These designs calculated result form the basis of the machine development as could be seen in the main drawings. Plate 10 shows the view of designed and fabricated banana fiber machine.

Plate X: front view of designed banana fiber machine

4.9.3 Design considerations of banana stem

The assuption or measured values of banana stem are shown in Table 4.2;

Table 4.2: Assumptions or measured values of banana sliced stem

Components	**Values**
Length of sliced banana stem	600mm
Width of sliced banana stem	150mm
Thickness of sliced banana stem	10mm
Maximum deflection of stem after feeding y	4mm
Modulus elasticity of banana stem Eb	29GPa
Area moment of Inertial of stem, I	$450mm^2$

4.9.4 Test of banana machine performance

A banana fiber machine was designed, fabricated and tested for extraction efficiency**.** The analysis of banana fiber machine performance and some of the parameters used such like steady voltage power supply, sliced length of banana trunk, the width, thickness and machine extracting time. Extracting time is the time taken by the machine in seconds to finish extracting one sliced measured banana trunk completely using a stop watch. The parameters are computed in Table 4.3;

Table 4.3: Test runs result of banana fiber machine

S/N	**Voltage (V)**	**Length (mm)**	**Width (mm)**	**Thickness (mm)**	**Extracting time (s)**
1	220	100	30	8.00	12
2	220	150	30	7.00	13
3	220	300	80	8.50	22
4	220	350	86	8.54	24
5	220	550	100	9.00	29
6	220	600	150	10.00	32

Average extracting time $= \frac{\text{Total value of extracting time}}{\text{number of test run activity}}$

$= \frac{132}{6} = 22$

Therefore, the average extracting time for fiber machine extractor is 22seconds.

4.9.5 Banana fiber machine capacity

Assume 600mm length, 150mm width and 10mm thickness of a sliced banana stem weighed 350g.

600mm length, 150mm width and 10mm thickness of a sliced banana stem, takes 32 seconds extracting time.

Then in 1minute= $\frac{60}{32}$ x 350

= 656.25g

In 1 hour, the machine will extract 656.25 x 60

= 39.375kg/h

Therefore, the capacity of machine in one hour is 39.375kg/h

4.9.6 Alkali treatment of banana fiber

The banana fiber treatment using alkali, increases surface roughness which results in better mechanical bonding and the amount of cellulose exposed on the fiber surface according to (Mohd*et al.,*2011), who experimented the effect of Sodium Hydroxide solution (NaOH) on kenaf fiber reinforced polyester composite. The result shows that the mechanical properties of the composite, was increasing proportionately with the correspondent concentration of the alkali. This brought the increase in all sides of the possible reactions and allows better fiber wetting. For this reason, the produced banana fibers were washed with detergent and tap clean water and later immersed in 8% of sodium hydroxide solution (NaOH),for about 2 hours at room temperature to remove the impurities present in the raw fiber and later, wash it thoroughly in a clean tap water bowl again to remove the un-reacted alkali and then filtered. The fibers that were being filtered are then dried in sun light for 24 hours. It was discovered at the end of experiment that colour, texture and strength of fiber is no longer the same, this shows an increase in mechanical strength and has equally degummed the fiber.

4.9.7 Discussion of results

In this work, two methods of banana fiber extraction were adopted; manual and mechanized method. Processes involved in manual production are the use of scrapper and human force while in mechanical production is the use of electrical machine to extract the fiber. Mechanical method employed, dealt with appropriate selection of materials, design, fabrication and assembly of all the various machine components. It shown that 2 hp electric motor could be used to drive the fiber machine efficiently. The total length of flat belt to drive the pulley is equal to 1.33m at an angle of lap on the smaller pulley of 2.58rad and velocity of 4.46m/s. The resultant load of 292.2N acts on a diameter shaft of 14mm with maximum bending moment of 17.946Nm. The machine was tested to ascertain the efficiency of the device. At the design stage, the computation of the length, width and thickness of the banana sliced stem were determined. The thicknesses of banana sliced stem used for this test was: 8.0mm, 7.0mm, 8.50mm, 8.54mm, 9.0mm and10.0mm. The test was done on a steady voltage supply of 220V single phase induction motor using a stop watch to determine the extraction time. The machine capacity was calculated to be 39.375kg/h. From the test result obtained, the machine could extract a sliced stem of maximum width of 150mm and thickness of 10 mm respectively, while the length varies. The alkaline treatment was done using 8% of sodium hydroxide (NaOH) solution to increase mechanical properties of fiber like strength and texture. The results obtained from the test were summarized in the Table 4.3.

4.10 Beneficial Features Of Machine Over Manual Processing

The banana fiber extracting machine enables a greater chance of getting more fiber which is more marketable in terms of quantity and quality. These are the various advantages;

a) It can extract up to 30 kg fiber within some limited hours.
b) Fibers of good qualities in terms of strength, length, softness and colour were provided.
c) Less cost of maintenance, easy and safe to operate.
d) It enables clean work environment.
e) It reduces drudgery or tediousness.
f) It is for mass production of fiber.

4.10.1 Machine operational guide

This banana fiber extracting machine can be powered either by the use of prime mover machine or an electric powered supply. It requires a supply voltage of 220V – 240V to operate efficiently with good fiber extraction as output. The operational guide of the extracting machine is stated as follows:

i. Ensure that the machine is connected to the appropriate power supply source or to the prime mover machine (mechanical power).

ii. Ensure that there is enough space around the machine for the operator to avoid unnecessarily accident.

iii. Ensure that you cut and sliced the pseudo stem of banana stem into appropriate measurement.

iv. Feed the banana sliced pseudo stem into the extracting machine one after the other gently

vi. Repeat step 4, to obtain the fibers needed.

vi. Ensure you sundry the extracted fiber for about 24 hours.

Vii. Pack the dried fibers and store for further uses.

CHAPTER FIVE

5.0 CONCLUSSION AND RECOMMENDATIONS

5.1 Conclusion

The design and fabrication of banana fiber extraction machine was achieved with good efficiency. This machine is capable of reducing manual extraction time and is also suitable for industrial purpose. It is portable and easy to maintain, assemble and disassemble by the operators. Some of the factors which may affect the qualities and quantities of fiber production are feed angle, roller speed and clearance angle. During the design and fabrication of this machine, all these aforementioned factors were considered. By considering these factors effectively, the qualities and quantities of production of fiber could be increased. Therefore,

Banana fiber production was achieved.

The design and fabrication of banana fiber extraction machine has been achieved.

Performance evaluation of the machine was conducted to ensure machine efficiency.

Banana fiber treatment with alkaline solution has increased the mechanical properties of the fiber.

Banana wastes are means of increase in economy of different countries of the world today, such like in Philippines, India, Nepal and some other countries of the world. It has become business excellent opportunities to the populace of the country. Some of these countries have been using banana fiber in producing different products for more than two decades. They had wanted to replace cotton in the market which is the most expensive product. In fact, developing nation like our country Nigeria should developed this type of business idea, so far as our land is suitable for the production of banana plant. This will create lots of business employment opportunities for school dropout, youths and young adults, therefore increases their socio economic way of living.

5.2 Recommendations

The performance of the machine indicates that the fiber extractor machine will be able to extract a reasonable quantity of fiber but there is still room for improvement. The followings are being recommended based on researcher experience during the research work;

1. The factors which affect the qualities and quantities of fiber are the roller drum, motor speed, feed angle and clearance, must further work on for better efficiency of the machine.
2. By improving on these factors mentioned above correctly, the quantity and quality of fiber production would be increased.
3. Development of automatic multiple feeder of sliced pseudo stem could increase the production quantity also and reduce the production time, instead of feeding one after the other manually.

5.3 Contribution of the Study to Knowledge

Banana wastes are being used in different countries of the world like India, Uganda, China and Philippines just to mention but a few as an excellent business idea. These countries have been developing interesting products such like: bags, baskets, ropes, foot wears, socks, decorative papers, floor mats, rugs, currency paper and home furnishingsfor over a decade and have been trying to replace cotton that is more expensive at market value. As a matter of fact developing country like Nigeria should begin such kind of business since the land of our country is suitable for banana production. Besides, farmers will be interested to cultivate banana for extra income by transforming the waste into fiber. The major challenge they would have encountered which is the high cost of existing machinery from transforming banana stalks into more useful material that could improve their economic well-being had been solved in this project. We have huge barren land that can be productive due to the demand of raw materials of this business through the plantation of banana. If the pseudostem can be utilized for fibre extraction, it will create lots of employment opportunities and make rural youths and young adults' school drop outs empowered and improve their socio-economic level and standard of living.

REFERENCES

Aiswarya, G., Amala D., Anjitha. G. N., Drisya, V.A. & Justin T. (2017)Fiber Reinforced Pervious Concrete Using Banana Fiber, International Journal of Engineering and Management Research ISSN (online): 2250-0758, p127-132.

Aurore, G., Parfait, B. & Fahrasmane, L. (2009). Bananas-raw-materials for makingprocessed food products. *Trends in FoodScience Technology,* 20: 78-91.

Barreto, A.C.H., Costa. M.M., Sombra. A.S.B., Rosa D.S., Nascimento. R.F. & Mazzeto S.E. (2010)chemically modified banana fiber: structure, dielectrical properties and biodegradability, *Journal of Polymer and Environment.* 18: 523-531.

Bello, H. (2008), Production of Fiber for Plaster of Paris using Bamboo Tree. Unpublished B.Eng. Project submitted to Chemical Engineering Department, Federal University of Technology, Minna, Nigeria.

Bilba, K., Arsene, M.A., & Ouensanga, A. (2007). Study of banana and coconut fibers, Botanical coamposition, thermal degradation and textural observations. *Bio resource Technology* 98: 58-68.

Cordeiro, N., Belgacem, M. N. Torres, I. C. &Moura, J. C. V. P. 2004. Chemical composition and pulping of bananapseudostems. *India Crops Production,* 19:147-154.

Das, P.K., Nag D., Debnath S., & Nayak LL.K., (2008) Machinery for extraction and traditional spinning of plant fibers, National institute of Research on Jute and Allied Fiber Technology, ICAR, 12, Regent part, Kolkata 700 040, West Bengal.

Emaga, T. H., Andrianaivo, R. H. Wathelet, B.Tchango, J. T. & Paquot, M(2008). “Effects of the stage of maturation andvarieties on the chemical composition ofbanana and plantain peels”*FoodChemistry*, 103: 590-600.

FAO(Food and Agricultural Organization, Geneva) 2007; www.fao.org/production/faostat.

FAO(Food and Agricultural Organization, Geneva) 2009; www.fao.org/production/faostat.

Girisha, C., C. Sanjeevamurthy, & Guntiranga S. (2012). “Effect of Alkali Treatment, Fiber Loading and Hybridization on Tensile Properties of Sisal Fiber, Banana Empty Fruit Bunch Fiber and Bamboo Fiber Reinforced Thermoset Composites”. *International Journal of Engineering Science & Advanced Technology*. 2(3):706–711.

Goswami, T., Kalita, D. & Rao, P.G. (2008), Grease proof paper from banana (*Musa paradisiaca*L.) pulp fiber, *Indian Journal of Chemical Technology*. 15: 457-461.

Goswami, B.C. (1977), Textile yarn technology structure and applications pg.17-24.

Hall, A.S., Holowenko, A.E., & Laughlin, H.G. (2002). Schaum's outline series theory and problems of machine design. (1st ed.). New York; McGraw-Hill Companies Inc., p12-22,113-115.

Hull, D. and Clyne T.W. (1996), An Introduction to Composite Materials, published by Syndicate of the University of Cambridge, ISBN: 0-521-381908.

Indira, K. N., Jyotishkumar, P. and Sabu, T., (2013) "Mechanical Properties and Failure Topography of Banana Fibre PF Macro Composites Fabricated by RTM and CM Techniques" Hindawi Publishing Corporation, ISRN Polymer Science.

Indrani, S. & A.C. Deka, (2016). Banana Fiber Extraction ByMycogenic Pectinase Enzyme(S)- An Eco-Friendly Approach, Imperial Journal of Interdisciplinary Research (IJIR),
The Energy and Resources Institute, North Eastern Regional Centre, Guwahati Vol. 2, P997-998.

Joseph, S., M. S. Sreekala, Z. Oommen, P. Koshy, &Sabu T. (1999). A Comparison of the Mechanical Properties of Phenol Formaldehyde Composites Reinforced with Banana Fibers and Glass Fibers, Composites Science and Technology, 62(14), pp. 1857–1868.

Kiruthika, A.V, &Veluraja, K. (2009) Experimental Studies on the Physico-chemical Properties of Banana Fibre from Various Varieties. Fibers and Polymers 10: 193-199.

Khurmi, R. S. & Gupta, J. K. (2013). A Textbook of Machine Design, (8th Edition). New Delhi; Eurasia Publishing House (PVT) Ltd.

Khurmi, R. S. & Gupta, J. K. (2010). A Textbook of Theory of Machine, (latest Edition). S. Chand publishing House (PVT) Ltd. Ram Nagar,New Delhi, India.110-055.,p325-360.

Khanum, F., Swamy, M. S., Sudarshana, K. K.R., Santhanam, K. & Viswanathan, K.R. 2000. Dietary fibre content of commonlyfresh and cooked vegetables consumed inIndia. *Plant Foods and Human Nutrition,*55*:* 207-218.

Kulkarni, A G, Sathyanarayana K G, Rohatgi P.K & Kalyani V. (1983). Mechanical properties of banana fibers. *Journal of Material Science*, 18, p2290.

Kumar, K. P. S., Bhowmik, D., Duraivel, S. & Umadevi, M. 2012. Traditional and medicinal uses of banana. *Journal Pharmacognosy and Phytochemistry*, 1:51-63.

Kumar, S.S. & Anbumalar .V. (2015);A literature review "selection and evaluation of natural fibers" Department of Mechanical Engineering, Velammal College of Engineering and Technology, Madurai, Tamil Nadu, India. International Journal of Innovative Science, Engineering & Technology, Vol. 2; ISBN: 2348 – 7968.

Maleque, M.A., Belal F.Y. & Sapuan S.M., (2006) Mechanical properties study of pseudo-stem BananaFiber Reinforced Epoxy Composites. The Arabian Journal of Science and Engineering, Vol. 32, pp. 359-364.

Manandhar, P. (2010). Waste banana stump basedmicro enterprises. A fact-finding study Ona project implementing under Nepaldevelopment marketplace.

Manogna, A. (2017), A study on banana fiber clothing. Dissertation submitted to National Institute of Fashion Technology, Mumbai.

Michael, P. (2002). Load Bearing Fiber Composites; Published by Kluwer Academic Publishers New York, ISBN: 0-306-47591.

Mohapatra, D., Mishra, S. & Sutar, N. (2010). Banana and its by-product utilization: an overview. *Journal Scientific & IndustrialResearch*, 69: 323-329.

Mohd, Y.Y., P.T. Phongsakorn, S. Haeryip, A.R. Jeefferie, P. Puvanasvaran, A.M. Kamarul, & R. Kannan. (2011). Mechanical Properties of Kenaf/Polyester Composites. *International Journal of Engineering & Technology IJET-IJENS*. 11(01): 106 – 110.

Mohiuddin, A. K., M. Manas, KantiS, M.D. Sanower& Aysha F. (2014); A Review on Usefulness of Banana (*Musa paradisiaca*) Wastes in Manufacturing ofBio-products,A Scientific Journal of Krishi Foundation, *The Agriculturists 12(1):* 148-158.

Mohiuddin, A.K.M., Saha, M.K., Hossain, M.S. & Ferdoushi, A. (2014). Usefulness of banana bio-products: A review. *The Agriculturists,* 12(1): 148-158.

Mukhopadhyay, S., Fangueiro, R., Yusuf, A. &Senturk, U.(2008). Banana fibersvariabilityand fracture behaviour. *JournalEngineered Fibers& Fabrics*, 3(2): 39-45.

Mwaikambo, L., (2006). "Review of the history, properties & application of plant fibers," African Journal of Science and Technology, vol. 7, p. 121.

Oliveiro, L., Cordeiro, N., Evtuguin, D. V.,Torres, I. C. & Silvestre, A. J. D. (2007). Chemical composition of differentmorphological parts from 'DwarfCavendish' banana plant and theirpotential as a non-wood renewable sourceof natural products. *India CropsProduction,* 26: 163-172.

Oreko, B. U., Okiy S., Emagbetere E., & Okwu M. (2018). "Design and development of plantain fibre extraction machine". Faculty of Engineering, University of Nigeria, Nsukka. Vol. 37,pp.397 – 406.

Patil, R. G. & Kolambe, B. N. 2011.Development of value-added productsfrom banana pseudostem. An Overview ofProgress. National Agricultural InnovationProject (Component 2), 1-23 pp.

Phirke, N. V., Patil, R. P., Chincholkar, S. B. &Kothari, R. M. (2001). Recycling of bananapseudostem waste for economicalproduction of quality banana. *ResourceConservationRecycle*, 31: 347-353.

Pothan, L. A., Sabu T. & Neela K. (1997), Short Banana Fiber Reinforced Polyester Composites: Mechanical Failure and Aging Characteristics, J. Reinforced Plastics and Composites, 16(8), pp.744–765.

Rahamaththulla, S., S. Premnath, V. Ravi, S. Madheswaran, & Jayakumar N. (2018), Designand Fabrication of Banana Fiber Extracting Machine, International Journal for ScientificResearch & Development, Bannari Amman Institute of Technology, India. ISSN (online): 2321-0613, P390 – 393.

Ravi, B., Gourav, G. & Sachin Y. (2015), A Review on Composition and Properties ofBanana Fibers, International Journal of Scientific & Engineering Research, Volume 6, ISSN 2229-5518, Pg49-52.

Sapuan, S.M., Harun, N. & Abbas, K.A, (2007). Design and fabrication of a multipurpose table using a composite of epoxy and banana pseudo stem fiber. Journal of tropical agriculture. 45, p67-69.

Sapuan, S.M. & Maleque, M.A, (2005). Design and fabrication of natural fiber reinforced Composite for household application. *Journal of Materials and Design*, 26(1):65-71.

Sharrock, S. & Lustry, C. 2000. Nutritive value of banana, in INIBAP Annual Report (INIBAP, Montpellier, France), Pg.28-31.

Sheikh, A.S.& Awata, N. P. (2016) "A Review Paper on Design and Development of Banana Fibre Extraction Machine". International Journal of Engineering Sciences and Research Technology.

Shigley, J.E& Mischke, C.R (2001). Mechanical Engineering Design. (6th edition). New York; McGraw-Hill Companies, Inc.

William, D. & Callister Jr (1997). Material science and engineering fourth edition pg. 518-519.

APPENDIXES

The engineering drawing of parts of banana fiber machine using solid works are shown below:

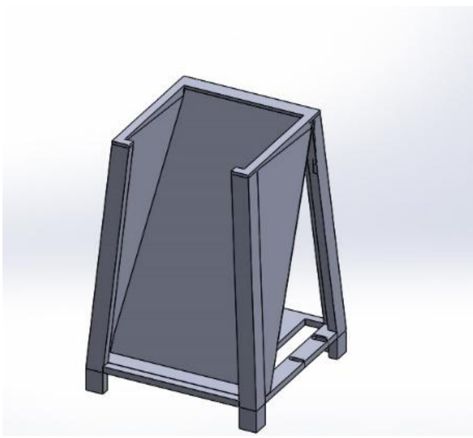


Figure A: Machine frame

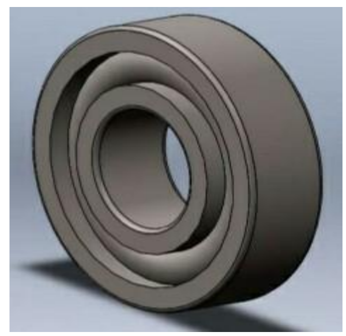


Figure B: Ball bearing

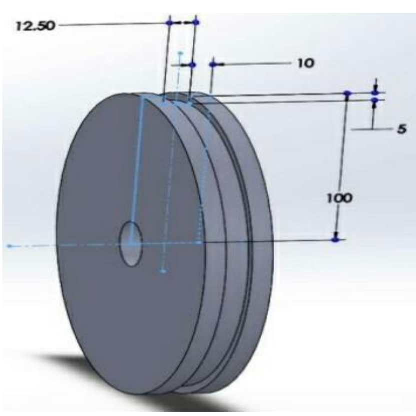


Figure C: Pulley

Figure D: Belt drive

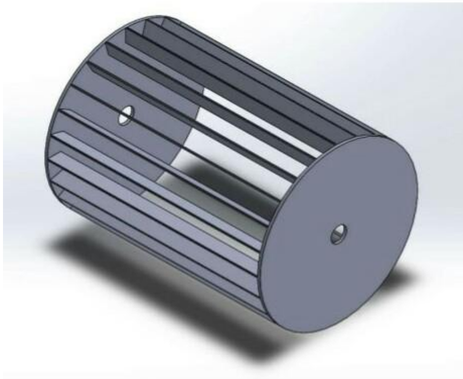


Figure E: Roller drum with beating blade

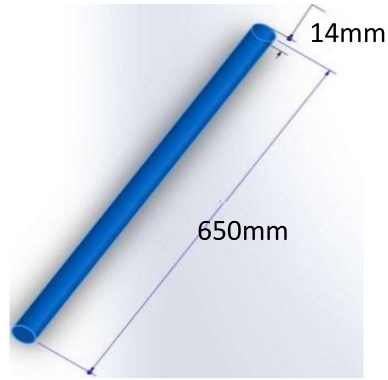


Figure F: Machine shaft

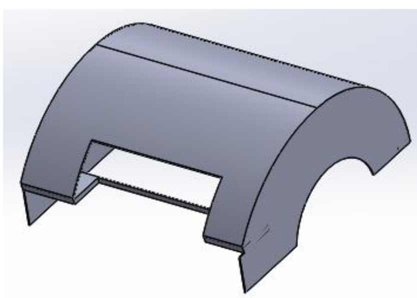


Figure G: Roller drum compartment

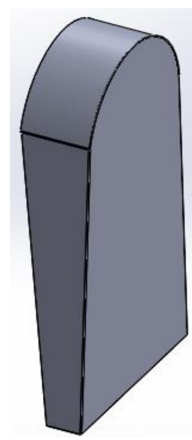


Figure H: Belt drive cover

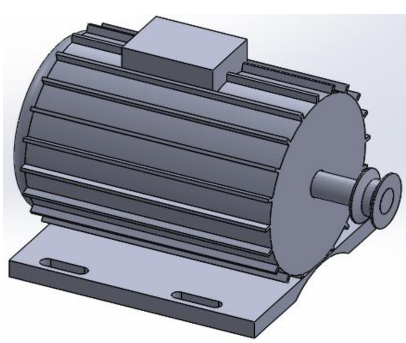


Figure I: Single phase electric motor

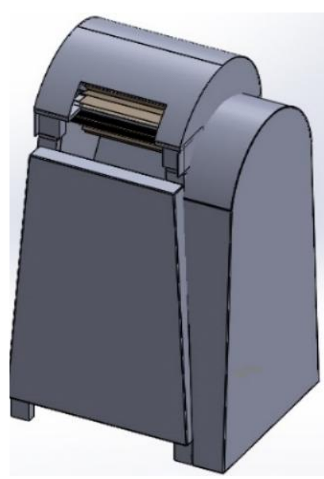


Figure J: Machine assembling