DESIGN AND FABRICATION OF A BELT CONVEYOR WASHER

BY

FAYAM ABIDEMI ESUGA

2006/24105EA

DEPARTMENT OF AGRICULTURAL & BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

FEBUARY, 2012

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

DECLARATION PAGE

I hereby declare that this project work is a record of a research work that 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 Information derived from personal communications, published or unpublished work were duly referenced in the text.

(Signature) 2/3/2012

Fayam, Abidemi Esuga Date

CERTIFICATION

This is to certify that the project entitled "Design and Fabrication of a Belt Conveyor Washer" by Fayam Abidemi Esuga meets the regulations governing the award of Bachelor of Engineering (B. ENG) of Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

Mr Segun Adebayo Emmanuel	28-02-2012. Date
Engr. Dr. P. A. Idah	29/02/2012 Date
External Examiner	22-02-2012 Date

DEDICATION

This project is dedicated to Arc A.S Fayam.

ACKNOWLEDGEMENTS

I give thanks to my creator, Almighty God for his undying love, care, direction, guidance, wisdom and understanding he showed me throughout my year of studies and for allowing me to complete this programme in good health and sound mind. To him I give all the glory

I also want to appreciate my project supervisor Mr. Adebayo Segun for sincere love and care, his comments and corrections on this project work, made it a success.

My special thanks also go to the Head of Department Agricultural and Bioresources Engineering Dr P. A. Idah, my level adviser Engr.Mrs. B.A Orhevba, all academic staff and the non academic staff, Dr I.E Ahaneku, Mr. Kehinde, Mallam. Mudi, thank you very much. Also I would like to thank my parents Arc and Mrs. Azo Solomon Fayam, My dear mum Mrs Funmilayo Hamza, Mr and Mrs. John Deffi, Brig Gen and Mrs J.G.S Hamakin, Miss Deborah Fayam, for their immense contributions both spiritually, financially and morally in making this dream a reality. I pray that God in his infinite mercy spare your lives to eat the fruits of your labour (amen). My project group members, Mr. Abduljelil Oladebo, Mr. Oladipo Olatunde, Mr. James Zechariah Garba.

I also wish to appreciate the effort of Late Mr. F.Enemodia and also, my sibling's, Yemialeye, Ahmed, Bala, Ayam, Ayekame, Tunji, Sokoeyame, Kabo and Eriatwasoko. Also my friends Terry, Emmanuel Ocholi, Andrew, Jibril, Tosan, Dapor, Frank, Haruna, Asoto, Uyo, Ega, my coursemates and specially Duniya Jeremiah, thank you and God bless you.

ABSTRACT

The belt conveyor washer was designed and fabricated to handle biomaterials, basically to effectively clean and transport agricultural products. The principle of transport of materials coupled with cleaning was applied to the design of this machine which is made up of a conveyor, water system (nozzles, pipes, control valves), water collector, belt conveyor cover, intake chamber (hopper), processing chamber, an outlet and a variable resistor which would clean biomaterials effectively immediately after harvest. This machine helps to increase the rate of washing operation in the industries, mostly in food processing industry in order to meet up with the increasing population demand. The evaluation test carried out on tomato gave the following results and thus, the washing efficiency of the machine as related the biomaterial (tomatoes) used which were samples A, B, C, D, E and F at variable speed and time are 58%, 65%, 68%, 72%, 75% and 93% respectively. The dirt remove increases as the time of washing increases (provided the biomaterial have no started absolving water) and decreases in the speed of the belt conveyor.

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Abbreviations or Symbols or Notations

Fa = Conveyor belt drive force N

N_2 = speed of the driven shaft in rpm rpm

N_1 = speed of the driving shaft (electric motor) selected rpm

D_2= diameter of the driven pulley selected m

D_1 = diameter of the driven pulley selected m

L = Length of the belt m

C = Centre distance between the two pulleys m

d_m = mass of the belt element; kg

R= pitch radius m

V= belt speed m/s.

ρb = density of the belt material Kg/m^3

a = belt across section area m

θ = Angle of wrap rad

$d\theta$ = elemental wrap angel, rad

T_1 = tight side tension of the belt.

T_2 = slack side tension of the belt (N)

μ = coefficient of friction between material of belt and pulley

α = angle of lap obtained

P= Power transmitted, kw

t = tongue

F = force required to chip

r = radius of shaft

Me= Effective /equivalent mass /wave of moving parts of the conveyor (belt mass) and load (N)

F = Effective belt tension (T1 +T2)

V = Linear speed of conveyor belt (m/s).

V_0 = velocity of dropping load (m/s).

V = linear belt speed m/s

T = maximum belt tension = $T_i + T_c$

b = Total width of conveyor belt

T_c = centrifugal belt tension N

m = mass per unit length of belt

δ = Allowable stress in the conveyor belt`

C= Basic dynamic load rating

$\times$ = Radial load factor ,

W = Equivalent dynamic load

v = a rotation factor

W_b = weight of the conveyor belt

M_b = mass of the conveyor belt kg

S_s = Allowable shear stress for a shaft without key way N/m^2

K_b = Combine shock and fatigue factor applied to bending moment.

K_t = Combine shock and fatigue factor applied to tensional moment.

M_b = Bending moment Nm.

M_t = Tensional moment Nm

W = Weight of the conveyor belt

APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

After harvesting fruits, food materials and vegetables during processing of biomaterials, the major problem encountered by farmers, industrialists, and individuals is the removal of soils, dirt, pests, bacteria, and other unwanted materials that affect the shelf life of the biomaterials which brought about the need to clean these materials in order to either improve the quality, shelf life or preserve the food and make it safe for consumption by individuals.

Material handing is movement of materials through the use of various forms of energy before they are further processed into the desired product, material handling equipment are essential accessories for large scale storage and structures. Material transport in these structures involves the use of facilities such as:

- Folk lift
- Screw conveyor
- Bucket elevator
- Pneumatic conveyor
- Belt conveyor

Cleaning of food materials are carried out essentially by some of the machines below, they help in removal of unwanted materials from biomaterials such as fruits, vegetables and foods in some food processing industries before further processing is carried out on them for final production:

1) Vibratory Feeders / Screens:

Are used in conveying, cleaning and the screens are manufactured in a wide range of sizes for various production demand and application which it is required for. Each unit of vibratory feeders or screens is compatible with all screening systems and separating of unwanted waste material, distributing and draining the products. These machines can be integrated into existing and current processing plants, and major merit of using the vibratory feeders or Screens includes accuracy of sizing, saving installation space and weight; which is an essential aspect of material handling of biomaterials.

2) Inspection or Sorting Conveyor:

This type of conveyor is composed of lane troughs, curves, and chutes, which are used to separate unwanted materials and design of this conveyor is to maintain the quality; they also collect waste materials separately and biomaterials in a different part also during processing of agricultural products.

3) Grading Machine:

These machines are used for cleaning, grading, processing, handling food, vegetables and fruits depending on the individual requirements; they are also used to storage of seeds, grains, spices, pulses, oilseeds. Grading machines are designed according to the need, use and demand of the customer or individual. (Maggs, 1973).

4) Fruit and Vegetable washing machine:

Fruit and vegetable washing machines such as; Brush Washer, Rotary drum washer, Continuous Roller brush, Jar washer, Rinser machines which are also manufactured according to requirement, and they are as follows:

- a) Brush Washer: are used for washing food materials, Vegetable, Fruits for piece products, and they are made with vertical rotating brushes and discharge belt insertable side brush panels on inside walls.
- b) Rotary drum washer: Rotary drum washer is used for washing cucumber, vegetables and fruits for piece products. The drum is fully lined with brushes. Inside water jet sprayers provided for efficient and effective cleaning of biomaterials.
- c) Continuous Roller brush: This type of brush is used for cleaning biomaterials which are round in nature like tomato, apple, and orange etc. The materials moves on series of roller brushes, and cleaning is provided by the water jet spray nozzles inside the machine.

A Conveyor is a vertical or horizontally inclined mechanism which can be used in moving or transporting bulk material packages, or objects in a path predetermined by the design of the service and having points of loading and discharge fixed or selective which can be powered by gravity. Belt conveyor over the years has been an important machine used to transport products either in straight or directional changes and elevation, and the major purpose of the belt is to provide controlled movement of the product. Belts are designed in different sizes which mostly operate in different speed ranges. The belt conveyor is perhaps the most widely used equipment in transporting; they are also used to transport material into processing equipment used to deliver the product to cooking or sealing equipment, then off to packaging, essentially it consists of an endless belt running over a set of drive and driven pulleys, supported by idlers in between. There are different types of drives generally used in driving the belt conveyors such as single pulley drive, two pulley drive and multiple pulley drives etc. Belt conveyor can be classified in to two types, the heavy type such as for mining conveys and the light type for plastic, food and chemical industry etc.

The belt conveyor washer operates under a very high pressured water which are transmitted through nozzles and the effect of the action combined with pneumatic, gravitational and mechanical inertia to bring about effective cleaning of the biomaterials (mostly spherical food materials) and this is possible due to the nature of the belt conveyor, thus the food materials present their body and roll over the belt for effective cleaning during processing, after harvest.

1.2 Statement of Problem

Over the years the preliminary operation in processing of food, fruits, vegetables and other biomaterials have been a major problem because most industrialists, farmers and food engineers consider the cleaning of biomaterials to be very tidious and stressful but due to the essentiality of this process in production, cleaning cannot be neglected which now brings about a need to develop a machine to carry out this operations. The machine enhances effective cleaning, improves efficiency and reduces drudgery and thereby reducing the cost of labour, increasing production yield and saves a lot of time.

1.3 Objectives

The objectives of the study are:

1. To design and develop a belt conveyor washer for preliminary cleaning processes.

2. To carry out a performance evaluation on the machine designed.

1.4 Justification

The design of this machine will reduce stress and drudgery involved in cleaning of biomaterials immediately after harvest from the farm before processing into finished food materials for sale and consumption. Thus, this will reduce the cost of production, make cleaning more pleasant, and extend the shelf life of the biomaterials.

1.5 Scope of study

The project reports the design and fabrication of small scale washer used in batch process of cleaning biomaterials, the conveyor belt washer was made from the readily available materials which can used in effectively cleaning biomaterials like oranges, tomatoes, pepper, mangoes, Irish potatoes and vegetables thoroughly.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Cleaning of Biomaterials

In agricultural processing the preliminary preparative operation of cleaning goes along with sorting and grading of foods, fruits and vegetables and all these operations are referred to as unit operations and they are very essential in processing in order to obtain the desired output and save cost and effectively manage time. The various classes involved in cleaning of biomaterials are:

(i) Cleaning: cleaning seperates contaminants like micro organisms, dirts and sand from the biomaterial before they are further processed.

(ii) Sorting: sorting seperates the biomaterials into groups and categories of different physical characteristics like shape, size, and colour etc. Sorting and Recycling are also an important mechanism when sorting reusable products. Cairncross (1992) and Srivastava (2007) suggested, that collection schemes should be classified according to materials whether separated by the consumer (separation at source) or centralised unwanted materials. (Laperiere and ElMaraghy, 1992).

(iii) Grading: grading is processing operation which specifically seperates biomaterials into their various quality.

The classification is very essential since cleaning, sorting and grading are dependent on each other in which both cleaning and sorting leads to grading and grading always involves sorting of some kind in the processing of agricultural products and they are all carried out to improve quality and obtain the best yield from the product and for food safety for both human and animal consumption. (Anon, 1985).

2.1.1 Functions of Cleaning

In cleaning of agricultural raw materials during food engineering the industrialist or processor aims at achieving the following functions:

- The control of microbial loads, chemical and biochemical reactions which impair subsequent process effectiveness and product quality.
- The removal of contaminants which are aesthetically unacceptable and constitute a health hazard on both man and farm animals. (Hersom, 1980)

2.1.2 Requirements of an effective cleaning

1. The contaminants must be removed completely after separation in order to prevent recontamination of the cleaned fruits, vegetables and food materials.

2. The process and equipment should be designed in such a way to limit recontamination of the cleaned food material, for example by contaminated wash water from previous batch cleaning processes, and by flying dust. (Anon, 1984).

3. Damage of the product must be avoided.

4. The efficiency of the separation process must be very high and should be consistent with minimum wastage of good fruit and food materials.

5. The volume and strength of liquid effluents must be kept to a minimum.

6. The cleaning process must leave the cleaned surface in an acceptable condition.

(Gorham, 1981).

2.1.3 Contaminants in Food Raw Materials

Generally contaminants in food raw materials affect the shelf life of fruits and food materials, the contaminants involved in cleaning ranges in molecular size, such as trace toxic metals, taints are substances that contaminate food materials with dangerous and undesirable produce, spray residues etc. These substances are gotten through microorganisms which are found on the tractor and machinery parts during harvest, processing, handling and storage of food materials, and thus there is an occurrence of mineral, plant and animal contaminants in food raw materials. Similarly the use of agricultural sprays provided an added hazard in food processing which makes cleaning of food materials very difficult. (Smith, 1983).

2.1.4 Types of contaminants

1. Mineral contaminants: These types of contaminant includes soil, sand, grease, stones, glass fragments, particles and oil that are found in the food raw material after harvesting of fruits and food materials before they are processed in food production industries.

2. Animal contaminants: These are contaminants which might have dropped when manure is being added to a plant or during grazing by farm animals and during farm operations, these contaminants includes excreta, hairs, feathers, insect eggs and body parts.

3. Plant contaminants: these type of contaminants are found on the plant body during the growth of a particular crop and are inevitable because the crops need them for respiration and other plant activities, and these contaminants have to be removed during processing. They include; twigs, foliage, stalks, pits, skins, husks, wood pieces, string and rope.

2.2 Cleaning Methods

In food processing the wide variety of contaminant encountered in raw food materials and the low tolerance permitted for these contaminants calls for a variety of cleaning methods to be adopted. The methods in use fall into two groups:

(i) Dry Cleaning Methods: the dry cleaning methods is an operation carried out to separate unwanted materials without the use of water and they are; screening, brushing, aspiration, abrasion, abrasion, magnetic separation.

(ii) Wet Cleaning Methods: in this method of cleaning water is employed to remove unwanted materials effectively and they are; soaking, spraying, fluming, flotation, ultrasonic cleaning, settling and filtration.

This process is used, almost invariable, in combination the methods employed depends on the nature of the raw material, the contaminants to be removed and the desired condition of the cleaned material.

2.2.1 Dry Cleaning Methods

These methods have the advantages of relative cheapness and convenience whilst the cleaned surface is left in a dry condition. However, unless considerable care is taken to minimize the spread of dust, recontamination can occur. Further, the dusty conditions encountered during dry cleaning can give rise to fire and explosion hazards.

2.2.1.1 Screening:

Screens primarily are size separators which fall into the category of sorting equipments and the remove contaminants of different sizes from that of the raw material, a screen simply is a perforated bed which is supported on a frame. The screens used in most food processing industries have an elementary pattern and they are of two types namely; Rotary drum screens and Flat bed screens. (Greg, 2008).

2.2.1.2 Abrasion Cleaning:

In this type of cleaning, abrasion between food and moving parts of the machinery used in cleaning that particular material, in this process adhering contaminants are removed, and this can be achieved by using tumblers, trommels, abrasive discs, rotating discs and vibrators. (Quaas, 2004).

2.2.1.3 Aspiration Cleaning:

This method of cleaning is also referred to as winnowing and it is used in removing debris which differs in buoyancy and aerodynamic properties. This method uses the principle in which the material to be cleaned is fed into a stream of air at a controlled velocity and it is separated into two or more streams which are light, middle and heavy. It is usually arranged from the cleaned product to the discharged as the middle stream leaving heavy debris like stones, pieces of metal or wood behind whilst floating off light debris such as stalks, husks and hairs. An example of this type of cleaning machine is the Sortex air separator and it cleans onions, melon, eggs and other foods which cannot be cleaned by wetting. (Hurburg and Buresch, 1996).

2.2.2 Wet Cleaning Methods:

This method of cleaning is very effective means of removing firmly adherent soils, and it also allows the use of sanitizers and detergents. It involves the use of water under high pressure on the surface of the materials like fruits and food that last long even after water is been applied and needs to be cleaned. Wet cleaning method has some major disadvantages such as; large quantity, quality and very reliable source of water is needed, very costly, treatment of effluent, wet surfaces spoil easily which brings about a need to remove the water (dewatering). As such when wet processes are carried out during production, attention must be paid to water conservation and management. (Krochta and Belows, 1974).

2.2.2.1 Spray Washing

This method of cleaning is most widely used in wet cleaning with the surface of the food being subjected to water sprays, and a small volume of water at very high pressure, is most effective for the cleaning operation. The spray washers are in a wide range of sizes and shapes depending on the pressure which is needed for that particular material and what it is meant for. It can also be identified by the nozzle "number", a four or five digit number that is stamped on the nozzle, which indicates the spray angle and orifice size. In all cases the first two digits of the nozzle number indicate the spray angle (disperse) in degrees, which range in 00 is 0^0, 15 is 15^0, 25 is $25^0$and 40 is 40^0 and it corresponds with the orifice size. The last two digits of the nozzle number indicate the orifice size, a standard industry designation, and the position of the nozzles in the machine effects the cleaning of these materials

The spray washers can be used for the following in agricultural processing;

1. Removing caked on mud from heavy construction, farm or lawn equipment (0^0 nozzles).

2. Light cleaning and washing of biomaterials (15^0 nozzles).

3. Removing grease or dirt from equipment (15^0 nozzles).

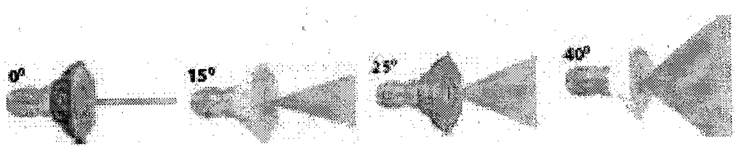


Plate 2.1 Different nozzle angles

However, damage can be caused to some soft and ripe fruits, such as strawberries, mangoes, delicate vegetables like asparagus and sometimes high pressure sprays are used to cut out damaged parts in peaches, berries and tomatoes, it also removes adherent soils and black moulds on citrus fruits, (Smith, 1983)

- Spray Drum Washers: The spray drum washer consist of a reel constructed of metal slats or rots spaced so as to retain the food whilst allowing debris to be washed through. The drum, which rotates slowly, is inclined to the horizontal. The speed of rotation and angle of inclination control both the movement of the food within the drum and the duration of the washing cycle. The washer is equipped with a central spray rod which is fitted with jets or slots through which water is sprayed. Whilst the abrasion which occurs in this washer is useful in loosening dirt, it may be cause damage to some foods.

- Spray Belt Washers: this type of spray washer is simply a conveyor (e.g. a perforated belt) which carries the food beneath banks of water sprays. With roughly spherical foods such as apples, contact is improved by using roller conveyors which cause the fruit to spin beneath the sprays. For smaller foods, movement under the sprays may be produced by using a vibratory conveyor. The problems of water conservation and effluent generation, already referred to, have spurred research into many aspects of food processing. Example includes the development of reduced –water blanching (section and peeling process). A development in the field of wet cleaning is the USDA Rubber –Disc Cleaner. In this process, tomatoes are first freed of gross contamination in a soak tank and are then conveyed mechanically into a shallow channel, 10m long by 0.3m wide, in which adherent soil is removed in 15-25 seconds by exposing the fruits to brushing action of soft rubber discs.

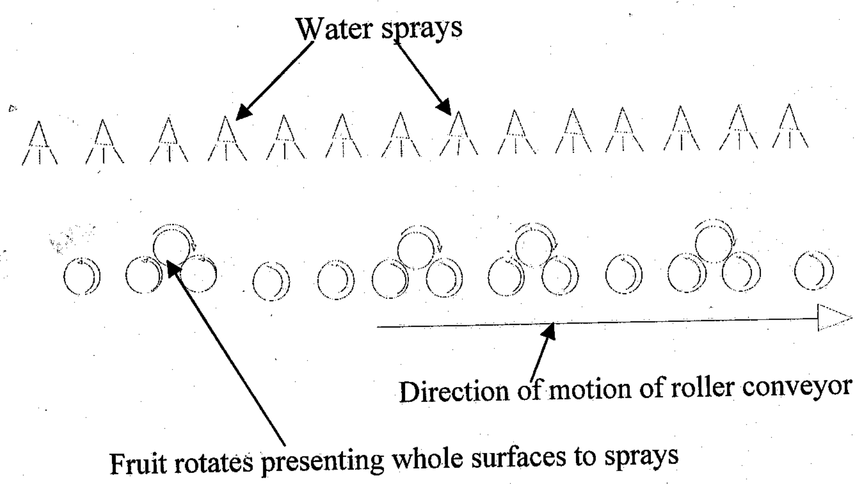


Fig 2.1 Water Sprays

2.3 Types of Washers

There are various types of washers which have been used over time in the making agricultural raw materials fit for during processing of biomaterials, each type of equipment vary in the mode of operation and particular type of material which is to be cleaned in order to increase the shelf life of the product.

2.3.1 Vibratory Washer

The vibratory washer washes and dewaters biomaterials in a single space-saving unit; ideal for some materials like peeled onions, radishes, strawberries, and peppers with several screen configuration options during processing.

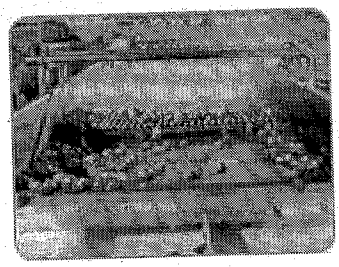


Plate 2.2 Vibratory washer

2.3.2 Flite Roller Table

The flite roller table removes impurities like dirt, debris, vines, and small loose product. This food roller-sizer cleans fruits, vegetables, and potatoes early in the process with minimal loss of good product in the biomaterials which is to be cleaned.

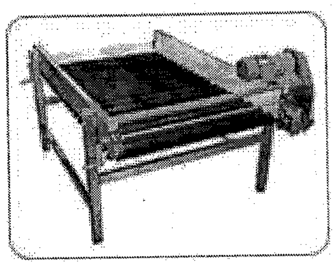


Plate 2.3 Flite Roller Table

2.3.3 Basket Washer

The basket washer makes use of minimal quantity of water for small batch runs, pre-washing or second washes with a wide range of fresh-cut greens, florets, or cut vegetables; this equipment also helps to save waste water on both the farm and food processing industries.

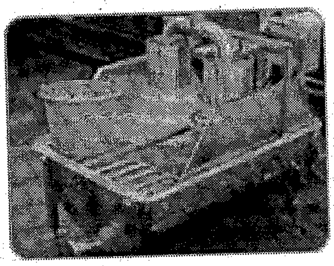


Plate 2.4 Basket Wash

2.3.4 Froth Flotation Cleaner

The froth flotation cleaner was developed over 50 years ago; the Froth Flotation Cleaner was the first in processing equipment line in some countries. Until today, it helps to effectively clean and remove insect fragments and eggs in flour and herbs from biomaterials like legumes such as peas, beans, corn, and other agricultural produce.

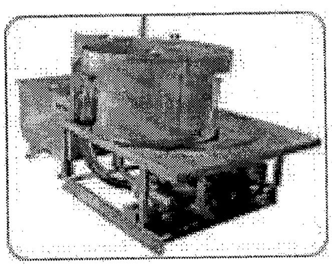


Plate 2.5 Froth Flotation Cleaner

2.4 History of a Belt Conveyor

The history of belt conveyors began in the latter half of the 17th century and since then, conveyor belts have been a major and essential part of material transportation. But it was in the year 1795 that conveyor belts became a popular means for conveying bulk materials and that period conveyor belts were used only for moving grain sacks to short distances only. (SUR, 1987).

The belt conveyor system and working were quite simple in the early days the system had a flat wooden bed and a belt that traveled over the wooden bed. Earlier, conveyor belts were made of leather, canvas or rubber and this ancient and primitive conveyor belt system was well known for conveying bulky items from one place to another and with this, in the beginning of the 20th century, the applications of conveyor belts became wider and relatively used(Jeffrey, 2006).

Hymle Goddard of Logan Company was the first to receive the patent right for the roller conveyor in 1908 after which the roller conveyor business did not prosper. Then a few years later, in 1919, powered and free conveyors were used in automotive production. Thus, belt conveyors became popular tools for conveying heavy and large goods within factories and production industries. (Hounsel, 1984).

2.5 Material Handling

Material Handling is simply the loading, movement and unloading of biomaterials during the processing of agricultural materials. Material handling is essential for large scale storage and processing of biomaterials. (Bal and Mishra, 1988).

Material handling is a process necessary to maintain the quality of agricultural products and the conveyor which is a major machine used in material handling is a mechanical system for transporting materials from one site to another; they are widely used in industrial and business operations. They include simple chutes, the unpowered roller conveyors used to move cargo across sidewalks from trucks to stores, and a wide range of powered systems in which materials are carried along by belt, bucket, screw, trolley, or other arrangement, during the first stage in the recovery process. Products are selected, collected and transported to facilities for remanufacturing, and the used products came from different sources and should be brought to product recovery facility to begin the converging process. (Moshenin , 1980; Aviara et al, 1999).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1.0 Design Consideration

The design of this machine was based on certain factor which will affect the performance of the machine. These factors were taken into consideration after carefully analysis of the information obtained from literature. Some engineering properties of materials are discussed below;

1. **Strength of material:** The strength of materials is relevant to resist the stresses and strains induced when the structure is in service.

2. **Durability:** Materials are considered durable if they retain their strength and other properties over a considered period of time. This characteristics will depend on the material and service condition; for example, a material maybe durable for some purpose and not for others.

3. **Resistance to Corrosion:** The degree to which material resist chemical combinations with other material with which it come in contact is a measure of its resistance to corrosion.

4. **Hardness:** The hardness of a material is a measure of its resistivity to indentation and how it can be maintain.

5. **Toughness:** Is the capacity of a material to resist fracture under impact loading.

6. **Workability:** This is the characteristics of a material which measures the ease with which it can be worked or shaped, work ability is dependent on the characteristics of the material, the working tools and the construction method applied.

7. **Ease of Cleaning:** This quality is important in surfacing wall cleaning of the machine. It is usually associated with the density of the surface material and hardness.

8. **Appearance:** Appearance embraces color and texture. These elements are to large subjective qualities. Other factors to be considered are cost of maintenance, cost of materials, and the cost of alternative materials that can be used.

3.2.0 Design Assumptions

1. Prime mover (Electric motor) used. 1hp (0.746KW) Single phase, 240v, 60Hz.
2. Speed of the motor 740 rpm (Khurmi and Gupta, 2004)
3. Diameter of the driven pulley (D_2) 190 mm.
4. Diameter of the driving pulley (D_2) 60 mm.
5. Flat belt linear speed 1.95 m/s.
6. Number of arms of pulley 6.
7. Factor of safety to evaluate the safeness of the shaft is 4.
8. Bearing of the shaft selected (Sealed pre-lubricated) Ø 25 mm.

3.3.0 Design Calculation

3.3.1 Design Calculation/ Kinematics of V- belt Drives

As a belt bend to conform to the sheave curvature, the over section stretches and the inner section is compressed. The diameter of the sheave is determined by the position of the load caring cords within the belt cross section. The pitch diameter other than outside diameter of the sheave should always be used in calculating speed ratio and belt ratio. If tow pulleys (the driving pulley and the driven pulley) are connected by a belt so that rotation of one causes the rotation of the other. The belt speed (m/s) is calculated as follows;

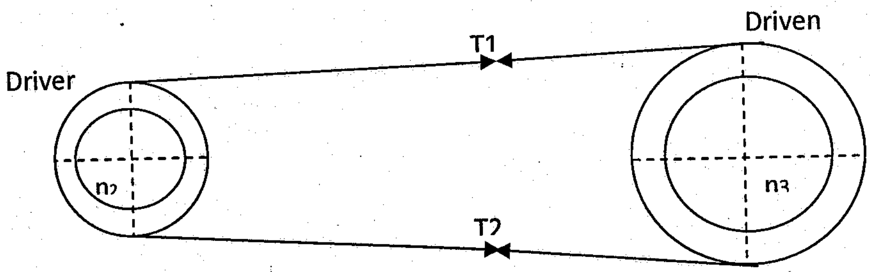


Fig 3.1 Belt tensions and moment on the sheaves.

$$V= A = \pi n_2 Dp^2 = \pi n_3 Dp^3 \qquad (1)$$

$$\text{or} \quad \frac{n_2}{n_3} = \frac{Dp^3}{Dp^2} \qquad (2)$$

(Khurmi and Gupta, 2004)

Where $_2$, n_3 = angular speed of rotation of the of the driving and driven pulley respectively (rpm)

Dp^2, Dp^3 = pitch diameter of the driving and driven sheave respectively (m)

From equation (1) $N_2 = \frac{N_1 D_1}{D_2}$

N_2 = speed of the driven shaft in rpm

N_1 = speed of the driving shaft (electric motor) selected = 740 rpm

D_2 = diameter of the driven pulley selected= 190 mm

D_1 = diameter of the driven pulley selected = 60 mm

Therefore the speed of the driven pulley is given as; $N_2 = \frac{(740)(60)}{190} = 233.6$ rpm

3.3.2 Belt selection

The standard sized of V-belt for power transmission have been adopted and designated by sizes A, B, C, D and E. The commonly used are A and B. Below is the table which shows the selection and dimension of the V- belt.

Table (3.1) Belt selection

Normal horse power	1,800 (rpm)	1,200 (rpm)	900 (rpm)	720 and below (rpm)
0.3 to 1.5 hp	A	A	A	A
2.0 to 5 hp	B	B	B	B

Source (khurmi and Gupta, 2004)

The A type of belt was selected for the purpose of this project. This was due to the one horse power (1hp) used.

3.3.3 Determination of the Centre Distance of the Belt

$C_{min} = 0.55(D_1+D_2) + 3t$ (3)

$C_{max} = 3(D_1+D_2)$ (Shama and Aggarawal, 1998) (4)

$C_{min} = 0.55(190+60) + 3(8) = 0.55\ (250) + 24 \quad = 161.5$ mm

$C_{max} = 3(190+60) \quad 3(250) \quad = 750$ mm

$C_{min} < C < C_{max}$

Using $C = 2.5(D_1+D_2) = 2.5(250) \quad = 625$mm

3.3.4 Determination of the Length of the V-Belt

$$L = 2c + \pi\frac{(D_1-D_2)}{2} + (\frac{(D_2-D_1)2}{4c})$$

Where L = Length of the belt (mm)

D_1 and D_2 are the diameters of the smaller and larger pulley (mm)

C = Centre distance between the two pulleys = 625 mm

$$L = 2(625) + 3.142\ (\frac{190-60}{2}) + (\frac{(190-60)2}{4(625)})$$

1250+ 204.23 + 6.76 = 1460.99mm = 1.46 m

3.3.5 Force Acting On an Element of V-Belt

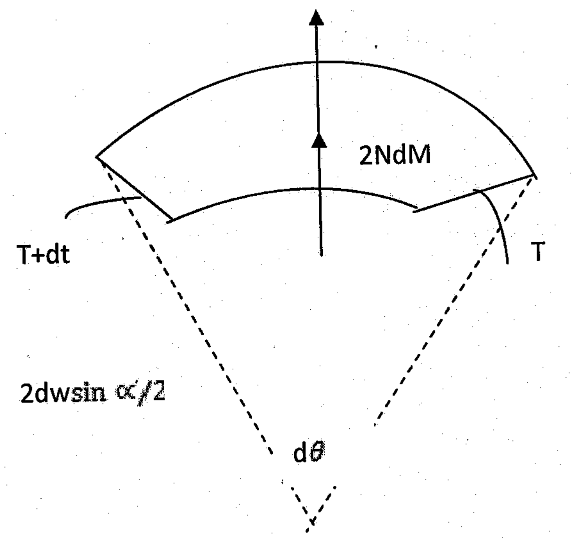


Fig 3.2 Force acting on an element of V-belt

The centrifugal force (dc) is given as;

$$dc = \frac{dmv^2}{R} \tag{5}$$

Where dm=mass of the belt element; kg

R= pitch radius; m

V= belt speed; m/s.

Elemental belt mass (d/m) can be obtained by multiplying the design of the belt material by its volume as follows;

$$dm = \rho b a R d\theta \tag{6}$$

Where ρb = density of the belt material. Kg/m^3

a = belt across section area, m^2.

$d\theta$ = elemental wrap angel, rad.

Substituting equation (3) into (4) we obtain;

$$d_c = \rho b a v^2 d\theta \quad (7)$$

Summing forces in the radial direction we get;

$$d_c + 2d \sin(x/2) - T\sin(d\frac{\theta}{2}) - (T-dT)\sin(d\frac{\theta}{2}) \quad (8)$$

Let $d_N = P_N R d\emptyset$ where Pw is the normal reaction force per unit belt length. Substituting the expression for dc and dN in equation (7) and taking the limit we get

$$\rho b a v^2 + 2P_N R \sin(\frac{x}{2}) - T = 0 \quad (9)$$

If the belt is not transmitting any power, the tension in the belt would only be due to the centrifugal force. i.e. $Tc = \rho b a V^2$ Substituting this in equa. (9) and solving for P_N we get;

$$P_N = \frac{T - Tc}{2R\sin(\frac{x}{2})} \quad (10)$$

Summing force in the tangential we get $(T+d_T)\cos(d\frac{\theta}{2}) - T\cos(d\frac{\theta}{2}) - 2wP_N R d\theta = 0$ (11)

which in the limit become;

$$dT - 2NP_N R d\theta = 0 \quad (12)$$

Substituting for P_N, letting $k = N/\sin(x/2)$ and rearranging we get;

$$\frac{dT}{T - Tc} = \frac{N}{\sin x/2} d\theta \quad (13)$$

Integrating we get $\int_{T_2}^{T_1} \frac{dT}{T-Tc} = K\int_0^{\theta} d\theta$ (14)

Carrying out the integrating, applying the limit and rearranging we get;

$$\frac{T_1-Tc}{T_2-Tc} = e^{k\theta} \quad (15)$$

If the belt speed is low, Tc may be eliminated in the above equation to give;

$$\frac{T_1}{T_2} = e^{k\theta}$$

The k or μ are usually referred to as the effective coefficients of friction.

T_1 and T_2 are the tight and the slack section of the belt.

θ = Angle of wrap (rad)

3.3.6 Design Analysis of Belt Tension

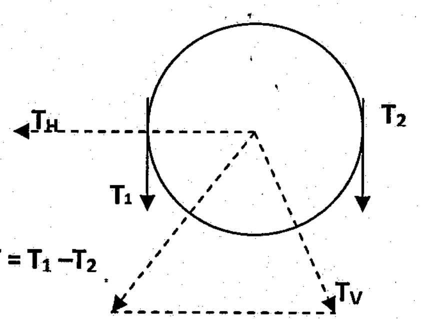


Fig 3.3 Prime mover belt tension

F= $T_1 + T_2$

To obtain T_1 and T_2

From belt tension ratio equation;

$T_1/T_2 = e^{\mu\theta}$ (16)

Where T_1 = tight side tension of the belt.

T_2 = slack side tension of the belt (N)

μ = coefficient of friction between material of belt and pulley

θ = Angle of warp (rad)

To obtainθ;

$\theta = (180-22)\ \pi/180$ (radian) (17)

Where α = angle of lap obtained

To obtain α;

$$\text{Sin}\ \alpha = \frac{r1-r2}{x}$$

α = lap angle

V_1 = radius of larger pulley = 190/2 = 95 ≈ 0.095 m

V_2 = radius of smaller pulley = 60/2 = 30mm =0.03 m

X= pulley center distance = 625 mm = 0.625 m

$$\text{Sin}\ \alpha = \frac{0.095-0.03}{0.726}$$

$\alpha = \sin^{-1}(0.089) = 5.10$

Putting this in equation (17)

$\theta = (180-2(5.1))\ \pi/180$

$\frac{533.44}{180} = 2.96$ rad

To obtain coefficient of friction (μ) in flat belt drive

$\mu = 0.54 \frac{42.6}{152.6+V}$

Where V = linear flat belt speed per minute = 2π ND

And N_2 = speed of pulley = 233.6 mm

D = diameter of larger pulley 0.190 m

$V = 2(3.142)\ (233.6)\ (0.190)$

$=278.87 \approx 279$ m/min

$\mu = 0.54 - \frac{42.6}{152.6+278}$

$= 0.54 - 0.0975$

$\mu = 0.442$

From equation (16)

$T_1/T_2 = e^{\mu}\theta$

$e^{(0.442 \times 2.92)}$

$T_1/T_2 = 3.64$

3.3.7 Calculation of the Tensions of the V-belt Drive

$$P = \frac{(T1 - T2)}{1000} V \quad (18)$$

Where T_1 = tight-side tension, N

T_2 = slack-side tension, N

P= Power transmitted, kw 1hp = 0.746 kw

V= belt speed, m/s

$T_1 - T_2$ = effective pull, N

It is customary to calculate tension. On the basic of a design power load that is somewhat greater than the average load to be transmitted, this allowing for the effect of over load or fluctuating loads. The design power for each driver wheel in a drive system is determined by multiplying the actual power by an appropriate service factor.

From equation (18)

Power = $(T_1 - T_2)$ V. (watts)

Power selected 1hp = 0.746 kw

V = flat belt linear speed = 1.95 m/s

$T_1 - T_2 = P/V$

$= 746/1.95$

$T_1 - T_2 = 382.56$

But $T_1 = 3.29T2$ (khurmi and Gupta, 2004)

$3.29 - T_2 = 382.56$

$2.29\ T_2 = 382.56$

$T_2 = 382.56/2.29$

$T_2 = 167.06$ N

$T_1 = (3.29)\ (169.06)$

$T_1 = 549.62$ N

3.3.8 Torque Transmitted (Nmm)

$$P = \frac{2\pi N_2 t}{60} \tag{19}$$

From equation (17)

$$T = \frac{P(60)}{2\pi N_2}$$

P = power required

N_2 = speed of rotating shaft

t = tongue

F = force required to chip

r= radius of shaft

Diameter of shaft = 0.026 mn

Radius of the shaft=0.013 m

$$T = \frac{P(60)}{2\pi N_2} = \frac{(0.746)(60)}{(2)(3.142)(233.6)}$$

T = 30.5 Nmm

3.3.9 Dimension of Arms of the Pulley

The number of arms may be taken as four for pulley diameter from 200mm to 600mm (Khurmi and Gupta, 2004). If it is assumed at any given time, the power is transmitted from the hub to the rim or vice-versa through only half the total numbers of arms.

Tangential load on arm (wt)

$$Wt = \frac{2T}{R \times n} \quad (20)$$

Where; T= tongue transmitted=30.5 Nmm=0.0305 Nm

R = radius of pulley selected = 95 mm

N = number of arms = 6

$$W = \frac{2 \times 0.0305}{6 \times 0.95}$$

Wt = 0.0107 N

3.3.10 Conveyor Belt Design

The force transmitted for conveyance for conveyor belt is given b y

$$Fa = Me\,(a) = Me\,\frac{(V-Vo)}{t} \quad (21)$$

Fa = Conveyor belt drive force

M_e = Effective /equivalent mass /wave of moving parts of the conveyor (belt mass) and load (N)

F = Effective belt tension (T_1- T_2)

a = belt linear acceleration = $\frac{(V-Vo)}{t}$

V = Linear speed of conveyor belt (m/s).

V_o = velocity of dropping load (m/s).

t = time for load to drop onto the belt (sec).

V=linear belt speed =1.95 m/s

T=Time for load or biomaterial to drop on the belt = 2.0 sec

$$F = T\,e = T_1+T_2 \quad (22)$$

F = 549.62+167.06

F = 716.68 N

Me = maximum load that can be carried by the moving conveyor belt (kg)

$$Me = \frac{(T_1 - T_2)t}{V - Vo} = \frac{716.68 \times 2.0}{1.95 - 0} = \frac{1433.36}{1.95}$$

Me = 735.1 N = 0.735 kN

This is the combine load that the conveyor belt can convey, but for effective conveyance, the load of the belt should not be more than 2/3 of this value for longer life of the belt.

3.3.11 Allowable Stress in the Conveyor Belt (δ)

This is obtain from the equation below

$$\delta = \frac{T}{bt} \tag{23}$$

Where delta = Allowable stress in the conveyor belt.

T = maximum belt tension = $T_i + T_c$

b = Total width of conveyor belt = 500 mm

t = thickness of the belt 6mm = 0.006 m

T_i = Tight side tension = 549.62 N

T_c = centrifugal belt tension = mv^2

Where m = mass per unit length of belt = belt mass density X cross sectional belt area.

For the canvass stitched belt used, mass density = 1220 kg/m^3

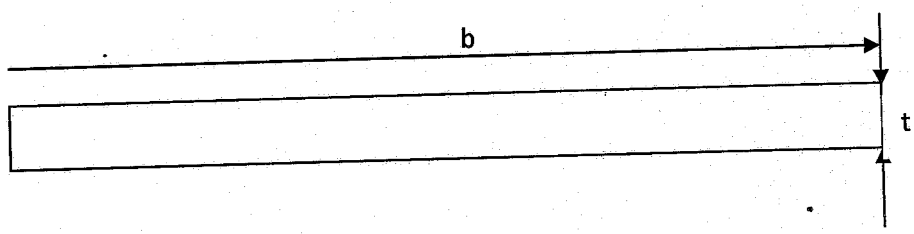


Fig (3.4) Section of the Belt.

Belt cross sectional area = b×t = 0.50(0.006) = 0.003 m^2

Volume= L×b×t

L= Length of the Conveyor belt (loopy) 6 m

Volume 6×0.50×.006 = 0.02 m^3

Mass of the conveyor belt = 1220kg× 0.02 = 24.4 kg

M = mass density × belt cross sectional area = 1220×0.003

=3.66 kg/m

While the conveyor know speed v = 1.95 m/sec

$$T_c = mv^2 = 3.66 \times (1.95)^2 = 13.92 \text{ N}$$

So $T = T_i + T_c$

T = (649.62 + 13.92) N

$T = 663.5N$

$\delta = T / bt = 663.5 /(0.5 \times 0.006)$

$= 221166.7\ N/m^2$.

$\delta = 0.2211\ N/mm^2 = 0.221MPa$

The stress is less than 1.75Mpa (khurmi and Gupta, 2004). Hence it is safe.

3.3.12 Ball Bearing Selection

The approximate rating (or service life of ball or roller bearing is based on the fundamental equation below (khurmi and Gupta, 2004)

$$C = W\left(\frac{l}{10^2}\right)1/x \qquad (24)$$

Where L = Rating life

C= Basic dynamic load rating

X = Radial load factor

W = Equivalent dynamic load

K = 3, for ball bearings

The relationship between the life in revolution (L) and the life in working hours (LH) is given by.

$L = 60 \times N \times LH$

The dynamic equivalent radial load under combined constant axial or dust load (wA) is given by

W = X .V. Wr + Y. W

Where v= a rotation factor.

For all types of bearing when the inner race is rotating, the values of radial load factor (x) and axial load factor (y) for the dynamically bearing may be taken from tables of standard. The value of x and y for single row bearing are 1 and 0, but in this type of loading , thus load are not applied hence.

Fa = 0 (khurmi and Gupta, 2004)

But $W_r = p/2\pi \times 60/60\times0.0125$

$= 108.59$ N

But W - (X.V.W) = Y.W

$=108.59-(1\times1\times0)$

W = 108.59 N

For the machine working, 8 hours per day and not always fully utilized. The life of bearing in hours is given as 12000-20000 (khurmi and Gupta, 2004) therefore;

L= 43200000

C= 1018.59 (43.2×10^2) = 3574.1 N

In order to select a suitable ball bearings the basic dynamic radial load is multiplied by the service factor (K_s) to set the design basic dynamic radial load capacity the services factor for the ball bearing of rotate shock load is 2.0 N. (khurmi and gupta 2004)

Therefore $C_k \times K_s$

$$= 3574 \times 1 \times 2. \quad = 7148.1 = 7.148 \text{ kN}$$

The bearings selected are based on static and dynamic load capacity with respect to calculated value. From the catalogue of a manufacturer bearing number 205 was selected. The dimensions for bearings are as follows;

Bearing number 205, bore diameter =30 mm, outs diameter =65 mm, width=15 mm

3.3.13 Calculation of the Size of the Washing Chamber

In calculating for the size of the washing chamber the following formula was used;

$$V = L \times W \times D \quad \text{(Sitkel, 1986)} \tag{25}$$

V = volume of the washing chamber (m^3)

L = Length of the washing chamber used. 3 m

W = width of the washing chamber used. 0.45 m

D = Depth of the washing chamber from the bed. 0.6 m

$$V = 3 \times 0.45 \times 0.6 = 0.81 m^3$$

In other to obtain an effective and efficient washing operation, the washing chamber should not be completely filled up. So it was assumed the biomaterial should occupy just one third (⅓) of the total volume. The volume occupied by the biomaterial is;

$$V = \frac{1}{3} \times 0.837m^3 = 0.279m^3$$

3.3.14 Expression of the Capacity in Volumetric Rate

Considering the shape of an Irish potato, having three intercept, which are $X_1, X_2, and\ X_3$. Where $X_1, X_2, and\ X_3$ are the major, intermediate and minor diameter of the samples in which their mean from 30 pieces were obtained.

$X_1 = 0.0785m,\ X_2 = 0.0402, and\ X_3 = 0.029.$

Equivalent diameter (de) = $(X_1\ X_2\ X_3)^{1/3}$ (Sitkel, 1986)

$$= (0.0785 * 0.0402 * 0.029)^{1/3}$$

$$= 0.0464\ m^3$$

Equivalent volume (Ve) = $\frac{1}{6\pi} de^3$ (Sitkel, 1986)

$$Ve = \frac{0.0464^3}{6X3.142} = \frac{0.0000999}{9.425} = 5.3 \times 10^{-6}\ m^3$$

If 50 pieces of Irish potatoes could be washed in three (3) minutes, the effective volume would be;

$$Vef = 5.3 \times 10^{-6} \times 50 = 2.8 \times 10^{-4}\ m^3$$

The angle of repose of Irish potatoes = 31.5° and their average density is 670 kg/m^3 (Suzuki,*et al,* 2002)

Density = $\frac{Mass}{Volume}$

Therefore, the average mass of the Irish potatoes on the conveyor belt is

M= 670 $\times 2.8\times 10^{-4}$= 0.19 kg

If 2.8$\times 10^{-4}$ m^3 of Irish potatoes is to be washed in three minutes, therefore the expression of the machine in volume per hour is Cvph = $\frac{2.8\times10^{-4}\times3600}{3}$= 3.4$\times 10^{-1}$ m^3/hr

3.3.15 Determination of the Volume of the Water Collector

The water collector was design to regulate the flow and discharge of effluent during washing operation. The effluent collector is made up of two different compartments, the larger and smaller type.

For larger compartment the volume was be calculated as V = L$\times$W$\times$H

L, W and H are the Length, width and height of the larger compartment respectively.(3m, 0.5m and 0.2m)

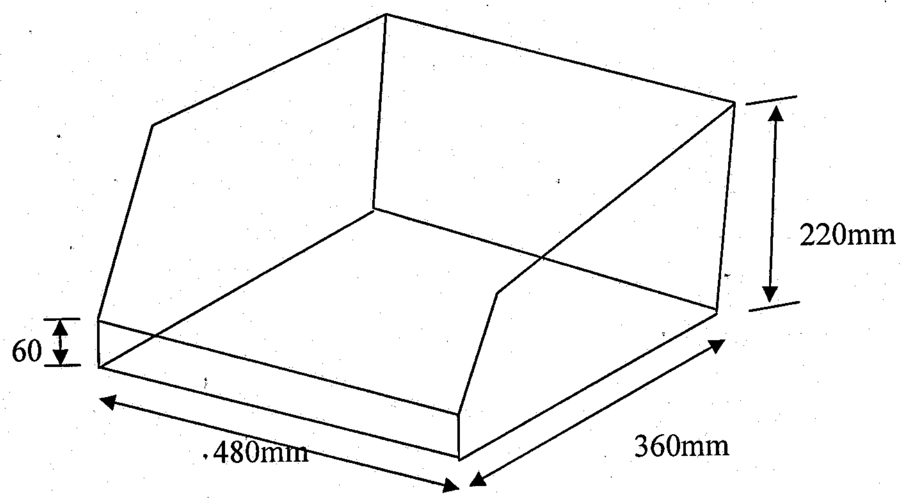
Volume= $3\times 0.5 \times 0.2 = 0.3\ m^3$

For smaller compartment, volume= L$\times$w$\times$h w, and h are the width and height of the smaller compartment respectively. (3m, 0.1m, and 0.085)

Volume= $3 \times 0.1 \times 0.084 = 0.026\ m^3$

Total volume of the effluent discharge= 0.3+0.026 =0.3255 m^3

3.3.16 Volume of the Hopper



Fig(3.5) Hopper

The shape of the hopper used is trapezoidal and thus, The Volume of the hopper = V =L x (b_1 + ($b_2 - b_1$) x $h_i/h + b_1$) + $h_i/2$

Where b_1 = smaller base 42cm = 0.42 m

b_2 = larger base 48 cm = 0.48 m

h = Total height 22 cm =0.22 m

h_i = partial height 6cm = 0.06 m

L = length of the hopper 36cm =0.36 m

Using the formula above we have

0.36 x [0.42 + (0.48 – 0.42) x 0.06/0.22 - 0.42) + 0.06/2]

0.36 x [0.42 + (0.06) x 0.273 - 0.42) + 0.03]

0.36 x 0.0164 + 0.03 = 0.046 m^3

Volume of the hopper = 0.046 m^3

3.3.17 Total Vertical Force on the Pulley

$Te = T_1 + T_2 = 716.88$ N

T_1 and T_2 is the tight and slack tension of the belt. From equation (22)

$\text{Sin } 35 = \frac{Tv}{Te}$

T_v = t sin 35 (khurmi and Gupta, 2004)

T_v = 716.88 sin 35 = 411.2 N

T_v = 411.2 N

T_H = T cos 35 = 716.88N cos 35 = 587.2 N

$F_v = T_v$ + weight of pulley

Mass of weighed pulley 1kg = 1× 9.81 = 9.81 N

F_v = 411.2 + 9.81

F_v = 421.01 N

$F_H = 587.2 + 9.81 = 597.01$ N

3.3.18 Determination of Shearing Force and Bending Moment in the Conveyor's Driven pulley

The weight of shaft pulley is expressed as $W_p = M_p g$

Where W_p = weight of the shaft pulley

M_p = mass of the pulley weighed as 1kg, g = acceleration due to gravity 9.81 kg

Therefore $W_p = 1 \times 9.81 = 9.81$ N

Total weight = $T_v + W_p = 411.2 + 9.81 = 421.01$ N

Also, the weight of the conveyor belt on the shaft is expressed as $W_b = M_b g$

W_b = Weight of the conveyor belt

M_b = mass of the conveyor belt 24.4 kg

$W_b = 24.4 \times 9.81 = 239.4\ N$

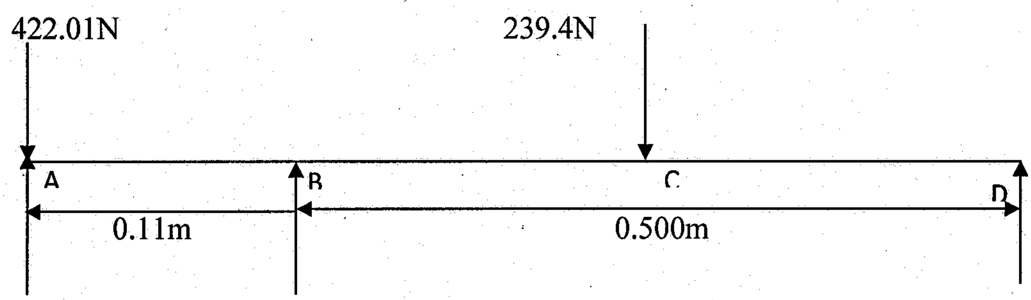


Fig (3.6) Free Body Diagram of the Loading System of the Shaft.

From the above, summation of the vertical forces; $[+\sum V = 0]$

$R_B - 421.01 + R_D - 239.4$

$R_B + R_D = 421.01 + 239.4$

$R_B = 660.41 - R_D$

Taking moment about point B ; $[+\sum MB = 0]$

$239.4 \times 0.25 = 421.01 \times 0.11 + R_D - \times 0.5$

$59.85 = 46.3 + R_D \text{ x } 0.5$

$59.85 - 46.3 = 0.5R_D$

$13.54 = 0.5R_D$

$R_D = \frac{13.54}{0.5} = 27.08 \text{ Nm}$

$R_B = 660.41 - 27.08 = 633.33 \text{ Nm}$

3.3.19 Determination of the Vertical Shear Forces.

$Fv_A = -421.01 \text{ for } 0 \leq \times$

$Fv_B = -421.01 + 633.33 = 212.320 \leq \times \leq 0.11$

$Fv_C = 212.32 - 239.4 = 27.080 \leq \times \leq 0.36$

$Fv_D = -27.08 + 27.08 = 0,0 \leq \times \leq 0.01$

3.3.20 Determination of the Vertical Bending Moment.

$M_A = M_D = 0$

$M_B = -\ 421.01 \times 0.11 = -46.3$ Nm

$M_C = -\ 421.01 \times 0.36 + 633.33 \times 0.25 = -\ 151.56 + 158.33 = 6.77$ Nm

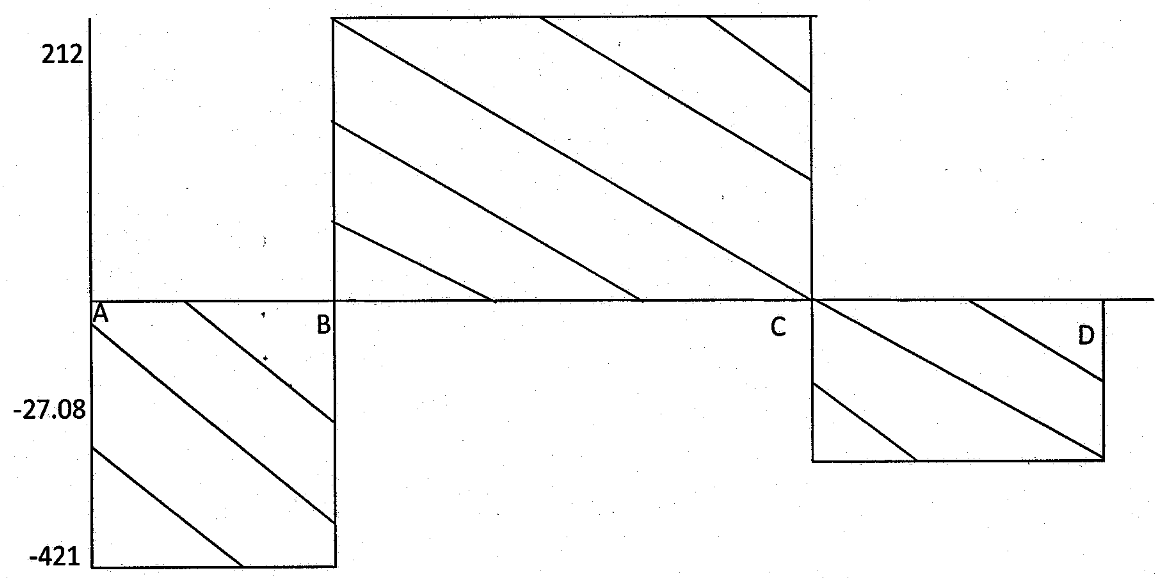


Fig (3.7) Vertical Shear Force Diagram

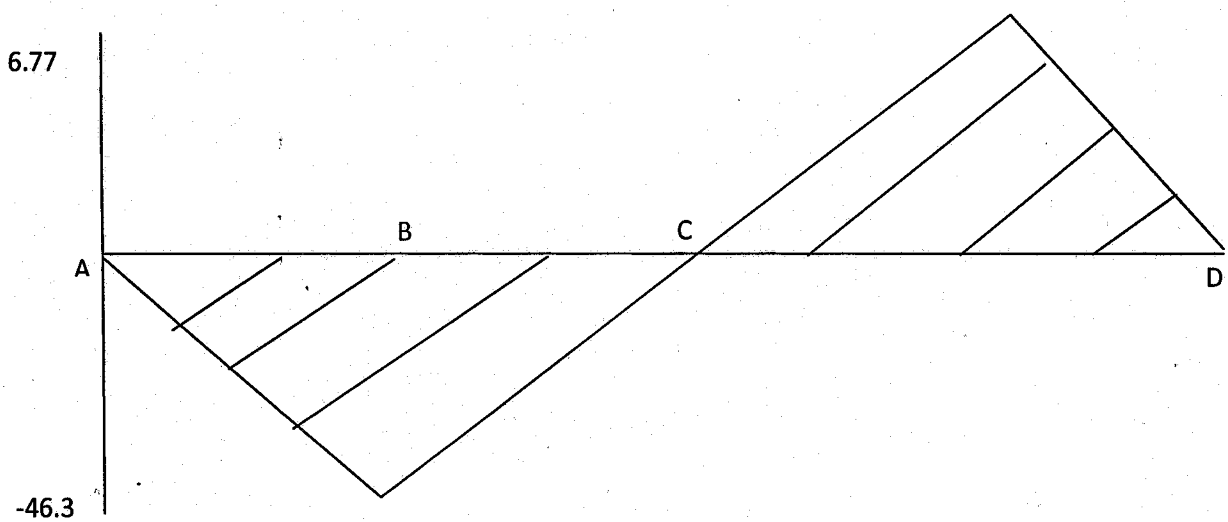
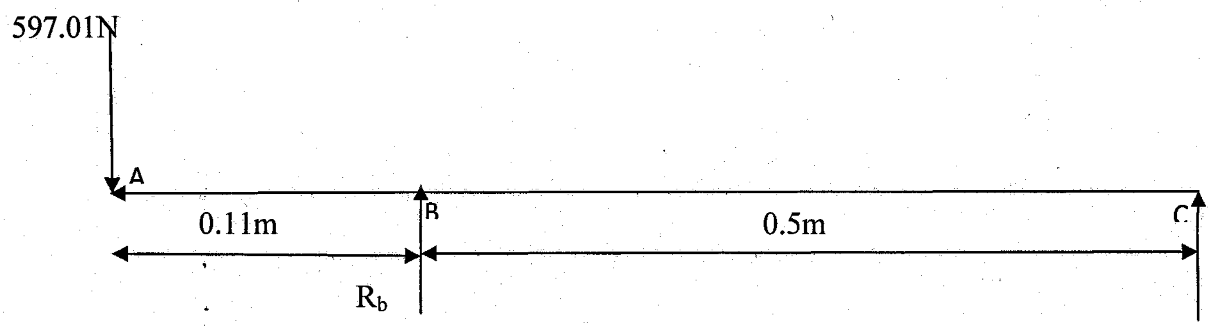


Fig (3.8) Vertical Bending Moment Diagram

3.3.21 Horizontal resolution of forces

Forces of shaft resolved horizontally is given as below



R_c Fig (3.9) Horizontal Force Loading

From the above figure, the summation of the horizontal forces =0

$[+\uparrow \sum B = 0]$ $R_B + R_C - 597.01 = R_B + R_C = 597.01$

Taking moment about a point C

$0.5 x R_B - 597.01 x\ 0.61 = 0$

$0.5 R_B = 364.2$

$R_B = \frac{364.2}{0.5} = 728.4$ Nm

$R_C = 597.01 - R_B$

$= 597.01 - 728.4 = -131.39$ (Compression)

3.3.22 Determination of Horizontal Shear Force Diagram

$F_{HA} = -597.01$ for $0 \leq X$

F_{HB} = -597.01 + 728.4 = 131.39N for 0≤ X ≤ 0.11

F_{HC} = 131.38 – 131.38= 0 for 0 ≤ X≤ 0.61

3.3.23 Determination of the Horizontal Bending Moment

$M_A = M_C = 0$

M_B = -597.01 x 0.11 = 65.67 Nm.

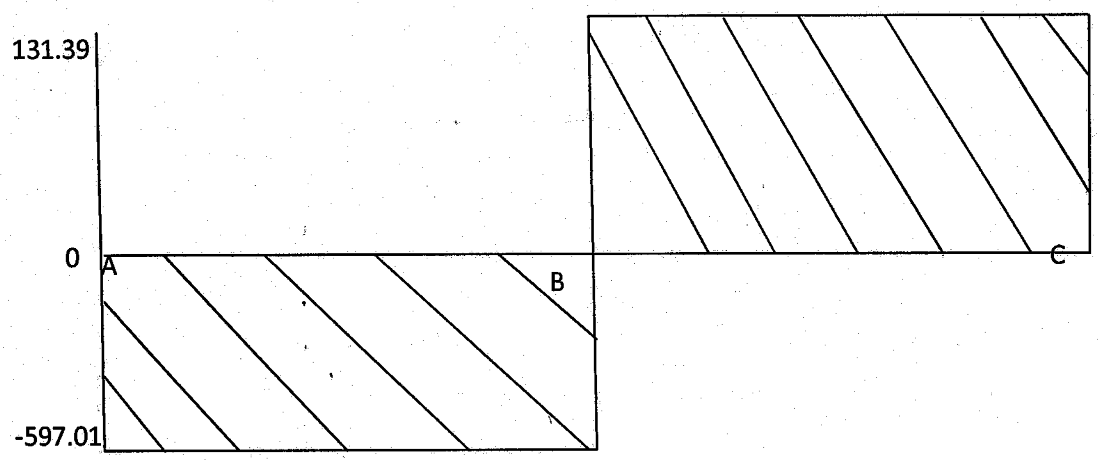


Fig (3.10) Horizontal Shear Force Diagram

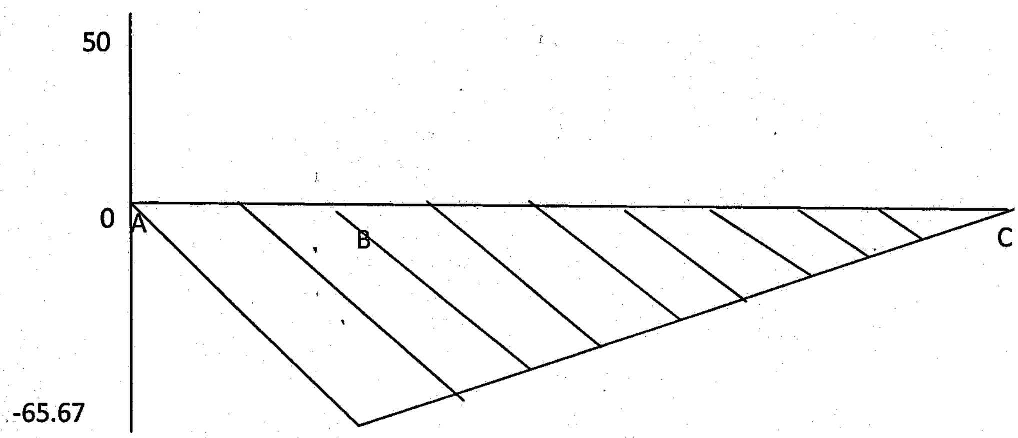


Fig (3.11) Horizontal Bending Moment Diagram

3.3.24 Determination of the resulting bending moment

The resulting bending moment is determine using

$M_{BR} = \sqrt{M_{BV}^2 + M_{BH}^2}$

Where, M_{BR} = Resultant bending moment.

M_{BV} = Vertical bending moment.

M_{BH} = horizontal bending movement.

At x, $M_{BRA} = 0$

At x = 0.11m, $M_{BRB} = \sqrt{(-46.3)^2 + (65.67)^2}$

=80.35 Nm

At x = 0.36, $M_{BRC} = \sqrt{6.77^2 + 0^2}$

= 6.77Nm

At x = 0.61m, $M_{BRD}\ \sqrt{0^2 + 0^2} = 0$

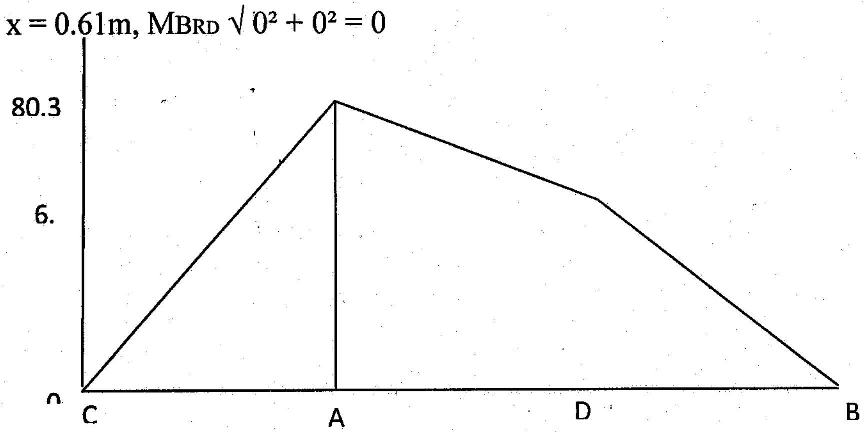


Fig (3.12) Resulting bending moment diagram

3.3.25 Shaft Design

The only shaft to be designed is that of the large pulley as it the one transmitting power to

The shaft is subjected to both twisting or tensional and bending moment. According to Joseph Shigley, (1996), the diameter for a solid shaft is given as below;

$$d^3 = \frac{16}{Ss}\sqrt{(Kb \times Mb)^2 + (Kt \times Mt)^2} \quad (23)$$

S_s = Allowable shear stress for a shaft without key way. 55 MN/m²

K_b = Combine shock and fatigue factor applied to bending moment.

K_t = Combine shock and fatigue factor applied to tensional moment.

For rotating shaft of gradually applied load, Kb and Kt are 1.5 and 1.0 respectively.

M_b = Bending moment. From equation (28) M_b = 80.35Nm.

M_t = Tensional moment $M_t = (T_1 - T_2)\ R$

T_1 = Tension of the belt at the tight side. 549.62 N

T_2 = Tension of the belt at the slack side. 169.06 N.

R = Radios of the pulley of the shaft. 95mm = 0.095 m

$M_t = (549.62 - 169.06) \times 0.095 = 36.24$ Nm

$$d^3 = \frac{16}{\pi 55 \times 10^6}\sqrt{(1.5 \times 80.05)^2 + (1 \times 36.34)^2}$$

$d^3 = 0.0000000926 \times 125.88 = 0.0000167$ m

d = 0.025.6 m = 26 mm

3.3.26 Reaction at Idlers End Support

Consider the idlers as a rotating body which prevents the conveyor belt from sagging as well as a free loopy motion. The idlers are loading at centre and the end stud shaft acting as simple support.

The weight of the conveyor belt (W) = 239.4 N since there are seven (7) rollers.

Then average load area idler = 239.4/7 = 34.2 N

(i.e for 24.4kg load) running over 7idlers per unit length of 374mm idler separate distance.

W = 4.2 N

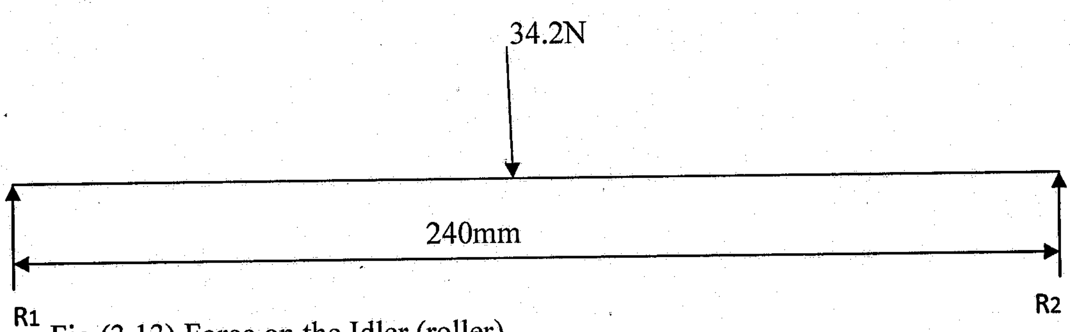


Fig (3.13) Force on the Idler (roller)

3.3.27 Vertical forces resulting

$[+\uparrow\sum v = 0] = R_1 + R_2 = 34.2$ N (24)

Taking moment about R_1

$[+\uparrow\sum MR_2 = 0]$

$R_2 (0.5) = 34.2 (0.25)$

$0.5 R_2 = 8.55$

$R_2 = 8.55/0.5 = 17.1$ N

From equation (24)

$R_1 = 34.2 - R_2$

$R_1 = 34.2 - 17.1$

$R_1 = 17.1$

Therefore $R_1 = R_2 = 17.1$N

3.3.28 Shear Stress Exerted on each Stud

Shear stress = load (W)/Cross sectional Area (A)

Where load = 17.1 N

A = cross sectional of stud = $A = \pi r^2$

r = radius of the stud 22 mm/2: 11 mm = $(0.11)^2$

= 0.00038 m^2

Shear stress = 17.1N/0.00038 = 45000 N/m^2

= 0.045 Mpa

This is far less than allowable stress of 42 Mpa (In Hall *et al.*1980)

3.40 Machine Description

The belt conveyor washer was constructed using the available but suitable materials. Namely;

1. Angle iron (mild steel) 40mm× 40mm
2. Shaft (rod) Mild steel.
3. Metal sheet- Mild steel – gauge 16
4. Conveyor belt – Rug material
5. Pulleys- caste iron

The design of the conveyor washer system is made up of the following major components:

1. The Main Frame

This is the frame on which other functional parts are assembled. It's made up of the two parallel (0.10× 0.5)m by 3.0m long U channel steel bar.

This frame carries 0.26m driving shaft close to the edge of the frame and $\emptyset 0.021m$ end support stud shafts for the idlers on end support shaft stator. The frame was then fastened with pairs of M10 ×1.5mm bolt and nuts each and about 16 pairs in all supporting 16 idlers rollers spaced at about 0.375m apart.

The frame is supported with five (5) set of H- shaped stand giving it necessary strength and rigidity. The anterior stand accommodates the main prime mover unit in functional relationship with the conveyor main drive pulley (Ø60). While the posterior carries the running pulley (Ø190mm)

2. The Stands

These are H- brazed structure mean to carry the main frame idler, shaft and pulley, the upper cover which serves as the washing chamber, conveyor belt, drive unit and the and V-belt for the purpose of rigidity and ergonomics. It is made up of U- channel (0.21 × .10) m and of 1.45m and height bar, based up by two angle bar(0.1 × 0.1)m welded at both ends to the two upright U-channel for strength and rigidity.

The upper U-channel is fastened to the main horizontal parallel U-channel with two pair each of M10 × 1.5 bolt and nut at their respective position of support.

3. Idler End Support Stud Shafts/Stators

This is made up of stator bar of (0.1 × 0.05 × 0.01) m cut and drill for two (2) nut to be nut at two end to accommodate bolt to keep the bearing in good form for easy driving of the Ø21.0*mm* stud end-support stud shaft. It was nut for easy replacement of worn out bearing.

Plate 3.1 Idler end Support

4. Reduction Gear Motor(variable resistor)

The variable resistor is an electronic device measured in ohms which is used in place of a gear to vary and control the speed of the belt during its operation.

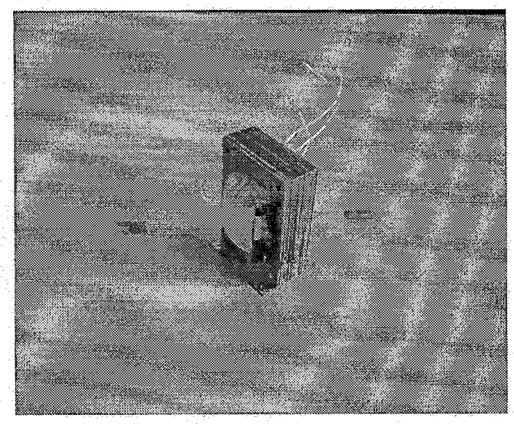


Plate 3.2 Variable Resistor

5. Washing Chamber

The washing chamber is made up of rectangular shaped casings that cover the main frame and the conveyor belt to carry out the washing operation. The washing chamber is also supported by five (5) U-shape stands that is nut to the main frame bed, having the same size with the height and width of the casing or cover. The casing was welded to the support for rigidity as well as high efficiency of washing. The washing chamber is also made of the injected nozzle and hose that are uniformly arranged to carry out the spraying operation during washing.

6. Main Horizontal Conveyor Belt Drive Pulley

This is a driven pulley that is use to drive the flat conveyor belt running at spherical speed of the 1.95m/sec. It is a (Ø190mm) on flat pulley of hollow cylinder, covered at both end and bored to accommodate the main pulley shaft stepped by 2.5mm to $\emptyset 0.021m$ at both bearing ends. It is made of cast iron material.

7. Prime Mover

The motor used was 1hp (0.746watt) at the speed of 740rpm (Khurmi and Gupta 2004)

8. Water/Effluent Collector

This is a double rectangular compartment used to collect the effluent during and after the washing to uniformly discharge it to canal or drainage through the squared shape outlet at the base of the smaller rectangular compartment that is situated just below the larger compartment of the collector.

9. Conveyor Belt

This is made up of cotton material of (100×01) mm $\times$ $6090mm$ long. It is a long flat belt conjoined from each end with binding wire/clip.

10. Stopper

This is a flat plate in a vertical position used to prevent the biomaterial from discharging during washing operation. It can also be raised to allow the discharging of the washed biomaterial after washing.

11. Driving Shaft

This is the main shaft that is used in driving the conveyor in a loopy motion. It is enclosed in a cylindrical galvanized pipe and guide from both end with the aid of bearings, welded to the pipe to centralized the shaft in the cylinder. The shaft is of diameter Ø26*mm* and 610mm long.

12. Biomaterial Discharge outlet: This is a rectangular tray of 500mm by 580mm welded to the casing on the main frame at an inclined angle of 130° for effective discharge of the biomaterial. It is made up of angle iron (mild steel) and mild steel plate of gauge 16.

13. Wheel: This is one of the major components of the machine. It is about 250mm diameter. The wheel is divided into four equal arms. It was made of cast from aluminum and machinery on the machine to give proper finishing.

14. Bolt and Nuts: They serve as materials for holding or fixing two components together to make them act as one. The bolts and nuts are used to hold the bearing to the main frame.

15. Hose, Shower, Nozzle and Regulator: These are the means or medium throw which pressurized water is sprayed onto the biomaterial in the washing chamber.

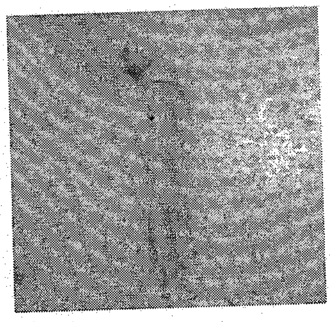


Plate (3.3) Hose with Cap

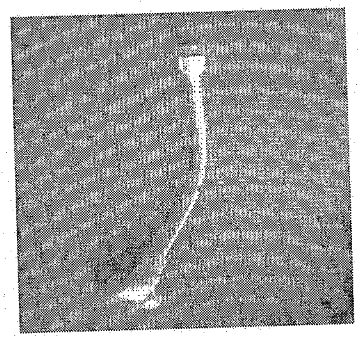


Plate (3.4) Nozzle

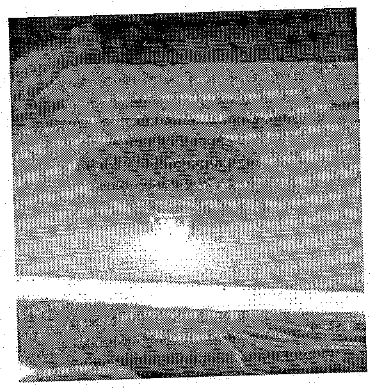


Plate (3.5) Shower

3.5 Assembling and Installation

All fabricated parts were assembled to engineering details and bought parts such as bearings (deep groove and self aligning), injector nozzle, hose etc. were installed and fastened appropriately to details of drawing and design calculation.

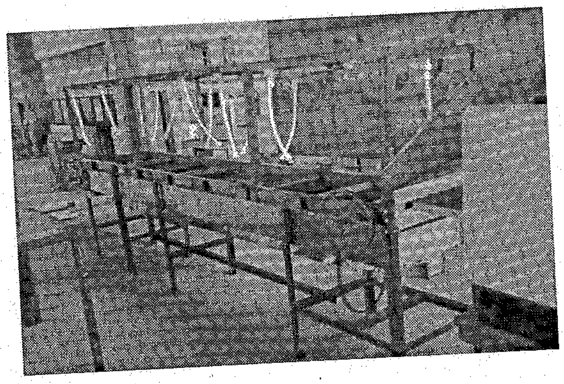


Plate 3.6 Belt conveyor washer without cover

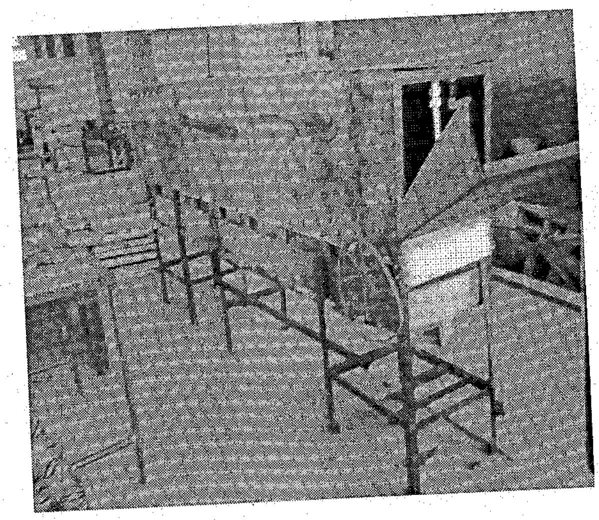


Plate 3.7 Belt conveyor washer with cover

3.60 Test performance

The change in the weight of the biomaterial after washing in the belt conveyor washer was used in determining the performance of the washer to remove dirt from the biomaterial (Tomatoes). A weighed balance was used, Six (6) samples of 3kg each was used as sample A, B, C, D, E and F. Three (3) of the samples (A, B and C) were fed into the belt conveyor washer at the interval of 1, 2, and 3min respectively at constant speed of 740rpm. The final weight of each sample was recorded and compare to the initial weight to know the weight of the dirt.

The other three (3) samples (12kg each) were also fed one after the other to be washed at a constant time of one minute (1min), but with variable speed of 740rpm, 450rpm and 240rpm respectively.

3.70 Bill of Engineering Measurement and Evaluation

This includes the cost of material and labour. The material use and their cost as at the time of fabrication or the belt conveyor washer are as stated below;

Table 3.2 Material list and cost.

S/No	Description of items	Quality	Unit Cost(#)	Total Cost (#)
1	Angle Iron (40mm×40mm)	15	2000	30000
2	Mild steel gauge 16	6	3900	23400
3	Bearing 6205 (complete	8	120	960
	housing) 6204	24	60	1440
4	V- belt A 55	1	450	450
5	Shaft(Ø26mm)(610mm) length	1	1000	1000
6	Nozzles with knobs	20	150	3000
	PVC pipe (2mm)	9	200	1800

7	Electrode (G 10)	1 pack	10	2000
8	Driven pulley	1	1000	1000
	Driving pulley	1	450	450
9	Bolt and Nuts (assorted)	60	10	600
10	Filler rode	1 bundle	600	600
11	Paint	1	2000	2000
12	Thinner	1	1500	1500
13	Variable Resistor	1	5000	5000
14	Sealant (potash powder and thickener)	1container	1500	1500
15	Galvanized cylinder pipe	8	350	2800
16	Conveyor Belt	1	3000	3000
17	Cutting Disc	1	200	200
	Grinding Disc	1	200	200
	Saw blade	2	50	100
18	Lining cover for the cylinder	2 yards	600	1200
19	Drill bit	4	80	320

				400
20	Sand paper	4	100	8000
21	Miscellaneous			
			Total	92920

Labour cost is 30% of material cost: ₦23230

Overhead cost is 60% of the labour cost: ₦13938

Factory cost = material cost + labour cost + overhead cost: ₦92920 + ₦23230 + ₦13938

= ₦133088

The cost of electric motor and water pumping machine were not added to the total cost of the project. They were borrowed from Agricultural and Bioresources Engineering the Department.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.10 Results

Total weight of the Biomaterial (tomatoes) used = 18kg

Total sample = 6 samples (A, B, C, D, E, and F)

W_1 = Initial weight of each sample of the biomaterial (tomatoes) before washing. 3kg

W_2 = Weight of each of the sample of the biomaterial after washing with the machine.

W_3 = Weight of each of the sample of the biomaterial washed manually after been washed by the machine.

W_{D1}= Weight of the dirt removed after washing with the belt conveyor washer.

W_{D2} = Weight of the dirt removed after the biomaterial was further washed manually.

$W_{D}T$ = Total weight of the dirt in each sample.

Table 4.1 Performance data of the belt conveyor washer using three (3) weighed samples (3kg each) of the biomaterial at 740rpm.

Sample	Time (min)	Speed (rpm)	W_1 (Kg)	W_2 (Kg)	W3 (Kg)	W_{D1}(Kg)	W_{D2}(Kg)	W_DT (Kg)
A	1	740	3	2.976	2.961	0.021	0.015	0.036
B	2	740	3	2.949	2.921	0.051	0.028	0.079
C	3	740	3	2.926	2.891	0.074	0.035	0.109

Percentage weight of dirt removed in washing is given as $= \frac{\text{Weight of dirt removed}}{\text{Initial Weight}} \times 100$

Percentage weight of dirt removed in sample A $= \frac{0.021}{3} \times 100 = 0.7\%$

$$\text{Efficiency} = \frac{\textit{Weight of dirt removed after washing with the machine}}{\textit{Total weight of dirt removed after further washed manually}} \times 100$$

Efficiency of washing Sample A $= \frac{0.021}{0.036} \times 100 = 58\%$

Percentage weight of dirt removed in sample B $= \frac{0.051}{3} = 1.7\%$

Efficiency of washing Sample B $= \frac{0.051}{0.079} \times 100 = 65\%$

Percentage weight of dirt removed in sample C $= \frac{0.074}{3} \times 100 = 2.47\%$

Efficiency of washing Sample C = $\frac{0.074}{0.109} \times 100 = 68\%$

Table 4.2 Performance data of the belt conveyor washer, three (3) other weighed samples of the biomaterial at constant time of five minutes but with variable speeds of washing.

Sample	Time (min)	Speed (rpm)	W_1 (Kg)	W_2 (Kg)	W3 (Kg)	W_{D1}(Kg)	W_{D2}(Kg)	W_DT (Kg)
D	5	740	3	2.906	2.874	0.094	0.038	0.132
E	5	450	3	2.889	2.851	0.111	0.038	0.149
F	5	240	3	2.870	2.861	0.130	0.009	0.139

Percentage weight of dirt removed in sample D = $\frac{0.094}{3} \times 100 = 3.13\%$

Efficiency of washing Sample D = $\frac{0.094}{0.132} \times 100 = 72\%$

Percentage weight of dirt removed in sample E = $\frac{0.111}{3} \times 100 = 3.7\%$

Efficiency of washing Sample E = $\frac{0.111}{0.149} \times 100 = 75\%$

Percentage weight of dirt removed in sample F = $\frac{0.130}{3} \times 100 = 4.33\%$

Efficiency of Sample F = $\frac{0.130}{0.139} \times 100 = 93\%$

4.20 Discussion of Results

At the end of the performance evaluation, at constant speed of 740rpm, the percentage weight of dirt removed from the sample A, B and C by the machine at 1min, 2min and 3min are 0.7%, 1.7% and 2.47% respectively, having the efficiency of washing to be 58%, 65 % and 68% respectively. Also the percentage weight of dirt removed from the other three (3) samples at constant time of five minutes (5min) when washed with the machine are 3.13%, 3.7% and 4.33% respectively, having the washing efficiency to be 72%,75% and 93% respectively.

The result from the first three (3) samples at constant speed shows that an increase in the time of washing (that is, the time of subjecting the tomatoes to sprays of water) usually increases the percentage of the dirt removed from the biomaterial, provided it's not left for a very long period of time which can cause recontamination of dirt and increase in weight due to absorption of water by the biomaterial.

Considering the other three (3) samples at variable speed, is was discovered that a decrease in the speed of the conveyor belt increases the time at which the tomatoes is subjected to sprays of water , thus increases the percentage of dirt removed.

Since most of the agricultural materials are hygroscopic that is sensitive to water, washing of the tomatoes for a long usually add to its weight because it absolves water easily compared to some agricultural material such as oranges, Irish potatoes mangoes, sweet potatoes etc. Tomatoes also do not have a high resistance to high pressure of water due to the nature of the surface of the material and as such, washing of the biomaterial (tomatoes) should not be washed for a long period with the machine, but only when it is time for its immediate further processing operation to prevent deterioration due to their sensitivity to water.

4.3 Maintenance of the Belt Conveyor Washer

Maintenance is an improvement program design to prevent or correct deviation from optimum performance condition such as efficiency, production/washing capacity and product quality after processing or pre-processing operation. The preventive type of maintenance is how ever recommended as follows;

i. The load capacity of the conveyor washer should not be exceeded.

ii Alignment of the belt should be maintained in line as much as possible in order to increase the washing efficiency of the machine.

ii. Removal of dirt or plant residue such as straw from the spray nozzle to prevent obstruction to the flow of water.

iii. Regular cleaning of the washing chamber after use to prevent re-contamination of the washed biomaterial (tomatoes) which can in turn reduce the washing efficiency of the washer.

iv. Worn out parts should be repair or replaced immediately to forestall further damage to other part of the conveyor washer.

v. Lubrication of all the bearings of the rollers as well as all other moving parts.

vi. Effective collection and discarding of the waste water or effluent to prevent re-contamination.

vii. Drying of the conveyor belt after use by the use of dryer or allowing ventilation into the washing chamber to prevent the smelling or pollution of the biomaterial as well as the environment. The conveyor belt can also be removed and dried after every operation.

viii. Control of airborne dust as belt conveyor transfer points is essential to improving conveyor efficiency. A full range of dust control system will provide the best fit for specific operation.

ix. For effective transfer point, it is essential that the conveyor belt line be stabilized. If the conveyor belt is allowed to sag or flex under the stress of the material load, dust and fines will escape.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the designed and fabricated machine, problems of stress, time, and cost involved in cleaning, processing, and material handling of agricultural biomaterials after harvesting were properly checked and the machine ensures effective cleaning over a short period of time, saves cost and increases the shelf life of agricultural products.

The performance evaluation carried out on the machine, showed that the percentage of dirt removed from the food material and the efficiency of washing the biomaterial increases with an increases in time while the percentage weight of the biomaterial decreases with an increase in time and this was obtained from the sample A, B, C, D, E, F, which were washed at regular time intervals. The belt conveyor washer was also designed and fabricated and with the performance evaluation carried out, it can be concluded that mechanical washing is more effective than manual/hand washing of biomaterials.

Conclusively since most agricultural products are hygroscopic in nature, the time in which the food material will be subjected to washing varies from one material to the other depending on the rate at which the material absorbs water, in order to avoid damage to the biomaterial. The physical properties of the material such as hardness and surface area should be put into consideration in order to determine the pressure of water to be applied to the food material, thus the tomatoes which was used required a little amount of pressure for washing the biomaterial to enhance the shelf life and to avoid damage of the material.

5.2 Recommendations

From the design and fabrication of the belt conveyor washer, the following recommendations were made:

1. Better materials should be used for fabricating machine to ensure food security and damage of the agricultural product which is to be processed.

2. Provision should be made for proper discharge of effluents from the material in order to avoid pollution of the environment and prevent the dangerous effect in which the waste water can affect the soil and plants.

3. Provision should also be made for water conservation; therefore the water obtained from the washing process should be recyclable.

4. Most food processing industries both small and large scale industries should take into consideration the hygroscopic nature of the material which is to be cleaned to reduce the effect of moisture on different food materials and note the time allowable for washing a particular product during processing.

5. In order to avoid corrosion and rust of the machine components and ensure proper maintenance of the machine, better quality materials should be used for fabricating the machine and proper aeration should be provided.

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