DESIGN AND PROTOTYPE DEVELOPMENT OF A CENTRIFUGAL CREAM/SKIM MILK SEPARATOR

BY

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CERTIFICATION

This is to certify that this project "design and prototype **development of** centrifugal cream/skin milk separator" has been **presented by SALAMI AKEEM** OLUSESAN of the department of Agricul**tural Engineering,** School of Engineering and Engineering Technology, **Federal University of** Technology, Minna.

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DEDICATION

This project is dedicated to my parents,

ALHAJI PA. G. O. SALAMI and ALHAJA H. A. SALAMI.

ACKNOWLEDGEMENT

I thank God, the most merciful and the most beneficient, despite all hardships along the lines, has guided me all through the period of stay in F.U.T. Minna Niger-State.

My profound gratitude goes to my father, Alhaji Pa G.O. Salami and my mother, Alhaja H. A. Salami (MAGHAJIA), for their effort. The love shown and showered on me since I was born and their immense struggle in ensuring that I secure that Essential and basic passport to a good living in life".

I also appreciate the untiring efforts and enormous contribution of MR. K. A. ADEKOLA my Project Supervisor and MR. T. ALABADAN who took their time to review this work and offer useful criticisms that have contributed to making this work a success.

Then to my head of department, DR. A. AJISEGIRI for his advice and encouragement and to other lecturers in the Agricultural Engineering Department for their contribution to this work.

I draw appreciation from the bottom of my heart to my sisters in person of ALHAJA TAWAKALITU A. OLOYINDE, MRS. MORENIKE A. EKUNRIN and MRS. MONSURAT F. ALABI for their love have given me the inspiration and encouragement towards my success.

I am also indebted to MISS ABIBAT OYINDAMOLA SALAMI and MASTER ABIOLA SUDIQ SALAMI for their cooperation and giving good atmosphere for me during the process of this project. I love you all.

Lastly, I would also express my appreciation to MISS SHERIFAT SHALEWA SHIYANBOLA who shared her love with me and her love to me is a source of joy. I must not put a stop without thanking friends such as MR. RASHEED A. IBRAHIM (KUSO D); MR. JIDE BUKOYE (Jemu dealer) and the rest of Salami family as a whole.

Once again, I say thank you and God bless you all, Amen.

SALAMI AKEEM OLUSESAN

ABSTRACT

A prototype centrifugal cream and skim milk separator for whole milk was developed to separate whole milk into cream and skim milk. The separation was done under centrifugal action by subjecting the whole milk to a speed of 5400 revolution per minute for six minutes with the aid of electric motor. The difference in densities between the skim and cream milk was one of the factors that was used to effect the separation.

The centrifugal cylinder bowl made of stainless steel has a capacity of $0.015m^3$ which revolve for 6 minutes before the separation take place. In order to maintain the temperature of the whole milk, the outside cylinder was insulated with cotton-wool. Before the introduction of the milk the initial outlets of the inner basin was blocked. The separated cream was collected through a separate outlet available at the bottom of the cylinder likewise the skim milk was collected through a separate outlet.

The average volume of cream milk obtained was $0.000036m^3$ per six minutes ($6.0 \times 10^{-6}m^3$ per minute)

While the average volume of skim milk obtained was $0.00046m^3$ per 6 minutes. ($7.83 \times 10^{-5}m^3$ per minute). The efficiency of the machine is 66.7%.

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INTRODUCTION

Milk is often described as nature's most nearly perfect single food. It is the natural food of the new born mammals which provides the sole source of nourishment directly after birth. Milk is defined as a secretion of the mammarg gland. (Ihekoronye and Ngoddy, 1985).

Milk is an exceptionally good source of proteins which is of high nutritional value in promotion the growth of children. It provides the best source of calcium in the diet and consequently supports sound bone and teeth development. It contains a useful miscellcneous of vitamins including vitamin A, Thiamin Riboflavin, Pyridoxin, Biotin, Niacin Panthothenic acid and vitamin D [Ihekoronye and Ngoddy, 1985].

A fresh cow milk contains about 87 percent of water in which we have various dissolved salts, carbohydrates and proteins. The density of milk varies between $1026kg/m^3$ and $1032kg/m^3$ at 20°c. The variation is due to difference in fat and solid contents. The density of cow milk increased as its temperature increases, until it get to the maximum density which is obtained after 12 hours of heating. (Ihekoronye and Ngoddy, 1985). This increase in density of the cow milk is due mainly to the liberation of gases such as carbondioxide and Nitrogen which are present in freshly drawn milk to the extent of 4-5 percent.

Cow milk in particular is the most predominant raw material for manufactured dairy products such as liquid milk, whole milk powder. Full cream unsweetened and evaporated milk.

In Nigeria, cow is most commonly used as the dairy animal, while goat and sheep are kept for the production of meat hides and skins.

Not all breed of cow are good milk producers, for example, the N'dama cattle, the Boran cattle and the Afrikander cattle are just good for beef production and they are also used as draught animal. [Mayhew and Penny, 1988].

This was so because of the protein content contained in the food taken by the dairy cattle which is of high importance in milk production.

The major characteristic of dairy cattle are body build and legs. A good dairy animal will be slim, well covered, but not too fat. The stomach should be large and dairy cows eat huge quantities of food.

The legs should be short and sturdy to support the body. Hind legs should be far apart to support the udder.

Examples of dairy cattle are white fulani, sudanese and sokoto breeds.

a) <u>White Fulani</u>

This is a multi-purpose breed which fattens well on natural grassland and is well suited to the dry tropics. It can be crossed with European dairy animals to produce a good savanna milk cow.

b) <u>Sudanese</u>

There are a number of related breeds classed under this heading. Some examples are the Kenana or Blue Nile, the White Nile, the Baggara and the Butana. The Kenana are probably the most productive of the African dairy breed. Most of these cattle have short coats and loose skin, with long ears. The males have a large hump; the females a very small one. [Mayhew and Penny, 1988].

c) Sokoto

These are short-horned Zebu cattle, both sexes having a hump and a pronounced dewlap. The Sokoto is a moderate milker under natural grazing conditions. It is docile, sturdy and reliable and thus well suited to regular milking.

Sokoto cattle are also used as draught animals but are rather slow. (Mayhew and Penny, 1988).

The choice of breed is essentially a personal matter. Among the exotic breed the Jersey is the most efficient producers of milk, it is clear that Jersey breed produces the highest percentage of fat (4.49%) and the highest percentage of crude protein 3.79%. Generally, the milk production efficiency of a breed is not based on average yield of milk but it based on fat and crude protein percentage, because this play a major role in milk grading.

Centrifugation is defined as the process of resolving multicomponents systems at least one phase of which is liquid by the application of centrifugal force (Ihekoronye and Ngoddy, 1985). With centrifugal separator, cream and skin milk are been separated from whole milk.

From cream one can manufacture table cream for coffee: Sour cream is used to enhance the flavours of other food such as salads. Other products from cream is the anhydrous butter oil which contains higher milk fat than the table butter. Skim milk which is the other products separated from whole milk. It can be processed to produce skim milk. It can be processed to produce skim milk powder, unsweetened or sweetened evaporated skim milk, and skim-milk based cultured dairy products such as Youghurt, Cheese and Kettir.

1.1 OBJECTIVES

The objective of this project is to design and develop the prototype machine to separate whole milk into cream and skim milk.

1.2 JUSTIFICATION

Considerable skim milk, cream milk, ice cream, cheese, Whey, Butter, Yoghurt etc. are believed to be obtained from whole milk. All these sources of whole milk requires separation before they are obtained. Several attempts have been made to improve on whole milking separating process.

This project is part of such attempts aimed at this improvement and specifically on whole milk. A lot of efforts equally have been put towards improving the lives of the populace by the Federal Government of Nigeria by encouraging the local production of small scale machines adaptable to our local technology.

In view of the earlier written facts to bridging the demand gap for whole milk component and since efficient mechanical method of skim and cream milk separation from whole milk are lacking in the rural areas except the inefficient and unhygienic traditional method.

Therefore, there is the need to design a simple machine inexpensive that can be afforded by individual households which will help to separate skim and cream milk from whole milk. This simple technology machine is important almost everywhere by the populace to supplement those being processed by some large scale milk industries. The machine is designed to carry out the tasks enumerated above.

1.3 SCOPE OF STUDY

The scope of this project will involve design prototype development and testing of the machine to separate whole milk into cream and skim milk.

CHAPTER TWO

LITERATURE REVIEW

Before the invention of money a man's wealth was measured by the number of cattle in his herd. So cows naturally become an accepted medium of exchange for the fact that milk is used as means of measure this means that milk play a significant role in the world, much so that it was designed in some country's money. For example, Island of Cruernsay shows the world that they have cow in abundance and this indicate how rich they are.

The foremost function of the diary industries is to provide milk and milk products for man. Although, it is known that man compete with calves for cow's milk, it is believed that milking operations start as far as 9,000BC. (Campbell and Marshall, 1985).

Due to the importance of milk to man, God described "Promised Land" as a Land flowing with milk and honey. This means a land of prosperity.

Historically, the origin and naming of milk continues to hold man's curiosity. Most of the hhypocrites recommended milk as a health food and medicine.

The cream of milk is a Non-newtonian fluid, that is it does not obey Newtons law. If the shear stress for a cream milk is plotted against the shear rate, it exhibits $n < 1$ which is a pseudoplastic form of Non-newtonian fluid. (EARIE 1983)
Where n = number of particles.

Cream milk also exhibits a laminar type of flow in which ther exist a layer in the fluid surface. Its thickness is influenced b the Density, Velocity and viscosity of the cream.

It has a Reynold number which is less than 2,100 (Earle, 1983).

The laminar flow of a cream produce a large range of residual time, for its individual particles to flow in a tube.

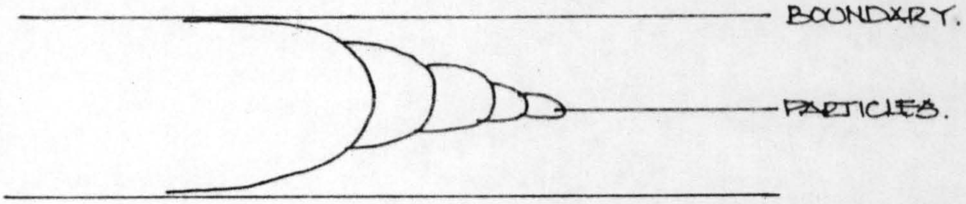


Fig. 2.1 The Diagram of a Laminar flow of Cream

$$Re = \frac{DV\rho L}{\mu}$$

where

Re = Reynold Number

D = Diameter (m)

V = Velocity (mS^{1})

ρ = Density (kgm^{-3})

L = Length (m)

μ = Viscosity ($NS^{-1}m^{-1}$)

The skim milk obey the newtonian law and this makes it to be a Newtonian fluid.

When the shear stress is plotted against shear rate, it gives n = (n = Number of particles)

Any fluid in this group is known as Newtonian fluid, it exhibits a Reynold number which is above 2100. It is a turbulent type of flow in which the layers of particle mix together. The turbulent flow produces thinner layer which permit high rate of heat transfer. The turbulent flow has a higher friction compared to the laminar flow.

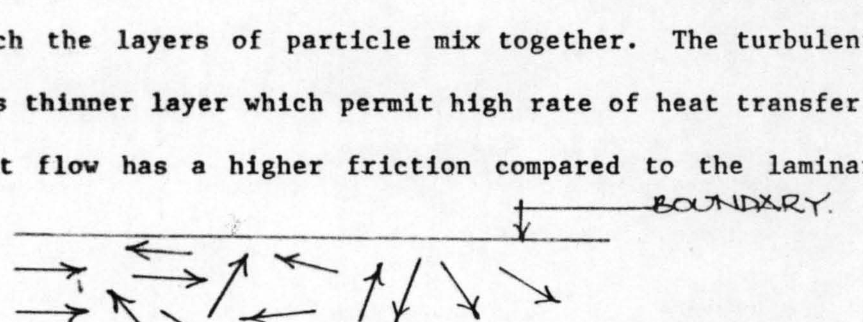


Fig. 2.2 The Diagram of a Turbulent Flow of Skim

2.1 Whole Milk Composition

The composition of milk vary considerably depending on a number of factors such as breed type, but an average figure for all types of conditions of all breed of dairy cow is as follows:

Fat	3.9%
Protein	3.4%
Lactose	4.8%
Water	77.1%
Ash	0.72%

[Ihekoronye and Ngoddy, 1985].

All these together with small quantities of other sustances such as citrates, enzymes, phospholipids form the milk composition. Milk composition may be affected by external factors such as the adulteration with water, the lack of agitation during sampling and similar factors.

Fat or lipid is present in milk in the form of myriads of small globules varying from 1 to 20 μm in diameter. There are generally about 1000 x 10 fat globules in each litre of milk. Apart from protein, vitamin A, carotenoid pigments, certain enzymes such as phosphatase phospholipids are also associated with the fat globule membrane.

Milk protein falls into two main groups namely: Casein which is precipitated by both acid and the enzyme, rennin and the whey protein which are denatured by heat at about 65°c.

Casein is the principal protein of milk representing about 80% of the total protein. It exists as a calcium casein, calcium phosphate complex and is present as a collidal suspension of complex particles called micelles.

After the removal of fat and casein from the milk the resulting liquid is known as Whey. About 0.5 - 0.7% of soluble protein materials is retained in Whey.

Lactose is the main carbohydrate found in milk. It is a disaccharide consisting of glucose and galactose. It exists in the true solution in milk and as such is readily assimilated as a food being hydrolysed into glucose and galactose by the intestinal enzyme.

Minerals occurs when the water of milk is removed by evaporating and the dry residue is incinerated at low red heat, there is left a white ash which contains the minerals substances.

Table 2.1 The Mineral Constituent of Milk

Vitamin	Content Per 100g Milk
Vitamin A	160 IU
Vitamin C	2.0mg
Vitamin D	0.5 - 4.4 IU
Vitamin E	0.08mg
Vitamin B	0.035mg

I.U is international units.

2.2 CREAM MILK PROPERTIES

The depth of the cream line is often taken as an index of milk quality. This is obtained when the milk is put into a basin and it been allowed for few hours to settle the level occupied by the milk in the basin after settlement is what is referred to as index of milk quality.

These depth of the cream layers depend on the following factors:

1. The amount of fat contained
2. The size of the fat globules
3. The extent of the heat treatment of the milk.

Cream milk is a non-Newtonia fluid and has a laminar type of flow when viewed under fluid flow.

The density of cream milk is 1010kg m^{-3} at 3°c temperature.

It has 6.2×10^{-3} NSm^{-2} as its viscocity and its viscocity depends on the solid component contained (Earle, 1983).

Milk colour ranges from bluish-white to a golden-yellow, depending on the breed of animal, the kind of feed, and the amount of fat and solids present.

The pH and buffering of cream milk falls between 6.5 and 6.7, with 6.6 as the usual value when measured at temperature of around 25°c.

The specific gravity of a substance is the ratio of its weight to the weight of an equal volume of water.

The specific gravity of cream milk is not only a resultant of densities of its components, but it is also dependent on variations in the ratio of solid to liquid fat and on the degree of protein hydration.

The freezing point of cream milk is primarily determined by the major constituents of low molecular weight the lactose and the salts and it nearly independent in concentration of colloidal proteins and fat globules. (Cross and Overby, 1988).

2.3 SKIM MILK PROPERTIES

Skim milk is a Newtonia fluid and has a turbulent flow pattern when viewed under fluid flow condition.

The colour of skim milk ranges between a bluish-white to brownish-yellow colour.

The natural taste of milk is scarcely discernable yet it is pleasant and slightly sweet. The sweetness arises from the lactose and saltiness arises from the presence of chlorides, citrates and other mineral salts coagulation can be brought about by enzymatic action or by addition of acid on the skim milk.

The viscosity of skim milk is 1.4×10^{-3} NSm^{-2} at the temperature of 25°c. The density of skim milk is 1040kg m^{-3} (EARLE, 1983).

2.4 MILK SEPARATION TECHNIQUES

There are two major milk separation processes known as:

a) Chemical milk separation and

b) Mechanical milk separation.

2.4.1 The Chemical Separation

The chemical milk separation is the oldest type of separation where chemical like hydrogen perioxide (H_2O_2) is been used. Temperature also play a major role in milk separation because the density of milk increased as the temperature increased.

There are four types of chemical milk separation available.

1. Holder method
2. High temperature short time method (HTST)
3. Pasteurisation
4. Ultra high temperature (UHT).

2.4.2 Holder Method

In the holder method type of milk separation the entire batch of milk is heated to a definite temperature for a given time. The usual time and temperature is 30 minutes at 65°c. Temperature above 60°c causes a cooked flavour in the milk and the phospholipid membrane around the fat globules may be destroyed reducing the tendency of the milk to form a cream layer.

This destroys 90-99% of bacterial present in the milk.

2.4.3 HIGH TEMPERATURE SHORT TIME METHOD (H T S T)

In this type of chemical milk separation, milk is held for 15-16 seconds at temperature between 71.7°c and 75°c through the use of a plate-type heat exchanger, a system in which close temperature control is critically important. The product is then cooled rapidly after heating it to prevent the growth of surviving bacterial in the milk.

This bring about 90 - 99% destruction of bacteria present in the milk, with a very little change in the lactose, and fat constituents. Vitamin C may be substantially destroyed along the process.

2.4.4 THE PASTEURIZATION

Pasteurization is the process by which bacterial are removed from milk by means of special heating process.

In this procedure about 0.03 - 0.04 percentage of hydrogen perioxide (H_2O_2) is added to the milk as soon as possible after milking before the heating process takes place. Another batch of hydrogen perioxide (H_2O_2) is added after 12-20 hours since the enzyme catalase in the milk destroys the hydrogen perioxide.

After all these stages, the fat globules of milk rise to the upper surfaces to form a distinct cream line. The depth of which is often taken as an index of richness of milk quality. The time taken for the cream to rise and the depth of the cream layer depends on the following three factors:

1. The amount of the fat
2. The size of the globules
3. The extent of the heat treatment of the milk.

Fresh raw milk that has been cooled to 4°c gives the maximum and most distinct cream line. Milk which is pasteurized for 15 seconds at 71.7°c has a slightly lower and less defined cream layer. Milk heated at 75°c will virtually lose its creaming properties altogether.

2.4.5 The Ultra High Temperature (UHT)

This is another method of chemical separation of milk. In this method the separation is done under a high temperature, when the whole milk is heated to high temperature.

The advantages of high temperature short time method over the holding process are:

1. Less floor space is required.
2. The original cost of equipment is lower although this saving may be partially offset by use of better heaters and controllers.
3. The capacity of the equipment is more easily expanded.
4. Labour can be better utilized because bottling can start almost as soon as pasteurization begins.
5. Equipment is more easily cleaned and sanitized by cleaning in place procedures.
6. Thermophilic bacteria are less troublesome.

The disadvantage of HTST when compared with holding process are as follows:

1. Bacterial reduction is sometimes not as great, probably because of a greater survival of thermodaric bacteria.
2. Where plate units are used, the gasilets require special care in cleaning.
3. Usually a sweet-water cooling system is an integral part of the HTST unit. (Judkins and Keener, 1960).

2.4.6 Mechanical Separation

In the mechanical separation method the forces considered are gravity combination of gravity with other forces such as centrifugal forces, pressure forces and the velocity of particle moving in the fluid.

Mechanical separation are divided into four(4) groups namely:

1. Sedimentation
2. Filtration
3. Sieving
4. Centrifugal separation.

2.4.7 Sedimentation

In sedimentation method two immiscible liquids i.e whole milk which consists of skim and cream milk or a liquid and solid skim and cream milk are separated by allowing them to come to equilibrium under the action of gravity, in which the heavier material, the skim milk fall with respect to the cream milk which is the lighter material. The process may be slow and it is often speeded up by applying centrifugal forces to increase the rate of sedimentation.

2.4.8 Filtration Method

Filtration is the separation of lighter particles (cream) from liquid in whole milk, by causing the mixture to flow through fine pores which are small enough to stop the lighter particles from passing, but large enough to allow the liquid particle (milk) to pass. The classification of lighter particles contained in whole milk involves in this system is often done by sieving.
The important characteristic of particles are size, shape and density. For the (liquid) the skim milk, the important characteristics used here are the viscosity and density.

2.4.9 Sieving Method

Restraint is imposed on some of the particle contained in the whole milk by mechanical screen which prevent their passage. This is done successively by using increasingly smaller screens to give a series of particle classified into sizes and ranges.

Actually, the filtration and sieving method of separation are very similar when compared together, but the only difference that exist between the two are, that, in the sieving method a sieve is been used and the size of the holes available in the sieve are bigger compared to the size available in the filtration method.

In filtration method the material used here are almost without any hole, their holes are very tiny that are hardly seen with naked eyes. A good example of one is the filter paper used in chemistry practical. They have no hole but liquid particle can pass through it.

In filtration method, much time is taken before the separation can be completed but with sieve method it is very fast.

2.4.10 Centrifugal Separation

The centrifugal method of separation is, the separation used for separating cream and skim milk from whole milk. The force involved is the combination of the centrifugal force with gravity. The centrifugal force depends upon the radius, speed of rotation of the centrifugal basin and upon the mass of the whole milk particle involved. This is the separations of one components of a liquid-liquid mixture, where the liquids are immiscible but finely dispersed, as in an emulsion and in the dairy industry in which the milk is separated by a centrifuge into skim milk and cream.

To examine the position of the two phases of immiscible liquid involved in the centrifugal as it operates.

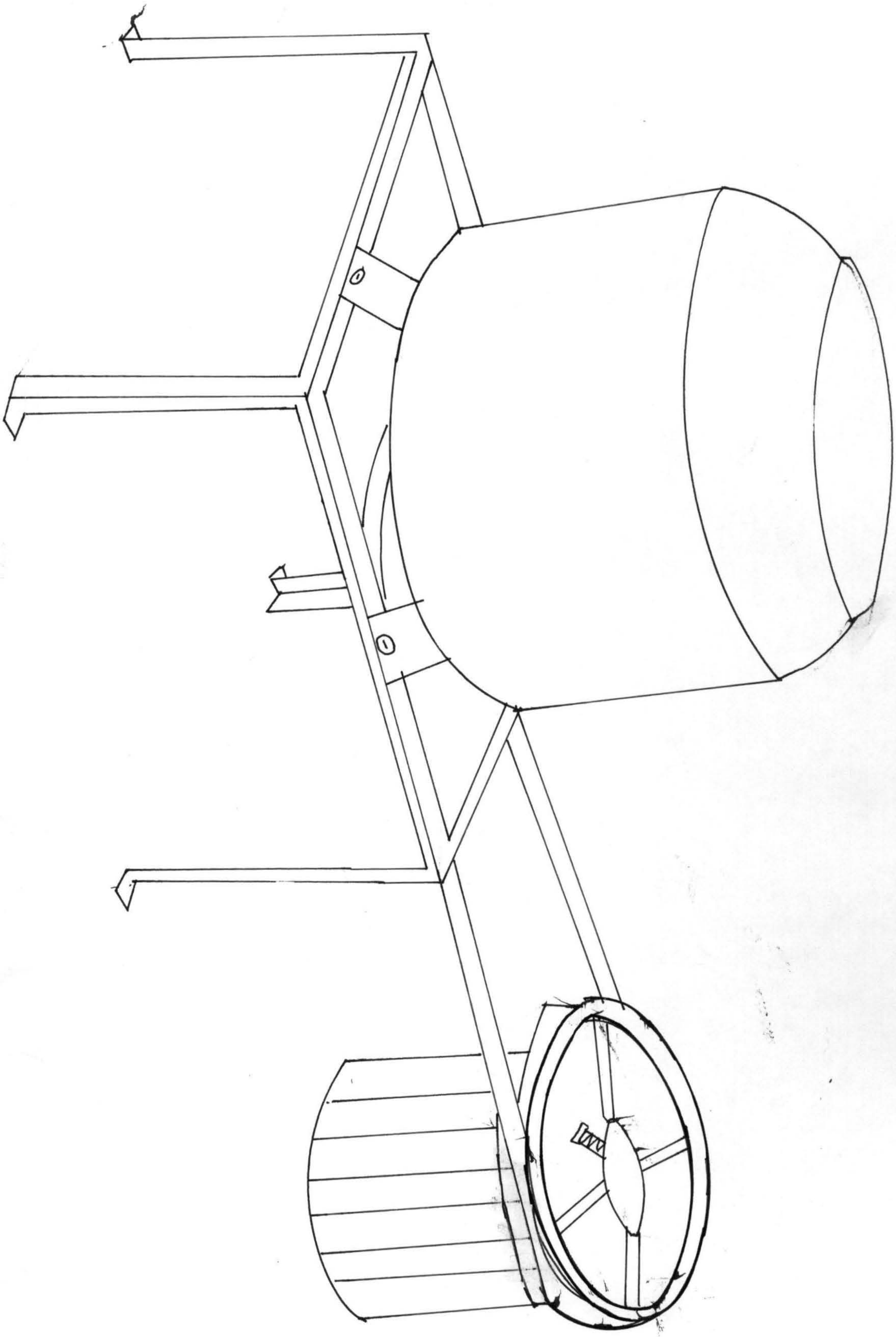


Diagram of a centrifugal skim
milk separation

One of the technique used in milk separation is centrifugal method.

The first continuous centrifugal milk separator was invented by prandtl of German. (Cross and Overby, 1988).

After this many improvement have been made by various scientists.

The separator is constructed much like a clarifiers, where a shaft with a bowl mounted on it. Milk is then put inside the mounted bowl as the bowl spins with the aid of an electric motor of 5400 revolution per minute. Which is 6500 times greater than gravity. (Cross and Overby, 1988).

The heavier skim milk is forced against the bottom of the bowl and lighter fat globules are displaced inward against the top of the bowl. Each form a stream, the skim milk at the side and the cream at the centre.

The purpose of the bowl is to divide milk into separate layers, so centrifugal force can separate fat globules from milk easily. This is possible because the fat globules need to travel only a short distance before being separated from milk once skim milk reaches the side of the bowl it is forced toward an outlet available at the bottom of the bowl.

Similarly cream is displayed at the top of the cylinder bowl. This can be removed manually by using a flat plate to park it or through an outlet available at the bottom.

An efficient centrifugal separator should produce skim milk with not more than 0.01 percent of fat if Bablock test is used or 0.06 to 0.10 percent if Mojonnier test is used. The separation efficiency of a centrifuge depends especially on the size of the ratio of the centrifugal acceleration to the accleration due to gravity, which is denoted the centrifugal constant.

$$Z = \frac{r w^2}{g}$$

where

Z, is the centrifugal constant

r, is the radius (m)

w, is the angular velocity (rad/s) and

g, is the acceleration due to gravity ($=9.81 m/s^2$).

2.5 STORAGE OF MILK

To prevent the rapid growth of bacteria within the milk it is essential that it should be stored under refrigerated conditions. To ensure good quality of milk such as it's taste, colour, flavour, oxidation - reduction potential of milk, pH and buffering of milk etc. it is important that the milk should be cooled rapidly to 4.4°c for 30 minutes after the end of morning milking. This cooling is used in controlling multiplication of bacteria.

Raw milk is stored in site-type tank which are to agitate milk with filtered, compressed air which is admitted at the bottom and stirs milk at it rises.

2.5.1 Storage of Milk Powder

It has generally been found that whole milk powder has a storage life of 4-10 months and skim milk powder has a life of 6-14 months at 20°c. (Ihekoronye and Ngoddy, 1985).
Bacteria do not multiply in dried milk, and infact they tend to decrease in numbers so long as the moisture content remains low.

2.6 DAIRY PRODUCTS

Other dairy products are:

2.6.1 Ice Cream

In manufactures of ice cream, the mixture of butter fat, milk sugar, gelating egg and flavouring such as vanilla, fruits, fruit juices, cocoa, chocolate and nuts are pasteurized by heating at 65.5°c for 30 minutes then homogenised while hot by forcing the liq through a small orifice. The fruits and nuts are added after homogenization, the mixture is cooled to about 2°c while being agitated then frozen by forcing the product under air pressure.

2.6.2 Cheeze

Cheese is made from milk by curdling the protein which is only soluble under certain conditions. When the acidity of the milk rises it curdles, success in cheese making depended on attaining the level of acidity.

This is brought about by innoculating fresh pasteurised milk strains of lactic acid producing bacteria. The enzyme rennin contained in an extract of the digestive stomach of the cow is also added to assist coagulation.

2.6.3 Whey or Ware

This is the product obtained from the fermentation of cow milk. The product is carrot-shaped and is normally solid in its whey. It is eaten fresh in its unripened and uncured in some urban areas it is further cooked with salt until the texture toughen and forms a substance which is eaten as meat substitute in stews.

The coagulator is derived from a joice extract of a local plant calotropic procera, (sodom apple), especially the young leaves and buds. The activity of the milk clothing factors is lost in the green leaves when dried but it could be retained for over a week if kept at refrigeration temperature

2.6.4 Condensed and Evaporated Milks

Both types of product are produced by vacuum evaporation of milk, either whole or skimmed and with or without the additio of sucrose.

The ratio of concentration of full-cream products is abo 2.5:1 and for skimmed products about 3:1.

In general the term "evaporated milk refers to the unsweete products".

2.6.5 Butter

Butter is a product made from fat to which salt may be added to improve the flavour and keeping qualities. The yellow colour of butter is due to the pigment B carotene in the cream. The nutritional value of butter relies entirely upon its fat contents and associated fat soluble in vitamin.

The first process in butter manufacture is separation of the cream from the milk. This is done by centrifuges which remove up to 99.5 percentage of the fat from the milk, prior to use the cream is usually standardized to a fat content of about 30-33 percentage.

2.6.6 Yoghurt

Yoghurt is a fermented milk product that evolved empirically some centuries ago by allowing naturally contaminated milk to sour at warm temperature probably in the temperature range of 40-50°c. In the manufacture of natural yoghurt the milk to be fermented is heated to 90°c for 15.30 minutes culture of lactobacillus bulgarious and streptococcus thermophilius, and held at this temperature for about 3 hours until the desired reach temperature which is 90°c. The product is then cooled to 5°c for packaging.

2.7 MATERIAL SELECTION

In designing an efficient skim milk and cream separation the most basic discussion involves the choice of materials. Beside their availability and cost which are always of primary consideratio Materials are chosen on the basis of their properties.

In selecting materials to achieve the main objectives of design, factors such as cost of the materials, availabili durability and amount of labour must be taken into considerati One should not be wholly sacrified in order to achieve the ot that is to say cost should not be sacrified for durability, s this would invariably affect its life span and more over efficiency of the machine. There are alot of engineering mate but how to select from this lot depends on the factors mentioned above and also machine ability. The availability of the materials within locality will reduce constructional cost and make it comparatively easier for customers to purchase due to its relative low cost.

The properties of the materials must include resistance to corrosion by the pressing element and the roasting container because corrosion may contaminate the milk thereby rendering it unfit for human consumption. Parts such as the shaft in the machine are so critically important that they require special materials to ensure reasonable working life. Also the type of material used for the construction of the basin actually stainless steel is the best because of its resistance to corrosion, wearing among others.

CHAPTER THREE

3.0 DESIGN METHODOLOGY

The step employed in design and fabrication of acentrifuge for skim and cream milk separation is that the machine is divided into three individual component units, which are then synchronised into a system to satisfy the overall machine capacity.

THE INDIVIDUAL UNITS ARE

1. The cylindrical shaped milk Basin
2. The Rotating centrifugal shaft
3. Power Transmission system.

3.1 DESIGN CONSIDERATIONS

- To rotate the cylinder at a speed of 5400 revolution per minute based on previous study
- To separate $0.015m^3$ of whole milk in 6 minutes ($2.5 \times 10^{-3}m^3/min = 0.15m^3/hr$).
- To apply the principle of centrifugal force in the separation of whole milk.
- To carry out whole milk separation under hygienic conditions, using stainless steel material for machine components.
- To determine optimum power (i.e 3KW) requirements of the machine. A three-phase electric motor power supply or diesel engine is selected as the power source.
- To reduce the foaming that always occur during the separation of the whole milk.
- To perform the separation operation in a very easy way and to make it possible to maintain the machine in a very simple way.
- To improve the efficiency of the milk separation to about 90%.

FUNCTIONAL REQUIREMENT OF THE MACHINE

To separate skim milk and cream from the whole milk.

To perform the separation process of whole milk in a highly hygienic condition.

To perform the separation in a more efficient way and using mechanical method of centrifugation.

3.2 MACHINE DESCRIPTION AND OPERATIONAL PROCEDURE

The construction of the centrifugal milk separator involves machining, cutting and welding work for the production of the components parts. The working drawing provides the detailed information required in the production of centrifugal milk separator components and parts.

However, most of the components used in the construction of centrifugal milk separator are standard parts obtained directly from manufactures through their marketing agents. All other components are fabricated and machined to the required dimension and specification. This is then followed by the installation of milk using centrifuge.

The activities of the installation of the centrifuge milk separator involves assembling the components and parts together. The electric motor of 3kw is connected to give power supply through a control switch.

However, considering the cost involvement in the purchase of material for construction of the centrifuge milk separator, a prototype machine was developed to demonstrate the operation of the centrifuge milk/cream separator from whole milk.

The cylinder is a container in which the whole milk will be introduced. It is inside this cylinder that the real separation process takes place.

The cylinder is constructed of a stainless steel of grade 18-8 cold rolled and of thermal conductivity of 215 $m^{-1}S^{1}OC^{-1}$.

The stainless steel used here have a moderate weight and a density of $7920kg/m^3$ in order to reduce vibration that is likely to occur during the separation process.

The basin which is cylindrical in shape has a diameter of 20cm and a height of 15cm it's volume is $0.015m^3$.

The space between the false bottom and the real bottom of the inner cylinder which contained the whole milk, housed the bearing that held the outer cylinder with the insulator and permit easy rotation of the shaft and the inner cylinder.

The weight of the pulley and the two bearings act through the shaft which stand at the centre of the basin.

As the electric motor is switched on the electric motor pulley transmits motion to the V-belt. The V-belt then transmit a speed of 2800 revolution per minute to the centrifuge pulley at the other end of the V-belt. i.e the shaft that turns the cylinder basin. The separation of whole milk into skim and cream takes place at a speed of 5,400 rpm.

After 6 minutes of revoluction the cream milk, which is the lighter layer migrate to the centre of the basin where there is long pipe for it's discharge. The other product, the skim milk which is left in the cylinder and which is a bit heavier than the cream migrate to the side of the basin where there is a pipe at the bottom of the cylinder which act as its discharge.

3.3 MACHINE COMPONENTS DESIGN CALCULATIONS

3.3.1 Flow Rate

Assuming 150kg of whole milk

Mass flow rate

$$\text{Mass flow rate} = \frac{150kg}{3600\ secs} = 0.042kg/s$$

Mass per batch for whole milk

Assuming ten loading times per hour

$$\text{Mass per batch} = \frac{150kg}{10} = 15kg/6min$$

$$\text{Density} = {}^{mass}/_{volume}$$

$$\text{Volume} = {}^{15}/_{1033} = 0.0145 = 0.015m^3/6min$$

$$= 2.5x10^{-3}m^3/min$$

$$= 0.15\ m^3/hr$$

3.3.2 Shape and Dimension of Bowl Milk

A cylindrical shape was selected for the milk bowl for efficiency.

with a cylindrical shape

$V = \pi r^2 h$

where

π = 3.14

r = Radius of the cylinder

h = Height of the cylinder

V = Volume of the cylinder

$V = \pi r^2 h$ i.e $0.145 = \pi r^2 h$

$= r^2 h$

Because of the high speed involved, the height of the bowl will be smaller than the diameter of the bowl to enhance machine stability from $0.0145 = \pi r^2 h$ and by trial

r = 0.1m and h = 0.15m

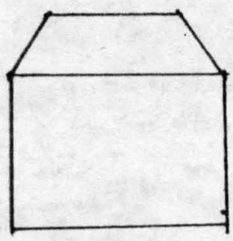
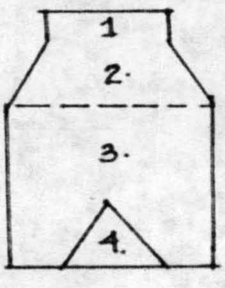


Fig. 3.1 The Outermost Cylinder

3.3.3 Volume of Bowl

Volume of bowl = volume of 1st cylinder + frustrum of cone 2 + volume of cylinder 3 - cone 4.



Volume of 1st cylinder $= \pi r^2 h$

$\pi (0.1)^2 \times 0.015 = 0.00047m^3$

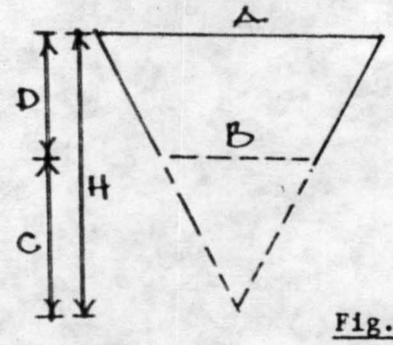
Volume of frustrum of cone 2

= volume of large cone - volume of small cone

Volume of large cone $= {}^1/_3 \pi r_1 H$

$= {}^1/_3 \pi (0.1) \times 0.06 = 0.006m$

Fig. 3.2 **The Sectioning of the Cylinder**



Volume of small cone $= {}^1/_3 \pi r^2 x L$

$= {}^1/_3 \pi (0.1)^2 \times 0.03$

$= 0.00032m^3$

Volume of frustrum

$= (0.002 - 0.00032) = 0.0197m^3$

Fig. 3.3 A Cone

$\frac{C}{B} = \frac{C+d}{A} \quad , \quad \frac{C}{0.1} = \frac{C + 0.03}{0.02}$

$0.02 = 0.1C + 0.003 \quad , \quad (0.2 - 0.1)\ C = 0.003$

$0.1C = 0.003, \quad C = 0.03$

$\therefore \quad H = 0.03 + 0.03 = 0.06m$

Volume of cylinder 3 $= \pi r^2 h$

$= \pi \times (0.1)^2 \times 0.110 = 0.0035m^3$

Volume of cone 4 $= {}^1/_3 \pi r^2 h$

$= {}^1/_3 \pi (0.02)^2 \times (0.015) = 0.0000063m^3$

Volume of bowl

$= (0.00047 + 0.0063 + 0.0035 - 0.0000063)m^3$

$= (0.01027 - 0.0000063)m = 0.0103m^3$

Area of bowl

Area of bowl = area of $(1+2;3-4)m^3$

see fig. 3.1

Area of 1st cylinder $= 2\pi rh + 2\pi r^2$

$= 2\pi (0.05)\ 0.03 + 2\pi (0.05)^2$

$(0.0094 + 0.0157)$

$= 0.025m^2$

Area of large cone - Area of small cone

$(\pi r_L L_L + \pi r^2) - (\pi\ rs\ Ls + \pi rs^2)$

$(\pi (0.1)\ (0.115) + \pi (0.1)^2 \quad (\pi (0.05) \times 0.06 + \pi (0.05)^2)$

$= 0.036 + 0.032 - 0.0094 + 0.0078$

$0.068 - 0.0173 = 0.0507m^2$

Area of 2nd cylinder $= 0.0507m^2$

Area of 3^{rd} cylinder $= 2\pi rh + 2\pi r^2$

$= 2\pi(0.1)\ (0.105) + 2\pi(0.1)^2$

$0.066 + 0.063 = 0.129m^3$

Area of 4^{th} cylinder $= \pi r_L + \pi r^2$

$\pi r\ (\ + r) = \pi\ (0.02)\ (0.025 + 0.02)$

$= 0.0028m^2$

Area of bowl $= (0.025 + 0.0507 + 0.129 - 0.0028)m$

$(0.2047 - 0.0028) = 0.202m^2$

3.3.4 **Wall Pressure Determination**

Static pressure (Ps) exerted by the milk

$$Ps = \frac{\text{Force, F(N)}}{\text{Area A } (m^2)} = \frac{\rho V g}{A}$$

where

ρ = density (kg/m^3)

V = Volume (m^3)

g = $9.8/m5^2$

$$Ps = \frac{1.033 \times 0.013 \times 9.81}{0.202} = \frac{131.74}{0.202}$$

$= 652.17N/m^2$

Centrifugal force

Because centrifuge imposed so much centrifugal force than gravity, the effect of gravity is usually neglected in the analysis of centrifugal separation.

Therefore, the centrifugal force Fe on a particle which is enclosed to rotate in circular path is given by

$$Fc = mrw^2 \text{ -------------(1)}$$

or $$Fc = \frac{mv^2}{1} \text{ -------------(2)}$$

$w = V/_r$

$w = \frac{2\pi N}{60}$, $m = \rho V$

Equation (1) can also be written as

$$Fc = mr\ (\frac{2\pi N}{60})^2$$

$$Fc = 0.0028\ (mrN^2)$$

$$Fc = 0.0028\ \rho vrN^2 \text{--------(3)}$$

$= 0.0028 \times 1033 \times 0.0103 \times 0.1 \times (5400)^2$

$= 86872.66\ N/m^2 = (0.09MPa)$

Therefore pressure exerted Pc on the bowl wall due to centrifugal action $Pc = \frac{Fc}{A}$

$$Pc = \frac{0.09}{0.202} = 0.45 \text{ MPa}$$

Combinal pressure P_T

The total pressure P_1 exerted on the wall of the centrifuge bowl $P_T = Ps + Pc$

$$= (0.202 \times 10^{-4} + 0.45) \text{ MPa}$$

$$P_T = 8.4 \times 10^{-6} \text{MPa } (0.45 \text{ MPa})$$

The number of gravitational force that can be obtained from this machine is

$$Ng = {}^{FC}/Fg = \frac{0.0028}{mg} mrN^2 = \frac{0.018rN^2}{g}$$

$$= \frac{0.0028 \times 0.1\ (5,400)^2}{9.81} \qquad \frac{8164.8}{9.81}$$

$$Ng = 832.3$$

This implies that the centrifuge in this design is 9174 times better than ordinary gravitational sedimentation.

3.3.5 Adequacy of Bowl Wall Thickness

For thin wall cylinder as in this design

$$0a = \frac{P_T r}{2t} \text{ and } 0_b = \frac{P_T r}{t}$$

This implies that a longitutidinar joints needs to be twice as strong as a transverse joint (Design data PSG TECH 1982).

Using a wall thickness of 0.00/m to minimise cost and load and using stainless steel (18-8) cold rolled - (Adekola, 1994).

$$0_a = \frac{0.45 \times 10^6 \times 0.1}{2\ (0.001)} = \frac{45.000}{0.002} = 2.2 \times 10^7 \text{MPa}$$

$$0_b = \frac{0.45 \times 10^6 \times 0.1}{0.001} = 1.0125 \times 10^7 \text{MPa}$$

For stainless steel (18-8) cold rolled with elastic strength and ultimate strength of 1140MPa and 1310MPa respectively, a thickness of 0.001m is adequate in terms of its ability to withstand the circumferential and axial stresses of 1012MPa and 2250MPa respectively (Adekola, 1994).

Speed ratio

Centrifuge speed = 5400 rpm (N_2)

Motor speed = 2,800 rpm (N_1)

motor pulley diameter = ?m (d_2)

centrifuge pulley diameter = 0.075m(d.)

from the relation $Nd = N_2 d_2$

$$d_2 = \frac{n_1 d_1}{n_2} \text{ (Design data 1982)}$$

$$d_2 = \frac{2,800 \times 0.075}{5400} = 0.039\text{m}$$

$\therefore$ diameter of motor pulley required = 3.9cm

3.5 V-BELT DESIGN

Assumptions

Considering the expected load for the machine type 'B' V-bell is chosen which is adequate for (2-15kw) machine (3) (Design data 1982). The dimension of the chosen belt are top width (17mm) and thickness (11cm)

Sheave groove angle, θ = 40° (standard for v-belts)

Friction between pulley and belt, μ = 0.25

Weight per metre = 0.189kgf (1.86N)

Bottom width of belt = 970 kg/m^3

Design data 1982.

$$\text{Angle of wrap, } B = \frac{180 - \theta}{2} = \frac{180-40}{2} = 70$$

$T = \frac{1}{2}W_1 \tan B$

$= \frac{1}{2}(17) \tan 70 = 24\text{mm}$

Using similar triangles concept.

$$\frac{W_2}{W_1} = \frac{t}{T_1}$$

$$W_2 = \frac{11 \times 17}{24} = 8\text{mm}$$

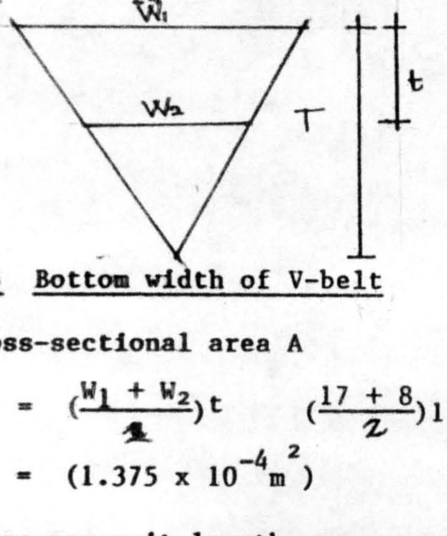


Fig. 3.4 Bottom width of V-belt

Belt cross-sectional area A

$$A = \left(\frac{W_1 + W_2}{2}\right)t \qquad \left(\frac{17 + 8}{2}\right)11 = 1375\text{mm}^2$$

$$= (1.375 \times 10^{-4}\text{m}^2)$$

I) Mass per unit length, m

$m = \rho A$

$= 970 \times 1.375 \times 10^{-4} = 0.133\text{kg/m}$

Belt maximum power Estimation

Belt speed = S d_2 n_2 = π 0.075 x $\frac{2800}{60}$

S = 10.9 $\simeq$ 11m/s

II) Small diameter factor, fb to account for variation of are of contact.

$$\frac{D_2}{D_1} = \frac{0.039}{0.075}$$

for $^{D_2}/D_1$ o 0.52, fb = 1.13

III) Equivalent pitch diameter , de = dp x fb

= 125mm x 1.13 = 142mm

IV) So the pulley pitch diameter chosen (142mm) is adequate i.e it is above the minimum pulley pitch diameter dp of 142mm.

V) The maximum power of the belt , p

$$P(kw) = (0.795^{-0.09} - \frac{50.8}{de} - 1.32 \times 10^{-4} S^2)S$$

Design data PSG Tech. 1982

$$= (0.79(II)^{-0.09} - \frac{50.8}{14.2} - 1.32 \times 10^{-4}(11)^2)11$$

(0.637-0.358-0.016)11

P = 2.8KW = 3KW

This power is suitable for the belt because for a belt speed off 11m/s at 142mm pitch diameter, the minimum power rating Pr for the belt is 3KW so it is safe.

Adequacy of Driver and driven pulley speeds for adequacy $\frac{n1}{n2} \leq {}^9/2$

1.C $\frac{5400}{2800}$ = 1.9 and $^9/0.98$ = 9.18

since 1.9 < 9.18, the selected driver and pulley driven speed are adequate.

Diameter of larger pulley

using $D_2 = \frac{dini}{n_2}$ η

$$= 3.9 \left(\frac{5400}{2800}\right) 0.98$$

$$\left(\frac{5400}{2800}\right) 0.98 = 7.56cm$$

= 0.075m

speed ratio , i

$$i = \frac{7.56}{40} = 0.19$$

The recommended ratio $^c/D$ = 1.2 from table in Design data 1982.

C = Centre distance

To determine C

$C = {}^c/D \times D$

$= 1.2 \times 7.6 = 9.12$

$= 9.00$

C = 30cm

= 0.3m

Nominal pitch length, L

$L = 2L + \pi/_2 \quad (D_2 + d_1) + \frac{(D_2 - d_1)^2}{4L}$

$2(30) \quad /_2 \; (9.00 + 4) + (9.0 + 4)^2$

$C = 1225.2 + \frac{(5)}{120} \; 4(30)$

$= 1225.2 + 0.208 = 1225.4cm$

$= 12.3m$

3.5.1 **No of belt required:**

I) Correction factor for industrial service, fa = 1.1

(for medium duty up to 10h for AC motor)

II) Rating for V-belt = 3KW (at 11m/s and 142mm pitch diameter.

Correcting factor, FC = 0.81

III) Calculation of arc of contact on Small pulley

Arc of contact , $\alpha = 180 \quad 2 \sin^{-1} \frac{R-r}{C}$

$\alpha = 180 \pm 2 \sin \frac{3.8 - 2.0}{30}$

$\alpha = 180 \pm 6.87$

$\alpha_1 = 180 + 6.87 = 173°$

$\alpha_2 = 180 + 6.87 = 187°$

Fd = 0.97 (V-belt)

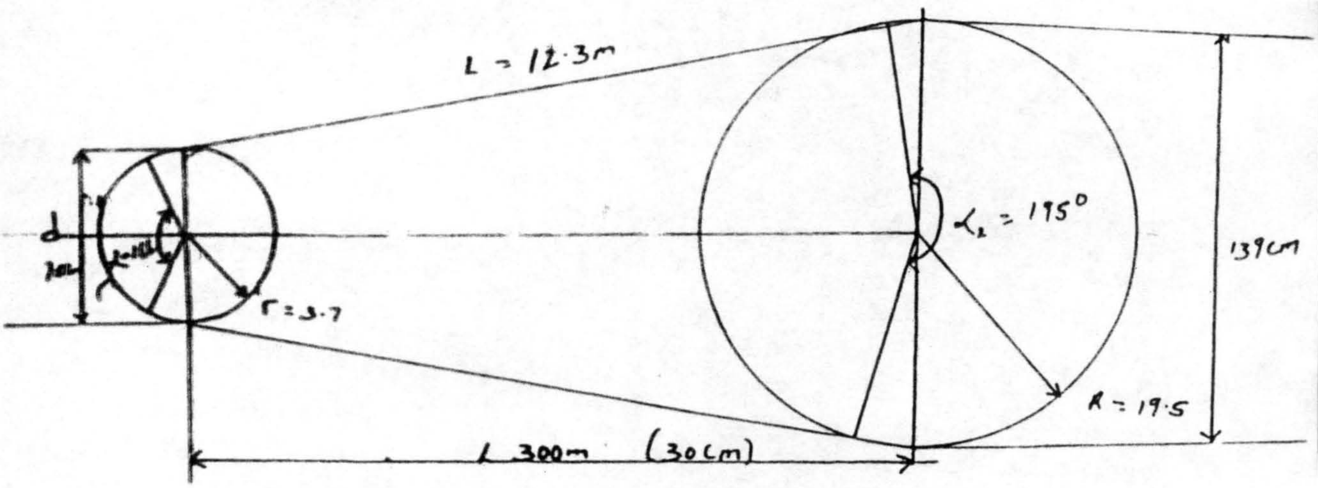
No of belt $= \frac{P \times Fa}{Pr \times F_L x Fd} \qquad \frac{3 \times 1.1}{3.29 \times 0.81 \times 0.97}$

$= \frac{3.3}{2.585} = 1.3$

So use 2 V-belts

Belt Tension

Belt velocity/speeds = 11m/s as calculated.



$$\alpha_1 = 166^\circ$$

$$\alpha_2 = 175^\circ$$

Fig. 3.5. The Pulley and the belt.

The maximum tension for leather belt = $2 \times 10^{6} N/m^{2}$

(Design data PSG TECH 1983)

$2 \times 10^{6} \times 1.375 \times 10^{-4}$, T_1 = 275N

Belt Tension in tight side,

II) Tension Rate

Allowable Tension rate, R for the V-belt is given by $R = \dfrac{e^{\mu\alpha}}{\text{Co sec}\ \theta/2}$

$$R_1 = \frac{e^{0.25 \times 173 \times \pi/180}}{\text{Sin } 20} = R_1 = 9.09$$

$$R_2 = \frac{e^{0.25 \times 187 \times \pi/180}}{\text{Sin } 20} \quad R_2 = 10.87$$

The value of R_1 is used in further calculation since it is less than R_2

III) Centrifugal force on Belt, FC

$$FC = mv^2$$

$$= 0.133 \times (11)^2 = 16.1N$$

V) Belt Tension in slack side, T2

from $\dfrac{T1 - Fc}{T_2 - T_1} = R$

$$T_2 = \frac{T_1 - Fc}{R} + FC, \quad T_2 = \frac{275 - 16.1}{8.31} + 16.1$$

$$T_2 = 31.15 + 16.1 = 47.3 \simeq 47$$

Selection of Inlet and Outlet Sizes

The outlet pipe is smaller in diameter compared to the inlet pipe diameter and there are four outlet pipes present. Two are for the heavier liquid i.e the skim milk while the other two pipes are for the lighter liquid i.e the cream milk.

The diameter of the outlet pipe for skim milk is 1cm each and the diameter for the cream milk outlet is also 1cm each.

3.6 Heat Insulation Load

Data

Ambient operating temperature = 30°c

Required whole milk temperature = 35°c

Retention time per batch = 6 min (360sec)

Thermal conductivity of stainless steel = $21J\ m^{-1}S^{-1}oC^{-1}$

Specific heat of cotton wool, C = $1.26KJKg^{-1}C^{-1}$

Density of cotton wool P = $80kg/m^3$

Thermal conductivity of whole milk = $056Jm^{-1}S^{-1}\ ^{-1}$ (Adekola 1994)

Heat conducted by stainless steel bowl with a cylindrical shape of the milk bowl,

Circumference $= \pi 2 r$

$= 2\pi(0.1) = 0.63m$

$\therefore$ Heat conducted away from the milk to surrounding air

$= 21 \times 0.63 \times 3.60 \times (35-30)$

$= 24KJ$

Heat released by the whole milk is

$= 0.56 \times 0.63 \times 360 \times (35 - 30)$

$= 0.64KJ$

Total heat cost $= (24 + 0.64)KJ = 2464KJ$

3.6.1 **Insulator**

To prevent heat loss, an insulator must be provided from the review of insulator available, cotton wool is selected because of its availability low cost, lower weight and high insulating capacity using the expression.

$\emptyset = mcDt$

mass of cotton wool needed, $m = {}^{\theta}/ct$

$= \frac{24.64}{1.26(35-30)} = \frac{24.64}{6.3} = 40Kg$

Volume of cotton wool required $V = {}^{m}/P$

$= {}^{40}/80 = 0.5m^3$

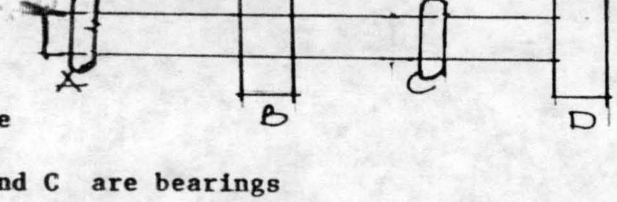
circumferential thickness of cotton wool required

$t_1 = t = {}^{V}/A = \frac{0.5}{014.2} \; t = 3.5$

The insulation load will be stationary while the centrifuge rotates inside it.

3.7 **Design of Centrifuge Shaft**

Sketch of shaft loading



where

A and C are bearings

B is driven pulley

D is the centrifuge machine load

Calculation of components weight

I) Weight of A and C are negligible

II) Weight of B = 2 r x width x Thickness x ρgCl x g

$2\pi(0.036) \times 0.02 \times 0.025 \times 7200 \times 9.81$

= 8N

where

ρg = density of grey cast iron

III) Weight of milk load = ρvg

where

Pss = density of stainless steel

$\rho vg = 1033 \times 0.0045 \times 9.81 = 45.6N$

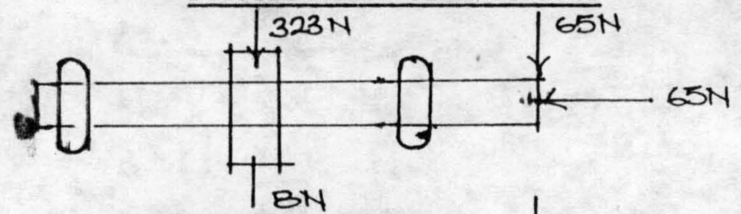
IV) Weight of bowl = Area x thickness x ρ_{ss} x g

$= 0.142 \times 0.001 \times 7920 \times 9.81 = 11N$

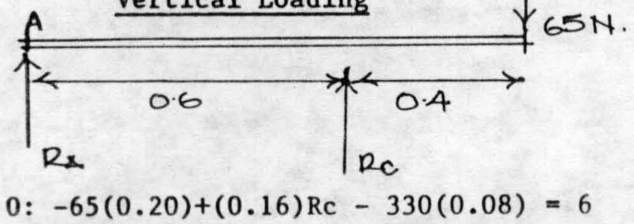
V) Miscellaneous weight of 8N is chosen for other minor elements

VI) Weight of D = (45.6 + 11 + 8)N = 65N

Determination of Reactions



3.7.1 Vertical Loading



$\Sigma MA = 0: -65(0.20)+(0.16)Rc - 330(0.08) = 6$

$-13 + 0.16Rc - 26.4$

$0.16RC = -26.4 + 13$

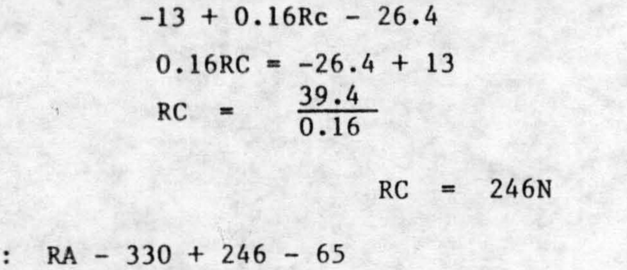
$RC = \frac{39.4}{0.16}$

RC = 246N

$\Sigma F = 0: RA - 330 + 246 - 65$

RA = 149N

3.7.2 Horizontal Loading



$\Sigma MA = 0 : -65(0.20) + 0.16RC = 0$

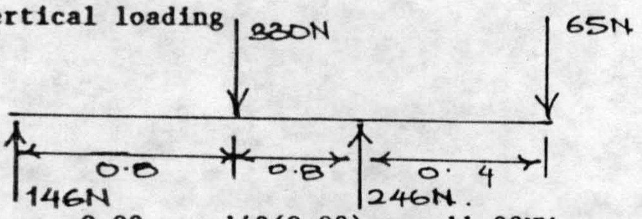
$RC = \frac{13}{0.16} = 81.3N$

$\Sigma R = 0$: RA + 81.3-65 = RA + 16.3

RA = -16.3

Bending moment Determination

i) Vertical loading



BMx at x = 0.08 : 149(0.08) = 11.92NM

BMx at x = 0.16 : 149(0.16) - 330 (0.08)

= 23.84 - 26.4 = -2.56NM

BMx at x = 20 : 149(0.20) -330 (0.12)+246(0.04)

29.8 - 39.6 + 9.84 = -19.64NM

l) Maximum vertical bending moment, MV = -19.64NM

Shear force (SFD) and bending moment diagram (BMD)

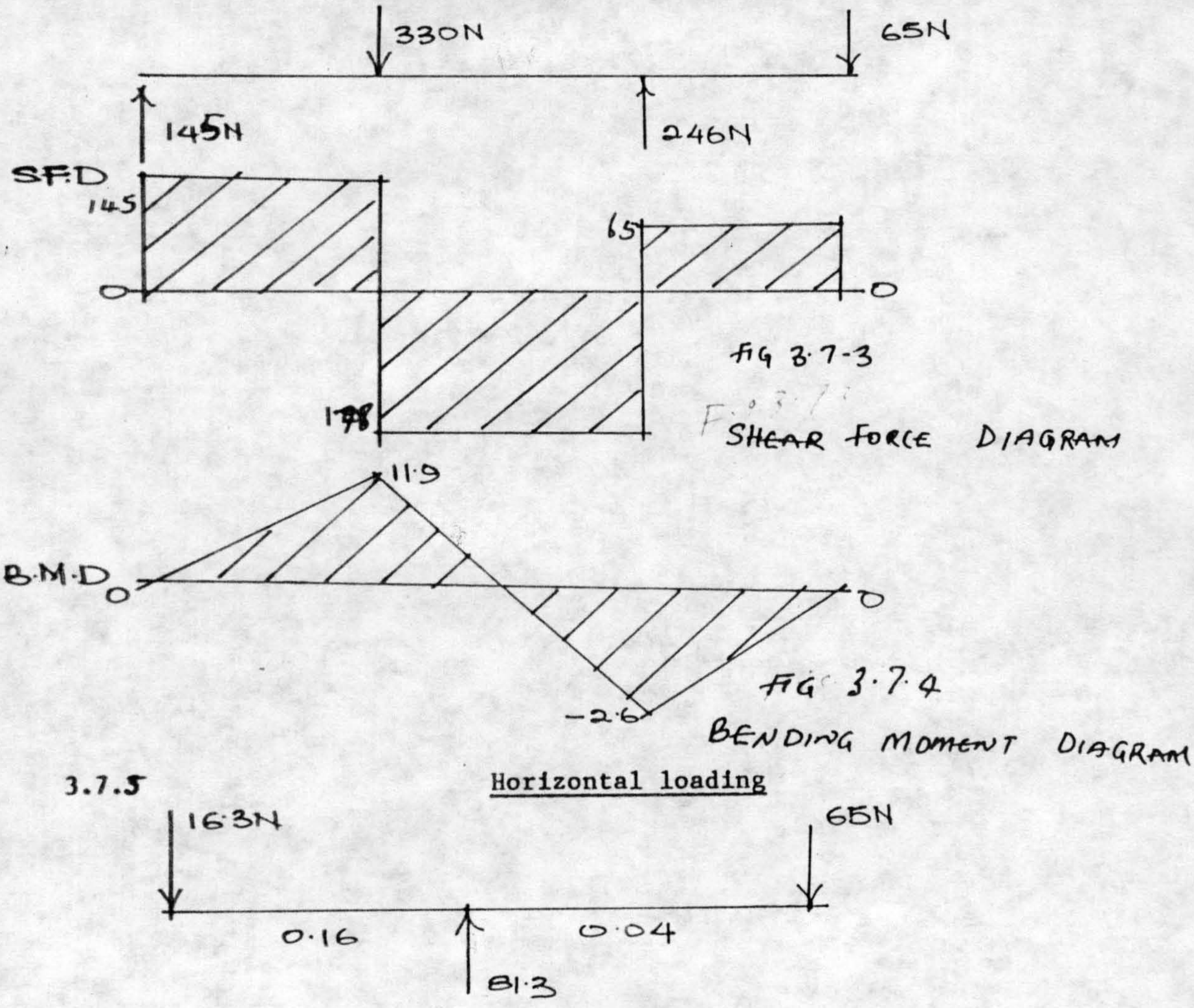
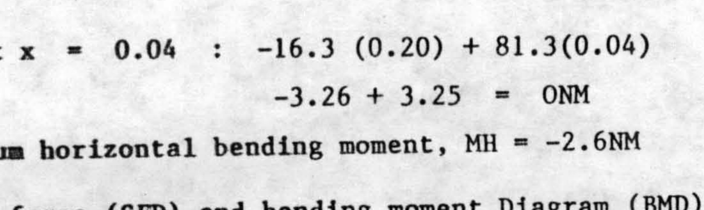


FIG 3.7-3 SHEAR FORCE DIAGRAM

FIG 3.7.4 BENDING MOMENT DIAGRAM

3.7.5 Horizontal loading



BMx at x = 0.16 : -16.3 (0.16) = -2.6NM

BMx at x = 0.04 : -16.3 (0.20) + 81.3(0.04)

-3.26 + 3.25 = ONM

Maximum horizontal bending moment, MH = -2.6NM

Shear force (SFD) and bending moment Diagram (BMD)

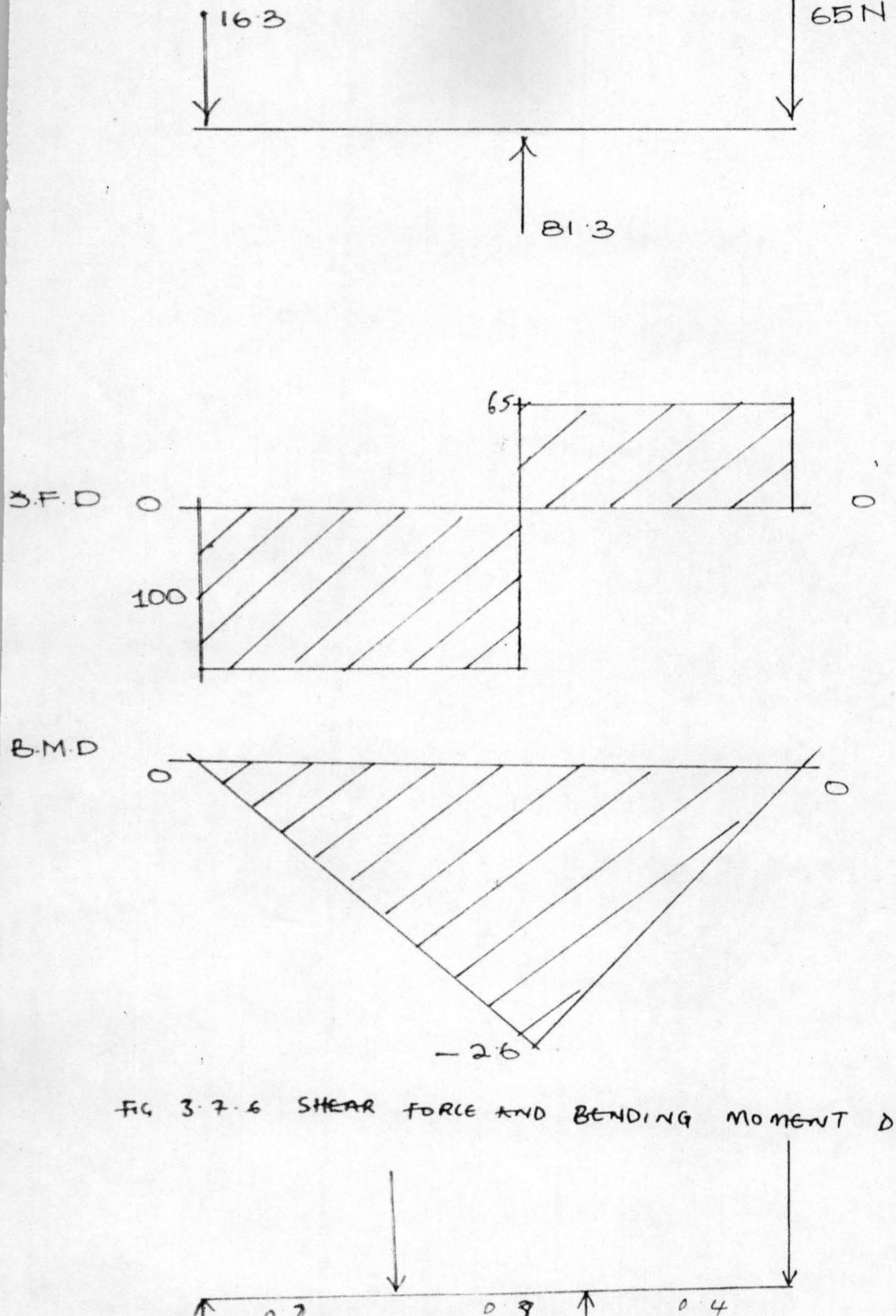


FIG 3·7·6 SHEAR FORCE AND BENDING MOMENT DIAGRAM

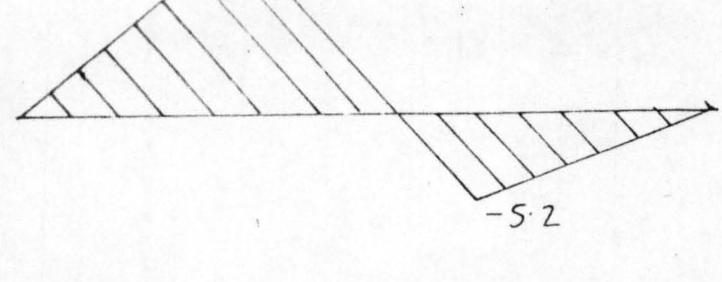


FIG 3·7·7 THE COMBINED BENDING MOMENT DIAGRAM

3.7.4 Determination of shaft Diameter

Maximum bending moment Mb

$$Mb = \sqrt{MV^2 + MH^2}$$

$$= \sqrt{(-26)^2) + (-2.61)^2}$$

$$Mb = \sqrt{(6.8)+(6.8)} = \sqrt{13.6} = 3.7NM$$

Torsional moment, Mt

$$(T_1 - T_2)R = (275 - 47)0.0195$$

$$Mt = 4.45NM$$

Diameter of shaft. d

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

(Schaum series machine design 1982)

where K_b = combined shock and fatique factor applied to bending moment

= 1.5 for rotating shaft with gradually applied load

Kt = Combined shock and fatique applied to torsional moment.

= 1.0 for rotating shaft with gradually applied load

S_s(allowable) = $40MN/m^2$ for shaft with key way.

$$\therefore d^3 = \frac{16}{\pi \times 40 \times 10^6} \sqrt{(1.5 \times 3.7)^2 + (1.0 \times 4.45)^2}$$

$$d^3 = 1.27 \times 10^{-7} \sqrt{30.8 + 19.8} = \sqrt{50.6}$$

$$d^3 = 1.27 \times 10^{-7} \times 7.11 = 9.04 \times 10^{-7}$$

$$d = \sqrt{9.04 \times 10^{-7}} = 0.0096m$$

or 1.0cm

A shaft of ½" (1.27cm) is selected to safeguard the design for additional load during operation.

3.7.5 <u>Power Requirement</u>

Power to driven the shaft

shaft volume $V = T\pi r^2 = (0.006)^2 \times 0.20$

$= 0.00002m^3$

Weight of shaft, $W = V\rho_s g$

where

ρ_s = density of steel = 7870

Torque on shaft, $T = F_r$

$1.75 \times 0.006 = 0.0105NM$

Power required, $P = T_w$

$$= 0.0105 \quad V \quad \frac{2\pi \times 5400}{60} = (5.93w)$$

$$= (0.0059KW)$$

power for driven pulley

$$T = 16 \times 0.0195 = 0.312NM$$

$$P = \frac{0.312 \times 2 \times \pi \times 5400}{60} = 176.4W$$

$$= (0.176KW)$$

power for centrifugal Action

$$\text{From } M_t = \frac{9550 \times KW}{rpm} \quad \text{Design data 1982}$$

$$= \frac{4.45 \times 5400}{9550} = 2.5KW$$

Total power required by the centrifuge

$$PT = (0.0059 + 0.176 + 2.5)$$

$$PT = 2.68KW = 3KW$$

Use 3KW to cater for variation during operation. A prime mover with a speed of 2800 rpm and 3KW power is adequate for the designed machine.

Bearing life.

The required life of bearing in million revolution is obtained thus

L = No of revolution per hour for shaft x operating life of bearing in h divided by 1 million

$$L = L_1 = L_2 = \frac{5400 \times 60 \times 400}{1000000} \qquad L = 1296$$

Dynamic capacity, L

$$\text{From } L = \left(\frac{C}{F_r}\right)^n$$

$$C = n \sqrt{L(Fr)^n}$$

where

n = 3.0 for bearing

$$C_1 = 3 \sqrt{1296 \ (16.3)^3} = 177.7\text{NOT } 18Kgf$$

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$$C_2 = \sqrt[3]{1296 \ (65)^3} = 708.6N \text{ or } 72Kgf$$

Bearing dimension

above calculation

(I) Dynamic capacity of 330Kgf which is far greater than maximum calculated capacity of 74Kgf.

(II) Maximum permissible speed is 10000 rpm which is greater than the designed speed of 5400rpm for the shaft.

(III) No of bearing required is two.

3.8 SELECTION OF BEARING

Deep groove ball bearing type is selected based on its wide application in carrying considerable thrust load apart from radial load at high speed which fits the present system. Radial load on the two bearing to be used for machine are

F_{r1} = 16.3N and F_{r2} = 65N

Axial load on the two bearing

Fa_1 = 330N and Fa_2 = 65N

Equivalent load. P acting on the bearing

$$P = (XFr + YFa)S$$

where

X = Radial factor

Y = Thrust factor

S = Service factor

To read X and Y from the table, we first obtain the values of es for all the loads on bearings

$$e_1 - \frac{Fa_1}{F_{r1}} = \frac{330}{16.3} = 20.2$$

$$e_2 - \frac{Fa_2}{Fr_2} = \frac{65}{65} = 1$$

from the table with a value of $^{Fa}/Fr >$ ve and a value of e = 0.31

X = X_1 = X_2 = 0.56 and Y = Y_1 = Y_2 = 1.4

S = 1.5 for rotary machine with no impact

P_1 = (0.56 x 65 + 1.4 x 330) 2.0

= (36.4 + 462) 20 = 996.8W

P_2 = (0.56 x 65 + 14 x 65) 20

(36.4 + 91) 20 = 254.8

For Agricultural processing machine operating life ranges between 400-800 working hours. For this work, a bearing working life of 4000hr is selected which is the minimum.

(I) Bore diameter 12 for shaft diameter 12mm for good fit

(II) Dynamic capacity of 324Kgf which is far greater than maximum calculated capacity of 72Kgf

(III) Maximum permissible speed is 10000 rpm which is greater than the designed speed of 5400 rpm for the shaft.

(V) No of bearing required is two.

3.9 DESIGN AND FORCE ANALYSIS OF SUPPORT

Shear force and bending moment diagrams

The support provided is square in shape and is made from 1½" angle iron. The dimension is 500mm x 500mm x 200mm. The area of the surface of the support can be determined from

$As = L \times B$ -------------0

where

As = Area of surface , m^2

L = length, m = 0.5

B = Breath , m = 0.5

$As = 0.5 \times 0.5 = 0.25m^2$

The forces acting on the support are the weight of empty cylinder plus (+) the weight of the content (whole milk) therein. The weight of the cylinders as was previously determined are

Wc = volume of the bowl (cylinder) X density X acceleration due to gravity X Thickness.

$= 0.0045 \times 7920 \times 9.81 \times 0.001$

$Wc = 0.4N$

Also, weight of the whole milk

= Wm = volume of the milk X density X acceleration due to gravity

$= 0.0025 \times 1033 \times 9.81$

$Wm = 25N$

Miscellaneous weight added to the machine

$We = 8N$

Weight of the pulley after being weighted = 14.5N

weight of the shaft

$$Ws = V\rho_s g = 0.0038 \times 7870 \times 9.81$$

$$= 293.37N$$

Total weight = Wc + Wm + We + Ws

= (0.4 + 25 + 8 + 293.4)N

= 326N = 328N

This weight acting on the support is analysed as shown below

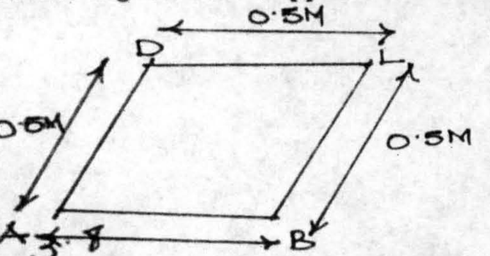

Fig3·8

weight on member AB = $\frac{\text{Total weight}}{4} = \frac{36}{4} = 9N$

Assuming that the load W_{AB} is uniformly distributed so that **the reaction at** A and B is given by

$$V_A = VB = \frac{W_{AB}}{2} = \frac{9}{2} = 4.2N$$

The intensity of load $W_{AB} = \frac{WAB}{L} = \frac{9}{0.5} = 18$

= 18NM

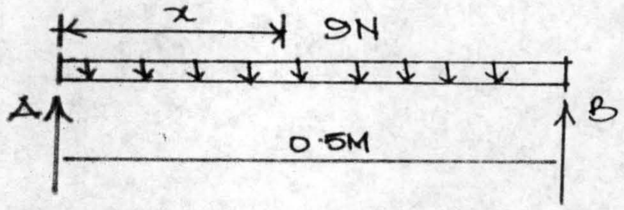

Fig3·4. **Showing** the uniformly distributed load on AB

The Shear Force Diagram Calculation

Qx for $0 \leq x \leq 0.25$

$\Longrightarrow$ $Qx = V_A - qx = 4.2 - 18x$

At x = 0 Qx = VA = 4.2N

At x = 0.25 Qx = 4.2 - 18 x 0.25 = 0

For $0.25 \leq x \leq 0.5$; Qx = VA-qx

= 4.2 - 18x

At x = 0.5; Qx = 4.2 - 18 x 0.5 = -4.8N

The Bending moment calculation

For $0 \leq x \leq 0.25$; $Vx = V_{AX} - q x^2$

(uniformly distributed load)

$$= 4.2 - 18 \times \frac{x^2}{2}$$

At $x = 0$ $\mu x = 0$

At $x = 0.25$; $\mu x = 4.2 \times 0.25 - 18 \times \frac{0.25^2}{2}$

$$= 1.05 - 0.56 = 0.49NM$$

For $0.25 \leq x \leq 0.5$; $Mx = V_{AX} - \frac{q x^2}{2}$

At $x = 0.5$, $Mx = 0$

The shear force and bending moment diagram are shown below

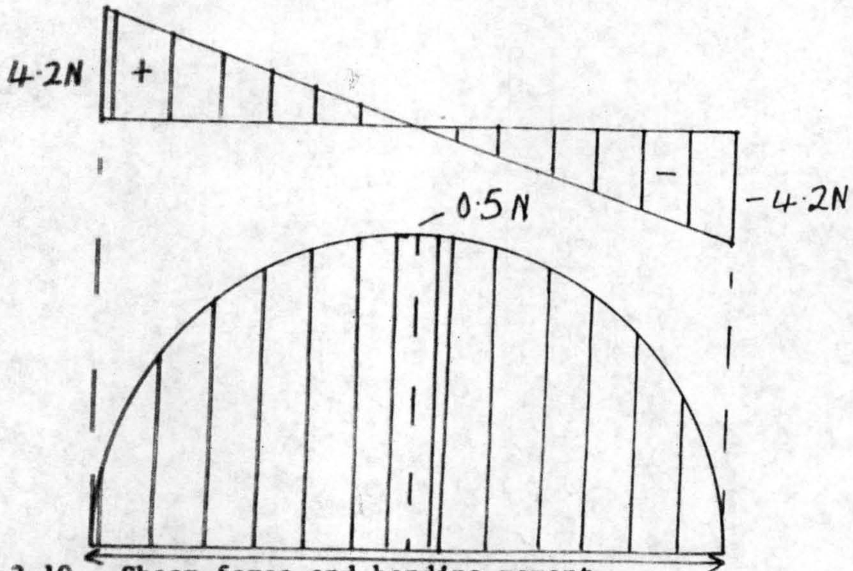

Fig. 3.10. Shear force and bending moment.

3.10 MACHINE MAINTENANCE AND REPAIRS

The following are the basic maintenance operation:

(a) Lubrication of the bearings as specified by the manufacturers for this design it is after 20,000 hours of operation or after two months whichever comes first.

(b) Regular inspection of the belt for slacken possible defect. The belt must be checked for slackness and defect every 1000hrs of operation or one month which ever comes first. Proper tension should be ensured. Driving tension and excess tension must be avoided.

(c) Cleaning of the inner cylinder basin must be ensured before daily operation. Loss or slack belt and nut must be well re-ti

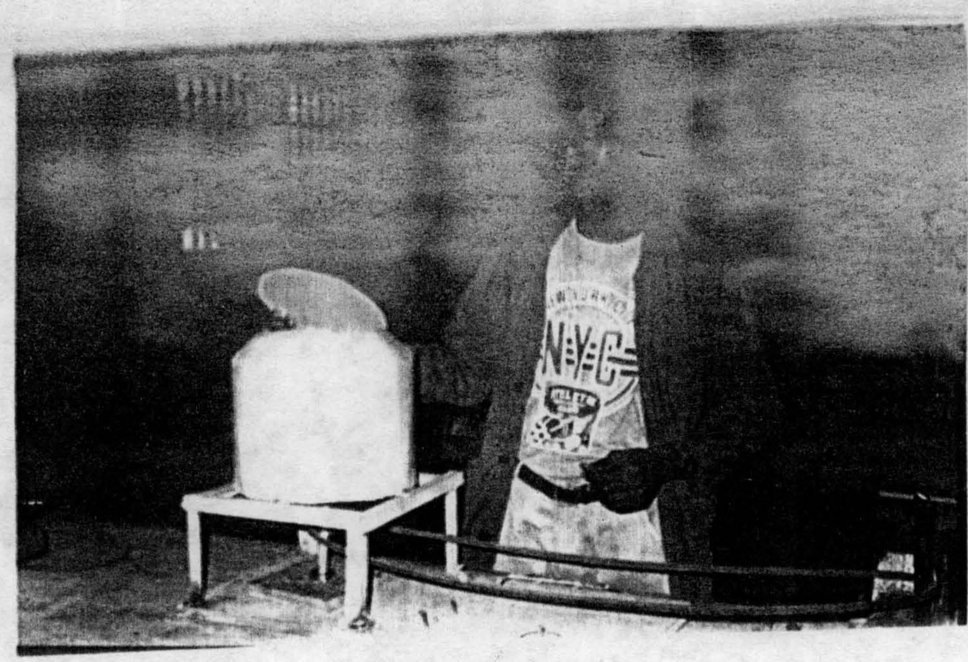

FIG 1:3 Centrifugal Separator.

CHAPTER FOUR

4.0 Testing, Results and Discussion

4.1 Test Parameters

The test parameters taken into consideration include the following:

(1) To ascertain the efficiency of the designed machine.

(2) To test the effect of heat treatment on whole milk separation.

(3) To ascertain that the machine capacity is achieved.

(4) To determine the stability of the machine under operation.

Test Procedure

The whole milk was steamed or heated to 35°c before been introduced into the inner cylindrical basin. The inner cylindrical basin has four outlets which initially blocked with a four-finger like structure. Then the steamed whole milk was then introduced into the inner cylindrical basin and was covered up with the lid. The cover has an inlet chute through which the steamed milk was introduced.

The outer cylindrical basin covered the inner cylindrical basin and the space available in the outer basin was filled up with cotton wool which acted as the lagging material to maintain the temperature of the steamed whole milk. The false bottom on the outer cylindrical basin has two circular path which connects the outlets in the inner cylinder through which the separated whole milk in the inner cylindrical basin will drop in before the final discharge from the outer cylindrical basin.

When the electric motor is switched on, it rotates the inner basin with the whole milk content for six minutes. After the six minutes the cream which is the lighter constituent of the milk migrated to the centre of the basin and the skim milk which is a bit heavier than cream milk moved towards the side of the basin where there are two outlets, one at each side through which the milk passed through to the outer circular basin available at the false bottom. Through the single outlet available at the outer circular path for the false bottom the skim milk was finally discharged into a separate plate provided for i

The cream milk which moved towards the peripheral of the inner basin passed through two outlets provided for it on both side around the shaft. The cream then passes through these outlets into the inner most circular paths available in the false bottom and passed it to the final point of collection where the cream was been collected into a separate basin.

Finally, the outer most cylindrical basin has two outlet the inner most outlet was used for the collection of the cream milk while the outer most outlet on the outside cylindrical basin was used for the collection of the skim milk.

CHAPTER FOUR

4.3 RESULT

CREAM MILK RESULT

S/N	Time Minutes	Mass of empty Container(kg)	Mass of the container and Cream milk (kg)	Mass of the Cream milk (kg)	Volume the cre V = M/D
1	6	0.055	0.0895	0.0345	3.3 x 1(
2	6	0.055	0.095	0.04	3.8 x 10
3	6	0.055	0.095	0.04	3.8 x 10

Average volume = 3.6×10^{-5} m^3

Average mass of cream 0.030kg

SKIM MILK RESUL

S/N	Time Minutes	Mass of empty Container (kg)	Mass of the Container and Cream ilk (kg)	Mass of the Cream milk (kg)	Volume of the cream V = M/D (m^3
1	6	0.055	0.55	0.480	4.6×10^{-4}
2	6	0.055	(40	0.485	4.7×10^{-4}
3	6	0.055	40	0.485	4.7 x 10-4

Average volume 4.7×10^{-4} m^3

Average mass 0.48 kg

Density of the cream = kg/m^3

Volume = Ma / De

Volume = 0345 kg / 40 kg/m^3

= 1010 kg/m^3

Density of

Volume =

/m/^{3}

Volume

x 10^{-4} m^3

DISCUSSION OF RESULT

At the end of the first six minutes of separation operation the volume of the cream milk obtained was $3.3 \times 10^{-5}\ m^3$. These separation operations were performed for three consecutive times, the volume of the cream milk obtained at the second experiment was $3.8 \times 10^{-5}\ m^3$ and for the third experiment the volume of the cream milk obtained was $3.8 \times 10^{-5}\ m^3$. The volume of the cream milk obtained at the second and third experiment were the same $3.8 \times 10^{-5}\ m^3$ and is a bit higher than the volume obtained from the first separation operation.

The same reduction in volume occur during the first separation operation of the skim milk. In the first skim milk separation experiment the volume obtained was $4.62 \times 10^{-4} m^3$ and the volume obtained for the second and third skim milk separation experiment were $4.7 \times 10^{-4} m^3$ and $4.7 \times 10^{-4} m^3$ respectively. The volume of the skim milk obtained in the second and third experiment operation were the same and is a bit higher than the volume obtained in the first skim milk separation experiment.

The variation in the volume of the first separation operation experiment of cream and skim milk was due to few number of the milk particles which adhered to sides of the inner cylinder and to the inside of the concentric cycles rings used for the final outlet of the product. More also the splashing of the whole milk from the cylinder during the operation process contributed to the low volume of the final products. Since a whole milk contained 3.9 percentage of fat and few percentages of fat soluble vitamins such as vitamin A, D, E and K were also contained in it. At the end of the experiment 21 percentage of the fat was able to be removed by centrifugal saparator.

CHAPTER FIVE

5.I CONSLUSION AND RECOMMENDATION

CONCLUSION

The design and construction of centrifugal separator for skim and cream milk as analysised in this project can be used for the quick separation of whole milk without getting sour skim milk at the end of the operation.

With this machine the separation of the whole milk is done in a highly hygenic process.

The machine enhances fast production of other products obtained from further process of skim and cream milk; product such as ghee, sweetened and unsweetened milk and youghurt.

The design was carried out with due considerations for the following major factors such as stability of the machine, capacity of the machine and the efficiency of the machine which is 67 percent.

Finally, the project had been designed to meet all the local conditions that allow for its application for the production such as the use of diesel engine in a place where there is no electricity.

5.2 RECOMMENDATIONS

The followings are recommended:

1. Large scale manufacture or production of this machine is highly recommended.
2. Investigation should also be carried out on better way of keeping the temperature of the whole milk constant.
3. The production of the machine in varying size with an appropriate electric motor is highly recommended so that every interesting individuals or organisation irrespective of their income can purchase it.
4. A better way of controlling the inner cylinder for the cream and skim milk should be developed.
5. In the separation of the whole milk a stand-by generator and a refridgerator are highly needed to keep the cream and skim milk away from spoilage.

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APPENDIX

COSTING

Below is the table showing the cost of material bought and cost of non-machining job and their specification used for the construction of 0.016m^3 capacity centrifuge for whole milk separation.

TABLE 1: BOUGHT OUT COMPONENTS

S/N	Component	Specification	Qty	Unit Cost (₦)	Total Price (₦)
1.	Electric Motor Diesel Engine	4.25KW (3 HP)	1	20,000.00	20,000.00
2	Galvanized steel	Thickness 0.5mm Length 2,500mm Breath 500mm	½	6,000.00	3,000.00
3	Bolt and Nut	M6 Length = 30mm Top Ø = 10mm Lower Ø= 5mm Nut Ø = 10mm	4	8.00	32.00
4	Nails	Length 50mm	8	2.00	16.00
5	Cotton Wool	Volume = 500mm Thickness = 3.5m	1	200.00	200.00
6	Shaft	Length = 130mm Ø = 12.7mm	1	400.00	400.00
7	Smallet Pulley	Ø = 45mm Thickness = 20mm No of groove = 1	1	300.00	300.00
8	Bigger Pulley	Ø = 170mm Thichness = 20mm No of groove = 1	1	300.00	300.00
9	V-belt	Length = 300mm Top Ø = 10mm Lower Ø = 5mm			
10.	Sealed Bearing	Ø 15mm	1	60.00	60.00
11.	Electrode	Grade 12	50 pieces	3.00	150.00
12.	Angle Iron	Length 160mm Breath = 25mm Thickness = 0.5mm	½	300.00	150.00
13.	Paint	Gloss, white 450ml	1	100.00	100.00
14.	Sand paper	Length 200mm Breath 150mm	2	15.00	30.00
15.	Galvanized Pipe	Ø ½" Length 10cm	1	50.00	50.00
				Sub Total Cost	₦24,788.00

TABLE 2: NON-MACHINE JOB

S/No	Job	Time Spent (min)	Labour Cost (₦)	Equipment Cost (hr)	Total Cost (₦)
1.	Welding	480	20.00	30.00	400.00
2.	Cutting	120	15.00	25.00	80.00
3.	Filing	90	5.00	20.00	37.50
4.	Machine Assembly	180	20.00	30.00	150.00
5.	Painting	60	10.00	20.00	30.00
6.	Sand papering	120	20.00	10.00	60.00
			Sub Total	=	₦757.50

TOTAL (₦24,788.00 + ₦757.50)

= ₦25,545.50