DEVELOPMENT OF AN IMPROVED YAM POUNDING MACHINE VIA ROTARY TECHNOLOGY.

BY

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FEBRUARY, 2010.

DECLARATION

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 Information derived from personal communications, published and unpublished work were duly referenced in the text

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17th FEB 2010

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CERTIFICATION

This project entitled "Development of an Improved Yam Pounding Machine via Rotary Technology" by Aroboinosen Hillary, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This project work is dedicated to God Almighty and to my lovely parents, Mr. and Mrs. Pius Aroboinosen, who brought me up to this stage of my life, and providing the financial assistance towards the completion of this project. I love you and appreciate you mightily

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Finally I wish to thank my colleagues and friends who have been responsible for bridging the gap between theoretical understanding and practice throughout the period of my career.

ABSTRACT

Electric yam pounding machine is a portable machine used to prepare pounded yam, and also to solve the problem due to fatigue resulting from manual pounding process of yam as well as reduce its preparation time. The improved yam pounding machine was developed and describes the design considerations involved in its construction using locally available materials at minimum cost which makes it affordable for middle and low class citizens. The machine comprises of five major parts which are made up of galvanized steel, stainless steel, mild steel, shaft and an electric motor and it is capable of pounding 12kg of yam. Upon completion the machine was tested filling the volume of the pounding bowl to 90% it's capacity of yam and allow to run which took less than 2 minutes and the yam dough completely crushed. It is a durable machine that has a calculated efficiency of 95.8%. This machine will contribute to solving the problem of importation of similar type.

TABLE OF CONTENTS

CHAPTER TWO

CHAPTER THREE

LIST OF TABLES

LIST OF FIGURES

NOTATIONS/NOMENCLATURES

Notations	Nomenclature	S.I Units
I	Moment of inertia of blade	kgm^2
M	Mass of blade	kg
m	Mass of yam	kg
L	Length of blade	m
V	Volume of yam	m^3
V_0	Volume of blade	m^3
V_2	Tangential velocity of blade	ms^{-1}
V_1	Volume of bowl	m^3
r_0	Radius of blade	m
A	Area of bowl	m^2
h	Height of bowl	m
ρ_2	Density of Galvanized steel blade	kgm^{-3}
ρ_1	Density of cooked yam	kgm^{-3}
ω_2	Angular velocity of the blade tip	$rads^{-1}$
ω_3	Angular velocity of motor	$rads^{-1}$
WI	Work index	Nm
W	Work input	Nm
P	Power of electric motor	watts

I_t	Torsion moment of shaft	Nm
I_1	Speed of motor	rpm
I_{S0}	Shear developed by the crusher blade	Nm^{-2}
Γ_t	Torque transmitted by electric motor	Nm
d	Solid shaft diameter	mm
I_S	Shear stress on shaft due to torsion	Nm^{-2}
I_b	Shear stress in shaft due to bending	Nm^{-2}
M_b	Maximum bending moment	Nm
K_b	Shock and fatigue factor for bending	-
K_t	Shock and fatigue factor for torsion	-
F_0	Output feed	-
F_1	Input feed	-

CHAPTER ONE

1. INTRODUCTION

1.1 Background to the Study

The evolvement of modern science and technology, especially in the 21st century has brought about ease in the development of time and labour saving equipment/machine, in a bid to improve and facilitate man's effort (Martin, 1969; Takeda, 1976).In recent times, designing, construction and manufacturing of high speed sensitive machines, equipments and instruments have been controlled by the field of engineering (Ayensu and Coursey, 1972).

The Strenuous pounding of the boiled yam tuber pieces into dough, has become increasingly distasteful to the modern and busy housewives and also an unpopular culinary activity among urban men, thus discouraging eating of pounded yam. Mechanical aids for the production of yam pounders have been introduced by Addis and National Company (Makanjuola, 1974) they have been well accepted in urban areas, although the cost is expensive and has some limitations thus leading to further improvement of this unique project.

The yam pounding machine is designed to perform pounding operations on cooked yam. It will help to dominate the manual pounding processes mostly used in various homes (Osagie, 1977; Stafford, 1988) it is capable of executing all the various motions carried out by manual mode of pounding.

For the machine to accomplish the required socio-economic importance of electro-mechanical yam pounding operation, it has been designed to perform pounding like operations using electro-mechanical way, to perform direct pounding by crushing, as well as grinding of the yam dough to a desired state suitable for human consumption

1.2 Statement of the problem

Drudgery and strenuous pounding processes of yam via manual effort is discouraging a larger proportion of the women folks in Africa from preparing pounded yam especially among the working class. In addition to this, the cost of importation of these machines (yam pounding) and their indisposition to the low class populace has become a major challenge to Agricultural and Bioresources Engineering.

1.3 Objectives of the Project

The objectives of this project are aimed at improving on the design and fabrication of a yam pounding machine and to obtain the most economic option in comparison with several manual methods of pounding yam. Other objectives are highlighted as follows;

i. To develop a yam pounding machine locally, so as to develop a technology for its manufacture.

ii. To reduce drudgery and better overall quality of product with little or no contaminant.

iii. To apply basic engineering principles and practical techniques, in ensuring the optimization of the electric yam pounding machine, through large power output, improved aesthetic design, little vibration and better overall quality of service.

iv. To eliminate fatigue during the pounding process and also to reduce the preparation time.

1.4 Justification of the Project

The development of an electrically-powered improved yam pounding machine, fatigue, stress and manual pounding could be eliminated, hence leading to reduction in preparation time.

1.5 Scope of the Project

The scope of this project work includes the analysis of the several design parameters considered in the construction of an improved yam pounding machine via rotary technology. The materials used in this work were sourced locally.

CHAPTER TWO.

:. LITERATURE REVIEW

The use of pestle and mortar were discovered by our ancestors as a means of pounding yam (Kishida and Fukui, 1966); however this traditional method of pounding was used to provide the technology of pounding yam in the olden days (Zeigen et al, 1987; Samarajeewaeta, 1988).This technological growth and recent development, has led to the improvement of the electric yam pounding machine, which is a domestic appliance designed for pounding yam for human consumption.

The yam pounding machine is made up of two major units, the driving unit and the pounding unit (Abdulkadir, 2006).The driving unit usually comprises of an electric motor and shaft connecting the blade, while the pounding/crushing unit consists of the pounding bowl and the blade required for crushing. The proposed improved yam pounding machine is capable of pounding yam for three people within the minimum possible time upon completion.

The yam pounding machine is mechanically driven, with enhanced service operation, clean and more hygienic complete system. The innovator of the domestic model performed a research work to make yam pounding less laborious (Makanjuola, 1974; Coursey, 1987), the prototype was produced in 1976, two years after the research work.

The innovator first produced three of these machines and sold one at the technological development of Agriculture cited between Oyo and Lagos state after the Japanese model was sold to Addis engineering. A local manufacturer that has produced the machines claims to have hundreds of it since 1977 (Makanjuola, 1974; Coursey, 1987).

2.1 Yams

Yams are one of the oldest food plant known (Lii and Tsai, 1985) they have been cultivated since 50,000 BC in Africa and Asia (Satoh et al, 1967). Yam plays a staple role in the diets of many different countries (Tanoue et al, 1988).Kochlar (1985) came up with a study that yam species provide food security and revenue.

Yams were originated in the Far East, spread west wards and have since evolved independently in the eastern and western hemisphere. The occurrence of *Dioscorea* species in Southern Asia and South America long predates human history and domestication of the different species in these areas, appears to have been by aboriginal man (Satoh et al, 1967).The most important species; *Dioscorea alata, Dioscorea cayenensis, Dioscorea rotundata and Dioscorea trifida* were originated in Southern Asia, West Africa (*Dioscorea cayenensis and Dioscorea rotundata*) and tropical America respectively.

Non toxic yams are prepared for consumption by variety of ways, often by boiling, frying or roasting (Decary, 1966; Coursey, 1967).For boiling, the yams are usually peeled and cut into bits and boiled until soft, although smaller tubers may be left whole and unpeeled.

It is believed that the total contributions of yams in feeding the people of the tropics is less than that of other crops (Kochlar, 1986; Asiedu, 1989; Osuji; 1985)

The yam plays an important role in socio-economic, cultural and religious festivals (Asiedu, 1989). However, yams continue to serve as the preferred staple food in Africa (Osuji, 1985; Omijeh, 1986). According to Akissoe (2000), depending on the country, yams are used to embrace many tubers. According to Egesi (2000), virtually all production is used for human food and the tubers are processed into various type of food including pounded yam, boiled yam, roasted yam, yam balls and yam chips.

With several varieties available today, yam could be grown extensively and in fact constitute delicious foods of high nutritive value (Akoroda, 1987).

2.2 Yam species

Yams are members of the genus *Dioscorea* in the section *Enantiophyllum* (Kochlar, 1986). *Dioscorea* is the largest genus of the family *Dioscoreacese*, containing between three hundred to six hundred species (Asiedu, 1989) but the main varieties of yam belongs to *Dioscorea dumetorum* (bitter yam), *Dioscorea cayenensis* (yellow yam), *Dioscorea alata* (water yam) and *Dioscorea esculenta* (lesser yam).
However, Asiedu (1989) argued that there are over six hundred species grown throughout the world, but in Africa there are three species, white yam, yellow yam and water yam.

Table 2.1 Major food yam species

Species	Common names
Dioscorea rotundata	White yam, White guinea yam
Dioscorea cayenensis	Yellow yam, Yellow guinea yam
Dioscorea alata	Water yam, Greater yam, Winged stem yam
Dioscorea esculenta	Burk lesser yam, Chinese yam, Cluster yam
Dioscorea dumetorum	Pax bitter yam, Trifoliate yam
Dioscorea bulbifera	Aerial yam
Dioscorea trifida	Cushy yam

Source: The internet (2009)

Akissoe (2000) estimated that about three hundred to six hundred species of yam are available. There are over half a dozen principal species that are grown for consumption, while others are grown for medicinal purposes. But according to Kochlar (1986) true yams belong to the genus *Dioscorea* and are grown through the tropics for their stem tubers.

(Osuji, 1985; Kochlar, 1986; Asiedu, 1989; Isouri and Antonio, 2002) stated that, the species used in Nigeria are mainly white yam (*Dioscorea rotundata*), yellow yam (*Dioscorea cayenensis*) and in a lesser extent tripoliate yam (*Dioscorea esculenta* and *dumetorum*).

Asiedu (1989) argued that the moisture content of fresh yam tubers is 60% to 75%.It was also observed that the high moisture content of yam (70% to 80%) makes them susceptible to attacks by micro organisms while in storage (Antonio, 2002).

Only few species of this yam are cultivated as food crops. Four species i.e. *Dioscorea alata, Dioscorea cayenensis, Dioscorea esculenta* and *Dioscorea rotundata* are regularly grown in Africa and Asia. Other species frequently seen are *Dioscorea bulbifera, Dioscorea nummularia* and *Dioscorea pentaphylla* (Ibeh et al, 1991; Osagie, 1992; Akissoe et al 2001).

2.3 Consumption and Preparation of Pounded Yam

Yam which is a source of carbohydrate stands out as a favorite delicacy among the different African delicacies especially in its pounded form (Telek et al, 1974; kouassi et al, 1990).

Yam is mostly consumed as freshly prepared dish (Misaki et al, 1972; Ravi et al, 1996).In West Africa, the preferred method of yam preparation is through pounding or reconstitution of yam flour to form a thick paste which is then eaten with a soup. Tubers may also be consumed directly after boiling or cooked in pottage with protein sources usually added (Okoh, 1984; Okoli and Green, 1987).

Furthermore, frying and roasting are important cooking methods of yam (Fotso et al, 1994; Asiedu et al 1997; Achi, 1999).In Ivory Coast, freshly pounded yam known as "Foutou"(boiled yam) and its sauce are the main consumed yam dishes among the populations (Konan et al, 2003).The name "Foutou" is not limited to yam, but commonly used for any other yam related products such as cassava (Ferguson et al, 1995; Konan et al, 2003).The choice of yam variety is not only based on the nutritional quality, but also due to its availability in the market (Francis et al, 1986).

Yam in Nigeria is consumed as boiled, pounded or fried yam; it is also used as baked products (Egesi et al, 2003).In Puerto Rico, yam flakes are produced for the purpose of preparing instant mashed yam alternatively to freshly prepared yam (Rodriquez, 1972). Salda et al (1988), observed that yam find its uses in ice cream flavoring, pounded yam and yam powder. Asiedu (1989) stated that yam tuber is economically the most important part of the plant.

2.4 Usefulness of Yam

Yams are used in a manner similar to those of potatoes in the western world (Bell and Favier, 1981). The tuber is cut into slices and boiled for about fifteen minutes, depending on the intensity of the heating chamber until tender. The skin may be removed before or after boiling, since it is not normally consumed along side the boiled sliced yam pieces by human.

In West Africa, the cooked tuber of yam of *Dioscorea rotundata* is pounded and kneaded into a sticky mass that is then eaten as small balls of dough often dipped into stew/soup. This traditional dish called pounded yam is relish and cannot be made from most other yam species and varieties (Asiedu et al 1997)

The tuber is peeled and cut into pieces and boiled until soft. The water is then drained off and the pieces pounded in a wooden mortar with pestle until stiff glutinous dough is formed, usually taking about few minutes (Coursey, 1967). Yams are a major source of alkaloid used in pharmacy and also a source of alcohol.

2.5 Chemical Composition of Yam

The chemical composition of yam is characterized by high moisture content and duly matter. The duly matter is composed mainly of starch, vitamins as well as sugars and minerals. Yam may also contain small quantities of polyphenolic compounds (*Tannins*), Alkaloids (*Dioscorine*), Steroid derivatives, Calcium oxalate crystals and Phytic acid.

2.6 Nutritional Valve of Yam

Yams are rich in vitamin C, dietary fiber, vitamin B_6, potassium and manganese while being low in saturated fats and sodium. All these promote good health. Furthermore, a product that is high in potassium and low in sodium is likely to produce a good potassium-sodium balance in the human body and to protect against Osteoporosis and hear disease. Having a low level of saturated fat is also helpful for protection against heart diseases.

2.7 Benefits of Yam

i. Yams are delicious and nutritious.
ii. Yams are rich in fiber.
iii. Yams protect the human body against diseases.
iv. Yams are great sources of vitamin C, vitamin B_6, magnesium and phosphorus.
v. Yams contain vitamin B_6, which reduces the risk of heart diseases.
vi. Yams are good source of potassium used to control blood pressure.
vii. Traditionally, the scraping of the yam is used to treat burns.

Table 2.2 Physical Properties of Yam

Special Features	Yam
Scientific name	*Dioscorea* species

Plant family	Yam (*Dioscorea ceae*)
Plant group	Monocotyledon
Flower character	*Dioecious*
Origin	Asia and West Africa
Historical beginning	50,000 BC
Edible storage organ	Tuber
Number to plant	1 to 5
Appearance	Rough and scaly
Shape	Long, cylindrical
Dry matter	20 to 35%
Taste	Starchy
Vitamin A	Low
Propagation	Tuber pieces
Growing season	180 to 360 days
Storage	34 to 41 degree Celsius
Climate requirement	Tropical
Mouth feel	Dry

Source: The internet (2009)

2.8 Facts of Pounded Yams.

The most favorite culinary product made from yam is pounded yam. The smooth mashed dough of is often eaten with a stewed vegetable soup. It is a very popular African food. In Nigeria, especially in the Middle belt, Eastern and Southern regions, pounded yam have an important cultural value and traditional affiliations.

Pounded yam is classified as a special delicacy and it is a highly prestigious meal all over Africa. Traditionally, pounded yam is made by boiling yam in a pot and once cooked, it is placed in a mortar and it is pounded into smooth textured dough with about three-five feet tall pestle.

With the advent of modern technology, there are now various ways to ease the preparation of pounded yam. One way is by peeling and slicing yam into small sizes, there after the yams pieces are placed in a yam pounder. This automated electrical device gets the yam cooked, once cooked it switches into a blending mode and crushes the yam. It then mashes it into a smooth semi solid paste or dough (Anyaegbunam, 2004).

Another alternative way of preparing pounded yam is by processing yam into a dried powder (dehydrated yam flour) either by sun drying the yam or commercially using desiccating machines. It is being made by sprinkling yam flour into a pot of boiling water and the mixture is stirred, until the desired texture is obtained and it is then allowed to cook for few minutes (Okafor, 1991).

2.9 Types of Yam Pounding Methods

The different types of yam pounding methods are discussed below:-

2.9.1 Manual Yam Pounding Method

This involves the application of force on the pestle which makes use of the human hands for pounding operations. The mortar and pestle are the major pounding devices used (Okocha, 1993)

It is also a traditional method of pounding, which involves yam being pounded to an optimum level of satisfaction which leads to fatigue and stress being imposed on the operator.

It has the following features:

i. It is manually operated.
ii. It is economical.
iii. Yam is pounded to an optimum level of satisfaction.

2.9.2 Electromechanical Yam Pounding Method

The major component in this type of pounder is the electric motor which powers and drives other mechanisms (belt, blade and shaft) for effective pounding operations (Anyaegbunam, 2004). It is easy to operate, but it is more expensive than all the available types of yam pounders. The components of the machine include a wood mortar, cams and gears, bottom board, shafts and electric motor. This machine enables an effective pounding operation.

Features of an electromechanical yam pounding method include:

i. It is most common in terms of demand.
ii. It is less laborious.
iii. It will pound yam to a desired state suitable for consumption.

CHAPTER THREE

3. MATERIAL SELECTION, DESIGN ANALYSIS AND CALCULATIONS

3.1 MATERIAL SELECTION

One of the basic tasks an engineer is expected to accomplish at the planning stage of a project is the selection of appropriate materials that will be suitable for the design. The choice of materials is governed by many factors, depending on the project design and environmental conditions. The choice of materials is also determined by its availability, price, reliability and suitability to design material composition.

The following factors were considered in the design of this machine;

i. The ability of the materials to withstand service conditions.
ii. The properties of the materials.
iii. Availability of the materials.
iv. Workability and ease of machining of the materials.
v. Cost of the materials, transportation and processing during the period of fabrication of the project.

Below are properties considered in selecting the materials for the fabrication of the project:

i. Mechanical properties such as strength, stiffness, fatigue, ductility, hardness and wear resistance.
ii. Chemical properties such as resistance to oxidation and corrosion.

3.2 Choice of materials.

The basic components of this machine are made up of galvanized steel, stainless steel, mild steel, aluminum and the shaft. The choice was as a result of their properties which include:

i. Low cost.
ii. High strength and durability.
iii. High resistance to corrosion.
iv. Ease of machining.

3.2.1 Galvanized Steel

These are plain carbon steel that had been coated with a zinc layer. The zinc preferentially corrodes and protects the steel. The process of galvanizing is one in which a layer of zinc is applied to the surface of the steel by hot dipping in the atmosphere.
Zinc also protects the steel by acting as a sacrificial layer. The choice of galvanized steel for the purpose of this project was greatly influenced by the following:

i. High resistance to corrosion.
ii. Easy availability of galvanized steel determined from market survey.
iii. Sustainability of galvanized steel to various service and working conditions.
iv. Relatively low cost of galvanized steel.

3.2.2 Stainless Steel.

Stainless steel is defined as an iron carbon alloy with a minimum of 11.5% weight chromium content. Stainless steel does not stain, corrode or rust as easily as ordinary steel. It is also called corrosion resistant steel.
The choice of stainless steel for the purpose of this project was greatly influenced due to the role it has on industrial engineering materials.

They are as follows:

i. Its high resistance to corrosion.
ii. Its low maintenance cost.

3.2.3 Mild steel.

Mild steel contains 0.25% to 0.3% of carbon. It has almost for all purpose replaced wrought iron.

The choice of mild steel was used in the production of the shaft due to:

i. Its cheapness.
ii. Its high stiffness.
iii. Its ease of machining.
iv. Its ease of welding.

3.2.4 Shaft.

The shaft was used to transmit power to the blade and it consists of a solid shaft machined from mild steel. In other to ensure satisfactory performance, the shaft was stiffened, supported on rigid bearings and properly balanced. It was equally designed to withstand bending, tensile, compressive or torsion loads all acting at the same time.

Table 3.1: Shows the component parts of the machine, material selection and its material properties.

S/No	Components	Material properties	Likely materials	Selected materials	Justification of reasons
1	Body frame	High resistance to corrosion	Galvanized steel	Galvanized steel	Resistance to corrosion, adaptability to working and service conditions.
2	Pounding bowl	High resistance to corrosion	Stainless steel	Stainless steel	It is a metal coated to avoid food poisoning.
3	Blade	High cutting ability	Aluminum	Aluminum	It imparts crushing on yam
4	Shaft	Good mach inability	Mild steel	Mild steel	Easy mach inability and high strength
5	Electric motor	Powers mechanical components	Armature coils	Armature coils	Source of power for driving mechanisms
6	Bolts and nuts	High strength	Mild steel	Mild steel	Its availability and relative cheapness
7	Capacitors	Ability to store electrical energy	-	-	It allows the passage of alternating current thereby blocking direct current
8	Wires	High electrical conductivity	Copper	Copper	Ability to conduct electricity
9	Switch	High insulation ability	Toggle	Toggle	Allows or stops the flow of electric current
10	Plug	High insulation ability	Plastic	Plastic	Houses all electrical connections in the machine

3.3 Fabrication Procedure

Each of the fabricated components went through two or more operations before the final assembly. The processes and machines employed for the operation as it applies to each component are shown in table 4.1

Table 3.2 Fabrication Procedure

S/NO	Components	Materials	Procedure	Machine/Tools
1	Bowl/Mortar	Stainless steel	The bowl used in this design was brought out in conformity to the design specification. A hole of 19mm was drilled at the centre of the base of the bowl so as to precision the shaft from the motor through the blade	Lathe machine
2	Blade	Galvanized steel	The blade was shaped into a flat bar and welded on both ends	Lathe machine and welding machine
3	Body Frame	Galvanized steel	Five plates;260mm by 260mm,260mm by 260mm and	Cutting machine and welding machine

	520mmby 260mm were cut for the back, top cover and the two sides respectively

3.4 Mode of Operation

The yam was first peeled and cut into bits of sizes before boiling. After boiling to a satisfactory state, the yam was drained of water and poured into the pounding bowl, after which the pounding operation took place.

The pounding operation was such that the yam was cut and stirred to form stiff glutinous yam dough ready for consumption. This simple process requires no addition of water, but rather uses the moisture derived from the boiled yam. The whole process took less than a minute or two or even less depending on the wattage of electricity supplied.

3.4.1 Cost Analysis

The actual cost of the machine goes beyond the cost of the materials. It includes the cost of maintenance, labour and the cost of transporting the machine and the materials during fabrication to the point where they would be used. For the cost analysis of the project, three major cost facts were put into consideration, they are;

i. Material cost
ii. Labour cost
iii. Overhead cost

3.4.2 Material cost

This shows the cost of the materials used for the fabrication based on current market prices as at November 2009.

Table 4.2 shows the material cost, quantities used and the current market prices of each component involved in the fabrication of the yam pounding machine.

Table 3.3 Material Cost

S/No	Components	Material	Unit cost N : K	Quantity required	Price N : K
1	Electric motor	2.h.p	8000	1 unit	8000
2	Bowl	Stainless steel	1000	1 quantity	1000
3	Blade	Stainless steel	1000	1 quantity	1000
4	Shaft	Mild steel	500	1 quantity	500
5	Capacitor	-	1000	1 quantity	1000
6	Electrode	Mild steel	500	1 quantity	500
7	Sheet	Galvanized steel	500	4 units	2000
8	Bolts and nuts	Mild steel	30	10 units	300
9	Switch	Toggle	200	1 unit	200
10	Wires	Copper	100	3 yards	300
11	Plugs	Plastics	100	1 quantity	100
		Total			**14,900**

3.4.3 Labour Cost

This refers to the actual cost of labour involved in this project and this includes cost of design and fabrication, cost of cutting, welding and machining. The labour cost is charged 35% of the material cost which is equal to 35% of 14,900 = N5, 215

3.4.4 Overhead Cost

These include cost of transportation of the materials from the market to the workshop, the overhead cost was # 500

3.4.5 Total Cost

Table 4.3 shows the total production cost which is a sum of the material cost, labour cost and the overhead cost.

Table 3.4 Total Production Cost

Description	Cost (#:K)
Material Cost	14,900
Labour Cost	5,215
Overhead Cost	500
Total Cost	20,615

3.5 Maintenance of the Yam Pounding Machine

Maintenance activities are carried out so as to prolong the life span of a machine and to obtain optimum performance

The important maintenance activities to be carried out regularly on the machine for effective and maximum performance include;

i. Lubrication of the moving parts before operation.

ii. Worn out machine components should be replaced before being used.

iii. The machine should be plugged into a grounded outlet to prevent mishaps. An extension cord should not be used.

iv. When carrying out repairs or maintenance, the machine should be unplugged or disconnected.

v. The machine should be washed immediately after used for prolonged life.

3.6 DESIGN ANALYSIS AND CALCULATIONS

3.7 The Moment of Inertia of Blade.

For flat bars, moment of inertial is calculated form the equation:

$$I = \frac{ML^2}{12} \tag{3.1}$$

Where:

I = Moment of inertia of Blade (kgm^2)

M = Mass of blade (kg)

L = length of blade (m)

3.8 Determinations of Volumes

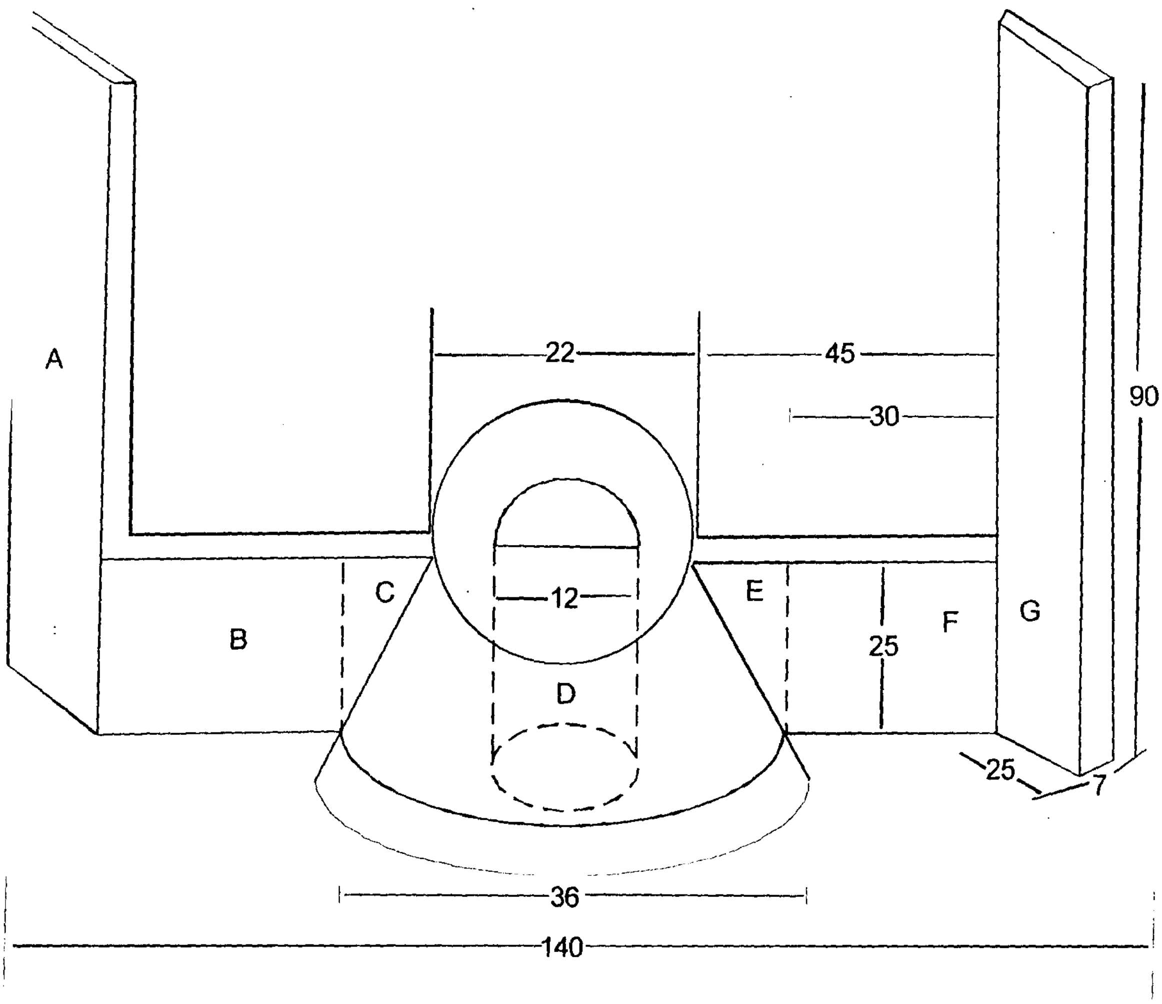
3.8.1 Volume of the Blade

The volume of the blade is estimated by splitting the blade into convenient sections as shown in figure 3.1

Therefore total volume (Vo) = $(V_A + V_B + V_C + V_D + V_E + V_F + V_{G)}\,cm^3$ (3.2)
Analyzing figure 3.1 above:

3.8.1.1 Volume of cuboids A and G

$V_A = V_G$ = (Length x Breath x Thickness) (3.3a)
= (9 x 2.5 x 0.7) = $15.75cm^3$
$V_A = 15.75cm^3$; $VG = 15.75cm^3$



All dimensions are in mm

Fig 3.1 Blade front view

3.8.1.2 Volume of cuboids B and F

$V_B = V_F =$ (Length x Breath x Thickness) (3.3b)

$= (3 \times 2.5 \times 0.7) = 5.25\text{cm}^3$

$V_B = 5.25\text{cm}^3$; $VF = 5.25\ \text{cm}^3$

3.8.1.3 Volume of triangle C and E

$$V_C = V_E = (\tfrac{1}{2} \text{ x base x height}) \text{ x Thickness} \quad (3.3c)$$

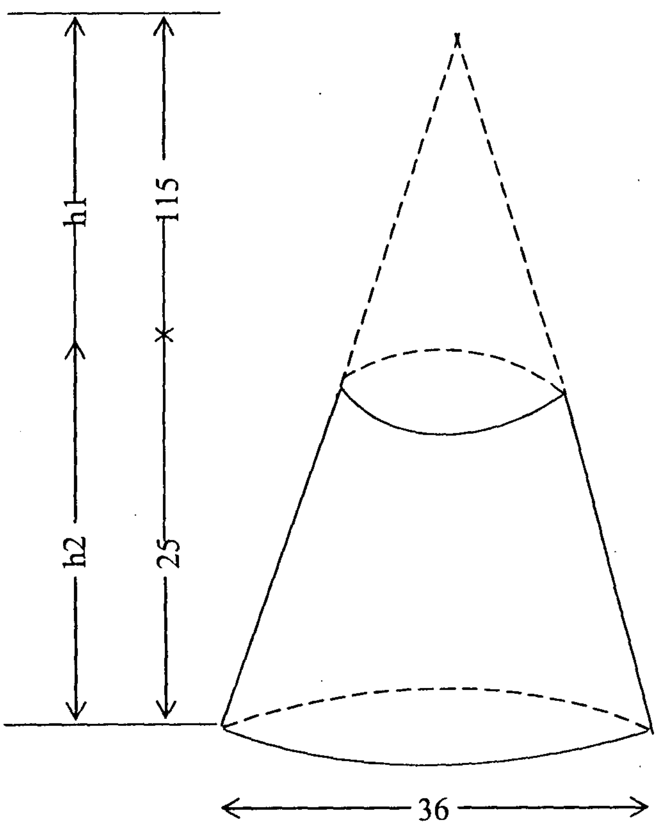
$$= (\tfrac{1}{2} \text{ x } 1.5 \text{ x } 2.5) \text{ x } 0.7$$

$$= 1.312\text{cm}^3$$

$V_C = 1.312\text{cm}^3$; $V_E = 1.31\text{cm}^3$

3.8.1.4 Actual volume of cone D

The cross section of the cone as shown in fig 3.2 is determined as illustrated below.



All dimensions in mm

Fig 3.2 Cross section of cone from the blade.

V_D = (volume of small cone + volume of large cone) – (volume of cylinder)

$$= (\tfrac{1}{3} \times \pi \times r^2 \times h_1 + \tfrac{1}{3} \times \pi \times R{+}2 \times h_1) - (\pi r^2 \times h_2) \qquad (3.4)$$

$$\therefore V_D = (\tfrac{1}{3} \times \pi \times 1.1^2 \times 11.5 + \tfrac{1}{3} \times \pi \times 1.8^2 \times 2.5) - \tfrac{1}{2}(\pi \times 1.1^2 \times 2.5)$$

$$= [(14.571 + 8.482) - (4.751)]\,\text{cm}^3$$

$$= (23.053 - 4.751)\ \text{cm}^3$$

$$\therefore V_D = 18.302\text{cm}^3$$

$$V_O = (V_A + V_B + V_C + V_D + V_E + V_F + V_G)\ \text{cm}^3$$

$$= (15.75 + 5.25 + 1.312 + 18.302 + 1.312 + 5.25 + 15.75)\ \text{cm}^3$$

$$= 62.926\text{cm}^3$$

$$V_O = 63\text{cm}^3 = 6.3 \times 10^{-5}\text{m}^3$$

3.8.2 Obtaining the mass of the blade:

This is obtained from the mass, volume and density relation.

$$\rho_2 = \frac{M}{v_o} \qquad (3.5)$$

$$\therefore M = \rho_2 \times V_0 \qquad (3.6)$$

Where:

ρ_2 = Density of blade (kgm^{-3})

V_0 = Volume of blade (m^3)
M = Mass of blade (kg)

The blade is made of aluminum which has a density of 2,700kg/m^3 (Callister, 1999)

And the volume of blade (V_0) = $6.3 \times 10^{-5} m^3$

$\therefore$ M= ($2700 \times 6.3 \times 10^{-5}$) kg = 0.170kg
$\therefore$ The mass (M) of the blade is 0.170kg

The moment of inertia of the blade is determined from:

$$I = \frac{ML^2}{12}$$

Given, m_1 = 0.170kg; L_1 = 0.14m

$$\therefore I = \frac{0.170x(0.14)^2}{12}$$

$$= 0.0002776$$

$$= 2.776 \times 10^{-4} kgm^2$$

$\therefore$ The moment of inertia of the blade is $2.776 \times 10^{-4} kgm^2$.

3.8.3 Volume of bowl.

$V_l = A \times h$ (3.7)

$A = \pi r^2$ (3.8)

Volume of bowl $= \pi r^2 h$ (3.9)

Where:

A = Area of bowl (m^2)

h = Height of bowl (m)

V_l = Volume of bowl (m^3)

Diameter of bowl	= 0.21m
Radius of bowl	= 0.105m
Height f bowl	= 0.20m

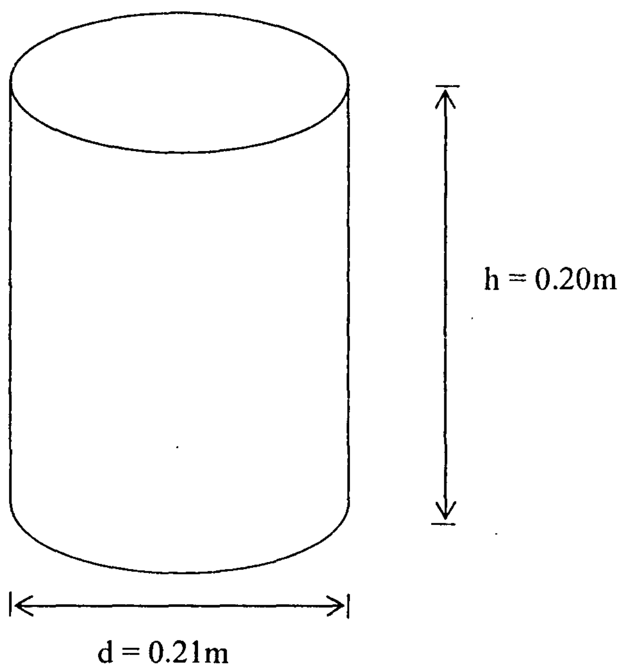


Fig 3.3 Stainless steel bowl

$V_1 = \pi\,(0.105)^2 \times 0.20$

$V_1 = \pi \times 0.011025 \times 0.20$

$V_1 = 0.006921\text{m}^3$

$= 6.921 \times 10^{-3}\text{m}^3.$

It is assumed that the volume of yam is equal to 90% of the volume of the bowl (90% of V_1)

$$V = \frac{90}{100} \times (6.921 \times 10^{-3})$$

$$V = 6.228 \times 10^{-3}\text{m}^3.$$

∴ The mass of the yam is calculated form its volume given that density of cooked yam (P_1) is 2000kgm^{-3} (Earle, 1998).

$$\rho_1 = \frac{m}{v} \tag{3.10}$$

$$\therefore\ m = \rho_1 \times V \tag{3.11}$$

Where:

ρ_1 = Density of cooked yam = 2000kgm^{-3}

V = Volume of yam = $6.228 \times 10^{-3}\text{m}^3$

m = mass of yam =?

m = (2000 x 6.228 x 10^{-3}) kg

m = 12.24kg

$\therefore$ The mass of cooked yam is 12.24kg

3.9 The Impact Crushing Strength (ICS) of the Blade

This is given by the relation

$$ICS = V_2 \times M \qquad \text{(Maithra, 1985)} \qquad (3.12)$$

Where:

V_2 = Tangential velocity of blade (ms^{-1})

M = Mass of the blade (kg)

$$V_2 = \omega_2 \times r_0 \qquad (3.13)$$

Where:

ω_2 = Angular velocity of the blade tip ($rads^{-1}$)

r_0 = Radius of the blade path (m)

Given; Blade speed = 1500rpm; $r_0 = \frac{L_1}{2} = \frac{0.14}{2} = 0.07m$

$$\therefore \omega_2 = \frac{2\pi x 1500}{60}$$

$= 157.08 rads^{-1}$

$\therefore V_2 = \omega_2 \times r_0 = (157.08 \times 0.07)\ ms^{-1}$

$= 10.995 ms^{-1}$

$\therefore ICS = V_2 \times M$

$= (10.995 \times 0.170)\ kgms^{-1}$

$= 1.86 kgms^{-1}$

$\therefore$ The impact crusting strength of the blade is $1.869 kgms^{-1}$

3.10 Determination of Work Index (WI)

In size reduction operations (crushing grinding) the work index is evaluated from the mathematical relation:

$$WI = 53.49 \times \frac{ICS}{S.G} \qquad \text{(Abdulkadir, 2006)} \qquad (3.14)$$

Where:

ICS = impact crushing strength ($kgms^{-1}$)

S.G = Specific gravity of cooked yam

WI = Work index (Nm)

Density of cooked yam is $2000 kgm^{-3}$ (Earle, 1998)

Specific gravity of cooked yam = $\frac{Densityofcookedyam}{Densityofwater}$

$$S.G = \frac{2000}{1000} = 2$$

$\therefore$ WI = $(53.49 \text{ x} \frac{1.869}{2}) = 49.9863$Nm

$\therefore$ The work index is 49.986Nm.

3.11 Determination of Work Input

Based on Bond's work (1982), the work input to an impact crusher is obtained from the relation.

$$W = 10WI\left[\frac{1}{\sqrt{Fo}} - \frac{1}{\sqrt{F1}}\right] \quad (3.15)$$

Where:

W = Work input (Nm)

WI = Work index (Nm)

F_0 = Output feed

F_1 = Input feed

Given: WI = 49.986 Nm; $F_0 = 1$; $F_1 = 10$

$$= 10 \text{ x } 49.986 \left[\frac{1}{\sqrt{0.1}} - \frac{1}{\sqrt{10}} \right]$$

$$= 499.86\ [2.84605]$$

$$= 1422.62\text{Nm}$$

∴ The work input is 1422.62Nm.

3.12 Power Requirements

From the work and time relation, power is given as:

$$P = \frac{W}{T} \tag{3.16}$$

Where:

W = Work input

T = Time taken to complete on cycle of pondering considering ¾ of the volume of the bowl.

Given; W = 1422.62Nm; T = 2 mins (120s)

$$\therefore P = \frac{1422.62}{120} = 11.85 \text{ Watts}$$

3.13 Torque Transmitted by the Rotor Shaft

The torque transmitted by the rotor shaft is evaluated using the mathematical expression.

$$M_t = \frac{9550xP(kW)}{N_1} \quad \text{(Sharma, 1999)} \qquad (3.17)$$

Where:

N_1 = Speed of motor (rpm)

P = Power of motor (kW)

Given:

N_1 = 1500 rpm

P = 2HP = 1.5kW (1hp = 0.75kW)

$$\therefore M_t = \frac{9550x1.5}{1500}$$

$$M_t = \frac{14325}{1500}$$

$$= 9.55Nm$$

∴ The torsion moment on the shaft is 9.55Nm.

3.14 Shear Developed by the Crusher Blade

The shear τ_{S0} developed by the crusher blade is given by:

$$\tau_{S0} = \frac{Mt}{I} \qquad (3.18)$$

Where:

M_t = Torsion Moment (Nm)

I = Moment of inertia of blade (kgm^2)

$$\tau_{S0} = \frac{9.55}{2.776x10^{-4}} = 34402Nm^{-2}$$

$\therefore$ The shear developed by the crusher blade is $34402Nm^{-2}$

3.15 Torque Transmitted by Electric Motor

$$T_t = \frac{P}{W_3} \qquad (3.19)$$

Where:

P = Power of electric motor (kW)

T_t = Torque transmitted by electric motor (Nm)

ω_3 = Angular velocity of motor ($rads^{-1}$)

Given: P = 1.5kw = 1500w; N_1 = 1500rpm

$$\omega_3 = \frac{2\pi N_1}{60} \qquad (3.20)$$

$$\omega_3 = \frac{2\pi x1500}{60}$$

$$\omega_3 = \frac{9424.777961}{60}$$

$\omega_3 = 157.08 \text{ rads}^{-1}$

$$T_t = \frac{P}{W_3}$$

$$= \frac{1500}{157.08} = 9.549\text{Nm}$$

$$= 9.549 \times 10^{-3} \text{ kNm}$$

$\therefore$ Torque transmitted by electric motor is 9.549Nm

3.16 Determination of Bending Moment

Torque = 9.549Nm.

Radius of shaft = 6mm = 6×10^{-3}m

$$\text{Load} = \frac{Torque}{Radius} = \frac{9.549}{6x10^{-3}} = 1591.5Nm. \quad (3.21)$$

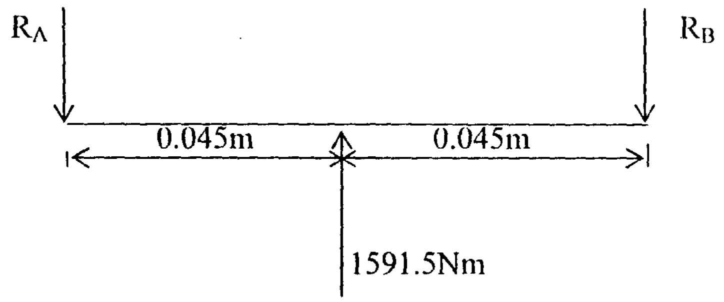


Fig 3.4 Line diagram of shaft loading

Reaction at support A and B

$\Sigma fx = 0$ (3.22)

$\Sigma fx = 0,\ R_A + 1591.5 - R_B = 0$ (3.23)

$R_A + R_B = 1591.5Nm$ (3.24)

Taking moment at support B

$R_A \text{ x } 0.09 + 1591.5 \text{ x } 0.045 = 0$

$0.09R_A + 71.617 = 0$

$$R_A = \frac{71.617}{0.09} = 795.75Nm$$

$R_A = 795.75Nm$

Recall from equation 3.22 above

$R_A + R_B = 1591.5N$

$795.75 + R_B = 1591.5$

$R_B = 1591.5 - 795.75$

$= 795.75Nm$

$\therefore R_A = R_B = 795.75Nm$

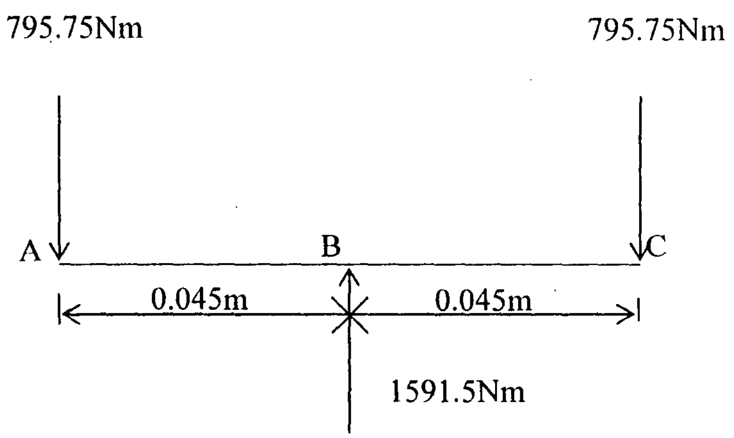


Fig 3.5 Free body diagram

Calculating Bending moment using the free body diagram above

At point A, BM = 0

At point B, BM = 795.75 x 0.045

= 35.808Nm

At point C, BM = 0

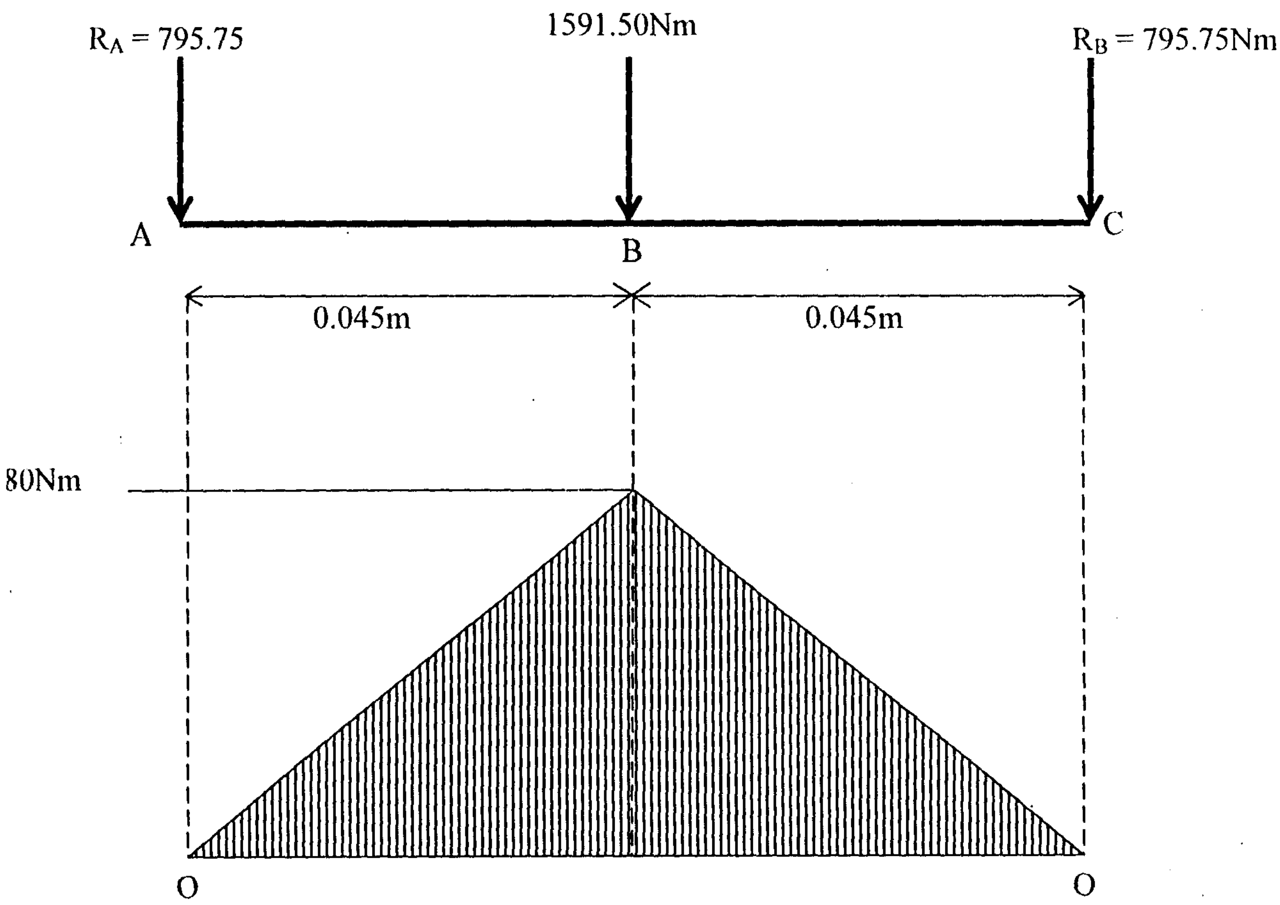


Fig 3.6 Bending moment diagram.

∴ The maximum bending moment is 35.80Nm.

3.17 Solid Shaft Diameter

For solid shaft having little or no axial load, the diameter is determined using the shear stress strength equation.

$$d^3 = \left(\frac{16}{\pi st}\sqrt{(KbMb)^2 + (KtMt)^2}\right) \quad (3.25)$$

Where:

d = Solid shaft diameter (mm)

M_b = Maximum bending moment (Nm)

M_t = Torsion moment of shaft (Nm)

K_b = combined stock fatigue factor due to bending

K_t = combined stock fatigue factor due to torsion.

S_t = Allowable stress in shaft (Nm^{-2})

Note

i. Allowable stress for shaft without key way is $55MN/m^2$ (Usman, 2009)

ii. For rotating shafts

	K_b	K_t
Load suddenly applied (heavy stock)	2.0 to 3.0	1.5 to 3.0 (Usman, 2009)

Given: K_t 1.5; K_b = 2.0; $S_t = 55 \times 10^6 Nm^{-2}$; M_b = 35.808Nm; M_t = 9.55Nm.

$$d^3 = \frac{16}{\pi x 55x10^6}\sqrt{(2x35.808)^2 + (1.5x9.55)^2}$$

$$d^3 = \frac{16}{3.142x55x10^6}\sqrt{(71.616)^2 + (14.325)^2}$$

$$d^3 = \frac{16}{3.142x55x10^6}\sqrt{(5128.85 + 205.20}$$

$$d^3 = \frac{16}{3.142x55x10^6}\sqrt{(5334.05}$$

$$d^3 = \frac{16}{3.142x55x10^6}\ (73.034)$$

$d^3 = 9.258 \times 10^{-8}$ (73.034)

$d^3 = 6.762 \times 10^{-6}$

$d = \sqrt[3]{6.762x10^{-6}}$

$d = 1.891 \times 10^{-2}m$

$d = 0.01891m$

$d = 18.91mm$

∴ The solid shaft diameter is 18.91mm

3.18 Allowable Shear Stress on Shaft Due to "Torsion Load"

The allowable shear stress on shaft due to torsion is determined using the relation below:

$$\tau_s = \frac{16Mt}{\pi d^3} \quad (3.26)$$

Where:

M_t = Torsion moment on shaft (Nm)

d = Solid shaft diameter (m)

τ_S = Maximum shear stress due to torsion loading on shaft (Nm^{-2})

Given:

M_t = 9.55Nm; d = 0.01891m

$$\therefore \tau_S = \frac{16x9.55}{\pi x(0.01891)^3}$$

$$= \frac{152.8}{2.124x10^{-5}}$$

$$\tau_S = 7193973.635Nm^{-2}$$

$$= 7.19397 \text{ x } 10^7 Nm^{-2}$$

$\therefore$ The allowable shear stress in shaft due to torsion is 7.19397 x 10^7Nm^{-2}

3.19 Maximum Shear Stress on Shaft Due to Bending Load

The maximum shear stress on shaft due to bending is determined using the relation:

$$\tau_b = \frac{32Mb}{\pi d^3} \qquad (3.27)$$

Where:

M_b = maximum bending moment (Nm)

d = Solid shaft diameter (m)

τ_b = Maximum shear stress in shaft due to bending load (Nm^{-2})

Given: $M_b = 35.808Nm$; $d = 0.01891m$

$$\tau_b = \frac{32x35.808}{\pi x(0.01891)^3}$$

$$\tau_b = \frac{32x35.808}{2.124x10^{-5}}$$

$$\tau_b = \frac{1145.856}{2.124x10^{-5}}$$

$$= 53948022.6Nm^{-2}$$

$$= 5.39480 \text{ x } 10^{8}Nm^{-2}$$

$\therefore$ The maximum shear stress in shaft due to bending is $5.39480 \text{ x } 10^{-8}Nm^{-2}$.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Results

Testing a constructed machine is the evaluation of confirmation of the workability of the theories, assumptions and design considerations which might have been adopted in physical terms. This serves as a guide to compare its efficiency with others in the market.

The machine was assembled with the required electric motor, supplied by the electric current through the shaft. The shaft transmits motion from the electric motor which in turn drives the blade used for the pounding operation inside the stainless steel bowl.

The boiled yam was poured into the pounding bowl. The pounding operation was carried out for 2 minutes, in which the yam was pounded to a parent particle after which on continuous pounding a smooth pounded paste of yam was obtained.

Thus the efficiency is evaluated as follows:

Efficiency = (output power/input power) x 100

Input power = 2.h.p = (2 x 0.75) kW (where 1 hp = 0.75kW)

= 1.5kW

= 1500Watts

Output = (Actual speed of pounder) x (Velocity of blade) x (mass of yam)

Since the speed at which the yam pounder can run varies, the actual speed is measured using the speed regulator, which is measured by the difference between the maximum speed and the minimum speed.

Maximum speed = 1450 rpm

Minimum speed = 1348 rpm

$\therefore$ Actual speed = maximum speed – minimum speed

= (1450 – 1348) rpm = 102 rpm

But output = actual speed x velocity of blade x mass of yam

Actual speed = 102 rpm = $(\frac{2\pi x102}{60})$ = 10.6814rad/s

Velocity of blade: V = ω x r

Speed of blade = 1500 rpm

Diameter of blade path= 0.14m

Radius of blade path = 0.07m

V = (2π x 1500)/60 x 0.07

= 11rad/s

Mass of yam = 12.24kg

∴ Output power = (10.6814 x 11 x 12.24)

= 1438.14

Calculated Efficiency (ʅc) = (1438.14/1500) x 100

(ʅc) = 95.8%

∴ The Calculated efficiency of the machine is **95.8%**

4.2 DISCUSSION

From the result the calculated efficiency of the machine was derived from the formula. (Output/input x 100%). The output of the machine being the actual speed of pounder which is usually the maximum speed minus the minimum speed of the electric motor multiply by the velocity of blade and the mass of yam. The input being the power of the electric motor.

Finally a calculated efficiency of 95.8% was gotten.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The development of an electric improved yam pounding machine has been undertaken. This idea was conceived with the sole aim of reducing fatigue and human stress associated with manual pounding operation in homes and hotels.

The machine has been optimized to perform as much as possible; the function of human pounding, but due to complexity of the human limb, its motions cannot be duplicated by a machine. The reason is that the machine should be able to produce pounded yam better than that produced by human hands within the possible shortest time and with better hygienic mode.

There was an improvement made when compared to similar past works that have been made. Belts and pulleys were not incorporated into the machine unlike other machines for high speed transmission. An electric motor of 2 horse power (2 hp) was used, the shaft was made of mild steel, the bowl and the blade were made of stainless steel, and the body frame were made of galvanized steel.

For the purpose of fabrication, the most economical choice of materials were determined using simple manufacturing processes, while taking into consideration the strength, availability and cost of the materials. But the problem is the acceptability of the machine by the society especially the rural dwellers who are used to the traditional method of pounding. During testing, the yam blending machine crushed the pieces of yam in less than two minutes, giving a high efficiency of 95.88%.

Producing a unit of this machine is expensive; its estimated cost is N21, 000. It is believed that producing in mass would eventually reduce the price to an amount affordable by an average household.

Conclusively, the yam pounding machine would save the unnecessary stress involved in the traditional yam pounding techniques.

5.2 RECOMMENDATION

For further work on the development of an improved yam pounding machine, it is recommended that;

i. A smaller higher speed electric motor of higher capacity is to be used to improve the output efficiency.

ii. A plastic mould is used in designing the blade to improve hygiene and avoid contamination of the yam dough as well as the use of plastic for the body frame.

iii. That belts and pulleys are introduced for a yam blending machine with lager capacity to blend yam for about 10-20 people to optimize efficiency and overall output.

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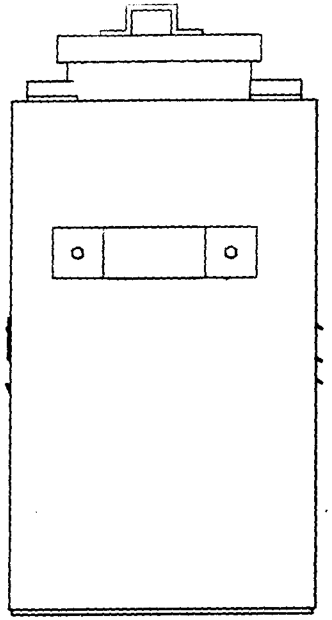

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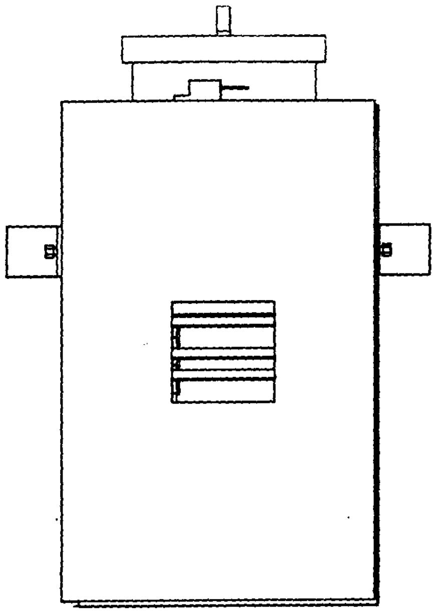

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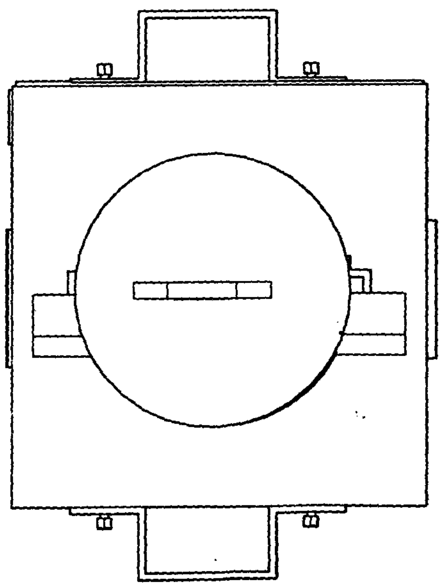

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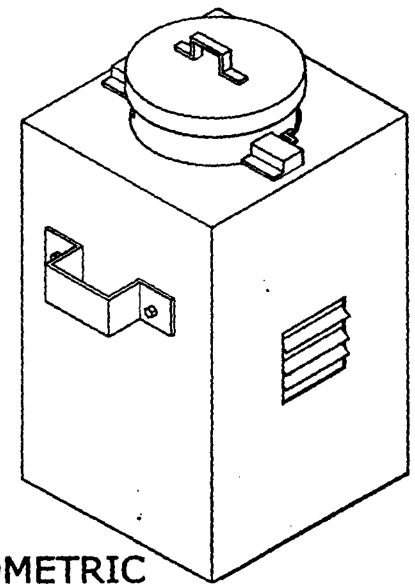

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MAT. NO:	2004/18357EA		
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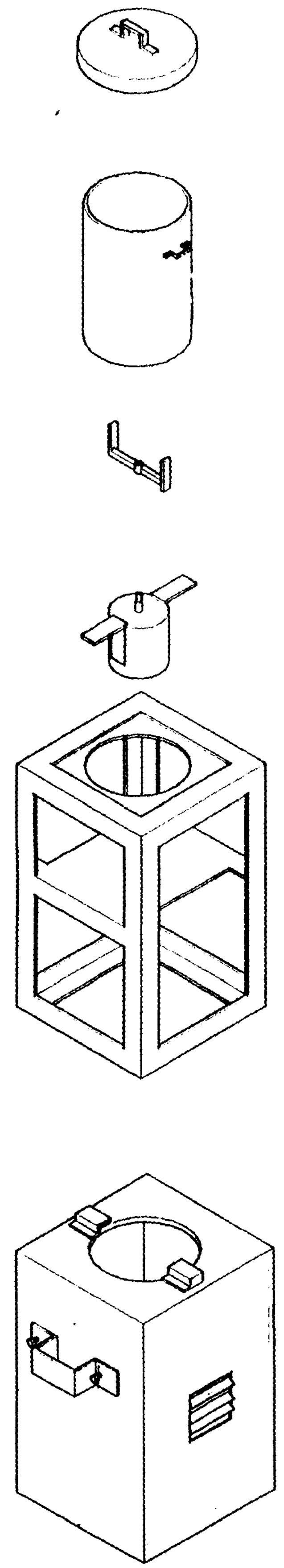

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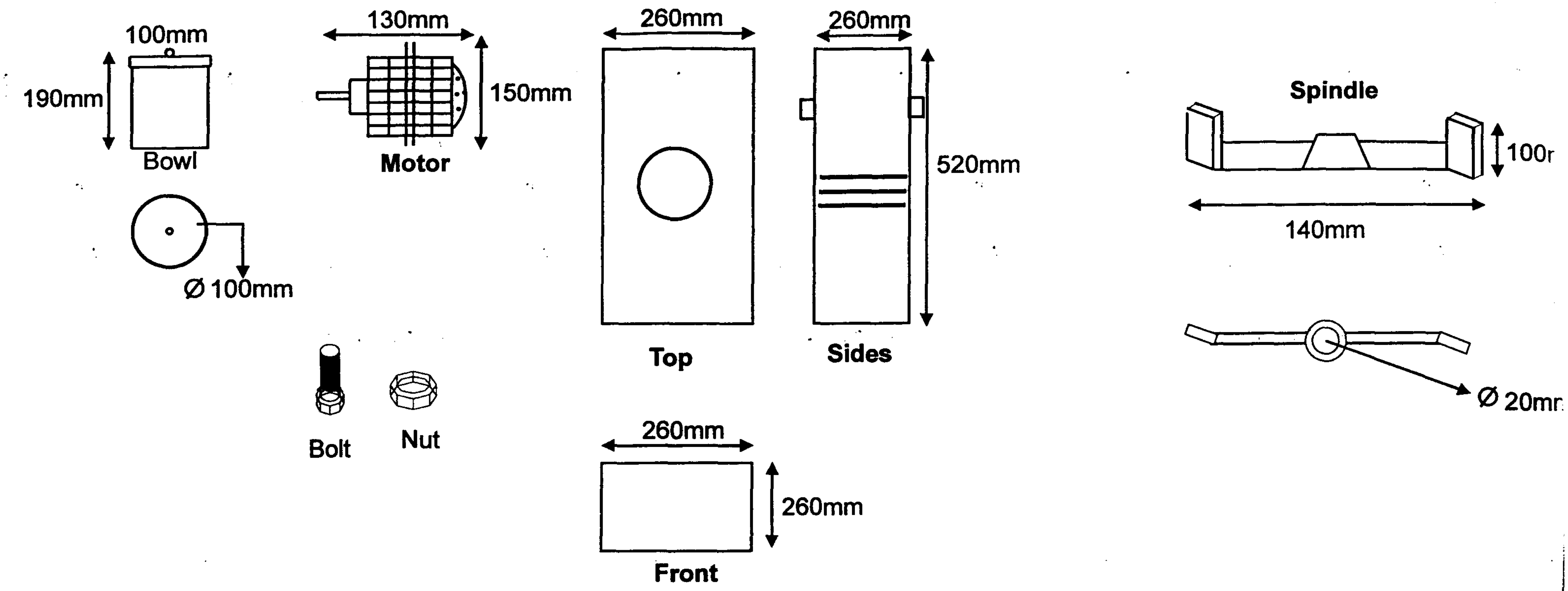

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