DESIGN AND CONSTRUCTION OF MANUALLY OPERATED SUGARCANE JUICE EXTRACTOR

BY

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2004/18376EA

DEPARTMENT OF AGRICULTURAL & BIORESOURCES ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY,

MINNA

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN 'ARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE WARD OF BACHELOR OF ENGINEENRING (B.ENG) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

FEBRUARY, 2010.

DECLARATION

I hereby declare that this project was undertaken and written by me. It has not been presented before, for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

Gbenro, Adebowale Reuben 17/02/10

Date

CERTIFICATION

This project entitled "Design and Construction of Manually Operated Sugarcane Juice Extractor" by Gbenro Adebowale Reuben, meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

16.02.10

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DEDICATION

This project is dedicated to Almighty God who makes it possible for me to complete the programme successfully, in whose hand lies my future and to my late daddy Mr. Michael Abodunrin Gbenro and my elder brother Gbenro James. May their gentle souls rest in peace.

ACKNOWLEDGEMENTS

Sincerely, my gratitude goes to Almighty God the Supreme Being, the ruler of the whole universe and the chief judge in the last day, for given me divine knowledge to successfully complete this project and the degree program.

I must specifically express my profound gratitude and priceless thanks to my project supervisor Engr.P.A.Idah, for his inestimable contributions to the success of this project. May God recompense him (Amen).

I would also want to express my appreciation to the department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, especially the head of the department and all the lecturers in the department for their constructive criticisms and for spending their time to take care of me.

My thanks goes to my dearest father late Mr. Michael Abodunrin Gbenro for his solid support while he was alive and for making my dream come to reality. My prayer is that God will grant him eternal rest (Amen).To my mother, I say thank you mummy for your love, sweet word of encouragement, your support morally, prayerfully and financially. I love you mummy, may you eat the fruit of your labour and may God bless you abundantly.

Equally, my thanks go to my brothers and sisters. I appreciate you all for your endurance and support. I am indebted greatly to Alade Idayat and to my next of kin, Adebowale Mayowa Precious for their support and love. I am very grateful for everything you have done; I can never forget you all. Thank you a lot God will reward and bless you all for your kind gesture and your good depositions towards me (Amen).

Finally, I am also indebted to friends and colleagues, my project mate, friends in the department, school and outside school, relatives and all well wishers. May God be with you all (Amen).

ABSTRACT

A manually operated sugarcane juice extractor was designed, constructed and tested to assist the small and medium sugarcane crusher to extract juice from sugarcane. The machine macerates vertically loaded sugarcane stem and presses the macerated stem against the cylindrical cone to extract the juice from the wet baggasse. The machine consists of the macerating part which is made up of the grating drum that runs through a cylindrical cone for the maceration process and a sieving unit for squeezing out the juice. The performance tests carried out on the fabricated machine showed that the extraction units could macerate but the rate of juice extraction was low. The design needs further improvement to make it more effective. However such small scale wet baggasse production can actually cut down the cost of transporting bulk cane to the distance markets. A device of this nature can be manufactured in small machine shops in the sugarcane producing areas for village level applications.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATE

Plate **Page**

CHAPTER ONE

1.0 INTRODUCTION

1.1 The Sugarcane Plant

The sugarcane plant is a perennial grass growing naturally in certain region of tropical Asia which is thought to be its land of organ. However as it was found growing in Polynesian Island by the first European explores, certain authors claims that the plant originated from the southern pacific.

Sugarcane is generally grown between the latitude 30^0 North and South, mainly because it requires a warm irrigation, its does not withstand prolonged frost conditions.

The botanical name of the Sugarcane is *saccharum spontaneum* and its composition well varies according to varieties, climate, soil types and agriculture practices. The plant itself can be divided into different component; the root stalk and leaves. For the processor it is the composition of the stalk that is of important. .

This manually operated juice extractor was designed in such a unique way, that it could extract juice from cane. However, it was hitherto and specifically designed and fabricated for sugarcane.

As a developing nation, where power supply is erratic, the use of this manually operated device is desirable, particularly at the local communities. It has also been noted that to meet the increasing sugar needs of the populace, there is the need to design and fabricate simple devices that are suitable to the rural settlement where small scale extraction of cane juice and the by-product can be carried out. Though, there are many extracting machines in the markets, most of these design arę not suitable for small scale extraction at the rural settlement.

1.2 Economics Importance of Sugarcane

The two most important by-products of the sugarcane are molasses and bagasses. About 10% of the molasses produced is used for the production of portable spirit, denaturated spirit, vinegar, drugs, perfumes and alcohol for export. Molasses is also used on a small scale as fertilizer on account of its potassium content. It is being utilized either alone or mixed with fine bagasses as feed for cattle.

1.3 Statement of problem

1. Lack of adequate transportation mechanisms, such as poor road network, non-availability of transport equipment like trailers to improve efficiency.
2. Non-availability of appropriate technology that is simple and easily operated sugarcane processing machine or equipment, spare parts and funds to procure them.
3. Poor storage facilities and practices to preserve harvested canes or extracted juice before been refined to sugar.

In addition to the above stated problems using the same transport device will be more economical to transport extracted sugarcane juice from the farm to the factory for refining into sugar than transporting harvested sugarcane to the factory for processing. This is because the quantity of extracted juice from trailer loads of sugarcane may not be up to 30% of a trailer load of cane sticks.

To achieve this, there is the need to design and construct an appropriate machine to aid the extraction of juice at the farm level. The suitability and efficiency of this technology i.e. Sugarcane juice extractor can be achieve through the evaluation of the present one and identifying its area of non-performance. These areas of non-performance are to be redesign and constructed for a better and more efficient performance.

Meanwhile, the extractor is very portable and durable, it stand better than other because immerse modifications were made from existing juice extractors.

However, in this design, some common but special features, which will enhance its acceptability over others for similar applications are enumerated below.

- Maintenance is very low
- Relatively low cost
- Very durable and portability.

1.4. Objectives of the Project

1. To design and construct a small scale sugarcane juice extractor that will be simple to operate and affordable by the peasant farmers.
2. To carry out a performance test of the developed machine.

1.5 Justification

- To find suitable and fast method of producing sugarcane juice in the local farm
- Enhance local capability in design and construction of machine for sugarcane juice processing
- To increase the production of sugarcane juice by developing an appropriate technology for extracting the juice.

1.6 Scope

The scope of this project work is limited to the:

i. Fabrication of the hopper using 0.5mm metal sheet by cutting and welding the culted plate.
ii. Construction of frame with stand by cutting and welding of angle bar
iii. Assembling of fabricated part to have a complete machine.

iv. Painting of the machine

v. Test the performance of the machine.

CHAPTER TWO

2.0 LITERATURE REVIEW

Sugarcane production practices throughout the world vary depending on soil types, climatic factors and custom. The production of sugarcane has increase significantly during the last few decades. It is a perennial grass of the tribe andropogones. (A.T Brief, 1989). Sugarcane planting is however very tedious, time consuming and expensive operation (Shkla, 1987).

Sugarcane which is a major raw material used in the manufacturing of refined sugar (by large-scale modern mill) is usually harvested manually or using cane harvester and then transported from the farm as the raw material in cane form to the sugar production industries for processing.

According to Haln and Tarry (1980), the crop was rapidly adopted by farmers and integrated into the traditional farming systems of Africa because of the following factors:

Adaptability to traditional farming and food system

Relative ease of cultivation and processing

Relatively high yield of food energy.

2.1 Importance of Sugarcane

Sugarcane is an essential crop with a cheap form of energy. In the body, sugar combustion releases energy which is partly used in warming the body and in doing work. One kilogram of sucrose produces 394 kilocalories of energy (Shian, L.S and Osman, A. 2000). Also, molasses is one of the most important by-products from sugarcane manufacturing. It has 50% of fermentable sugar, thus making it an industrial raw material (Yusuf, S. and Shian, 2000). Other importance of sugarcane includes.

(i) The bagasse which is the fibrous residue left after the extraction of juice form crushed sugarcane serves as a source of fuel in the sugar factories. Industrially, bagasse is used in production of corrugated board, writing and printing papers, cardboards, fiberboards and wallboards and a variety of chemical (Ajala 1980) and Hamilton and Longe (1980).

ii. Bagasse is also used in the production of plastics due to its characteristic chemical composition and potential availability (Purseglove 1997).

iii. Rum is produced by the fermentation of molasses it is a colourless liquid. However in order to obtain a colored rum caramet is added to produced particular flavour in the diluted liquid, which is then sold for consumption (Mauritius. Prosi 1996).

iv. Cane syrup, Know as "fancy molasses" is also papered form sugarcane (Ohler, 1997 and Wikipedia, 2008).

v. Molasses, an important by-product of sugarcane is industrially used in the production of yeast, citric acid, alcohol and livestock feed. 10% by weight of molasses tremendously increases the meat yield of cattle and poultry when added to their feed (Mauritius-Prosi 1996).

2.2 Sugarcane Processing Machinery

Sugar processors have long recognized the necessity for a cane mill to have simple provision for optimum recovery of extracted juice. Juice extraction from sugarcane is done by crushing and squeezing of the sugarcane stalk (Okogie, K.T 1980). The earliest known mill used for the extraction juice from the sugarcane consists of two vertical wooden or stone rollers driven by animal, water, wind, or human power (Hamilton and longe, 1980). Some early mills produced in West Indies which have different configurations of the crushing rollers. Another similar mill was later seen, but the rollers were placed horizontally with one roller above the other will the central one turning the other two as in the vertical Grobert et al, (1980).

Later the configuration of the rollers consists of two rollers below and one above (De Grobert et al, 1993). This modification allows the crushing of sugarcane on the entire surface of the mill which was not possible on the various types of mill earlier mentioned.

The various roller mills consist majorly of the following:-

i. Mill rollers and pinions

ii. Trash plate and bar

iii. Scrapers

iv. Knives

v. Heads tock and bearings

vi. Adjustment gear (wedge blocks)

vii. Hydraulics

viii. Juice tray

According to Dear (1990) thee earliest authentic use of the steam enquire for milling started in Cuba in 1797. crushers with Zigzag rollers came into use in 1883 and the shredder was invented by fished in Louisiana in 1886, however in 1813 at England, inverted the vacuum pan, discoloration of sugar solution by percolation through columns of bone char was also developed at this period and this was credited to Derosin- with these two innovations, (that is, vacuum boiling and bone char diccoloration), modern refinery practice began.

2.2.1 Processing Procedure

The processing of sugarcane involves first peeling of the stem which is subsequently followed by grating of the sugarcane ("Peeled" stem). The grated sugarcane which is known as

"Wet Bagasse" is then processed further into sugar by several processes. These processes which give white granulated sugar is carried out in the sugar factory in three stages:

(i) Extraction of Juice from the cane

(ii) Production of raw sugar crystals and

(iii) Refining of raw sugar to obtain white granulated sugar (Yusuf, S; Shian, L.S. and Osman, A. 2000).

In the first stage, which is the juice extraction phase, harvested canes are weighted automatically as they are unloaded from cane carriers to feed carriers in the mill house. The feed carries conveys the canes upward to a set of heavy knives (operating at about 600rmp) which chop the canes into small pieces. Juice is extracted as the chopped mass of canes pass through the mills, each of which squeezes the mass of canes under a pressure. The mass of cane passing through the second, third and fourth mills is rinsed with water to dilute the sucrose and enhance extraction the extracted juice (now referred to as mixed juice) is passed through a strainer and pumped to the process house for sugar manufacturing. Below is a flow chart (Fig 2.1) showing the processing of sugarcane for sugarcane juice (Olapade, 1999).

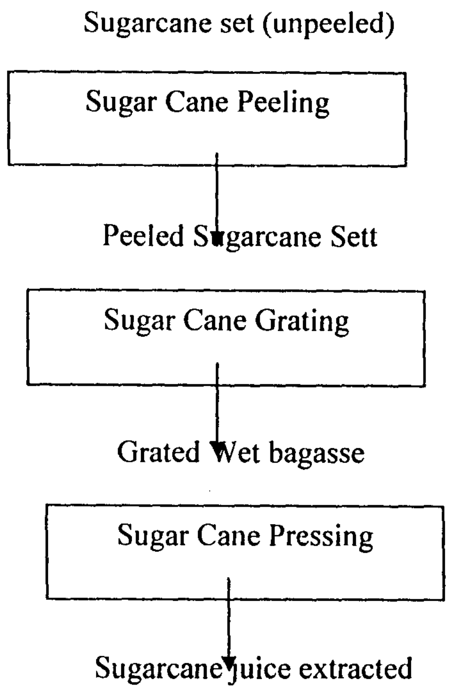


Fig 2.1: Sugarcane juice processing flow chart

2.2.2 Sugarcane Juice Extractor

Sugarcane juice extractor is a machine which is used for the extraction of juice from the sugarcane, whilst the cane in further processed into sugar. The sugarcane juice extractor can be manually or electrically operated. The manually operated sugarcane juice extractor employed the use of either hand pressing equipment or pedal (Olapade, B,C 1999).

Due to the level of education and poverty of the farmers the manually operated type is design for their use because of the following reasons.

i. Low initial cost

ii. Ease of operation

iii. Portability and compatibility (ease of movement between fragmented lands).

However, an improved sugarcane juice extractor has removable crushing rollers. The juice extractor preferably includes housing with a juice extracting compartment and a closure for accessing the compartment. The closure is preferably a clear plate which permits viewing of the compartment during operation and, when removed, allows access to the compartment for removal of the crushing rollers and cleaning of the rollers and the compartment. A safety switch can be provided to prevent rotation of the rollers when the closure is display. A guide in to the compartment is preferably provided to direct the sugarcane and any flavoring in to the crushing rollers. A waste channel is provided for the exit or crushed came pulp. (Neves, A. 2004).

2.3 Review of Existing Sugarcane Crushers in Nigeria

Adebisi (1992) compared the crushing equipment at local level into two, these are:-

i. Animal powered crushers

ii. Engine powered crushers

The sugarcane grower uses the crushers for the juice extraction.

2.3.1 Animal Powered Crushers

Thirty animal drawn crushers ("Kumar: Model) have been reported to be used in two villages in the northern part of the country (Nigeria). These were installed in or near the field and invariably run by a horse. In essence, the operation of the animal crusher is that the motion of a horse walking along a circular track is transmitted to a king (big) roller by means of a rigid wooden pole. The crusher requires two person, one feeding in cane and the second driving the horse. These person usually clear the accumulated bagasse and juice after crushing for about half an hour. The pulling force of the animal correspond roughly to one tenth of its weight e.g. cattle produced about 0.37kw (Mettre, 1989).

The performance parameters are: pulling speed, pulling force, crusher axle tongue and crusher capacity. The power available from the animal is given by

$$N = \frac{(P\ COS\theta)\ (\pi nR)}{30}$$ (Brief, A.T. 1989).

Where,

N = Power take-off from animal neck

θ = Angle between the direction of pull and actual travel.

P = Pulling force

n = Rotational speed of animal.

R = Radius of pull

The feeding rate can be increased by increasing the crusher axle tongue. Higher available tongue will help to crush more sugarcane. The only way to increase the crusher axle torque is by increasing the pull radius.

$$T = PRCOS\theta$$ (Brief, A.T. 1989).

Table 2.1 shows the average roller speed, crushing capacity pull or power juice output of horse and donkey.

Table 2.1: The average roller speed and crusher capacity pull of horse and donkey

Particulars	Horse	Donkey
Roller speed(rpm)	6	4
Puller of power	250 – 500	150 – 250
Crushing capacity cane Input (ton/hr)	0.30	0.15
Juice output for/hr	0.19	0.09

Source: Joukins, G.H. (1986).

2.3.2 Engine Powered Crushers

The operation of engine crusher involves power transmission from engines to crusher flywheel by means of flat belt. The engine crushing requires two or more persons for feeding, one for catching baggass and one to carry juice baggasses to the furnace and sun drying respectively. (Kalkat et al; 1980).

2.4 Industrial Processing of Sugarcane

The industrial milling process of sugarcane may be separated into two steps. The preparation of the cane by breaking down the hard structure and rupturing the cells and the actual grinding of the cane is done by revolving cane knives shredders that tears the cane into shreds and the crushers that break and crush the structure of the cane (Adebisi, 1992).

2.4.1 Cane Knives

The sugarcane delivered to the factory is loaded by different systems upon cane table from which, it is dropped onto cane carrier. Along the cane carrier the cane is leveled by "kicker" or by leveling knives. The cane is generally and disintegrated by two sets of knives before it is ground into pulp.

2.4.2 Shredders

For good extraction of sugar juice from the cane, fine shredding of sugarcane is essential. Knife rupturing of the cell is not enough for maximum successful extraction and the knife must be supported with a shredder (Olapade, B.C 1999).

With a well-designed shredder, 85% of the cells can be effectively ruptured. Shredders are indispensable for attaining a high crushing efficiency with high feeding rate and they also increase through put. (Olapade, B.C 1999).

2.4.3 Crusher

Crushers are two roller mills, widely used to prepare the cane for further crushing on three roller mills. The rollers of a crusher are normally grooved for a better grip. Crushers were once the only means by which the cane were disintegrated, but since the introduction of fast revolving knives and shredders. T/S important has diminished. In modern tandems the crusher installation has been eliminated (Okogie, K.T. 1980).

2.5 Existing Appropriate Technology for Sugarcane Crushing

The principle behind the operation of this appropriate technology in crushing sugarcane is simple. The machine can be operated by pedaling to rotate the grating drum hence crushing the cane fed into grating compartment via the hopper (Hassan, 2001).

Steps taken for its operation are:-

1. The hopper is fed with cut pieces of sugarcane stalk to be grated.
2. The power that is transferred to the drum via the shaft is first initiated by a temporary turning motion for it to accomplish full rotation by the pedal operated system that makes it rotate.
3. The grater crusher the sugarcane into rectangular chute and subsequently passed it to stage two for extraction of the liquid content from solid –liquid system of wet baggasses.

2.6 Crushing Force of Sugarcane

Crushing force is a measure of maximum load needed to cause failure or rupture in the micro structure of a material.

For sugarcane, a universal testing machine (impact or izod testing) is engaged. It is a direct reading instrument. The machine produces impact loading on the sugarcane stems. The stem (cut sections) is cut and load transverse along the axis of the machine. The crushing forces are recorded by the indicator of the machine in Newton (N) at initial development of failure under loading. This is done for several cut stem sections and varieties. The average result is taken (Adebisi, 1992).

2.7 Crushing Strength Variation

According to Adebisi (1992), the variation in the crushing strength of cane may be due to the toughness difference in the cane stalks. This may also be due to variation in the maturity period, the type of soil used for the propagation, soil condition, introduction of soil additive such as fertilizer or farmyard manure. Individual characteristic of cane could also be a factor. It was reported that for variety 1001 a maximum crushing force of 265 (N) for 1cm cut section of sugarcane state was obtained with a minimum crushing force of 140(N). Also, for variety 957 a maximum crushing force of 280 (N) for 1cm cut section of sugarcane state was obtained with a minimum crushing force of 95(N) variety 62175, a maximum of 260(N) for crushing force was required to rupture 1cm cut section of sugarcane stalks. It also has a minimum requirement of 115(N) for it to rupture.

2.8 Extracting the Juice

The prepared cane containing 70% to 80% of its weight as juice is pressed through various equipment as mentioned before.

The final product of the process is mixture of woody fiber and juice. It is a universal practice to add water to this juice or the baggasses after milling, thus diluting the contained juice and increasing the extraction rate as the juice is expressed. This process is termed maceration, inhibitions or saturation.

Maceration: - Sugarcane is almost 80% juice, yet after cutting the stalks into chips, the fiber retained the liquid like sponge, juice flows only when the shredded cane is squeezed in the crusher. About 60% of the cane juice is extracted in the crushers. Subsequently, the flows of juice diminishes, and the juice remaining in the baggasses after crushing has to be extracted by adding water or thin juice and squeezing (Yusof, S; Shuan, L.S. and Osmam, A. 2000).

The bagasses reabsorbed the sprayed water like sponge and swells. The swollen baggasses is fed into where the juice will be squeezed out and may burst additional cells from which maceration liquid washes the sucrose.

2.9 Need for Processing Sugar

Sugar grows with time and after reaching its peak, it deteriorates gradually, rapidly deteriorates from the moment of harvest. After cutting, sugarcane losses water (1-2)% daily for the first week, this loss gives an apparent but false increase in sugar contents (Yusof, 2000).

The enzymes invertase already present, converts sucrose to reducing sugar, thus lowering purity. Sucrose inversion varies with temperature and moisture and is most rapid. Deterioration can also occur as a result of mechanical damage during sugarcane handing. The dead and dying cells are invaded by leuconostoc, a bacterium that changes sucrose into dextran (William, 1980).

Dextran cause increase in juice viscosity slows crystallization, reduces yield, reduces quality throughout period of processing to refining state.

Olapade (2002) concluded that 19hrs delay is to long. Therefore the only control measure is to reduce the minimum time between the cutting of cane and it's crushing. Sugarcane must be processed immediately after cutting to prevent deterioration and sugar loss.

CHAPTER THREE

3.0 DESIGN METHODOLOGY

3.1 Design Concept

The objectives of this project is to design and construct a small scale sugarcane juice extractor that can be operated by hand (that is simplicity of operation) at relatively low cost. An effort is applied to the handle which holds the cane vertically with the aid of a cane holder and then presses the sugarcane against the drum, thus bringing about the extraction of juice from the sugarcane.

The calculations give the minimum permissible dimension on the basis of;

i. Allowable stress

ii. Stability

iii. Rigidity

iv. Wear

The following parameters were used in the design of the various components.

3.2 Design Considerations

The following factors were taken into consideration in designing and selecting the material for the construction of the machine;

i. **Availability of material:** Materials used were selected from locally available materials to aid the maintenance of the machine and parts damaged can be easily replaced at affordable prices.

ii. **Ease of Operation:** The operation of the machine was made easier by adopting electricity as the power source. This was achieved through the use of an electric motor.

iii. **Ease of Maintenance and Cleaning:** The machine was designed to allow for easy removal of its component parts to ensure machine durability and low maintenance cost.

iv. **Safety:** The proper covering of all moving parts to prevent direct contact by an operator using the machine so as to ensure safely.

3.3 Machine Description and Operational Procedure

The various parts of the machine (manually operated sugarcane crusher) are the frame, the turning handle, the shaft, the cane holder and the plat form.

The shaft is expected to be screwed and passed through a slot on a square hollow frame and held in such a way that is does not move up or down but only free to rotate. The shaft is to pass through the grating drum that carried the cylindrical gauge with the hopper joined to its top.

The cane handle is fitted with a regulator that enables the cane holder to firmly hold the sugarcane against the grating drum. There is also the platform on which the materials are loaded and also the supports.

3.3.1 Principle of Operation

The principle of operation is such that a cane holder enhances the vertical loading of the cane against the grating drum. The cane holder is fixed at one and on a pivot and a string attached to it at the other end to allow it exert a downward force on the holder and to at all time put the cane in contact with the grating drum.

A force is exerted on the handle to rotate the shaft while a force is applied to the handle to put the vertically loaded cane in contact with the grating drum to crush it.

The force exerted on the handle is transmitted down in form of torque to achieve the operating load for the crushing to take place.

3.4 Description of Component Parts of the Machine

The graphical illustration of the sugarcane juice as presented consist the following major component parts;

i. The grater unit hopper

ii. The grating drum

iii. Extractor chamber

iv. Shaft

v. Outlet

vi. Frame

vii. Bearings

i. The Grater Unit Hopper

This is a trapezoidal shaped container designed to hold the cut sugarcane and to keep it in contact with the grating surface. It is made from mild steel and designed with such shape to facilitate an easy flow and feeding convenience of sugarcane.

ii. The Grating Drum

It is cylindrical in shape and closed at both ends. It is made from a steel pipe of appropriate diameter. The crushing surface was then wound on the drum so that the action of the rotating shaft welded to the drum may be accomplished and in turn perform the crushing operation at the attached crushing surface.

iii. Extractor Chamber

This houses the grating drum as well as the product before discharging it through the outlet. It has a semi-circular shape.

iv. **Shaft**

It is stationary depending on its function and made of a solid circular cross-section. The grating drum rotates through the shaft which is directly attached to a pulley and belt powered by an electric motor.

v. **Outlet**

It is designed to channel the crushed cane from the grating limit to the hopper of the screw press.

vi. **Frame**

This component is constructed with angle iron. The frame gives support to the whole machine and makes it possible for the extracted juice and bagasse to be collected at an appropriate height from the ground level.

vii. **Bearing**

It permits relative motion of two parts in one or two directions with minimum friction, which tends to assist motion in the direction of applied loads. It has the same bore diameter with the shaft. Pillow bearing is used here to carry both axial and radial loads.

3.5 Design of Machine Component

3.5.1 Load Estimation

From the experiment performed, considering a surface area of 200mm x 200mm and a load of 20kg was placed on top of it. The maximum pressure required to rupture the cane is then calculated as;

$P = F/A$

Where, force is equal to the weight of the load = Mg

$M = 20kg$

$g = 10m/s^2$

$A = 0.2 \times 0.2 = 0.04m^2$

$F = Mg$

$F = 20x10$

$F = 200N$

Therefore, $P = F/A$

$$P = \frac{2000}{0.04}$$

$P = 5000N/m^2$

Designing for an average man exerting a force of 150N on the handle which is 350mm long. The force transmitted by the torque is calculated from the torque formula for power screw incorporated with collar radius.

$T = Fr$

Where $F = 150N$

$d = 350mm$

$$r = \frac{d}{2} = \frac{350}{2}$$

$r = 175mm$

$r = 0.175m$

$T = 150 \times 0.175$

$T = 26.25Nm$

Power delivered by an average man can then be calculated as;

$P_{man} = T\omega$

Where, $\omega = \frac{2\pi N}{60}$

$N = 30rpm$

$\omega = \pi$

$P_{man} = 26.25 \times 3.142$

$P_{man} = 82.48W$

$=0.0825KW$

3.5.2 Power Requirement for the Cane Extractor

There are 3 main components

1. Power to crush (Pc)
2. Power to drive wheel (P_w)
3. Power to drive crushing drum (Pd)

$P = P_c + P_w + P_d$

Diameter of cane = 45mm = 0.045m

Density of cane = 7840Kg/m^3

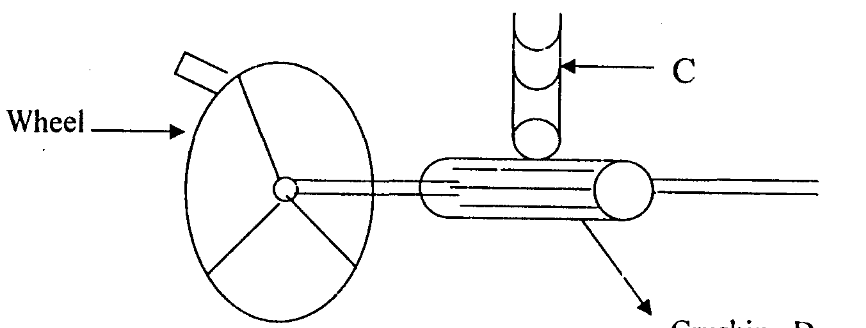


Fig 3.1: Crushing Force of Sugar Cane

i. Power to crush

$$P_c = \frac{F \times d}{t}$$

Where, $F = Mg = 20 \times 10$

$F = 200N$

$d = 0.045m$

$t = 1second$

$$P_c = \frac{200x0.045}{1}$$

$P_c = 9$ Watts

$=0.009KW$

2. Power to drive wheel

$P_w = M_w \times r_w \times \omega$

Where, M_w = Mass of wheel

r_w = radius of wheel

$\omega = \frac{2\pi N}{60}$ $N = 30$

$\omega = \frac{2\pi 30}{60}$

$\rho = 7840kg/m^3$

$V = \pi r_2 h$

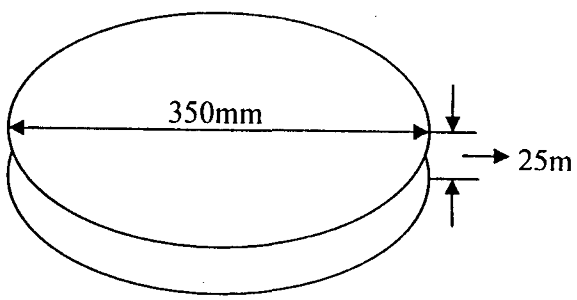


Fig 3.2: The Wheel

$M = \rho v$

$M = 7840 \times 3.142 \times 0.0306 \times 0.025$

$M_w = 18.85kg$

$P_w = M_w \times r_w \times \omega$

$P_w = 18.85 \times 0.175 \times \frac{60\pi}{60}$

$= 18.85 \times 0.175 \times 3.142$

$P_w = 10.36$watts

$= 0.0104$KW

3. Power to drive crushing drum

$P_d = M_d \times r_d \times \omega$

Where, M_d = mass of drum

r_d = radius of drum

$\omega = \frac{2\pi N}{60} = 3.142$

$\rho = 7840 kg/m^3$

$V = \pi r^2 h$

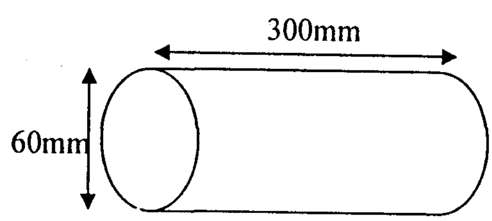


Fig 3.3: The Drum

$m = \rho v$

$= 7840 \times \pi \times 0.0009 \times 0.3$

$m_d = 6.65kg$

$P_d = M_d \times r_d \times \omega$

$P_d = 6.65 \times 0.03 \times 3.142$

$P_d = 0.627$Watt

$= 0.000627KW$

Therefore total power required for the cane extractor is then calculate as;

$P = P_c + P_w + P_d$

$P = 9 + 10.36 + 0.627$

$P = 19.99Watts$

$=0.0199KW$

The value obtained gives the power required by the machine comparing the power delivered by an average man with the power required by the machine i.e

$P_{man} > P_{machine}$

3.5.3 Bearing Design

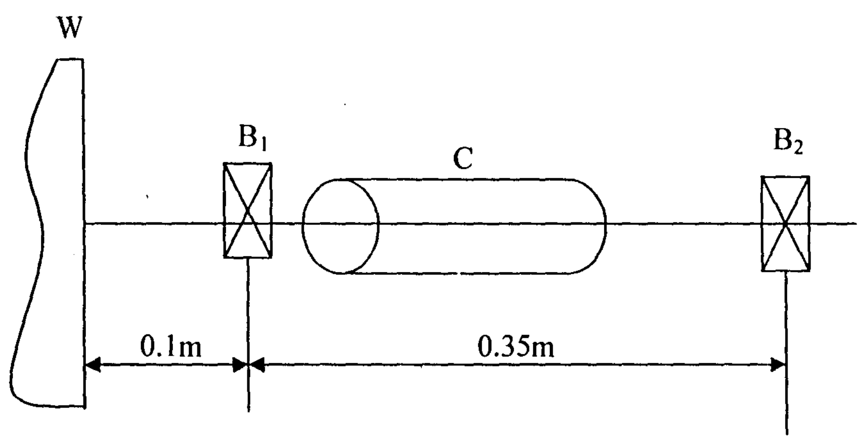


Fig 3.4: Free Body Diagram (A)

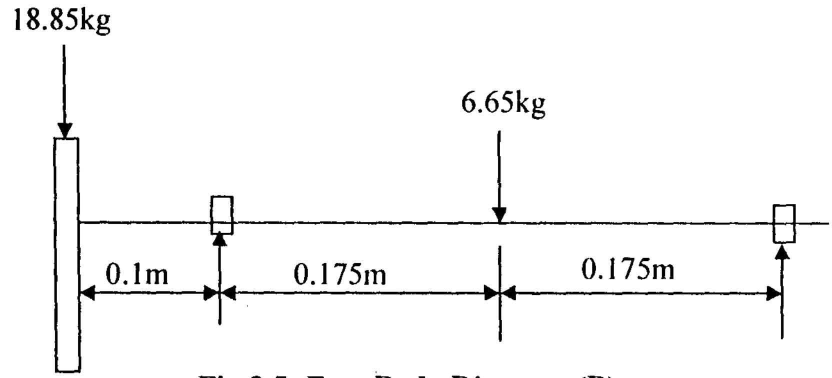


Fig 3.5: Free Body Diagram (B)

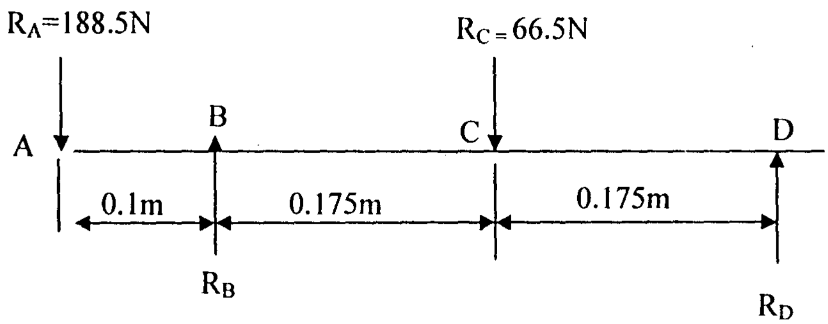


Fig 3.6: Free body Diagram (C)

$- R_A + R_B - R_C + R_D = 0$

$R_B + R_D = R_A + R_C$

$R_B + R_D = 0.1885 + 0.0665$

$R_B + R_D = 0.255$ 1

Take moment about point B

$(-0.1885 \times 0.1) - 0.0665 \times 0.175 + 0.35R_D = 0$

$- 0.01885 - 0.01164 + 0.35R_D = 0$

$$R_D = \frac{0.03049}{0.35}$$

$R_D = 0.0871KN$

From equation (1)

$R_B + R_D = 0.255$

$R_B = 0.255 - 0.0871$

$R_B = 0.1679KN$

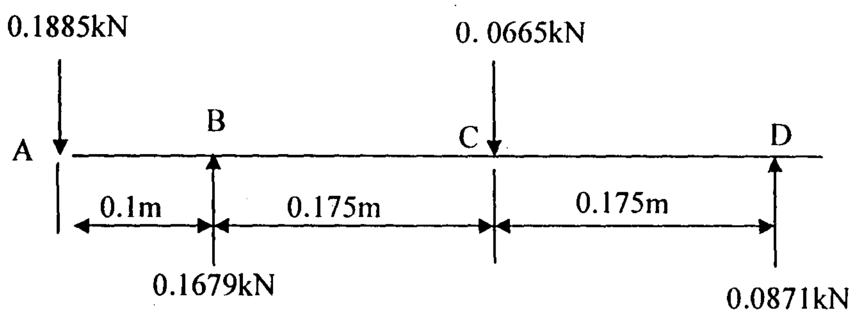


Fig 3.7: Free Body Diagram (D)

BM at point A = 0

BM at point B = -0.1885 x 0.1 = -0.01885KNm

BM at point C = (-0.1885 x 0.275) + (0.1679 x 0.175)

= -0.05184 + 0.02938 = -0.02246KNm

BM at point D = 0

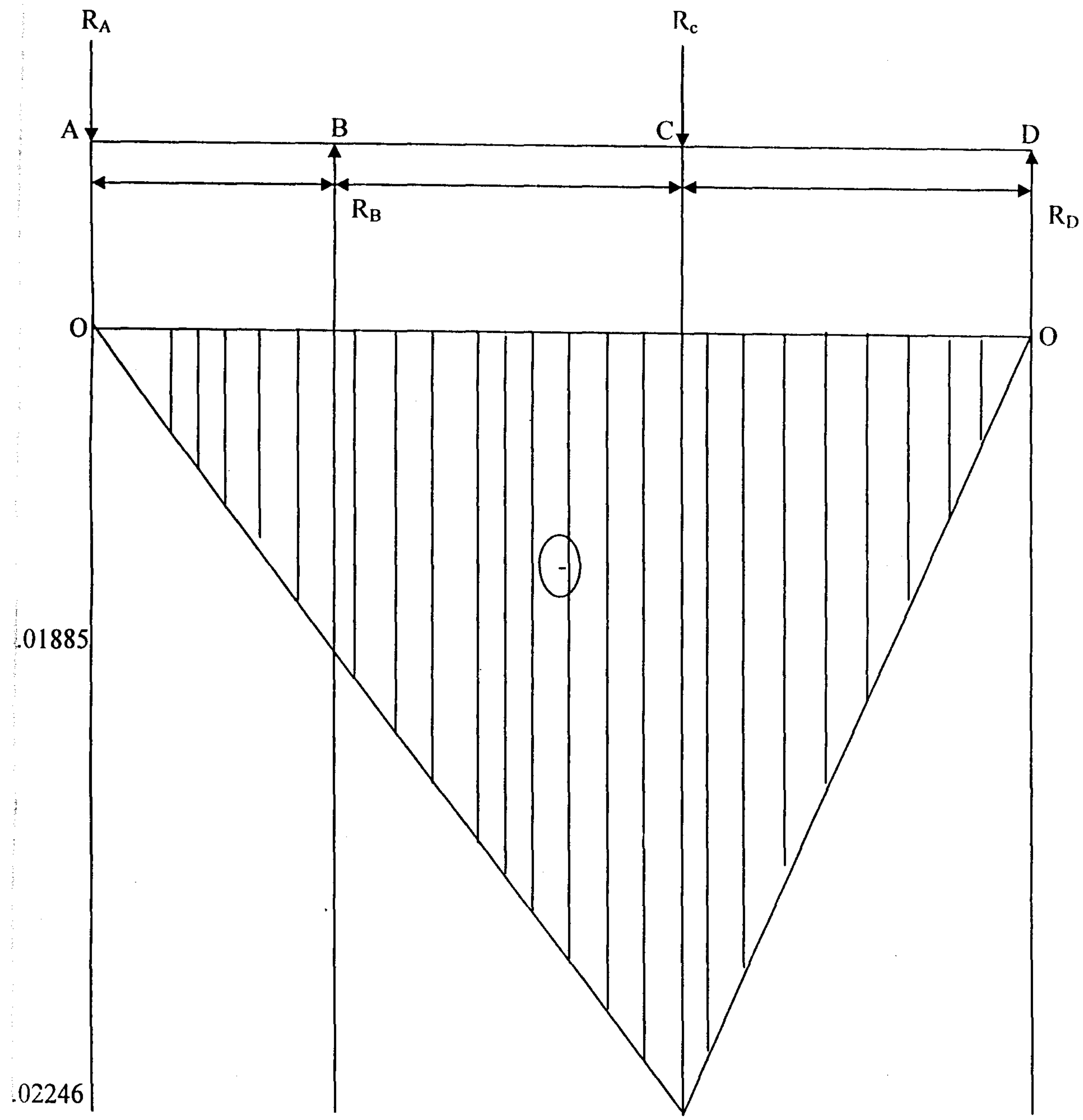


Fig 3.8: Bending Moment diagram

3.5.4 Shaft Diameter

The expression given below reveals the relationship between the maximum bending moment (M_b), the torsional moment (M_t), the diameter of the shaft (d), and also the allowable shear stress (S_A). From American Standard Equation (AMSE)

The expression writes thus:

$$d^3 = \frac{16}{\pi \delta a}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

Where:

$\delta a = 56 \times 10^6 N/m^2$

$M_b = 0.02246 \times 1000 = 22.46Nm$

$M_t = 26.25Nm$

K_b = combined shock and fatigue factor applied to bending moment = 1

K_t = combined shock and fatigue factor applied to torsional moment = 1

$$\therefore d^3 = \frac{16}{\pi \times 56 \times 10^6}\sqrt{(1 \times 22.46)^2 + (1 \times 26.25)^2}$$

$$d^3 = \frac{16}{175929188.6}\sqrt{504.45 + 689.06}$$

$$d^3 = \frac{16}{175929188.6}\sqrt{1193.51}$$

$$d^3 = \frac{16}{175929188.6} \times 34.547$$

$$d^3 = \frac{552.752}{175929188.6}$$

$$d = \sqrt[3]{\frac{552.752}{175929188.6}}$$

$$d = 0.0146m$$

$$d = 14.6mm$$

Therefore, the shaft of 15mm was used for construction of machine

3.5.5 Hopper Design

The hopper was designed to accommodate the maximum size of sugarcane with a clearance of 150mm on every side.

3.5.6 Cylinder Design

The cylinder was fabricated from a 1.6mm mild steel sheet to 100mm diameter, 300mm length. The square fed funnel of the hopper sits on an 80mm x 80mm opening on the cylinder.

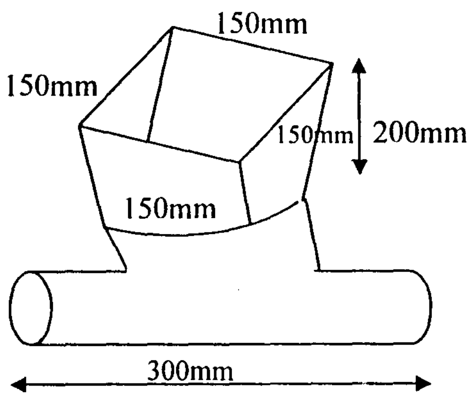


Fig 3.9: Cylinder with Hopper

3.5.7 Design of Crushing Surface

The crushing surface was designed using 8mm rods lined around the crushing cylinder at a distance of 30mm apart and angle of 36^0.

3.5.8 Design of the Turing Handle

The turning handle is made up of mild steel pipe attached to the wheel and the length is 150mm.

3.5.9 Frame Design

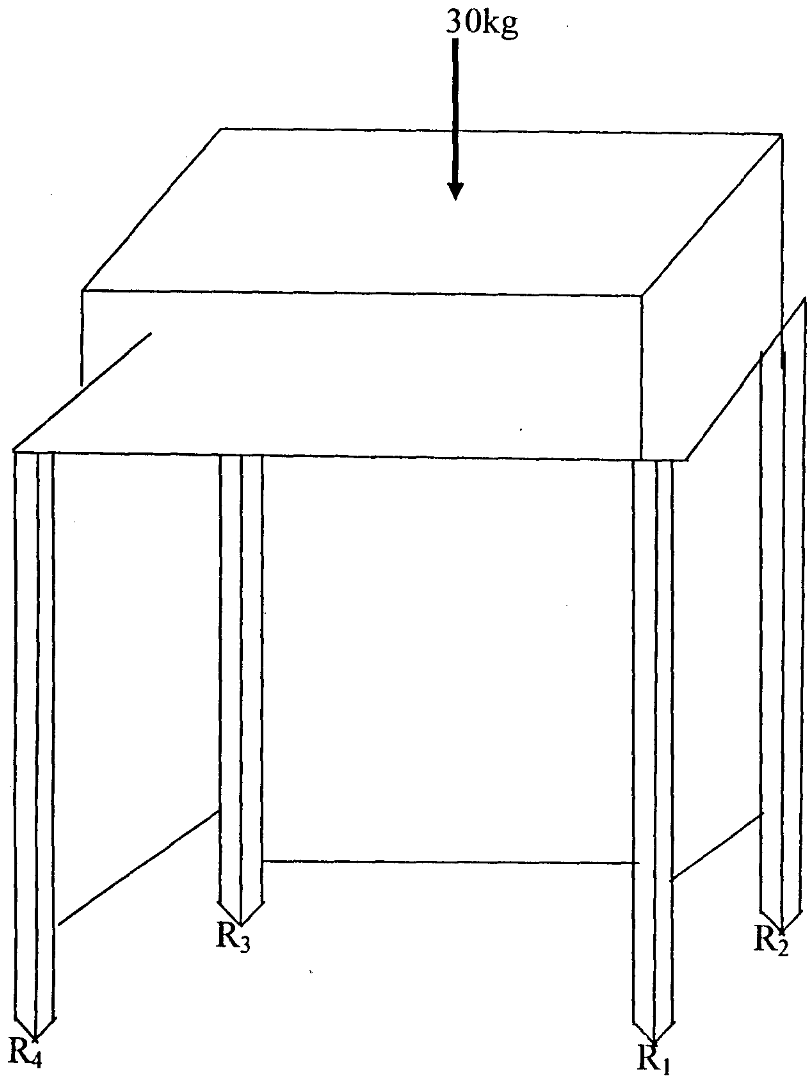


Fig 3.10: The Frame

Since the load is symmetrical, the reaction on each leg will be one quarter of the total weight that sacts on the four legs.

W = mg

Where, m = 30kg

g = 10m/s^2

w = 30 x10

$w = 300N$

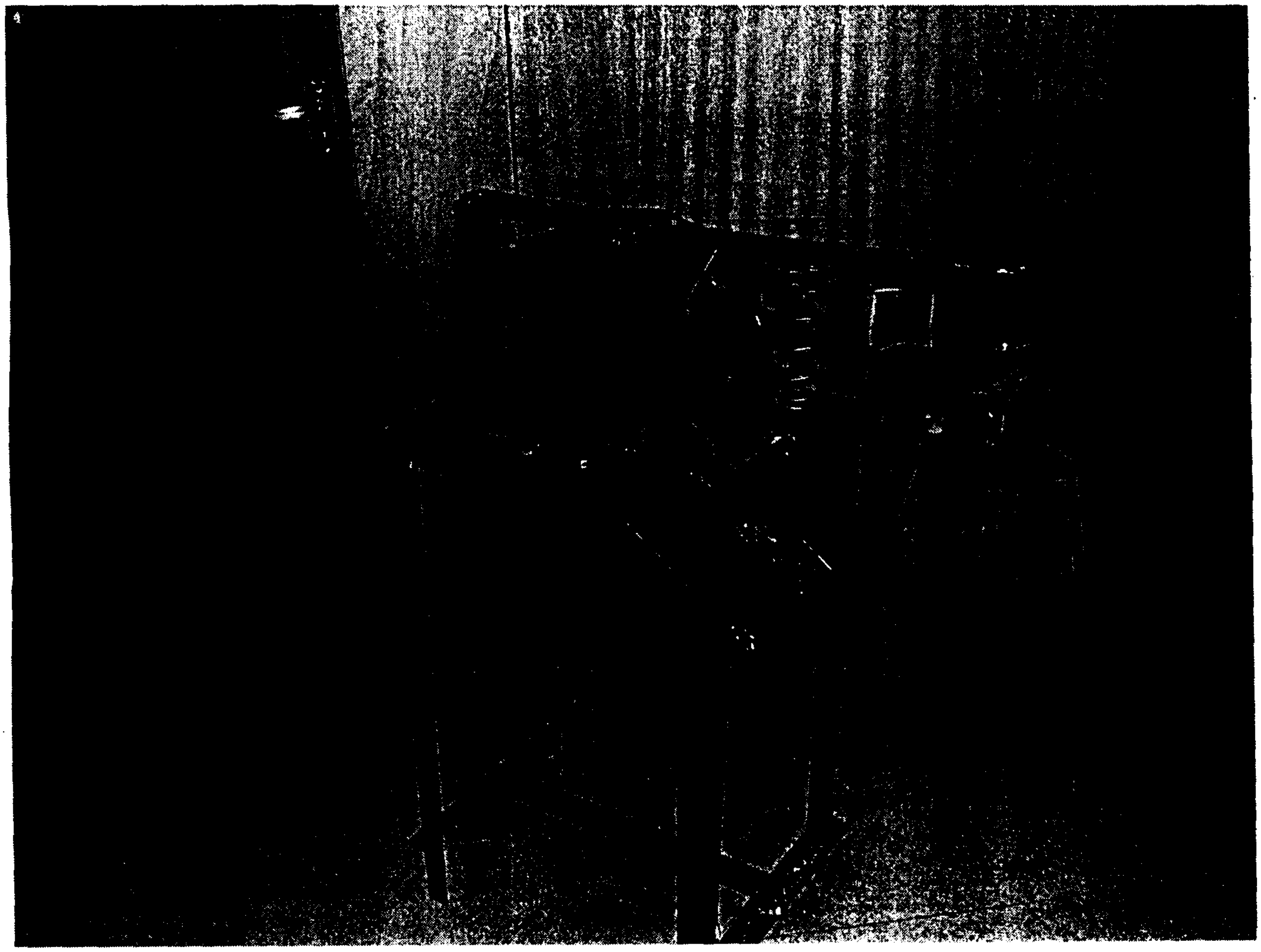
The total weight that acts on the four legs is 300N, then the reaction on each leg can then be calculated as;

$$\frac{W}{4} = \frac{300}{4}$$

$$= 75N$$

i.e. $R_1 = R_2 = R_3 = R_4$

$$= 75N$$



CHAPTER FOUR

4.0 RESULTS, DISCUSSION AND COST ANALYSIS

4.1 Machine Testing and Results

The manually sugarcane juice extractor machine was assembled together after all component parts were designed and fabricated, so as to carry out performance test of the machine.

Sugarcane stems were cut into uniform length of 50cm, after which the cut sections were weighed separately and divided into three and then fed vertically against the grating drum. The grating of the sugarcane was timed and the quantity of juice extracted quantified to determine the rate with which the machine extracts juice from the sugarcane. The table 4.1 shows the average extraction rate of the machine.

Table 4.1: The average extraction rate of the machine.

Portions	Wt. of sugarcane (kg)	Wt. of juice (kg)	Duration of operation T (min)
1	0.9	0.4	10
2	0.6	0.1	7
3	0.5	0.05	5
Total	2.0	0.55	22
Average	0.67	0.18	7.3

4.2 Discussion of the Results

The low quantities of juice extracted were due to some problems observed during the performance tests. It was observed that feeding the sugarcane vertically against the drum was not effective because the extraction unit of the machine was not functioning properly. It neither properly extract juice nor convey the baggasse off the extraction unit.

Secondly, the concave against which the grated sugarcane was pressed need to be reinforced with plate / bars to enhance squeezing out of the juice. It was also observed that the stability of the supporting stand of the machine need to be improved to make it more rugged as it required more people to keep the machine handing during operation in other for only one person to operate the machine with ease thereby reduce labour cost.

The low juice extract obtained were partly due to the rapid evaporation of the juice as soon as it gets out of the machine. Grating of peeled sugarcane was much easier manually than crushing unpeeled cane, because the fibre and nut nature of the sugarcane makes it somehow difficult for the grating drum to crush the unpeeled sugarcane easily.

The design is however an important step into making juice extraction from cane at the family / medium scale level a reality. It could provide jobs for some rural communities where this crop is abundantly produced to reduce rural-urban migration. Bulk transportation of cane is costly so if processing units can be established at the production areas it could solve such problems.

The recommendation for the improvement on the design is given here for further works to perfect the machine .The suitability and efficiency of this technology i.e. sugarcane juice extractor can be achieve through the evaluation of the present one and identifying its area of non –performance. These areas of non- performance are to be redesign and constructed for a better and more efficient performance.

4.3 Cost Analysis

Nigeria, as part of the developing country of the world has a very biting economy which had consequently affected the price of materials. There's being remarkably high prices of materials which and sequent hinders a plan for the future.

The material costs listed in the table below are the costs of the materials used for the construction of the machine as at December, 2009. These values may change depending on the market situation as at when visited.

Table 4.3: Material Costing and Analysis

S/No.	Material	Quantity	Cost (=N=)	Amount (=N=)
1	Mild steel	1 piece	1800	1800
2	Cylinder	1	1000	1000
	Metal bars	20	100	2000
3	Shaft	1	1000	1000
4	Angle bar	2 ½ length	1200	3000
5	Bearing	2	600	1200
6	Bearing house	2	500	1000
7	Paint	½ liter	500	500
8	Thinner	1 liter	150	150
9	Bolts & nuts	1 dozen	20	240
10	Wheel	1	1000	1000
	Total			**12890**

Material Cost = 12,890

Labour Cost

Labour cost involves the cost of machining, cutting, welding and painting. The project labour cost is determined as 60% of the total material cost.

Therefore,

$$\text{Labour Cost} = \frac{60}{100} \text{x } 12890 = 7734$$

Overhead Cost

This includes the costs that cannot be visibly accounted for (unseen expenditure) e.g. transportation, consumable materials, miscellaneous costs.

The overhead cost is 25% of labour cost

Therefore,

$$\text{Overhead cost} = \frac{25}{100} \times 7734 = 1933.5$$

Total Cost

The total cost could now be said to be the sum of the material cost, labour cost and overhead cost.

The total cost of the project

= material cost + labour cost + overhead cost

= 12890 + 7734 + 1933.5 = 22557.5 Naira

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

A sugarcane crusher that allows for vertical loading of sugarcane with the aid of holder was designed and constructed at family/ medium scale level. The manually operated sugarcane juice extractor machine was fabricated and tested. From the tests it was observed that the design needs further improvement to it more effective. However it can be concluded that such small scale wet baggasse production can actually cut down the cost of transporting bulk cane to distance markets and also stimulate local processing of sugar at village levels in the sugarcane production areas.

5.2 Recommendations

The results obtained after testing the sugarcane juice crusher necessitate the following recommendations for a more efficient machine:-

(i) For effective extraction of the juice, a perforated concave should be incorporated into the design with metal bar to avoid the chaff coming out with the juice.

(ii) For all parts coming in contact with the fruit, it is recommended that stainless steel should be used in place of mild steel due to its non-corrosive nature.

(iii) The shaft should be of screw type and the screw case should be perforated at bottom with a stopper to ensure maximum compression of the chaff / pulp.

(iv) Horizontal feeding instead of vertical should be adopted.

(v) The machine standing frame should be made of more rugged materials to ensure stability due to vibrations.

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