DESIGN AND FABRICATION OF MILLET THRESHER

BY

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

YUSUF, MOHAMMED BELLO	29/02/2012
(2006/24134EA)	Date

CERTIFICATION

This is to certify that the project entitled "Design and Fabrication of Millet Thresher" by Yusuf, Mohammed Bello 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 work is dedicated to the service of Almighty Allah whom in His infinite mercy has created and guided us through the struggle of life up to this stage. May his blessings and protection continue to be with us, Amen.

To my lovely parents whom Allah has chosen to champion the cause of bringing me to this temporary world, may Allah grant them internal blessing of paradise, Amen.

To my friends are so numerous to mention for their valuable suggestions and encouragement, may Allah bless them all too.

To the supervisor; for his valuable suggestion, critical reasoning and final approval of this project, may God continue to guide you throughout your endeavors Amen.

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ABSTRACT

A motorized *millet* thresher was designed, fabricated and assessed for performance. The main components of the thresher include hopper, threshing unit (cylinder drum and concave), cleaning unit (fan and sieves). The test performance at recommended electrical motor power of 3.75KW (5HP), with the speed of 1500rpm, moisture content of 13% wb, cylinder speed and fan speed of 800 rpm and 544.44 rpm respectively indicated a threshing efficiency of 63.20%, cleaning efficiency of 56.00% and percentage loss of 36.80. The thresher has a capacity of 250 kg/h. The performance of this thresher has indicated the possibility of exploiting the full industrial potential of millets.

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Abbreviations or Symbols or Notations

SYMBOLS	UNITS	DEFINITIONS
R	m	Radius
F	N	Force
T	Nm	Torque
C	m	Center distance
L	m	Length
P_{Total}	kW	Power required by the Machine
N	rpm	Speed required
V	m/s	Velocity
$\square_t$	Degree/m twist	Angle of twist
M_t	Nm	Torsional moment
E	N/m^2	Modulus of Elasticity
π		Pie
ω	rad/s	Angular velocity
V_s	m^3	volume of Shaft
g	m/s^2	Acceleration gravity
M	kg	Mass
$\square_c$	rad	Angle of contact
L_n	m	Norminal Pitch Length
d	m	Shaft Diameter

ω_s	rad/s	Critical speed
I	m^4	Inertial moment
□	kg/m^3	Density
G	Nm^2	Tortional Modulus
W	N	Weight
w_o	kg	Chaff Weight
w_s	kg	Threshed Grains Weight
w_c	kg	Clean Grains Weight
t_1	N	Tension on Tight Side
t_2	N	Tension on Slag Side
F_v	N	Vertical Force
F_H	N	Horizontal Force
D_1	mm	Motor Pulley Diameter
D_2	mm	Cylinder Pulley Diameter
D_3	mm	Shaker Pulley Diameter
D_{3i}	mm	Shaker Smaller Pulley Diameter
D_4	mm	Fan pulley Diameter
N_1	rpm	Speed of Motor
N_2	rpm	Speed of the Threshing Drum
N_3	rpm	Speed of the Shaker
N_4	rpm	Speed of the Fan
□	Degree	Angle of Inclination
P	kW	Power Required for Threshing
P_f	kW	Power Required by the Fan
P_s	kW	Power Required by the Shaker
M_b	Nm	Bending Moment
S_S	N/m^2	Allowable Shear Stress

e		Exponential
M_{BR}	Nm	Resultant Bending Moment
M_{BV}	Nm	Vertical Bending Moment
M_{BH}	Nm	Horizontal Bending Moment
K_t		Fatigue Applied to Bending Moment
K_b		Fatigue Applied to Tortional Moment
L_S	m	Length of Shaft
h	m	Height of Hopper

Abbreviations	**Meanings**
VBMD	Vertical Bending Moment Diagram
HBMD	Horizontal Bending Moment Diagram
RBMD	Resultant Bending Moment Diagram
VSF	Vertical Shear Forces
HSF	Horizontal Shear Forces

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Millet is a major source of energy and protein in the diets of poorer classes in many of the developing countries of the sub-tropical regions of the world. It is drought resistant and capable of growing and maturing quickly under short periods of .rainfall. The estimated annual production of millet is about 4 million tones (Central Bank of Nigeria Report, 1992).

In Nigeria, two main types of millets are cultivated. These are known as the "Gero" and "Maiwa" millets. The "Gero" millets are photo insensitive and early maturing while the "Maiwa" are photosensitive and late maturing. The "Gero" is estimated to be grown on more than 90% of the land occupied by millet, The millet breeding programmers' are aimed at developing improved genotypes or varieties capable of producing high stable yield, resistant to main diseases and possessing good grain quality. To achieve these aims, research efforts have involved population improvement methods and controlled crosses to produce experimental hybrids. (Central Bank of Nigeria Report; (1992).

Millet is widely grown and well adapted to many areas of India and Africa and has recently been introduced into the Americas. The plant is the crop of choice in many ecosystems where drought, poor soil quality and extreme heat predominate. For example, in the Sahel or sub-Saharan area of Africa it is the only cereal grain that will tolerate the climate where maize or even sorghum will fail. This grain is the crop of last resort where conditions and the people most struggle for survival, and because CTI's (Compactable Technology International) mission is to assist those most disadvantaged, it is a natural fit. Nutritionally, the grain is high in protein and has a good amino acid balance. It is also free from contamination by carcinogenic toxins such as aflatoxin which can affect other grains like maize. (National Research Council 1996).Millet is taken from the field by removing the long grainy head from the rest of the stock before it can be used for food it must be processed to remove the uneatable portion of the husk. The millet is first threshed to remove the usable grain from the hard husk and break-up the grain into smaller more manageable pieces. Further separation is then done by manual pounding. Grain is normally pounded with a wooden pestle in a wooden or stone mortar. It is common for the millet to first be moistened with about 10 percent water or soaked overnight to make the pounding easier. A woman working was hard can at best pound only 1.5 kg of grain per hour. After the usable portion of the grain has been separated by pounding the edible portion is removed winnowing or sieving. Winnowing is a process to separate grains from chaff by blowing air. The whole content is thrown up in the air, and the grain and chaff get separated out by gravity. The lighter chafe is blow away leaving behind the heavier usable grain. The final step in processing millet is making flour. Traditional grinding stones used to grind grain to flour usually consist of a small stone which is held in the hand and a larger flat stone which is placed on the ground. Grain is crushed by the backward and forward movement of the hand-held stone on the lower stone. The work is very laborious, and it is hard work for anyone to grind more than 2 kg of flour in an hour. (National Research Council 1996).

The principal use of millet grain in Nigeria is for human food. The grain is stored and the day's requirements of meal or flour are prepared as needed. The traditional method of preparing flour consists of pounding the grain in a wooden mortar with a small amount of water for about 10 minutes following, which the bran is winnowed off. The separated grain is pounded into flour. The flour is used in making porridges. (National Research Council 1996).

A major millet food in Nigeria is fura (Okoh and Eka 1978). In the preparation of fura, millet flour is made of into a paste by adding a small amount of water. The paste is compressed into balls and boiled for 20 to 30 minutes in water. The cooked balls are broken with the pestle and mixed with the cooking water. All or' some of the cooking water may be added while pounding. Spices (pepper, ginger, black pepper and cloves) are ground together and added at this point. The dough is removed to a local wooden bowl known as "calabash". Small pieces of dough are broken off and rolled into smooth balls weighting about 75gms each, some millet flour may be sprinkled over their surfaces. This flour not only makes them look nice but apparently also gives them better keeping quality if they are to be kept for any length of time, the maximum keeping time being three days. Fura is eaten with fermented milk called 'nono'. (Okoh and Eka 1978).

Ndaleyi is a fermented pearl millet food, which is very popular in Borno State, Nigeria (Nkama et al 1994). Ndaleyi production is very similar to the manufacture of Ogi from millet or sorghum except that the grain is steeped for longer days. The production procedure has been reported in detail by (Nkama et al 1994). In India and some other parts of the world, millet Hour is needed for baking flat, unleavened bread called chapatti, rod or bakery (Murty and House, 1980).

1.2 Statement of the problem

The traditional method of threshing and cleaning of millet from its straws is painstakingly, slowly, and tedious which make the all process of producing of the processed millets slow and time consuming. The hand process of threshing and cleaning of millets involves high cost of labor. As a result of these a more efficient machine, with energy and time saving and also with minimal cost is required.

1.3 Objective of the Study

1. To design and fabricate a machine that is capable of threshing and cleaning of millets.

2. To carryout performance test on the millet thresher.

1.4 Justification of the study

The introduction of new processing technology, millet threshing and cleaning machine offers a great prospect in the market for millets producers, so that millet can be made available in large quantity, because it is of high demand in rural area. Efficient method of threshing and cleaning will enhance the processing activities thereby reducing labor and save time. Threshing is one of time consuming unit operations in the production of processed millets.

1.5 Scope of the problem

The scope of the work is to design, fabricate and also test the performance of millet threshing and cleaning machine with a view to ascertain its efficiency and viability.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Euleusine Corarcana (L) Gaertn.

2.1.1 Common names

African finger millet, goose grass, osgras (Afrikaans), uphoko (Zulu), mpogo (Pedi), majolothi (Ndebele), mufhoho (Venda), vogel gierst (Dutch), tailabon (Arabic), petit mil, eleusine cultivée (French), Fingerhirse (German), wimbi (Swahili), ulezi (Swahili), dagussa (Amharic/Sodo), tokuso (Amharic), barankiya (Oromo), ragi (India), mugimbi (Kikuya), mawere, lipoko, usanje, khakwe, mulimbi, lupodo, malesi, mawe (Malawi), koddo (Nepal), ceyut (Bari), mbege (Tanzania), bulo (Uganda), kambale, lupoko, majolothi, mawale, amale, bule (Zambia), rapoko, zviyo, njera, rukweza, mazovole, poho (Zimbabwe). (National Research Council 1996).

2.1.2 Millet Varieties

Varieties of millet include pear millet (pennisetum glaucum) (Also known as Bajra in India, and as Kambu in Tamil). Foxtail millet (Setaria italic) (Also Known as Thinai in Tamil). Proso millet, common millet, Broom corn millet or white millet (Panicum miliaceu), Finger millet (Eleusine coracana) (Also known as Ragi or Mandwa in India, and as Kezhvaragu in Tamil). Other minor varieties are India banyard millet or Sawa millet (Echinochloa frumentacea), Japanese banyard millet (Echinochloa esculenta), Kodo millet (Paspalum scrobiculatum), Little millet (Panicum sumatrense), Guinea millet (Brachiaria deflexa or Urochloa deflexa). (Nkama et al.,1994).

2.1.3 Origin and geographic distribution

E. coracana is found in warm temperate regions of the world from Africa to Japan and also in Australia. It is present in archaeological records of early African agriculture in Ethiopia that date back 5000 years, and it probably originated somewhere in the area that today is Uganda (National Research Council 1996). It is an important staple crop in many parts of Africa and has been cultivated in eastern and southern Africa since the beginning of the iron age. Before maize was introduced it was the staple crop of the southern African region. It was introduced into India some 3000 years ago.

A tufted annual grass that grows to a height of 210-620 mm tall. The leaf blades are shiny, strongly keeled and difficult to break and are 220-500 mm long and 6-10 mm wide. The leaves and culms are typically green in colour. It has an exceptionally strong root system and it is difficult to pull out of the ground by hand (Van Wyk & Van Oudtshoorn 1999). The culms and the leaf sheaths are prominently flattened. The ligule is a fringed membrane. Inflorescence consists of spike-like main branches that are open or contracted and are digitate or sub-digitate. The spikelets are 5-8 mm long and 3-4 mm wide. The spikelets do not disarticulate (break apart at the joints) at maturity. The grains are globose. There are two subspecies of African finger millet, the wild form (E. coracana subsp. africana) and a cultivated form derived from it (E. coracana subsp. coracana). Wild African finger millet (E. coracana subsp. africana) is similar to Indian goose grass (E. indica) and may be confused with it, but the latter has smaller spikelets and oblong, not rounded, grains. The grains of Eleusine are unusual in that the outer layer (pericarp) is not fused and can be easily removed from the seed coat (testa) below (Van Wyk & Gericke 2000).

Archaeological excavations show that improved forms of finger millet were once the staple grain diet of southern Africa. In India it is still an important grain today. In east Africa, where it is cultivated as a cereal, five races are distinguished on the inflorescence morphology (Gibbs-Russell et al. 1989). It is the principal cereal grain of Uganda and is planted on more than 0.4 million hectares there. It has been successfully grown in the United States as far north as Davis, California, but with considerable problems of photoperiod sensitivity (National Research Council 1996).

It is a versatile grain that can be used in many different types of food. It is eaten by grinding the grains up for porridge or, as in Indonesia, eaten as a vegetable. Sometimes it is ground into flour and used for bread or various other baked products. The sprouted seeds are a nutritious and easily digested food that is recommended for infants and the elderly (NationalResearchCouncil1996).

The grain may be left to germinate to make malt, which is very popular in southern Africa due to the sweetness of the malt (Van Wyk & Gericke 2000). Its ability to convert starch to sugar is surpassed only by barley (National Research Council 1996). In Ethiopia a powerful distilled liquor called arake is made from finger millet. In India finger millet is widely enjoyed as a popped grain. Finger millet straw makes good fodder and contains up to 61% total digestible nutrients (National Research Council 1996). It is used in traditional medicine as an internal remedy for leprosy or liver disease (Van Wyk & Gericke 2000). Parts of the plant (the leaves and culms) are used to plait bracelets (Gibbs-Russell et al. 1989). Chemicals can be obtained from the plant, namely hydrocyanic acid. E. coracana is probably the most important weed in cultivated lands in southern Africa due to its exceptionally strong root system that makes it difficult to control mechanically. It is also a weed in many other parts of the world, namely North America, where it is listed as a weed. In Africa, the wild form (E. coracana subsp. africana) is considered to be a weed where the cultivated form (E. coracana subsp. coracana) is grown and is especially problematic since they are so similar in appearance.

2.1.4 Cytology

Chromosome base number, x = 9. E. coracana subspecies coracana is a tetraploid that derives from the wild diploid subspecies africana (National Research Council 1996).

2.1.5 Leaf blade anatomy

C_4 photosynthetic pathway. The wild form is found in areas with rainfall as low as 300 mm per annum in South Africa, but the cultivated form more commonly requires 500-1000 mm of rainfall per year. This should be well-distributed throughout the growing season and with an absence of prolonged droughts (National Research Council 1996). The altitude limits of the species are unknown, but most of the cultivated finger millet in the world is found from 500-2400 m elevation (National Research Council 1996). It tolerates cool climates, but thrives under hot conditions and can grow where temperatures are as high as 35oC (National Research Council 1996). E. coracana appears to be photoperiod sensitive, the optimum photoperiod being 12 hours, which is considered to be relatively short.

2.1.6 Soil requirements

It can be grown in any soil type as long as the rainfall is higher than 800 mm per annum (Van Wyk & Gericke 2000). Cultivated crops of E. coracana are frequently produced on reddish-brown lateritic soils with good drainage but reasonable water holding capacity (National

Research Council 1996). It has greater ability to utilize rock posphate than other cereals do (Flack et al. 1987).

2.1.7 Growth and development

From germination cultivated plants take 2.5-6 months to mature. In southern Africa the wild form flowers any time from October to May.

2.1.8 Diseases and pests

Suffers little from diseases and insects. However, it is subject to bird predators, most notably the quelea. A fungal disease called "blast" can devastate whole fields of finger millet. The seeds can be stored for years without insect damage, which makes them perfect for famine-prone areas (National Research Council 1996).

2.1.9 Performance

The cultivated form is considered to be a highly productive crop (National Research Council 1996). Yields vary tremendously from 600-5000 kilograms per hectare and are not affected much by bird damage. However, yield per unit labour is considered to be more important in rural areas and also that there is at least some yield during times of drought (Van Wyk & Gericke 2000). Cereal from this species is considered to be more nutritious than any other major cereal species. It has high levels of methionine, an amino acid which is lacking in the diets of poor people who live on starchy foods such as cassava and plantain (National Research Council 1996). This may be the major reason why people of central Africa are so physically healthy despite a limited diet.

2.1.10 Nutritive value

Finger millet has variable nutritive value; protein contents ranging from 6–14% have been reported, fat 1–1.4%, iron 5mg per 100g and food energy 323–350 Kc. These are the more frequently given levels but in some samples they are much higher. For the essential amino acids, the most noteworthy is methionine which is reported to be 3%, an exceptional figure for a cereal grain (National Research Council 1996).

2.2 Thresher

From the earliest time that man had used grains as food, the problem of removing the unwanted unedible glumes, straw or husk from the actual seeds had existed (Sutton, 1974). Until the middle of the 19th century, the principal methods of threshing grains were flailing by hand or spreading the ripe crop on a floor and beating with sticks, clubs, etc or treading by animals (Culpin, 1974). Hopfen (1960) stated that grains threshed by local methods need considerable cleaning before use. This local way of separating seeds from straw was hard, dirty, inefficient, uneconomical, time consuming and slow at a time when agriculture was undergoing rapid technological advancement in most developed countries (Olmstead and Rhode, 1988).

The first step in the mechanization of the threshing process came in the 17th century when fanning mills were developed for winnowing. In 1636, Sir John Van Berg produced a thresher which consisted of several flails operated by cranks (Encyclopedia Britannica, 1969). In 1976, Andrew Meikle built a threshing machine which combined the blow of the flails with the robbing action of the threshing floor (the prototype of the present day thresher), in which beaters were fastened to the revolving drum forcing the grain against the ribs of a concave sieve placed below the drum. This machine was capable of relieving arable agriculture from it's annual epic drudgery (Macdonald, 1975). Probably, the best known of the early American machines was developed by Hiram and John Pitts of Winthrop which combined the threshing, separating and winnowing processes in a single machine (Encyclopedia Britannica, 1969).

2.2.1 Threshing

Threshing machines have a long history, although their design principles have been largely static since the mid 1800's. They come in a variety of sizes, prices, and throughputs. Nevertheless, much of the millet threshing in rural Africa and India is still done by slow manual pounding that consumes up to 4 hours/day of women's time, and results in blisters and repetitive stress injuries. Threshing is followed by winnowing to clean the grain (rasnow Aug 10 2008).

Threshing is separating grains from ear heads. After threshing, grain and husk are separated by winnowing and cleaning. The different methods of threshing finger millet are discussed here.

2.2.2 Threshing under men feet:

It is suitable for threshing only the ear heads and small quantity under shelter even in bad weather conditions. Finger millet ear heads were threshed under men/women feet. It is very slow process and its output capacity is very low, needs cleaning after threshing and cost of threshing is high. It is a method of threshing with no damage to grain and hence there is no effect on germination of seeds.

2.2.3 Hand beating manuall

Threshing of dried finger millet ear heads by beating with sticks is a practice when small quantity for seed purposes. It is quite faster than threading under men feet, less grain damage and no effect on germination of seeds. The cost of threshing is more and also slow process with less output. Chandrakantappa kammar et.al, (2001) observed that, there was a mechanical damage of 0.13-0.60% in manual beating, when the seeds threshed at three seed moisture levels (10, 13 and 18%). Lower seed moisture content recorded a higher mechanical damage and less germination of finger miller cultivars MR-1 and HR-911 in the manual beating with a stick.

2.2.4 Passing stone roller with bullocks

Most of the farmers use this method (60%). Threshing of finger millet whole crop or ear heads is done with this method. It is faster than other two methods and suitable for large scale threshing. It requires a designated threshing yard. Threshing yard is prepared in a portion of the farmland by compacting the soil. It involves animal and human drudgery. It takes around four days to thresh the finger millet crop grown in one acre of land if only bullocks are used. This comes down to two to three days if granite rollers are used. It needs separate winnowing and cleaning operations and winnowing is depending on natural breeze. This method is limited to farmers owning bullock and threshing yard. Lots of wastage in threshing yard due to rains, birds, ants and other natural vagaries.

2.2.5 Passing bare tractor/ tractor with stone roller

Threshing of finger millet by passing bare tractor /tractor with stone roller estimated to practice by 30 percent of the farmers. It also a faster method of threshing. We can thresh either whole crop or ear heads with a higher output capacity and is limited to availability of tractor and threshing yard. Here also winnowing and cleaning are required after threshing. Wastage in threshing yard is more as broken grains and other wastages. It takes around one day to thresh the finger millet crop grown in one acre of land. A study conducted by Chandrakantappa kammar et.al, (2001) by passing a tractor-drawn stone roller at 3 seed moisture levels (10, 13 and 18%), on mechanical damage and germination of finger miller cultivars MR-1 and HR-911, resulted in the highest mechanical damage (1.70-3.90%). There was no significant difference in mechanical damage to seed between the 2 cultivars in the threshing methods. The seeds threshed at lower seed moisture content recorded a higher mechanical damage compared to those threshed at higher seed moisture content.

2001). Threshing studies conducted by Narayanaswamy and Javaregowda 1989 in "Almaco" plant and earhead thresher reveals that, irrespective of the variety both the threshing efficiency and mechanical damages were decreased with decrease in cylinder speed and the mechanical damages were higher at higher speed and decreased with decrease in cylinder speed. The decrease in germination and vigour index with increase in cylinder speed was observed. Decrease in germination is due to greater impact force on the seed. The threshing efficiency germination percentage and vigour index were found to be optimum with the ragi ear heads threshed at the cylinder speed of 1295m/min at a moisture range of 20-22 percent.

2.3 Types of Thresher

2.3.1 Spike-Tooth Cylinder Type of Thresher

It is a thresher with threshing unit consists of drum having rows of spikes with a closed cylinder casing and concave and equipped with a set of sieves and aspiratory blower for separation and. cleaning of grains (millet crops).

2.3.2 Components of Power Thresher

The main components are:

1. Concave
2. Cylinder or drum and
3. Cleaning unit.

2.3.3 The Threshing Drum, Concave and cleaning unit

The thresher works on rotating impact principle. Millets are fed uniformly into the hopper. The millet fall by gravity on the rotating cylinder and are threshed by impact of the studs and are whirled round between the perforated concave and the rotating cylinder. The chaff and the seeds fall through the concave openings and are directed to the seed outlet by the configuration of the casing. Just before falling on the seed collector, the fan's air stream blows off the chaff through the chaff outlet chute leaving behind the clean seeds on the seed collector. The seed collector is opened at intervals to discharge the seeds through the clean seed outlet. This arrangement was aimed at allowing some dwell time for the mixture of the seeds and chaff to be properly separated. Adigun and Alonge (2000)

Table 2.1 Showing Comparative Performance of Reapers for Harvesting Rainfed and Irrigated Finger Millet

Particulars	Power tiller mounted reaper		Self propelled KAMCO Make		Self propelled CIAE make		Self propelled Local make		Manual harvesting
Power Source	15 HP Diesel Engine		3.5 HP Petrol start Kerosene run Engine		6 HP Diesel Engine		3.5 HP Petrol start Kerosene run Engine		Man Power
Height of cut (cm)	136.00	(106.00)	102.00	92.00	121.00	(98.00)	102.00	(92.00)	53
Speed (km/hr)	3.23	(3.67)	2.27	(2.58)	2.04	(2.38)	2.38	(2.68)	-
Field capacity (ha/hr)	0.28	(0.28)	0.13	(0.13)	0.12	(0.12)	0.13	(0.14)	0.005
Mechhour (hr/ha)	3.60	(3.40)	7.90	(7.85)	8.37	(8.26)	8.00	(7.85)	-
Man hour (hr/ha)	15.00	(23.00)	25.00	(24.00)	20.00	(20.00)	3.42	(10.53)	-
Fuel consumed (lit/ha)	4.32	(4.23)	7.03	(6.89)	8.37	(7.93)	7.12	6.91)	-
Wheel Slippage (%)	11.13	(10.13)	9.78	(8.93)	10.09	(9.01)	9.83	(8.67)	-
Field efficiency (%)	96.00	(98.00)	90.00	(95.00)	88.00	(90.00)	90.00	(94.00)	99
Field loss (%)	3.10	(3.50)	2.78	(2.98)	2.65	2.92)	2.81	(3.09)	1.5

(Kumar et al., 2006)

Table 2.2 Showing Summary of Results of Mechanical Threshing of Finger Millet Using "Almaco" Plant and Earhead Thresher

	Cylinder speed (m/min)				
	2215	1665	1295	1095	Mean
Threshing efficiency (%)	95.79	94.42	93.08	90.53	92.31
Mechanical damage (%)	17.66	4.53	0.67	0.14	4.82
Germination (%)	66.28	73.72	77.27	79.72	71.42
Vigour Index	780.5	780.5	929.09	950.94	888.94

(Narayanaswamy and Javaregowda 1989)

Table 2.3 Showing Summary of Results of Mechanical Threshing of Finger Millet Using "LCT" Thresher

Particulars	Moisture content (%) of Indaf -5 variety finger millet			
	9%	11%	13%	15%
Threshing efficiency (%)	77.20	79.20	78.20	76.50
Winnowing Efficiency (%)	87	90	89	88
Breakage (%)	2	1.7	1.5	1.5
cost of threshing per quintal of grain (Rs.)	2.93	2.20	1.95	2.79

(Ramkumar et al 1988)

Table 2.4 Showing Finger Millet Harvesting and Threshing in Karnataka: A Case Study

Method of Threshing	Type of feed	Out put capacity (Kg/hr	Broken (%)	Unthreshed grains (%)	Threshing efficiency (%)	Recovery (%)	Germination (%)
Threading under men feet	Ear Heads	8.16	0.00	2.73	97.26	97.36	95.67
Hand beating manually	Ear heads	22.16	1.50	1.78	98.22	98.10	94.67
Passing stone roller	Whole Crop	96.8	1.65	4.96	94.35	95.13	94.67
With bullocks	Ear Heads	166.3	2.17	3.26	96.74	97.45	93.67
Passing bare tractor	Whole Crop	116	3.10	7.68	92.30	92.23	94.67
Passing tractor with stone roller	Whole crop	119.33	3.20	5.98	93.98	94.45	94.33
	Ear Heads	253	1.66	2.73	97.26	97.91	93.67
Proto type Thresher	Ear Heads	69.50	2.00	4.90	95.00	86.10	90.00

Jayapalaiah, 2000)

Table 2.5 Showing Performance of Different Threshers for Threshing Grain Crop Under Optimum Operating Conditions

S/n	Type of cylinder	Crop	speed Cylinder	Concave clearance /mm	Crop parameter	Cylinder dimension /mm	Performance index	Threshing capacity	Feed rate/kg·h-1	Power source	Source
1	Rasp bar	Sorghum	400 r/min (10.5 m/s)	7.0	Gs=4.33 mm G:S=1:3 d=0.22 g/cc ar =33° ai =32° Mc =16.2 %	D = 480 L = 640	Te = 98.3% Ce = 97.2% Gd = 1.12% Sl = 3.8% G = 85.3%	33.2 q/h	360	4.95 kW Electric motor	Desta and Mishra (1990)
2	Tooth Peg	Chick pea	580 r/min (14.6 m/s)	30	Yd = 517 kg/ha Mc = 14.2%	D = 480 L = 640	Te = 93.0% Gd = 2.2% Ml = 9.1%	190 kg/h	430	5.7 L/h Gasoline engine	Anwar and Gupta(1990)
3	Tooth Peg	Multi crop Wheat, Sorghum& Paddy Maize	(12.8 m/s) (10.5 m/s) (16.5 m/s) (15.0 m/s)	25 35-45 20	Mc = 20.2% Mc = 16.2% Mc = 15.5% Mc = 14.6%	D = 480 L = 640 D = 235 L = 830	Te = 99.0% Gd = 2.0% 4.0%	276 kg/h Wheat 200 kg/h Sorghum 392 kg/h Paddy	500 450 550 500	3.7285 kW Electric motor	Majundar Joshi(1985.)
4	Tooth Peg /s)	G.nut	400 r/min (6.3 m	25	Mc = 12.0%	D = 300 L = 1220 61 pegs	Ce = 95% Gd = 3% Sl = 6%	264 –367 kg/h		Tractor PTO	Zafar, et al.(1997)
5	Tooth beater /s)	Millet	800 r/min (9.8 m	6	Mc = 12.0% ar = 13.95o d =·798 g/cc Gs = 3.9 mm	D = 235 L = 830	Te = 96.8% Gd = 1.3% Sl = 4.5%		385	2.24 kW Electric motor	Ndirika (1993)

Note: Gs = Grain Size; G:S = Grain to Straw Ratio; d = Bulk Density; ar = Angle of Repose; ai = Angle of Internal Friction; D = Cylinder Diameter; L = Cylinder Length; Te = Threshing Efficiency; Ce = Cleaning Efficiency; Gd = Damaged Grain; Sl = Sieve Loss; G = Germination Rate; G.nut= Groundnut; Mc = Moisture Content (wet basis); Bl = Blower Loss; Yd = Yield; Ml = Machine loss; wb = wet basis.

CHAPTER THREE

3.0 DESIGN CALCULATIONS

3.1 Design Considerations

Consideration is given to the following

3.1.1 Engineering Properties of Millet

Engineering properties of millet are indispensable properties in the design of machine for threshing and cleaning of millet. According to Mohsenin (1970) engineering properties include; 1) physical properties 2) frictional properties 3) Rheological properties. For the purpose of this work, only physical properties are given consideration.

3.1.1.1 The Physical Properties of Millet

It is necessary to know the physical properties of agricultural products because this helps in designing appropriate machinery and systems for processing and storage. Mohsenin (1970) outline some of the physical properties of any given engineering material or biomaterial in general terms to include; size, shape, sphericity, seed weight, density, volume, surface area, and porosity.

3.1.2 Compactness

In carrying out this design work, much effort was directed towards obtaining a system that would give the desired compactness. The dimensions of the various components were calculated so as to minimize size and weight of the machine and at the same time not compromising the standard, strength and efficient functioning of the various parts.

The availability of the materials will reduce the cost of construction and hence will make the price to be comparatively low thereby making it affordable for the intended producers of millet grain. These conditions and material specification led into the selection of mild steel which is the most available and can be easily machined.

3.2.1 Selection of Bearing

In the selection of bearing for this design, careful consideration was given to the bearing life. Khurmi and Gupta (2005), defined the life of a bearing as the number of revolutions or hours at some given constant speed which the bearing runs before the first evidence of fatigue develops.

Haven't considered the reasons for fatigue to develop in a bearing, for this design, single row deep groove ball bearing was used. This is as a result of its high operating number of hours and fatigue of this type of bearings rarely develops.

3.3 Principle of Operation of the Machine

The machine for threshing and cleaning of millet has three compartments. These are the threshing assembly, the cleaning chamber and the winnowing system. The threshing drum houses the shaft on the drum concave with a clearance of 6mm. A 5 hp electric motor provides drive through belt connections via pulley to the threshing drum shaft. As the threshing drum shaft rotates with the help of bearings, it provides drive to the shaft of the cleaning chamber through belts and pulleys.

As the millet panicles are being fed into the threshing drum through the hopper, the grains are beaten out of the ears and separated from the bulk of the straw. This is done by a rotating cylinder fitted with beater pegs which rotates above a stationary grid known as a concave. The concave is also fitted with bars throughout its width and it is between these bars and the pegs of the cylinder that the grains are beaten out. After being beaten out, the bulk of the grain falls through the concave grid into the cleaning unit which consist of two sieves that undergoes to and fro shaking motion and an air blast which is directed into the sieves. The top sieve is referred to as the chaffer sieve which helps to retain the chaff and allow the passage of the millet grain into the bottom sieve called grain sieve full of holes that are of the grain size diameter. The purpose of the grain sieve is to carry out further separation of grain from trash and any broken grain. Whilst the grain is moving over these sieves a constant blast of air is being blown through them so as to allow little or no trash settle on the sieve and anything lighter in weight than the grain is blown out. The grain pans beneath the grain sieve conveys the grain, which at this stage should be quite free of any trash, to the clean grain outlet for collection while the other pan transfer the broken grains and any other dirt that is smaller than the grain to the other outlet.

3.4 Design of the Major Parts of the Machine

The following are the engineering properties and other assumed parameters used for the design of the major parts of the machine elements. The parameters are based on Ex-Borno variety of pearl millet with moisture content (% wet basis)= 13%.

Expected output capacity of the thresher = $2tones$ per day

Number of working hours per day = $8hrs$

Length of millet panicle = $350mm$

Thickness of millet panicle = $25mm$

Average width of millet grain= $2.65mm$

Average diameter of millet grain = $2.61mm$

Density of millet grain = $958.1kg/m^3$

Average thickness of millet grain = $1.64mm$

Angle of repose of millet grain = $32.67°$

Selected length of threshing drum = $0.5m$

The impact force required to thresh grains = $0.5N$ (Abu, 2006)

Speeds of threshing drum = $800rev/min$ (Ndirika, 1997)

Speed of motor pulley = $1500rpm$

Diameter of motor pulley = $60mm$

Speed of the fan = $544.44rpm$ (Epapala, 1998)

Power transmitted by the belt = $0.5kw$ (Gay *et al.*, 1984)

Allowable shear stress on solid shaft = $40 \times 10^6 Nm^{-2}$ (Hall *et al.*, 1980)

The combine shock and fatigue factor applied to torsional moment = 3.0 (Hall *et al.*, 1980)

The combine shock and fatigue factor applied to bending moment = 1.5 (Hall *et al.*, 1980)

The modulus of elasticity of mild steel = $0.2Nm^{-2}$ (Khurmi and Gupta, 2005)

Density of mild steel = $7850kg/m^3$ (Khurmi and Gupta, 2005)

Selected length of the shaft = $0.7m$

π =3.142 and g = 9.81 m/s²

3.4.1 Expression of the Capacity in Volumetric Rate

Mass of millet panicle to be threshed in one minute = $4.2kg$

Density of millet = $958.1kg$

Density = $\frac{mass(m)}{volume(v)}$ (Douglas, 2006)

Volume = $\frac{mass}{density} = \frac{4.2}{958.1} = 4.38 \times 10^{-3}m^3$

If $4.38 \times 10^{-3}m^3$ of millet is to be threshed in one minute, therefore the expression of the machines capacity in volume per hour is

$C_{vph} = \frac{4.38\times10^{-3}\times60}{1} = 0.2628m^3/hr$

Similarly the expression of the machines capacity in mass per hour is

$C_{mph} = 958.1 \times 0.2628 = 251.79kg/h$

3.4.2 Determination of the Threshing Drum Diameter

The threshing drum diameter is needed in order to determine the capacity of the threshing drum. Therefore the diameter of the threshing drum was determined using the formula below, which is related to a formula for calculating the volume of a cylinder.

Volume (V) $= \frac{\pi d^2}{4} \times L$

Therefore, d $= \sqrt{\frac{4 \times V}{\pi L}}$

But, Volume of millet to be threshed in one minute $= 4.38 \times 10^{-3} m^3$

For design purpose a tolerance of 10% of the volume of millet to be threshed was assumed.

Therefore design volume (V) $= \frac{10}{100} \times 4.38 \times 10^{-3} + 4.38 \times 10^{-3}$

$= 4.818 \times 10^{-3} m^3$

Where, d- the diameter of the threshing drum

L- the length of the threshing drum

Hence, $d = \sqrt{\frac{4 \times 4.818 \times 10^{-3}}{\pi \times 0.5}}$

$= 0.1108 m$

For this design volume ($4.818 \times 10^{-3} m^3$), the dimension of the threshing drum are $0.5m$ length and $0.1108m$ diameter.

3.4.3 Evaluation of Weight of Threshing Drum

The weight of the threshing drum was determined in order to know the amount of load being exerted on the shaft by the threshing drum. Therefore the weight of the threshing drum is expressed as

$$W = mg$$

Where,

W- weight of threshing drum

M - mass of threshing drum

But, mass of the threshing drum $m = density\ of\ the\ threshing\ drum\ material(\rho) \times volumeof\ the\ threshing\ drum(v)$

Where, $\rho = 7850kg/m^3$ (density of galvanized steel)

$$v = 4.818 \times 10^{-3}m^3$$

Therefore, mass of the threshing drum $(m) = 7850 \times 4.818 \times 10^{-3}$

$$= 37.8213kg$$

g - acceleration due to gravity ($9.8m/s^2$)

Hence, $W = 37.8213 \times 9.81 = 371.03N$

Therefore the weight of the threshing drum acting on the shaft is $371.03N$

3.4.4 Power Required to Thresh Grain from its Panicle

The power required to thresh grain from millet panicle is expressed as

$P = T\omega$

Where,

P - power required

T - torque of the drum

ω -angular velocity (rad/s)

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

Where,

N - speed of the threshing drum is given as 800rev/min (Ndirika, 1997)

$\omega = \frac{2\pi \times 800}{60} = 83.77 rad/sec$

Also T= Fr

Where,

F - the impact force required to thresh grain = $0.5N$ (Abu, 2006)

r - the distance of point of force application from axis of rotation (i.e. force radius)

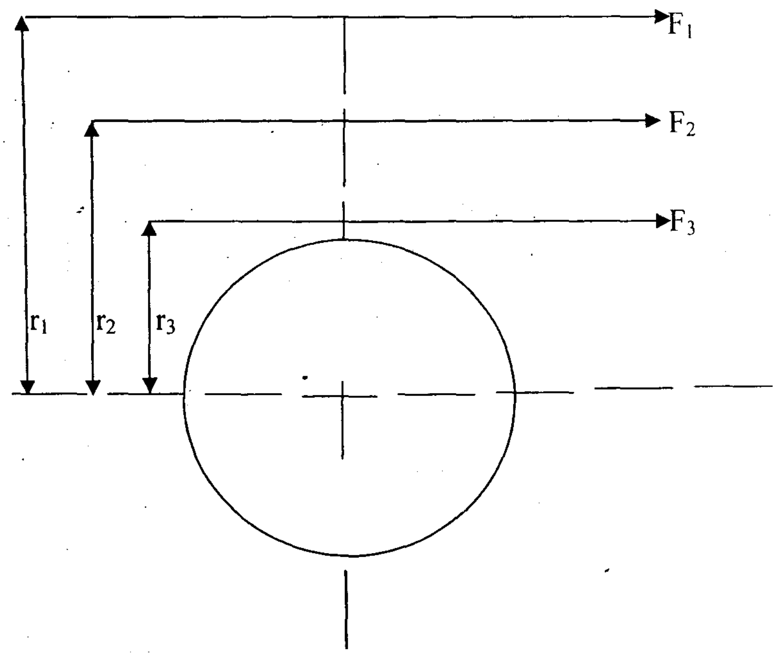

Fig.3.1 Cross Section of pegs on rotating drum.

The torque resulting from individual force is given by

T = $F_i \times r_i$

Where F_i and r_i are force and radius respectively

Resultant Torque (T_R) = $F_1r_1 + F_2r_2 + \ldots\ldots + F_ir_i$

i.e $\quad T_R = \sum_{i=1}^{i=n} F_i\, r_i$

Where n is the number of segments = 10

But, $\quad F_1 = F_2 = F_i$

Therefore, $\quad T_R = F\sum_{i=1}^{i=n} r_i$

$$= F[\tfrac{n}{2}(2a + (n-1)d]$$

But, $a = r_1 + \frac{L}{2}$

Where L - length of beaters (0.01m)

d - common difference (0.01m)

a - first term

Therefore; $a = 0.1 + \frac{0.01}{2}$

$= 0.105m$

Hence, $T_R = 0.5\left[\frac{10}{2}(2 \times 0.105 + (10 - 1)0.01)\right]$

$= 0.75Nm$

Total Torque (T) on the drum is calculated as follows

$T = T_R \times K_B$

Where, K_b is the number of beaters on the drum = 30

$T = 0.75 \times 30$

$= 22.5Nm$

Therefore, the power required to thresh grain from millet panicle is expressed as

$P = 22.5 \times 83.776 = 1884.96W$

$=146.25mm$

According to (Joseph and Charles, 2001), the centre of two pulleys must meet the condition which is stated as;

$D_1 \leq C \leq 2\,(D_1 + D_2)$

From the calculation above, C is safe for the design.

Hence, Nominal pitch length (L) $= 2 \times 146.25 + \frac{\pi}{2}(60 + 112.5) + \frac{(112.5-60)^2}{4\times 146.25}$

$=292.5 + 270.96 + 4.712$

$= 568.172mm$

From the standard of belt available in the market, A56 which is close to 568.172mm is therefore selected since the exact value of belt length calculated was not found in the market.

3.5.2 Weight of Threshing Drum Pulley

The weight of the threshing drum pulley was determined in order to know the weight of the pulley acting on the shaft. Therefore the weight of the threshing drum pulley is expressed as;

$W = mg$

Where, W- weight of the drum pulley

m- mass of pulley= $1kg$

g- acceleration due to gravity ($9.81m/s^2$)

therefore, $W = 1 \times 9.81 = 9.81N$

3.5.3 Threshing Drum-Shaker Belt Length

The nominal pitch length of the threshing drum to shaker belt was determined in order to know the actual belt size that is needed to transfer power from the threshing drum to the shaker. Therefore the nominal pitch length (L) is given as;

$$L = 2C + \frac{\pi}{2}(D_2 + D_3) + [\frac{(D_3 - D_2)^2}{4C}]$$ (Khurmi and Gupta, 2005)

Where; D_2- diameter of the threshing drum Pulley (112.5mm)

D_3 - diameter of the shaker Pulley

But; $D_3 = \frac{N_2 D_2}{N_3}$ (Khurmi and Gupta, 2005)

Where; N_2 - speed of the threshing drum Pulley (800rpm)

N_3 - speed of the shaker Pulley = N_2(since power is drawn from the pulley with the same diameter of pulley)

Therefore $D_3 = \frac{800 \times 112.5}{800} = 112.5$mm

C- the center distance between the threshing drum pulley and shaker pulley, which is expressed as

$$C = (\frac{D_3 + D_2}{2}) + D_2$$ (Khurmi and Gupta, 2005)

$$C = (\frac{112.5 + 112.5}{2}) + 112.5$$

$= 225mm$

According to (Joseph and Charles, 2001), the centre of two pulleys must meet the condition which is stated as;

$D_2 \leq C \leq 2\ (D_2+D_3)$

From the calculation above, C is safe for the design.

Hence, Nominal pitch length (L) $= 2 \times 225 + \frac{\pi}{2}(112.5 + 112.5) + \frac{(112.5-112.5)^2}{4\times 225}$

$= 450 + 353.429 + 0$

$= 803.429mm$

From the standard of belt available in the market, A58 which is close to 803.429mm is therefore selected since the exact value of belt length calculated was not found in the market.

3.5.4 Shaker-Fan Belt Length

The nominal pitch length of the shaker to the fan belt was determined in order to know the actual belt size that is needed to transfer power from the shaker to the fan. Therefore the nominal pitch length (L) is given as;

$$L = 2C + \frac{\pi}{2}(D_{3i} + D_4) + \left[\frac{(D_4 - D_{3i})^2}{4C}\right]$$ (Khurmi and Gupta, 2005)

Where, Diameter of shaker pulley (D_{3i})= $80mm$

Diameter of fan pulley (D_4)

But, $D_4 = \frac{N_3}{N_4} \times D_{3i}$

Speed of shaker pulley (N_{3i})= $800rpm$

Speed of fan pulley (N_4)= $544.44rpm$ (Epapala,1998)

Therefore , $D_4 = \frac{800}{544.44} \times 80 = 117.55mm$

C- the center distance between the shaker pulley and the fan pulley, which is expressed as

$$C = (\frac{D_4+D_{3i}}{2}) + D_{3i}$$ (Khurmi and Gupta, 2005)

$$C = (\frac{117.55+80}{2}) + 80$$

$$= 178.78mm$$

According to (Joseph and Charles, 2001), the centre of two pulleys must meet the condition which is stated as;

$$D_{3i} \leq C \leq 2\,(D_{3i}+D_4)$$

From the calculation above, C is safe for the design.

Hence, Nominal pitch length (L) = $2 \times 178.78 + \frac{\pi}{2}(80 + 117.55) + \frac{(117.55-80)^2}{4 \times 178.78}$

$$= 357.56 + 310.35 + 1.97$$

$$= 669.88mm$$

From the standard of belt available in the market, A56 which is close to 669,88mm is therefore selected since the exact value of belt length calculated was not found in the market.

3.5.5 Determination of the Velocity of Shaker-Fan Belt

The velocity was used to determine the co-efficient of friction acting on the belt. The velocity of the belt was therefore determined using the expression below;

$$V = \frac{\pi \times N_{3i} \times D_{3i}}{60}$$

$$= \frac{\pi \times 800 \times 0.08}{60} = 3.35 m/s$$

3.5.6 Determination of Angle of Contact of the Belt between the Shaker Pulley and the Fan Pulley

The angle of contact of belt between the shaker pulley and the fan pulley was determined in order to know the tensions which exist between the belt and the pulleys. Therefore the angle of lap of the belt between the two pulleys can be calculated from the expression below;

$\theta = (180 - 2\alpha) \times \frac{\pi}{180}$rad (Khurmi and Gupta, 2005)

Such that, $\alpha = \sin^{-1}(\frac{r_4 - r_3}{C})$

Where, θ-*Angle of contact of belt between the pulleys*

r_4-*radius of the fan pulley*(58.775*mm*)

Therefore, $\alpha = \sin^{-1}(\frac{58.775 - 56.25}{125.88}) = 1.15°$

Hence, $\theta = [180 - 2(1.15)] \times \frac{\pi}{180} = 3.10 rad$

3.5.7 Evaluation of the Tension in Shaker-Fan Belt

The tension is determined so as to ascertain the power transmitted by the shaker to fan belt, therefore the tension on the two sides of an open belt can be calculated as shown below,

$$\frac{T_1}{T_2} = e^{k\theta} \, (Khurmi\ and\ Gupta, 2005)$$

Where,

T_1- is the tension of the belt on the tight side.

T_2- is the tension of the belt on the slack side.

K- is the coefficient of friction between the belt and the pulley.

θ- is the angle of contact or lap of belt between the two pulleys= $3.10rad$.

But,

$$k = 0.54 - \left(\frac{42.6}{152.6 + V}\right) \, (Khurmi\ and\ Gupta, 2005)$$

Where,

V- is the velocity of the belt = $3.35m/s$

Therefore, $k = 0.54 - \frac{42.6}{(152.6+3.35)}$

$= 0.54 - \frac{42.6}{(155.95)}$

$$= 0.54 - 0.276 = 0.26$$

Hence, $$\frac{T_1}{T_2} = e^{0.26 \times 3.10} = e^{0.806}$$

$$\frac{T_1}{T_2} = 2.24$$

$$T_1 = 2.24T_2$$

The power transmitted by an open belt is given by $P = (T_1 - T_2)V$

Where, V- is the velocity of the belt= $3.35m/s$

P- is the power transmitted by belt= $0.5kw$ (Gay *et al,* 1984)

Therefore $$0.5 \times 10^3 = (2.24T_2 - T_2) \times 3.35$$

$$0.5 \times 10^3 = 7.73515T_2 - 3.35T_2$$

$$438515T_2 = 0.5 \times 10^3$$

$$T_2 = \frac{0.5 \times 10^3}{4.38515} = 114.02N$$

Hence, $$T_1 = 2.24 \times 114.02 = 255.40N$$

3.6 Shaft Design

3.6.1 Determination of Shear Force, Bending Moment and Resultant Bending Moment of Threshing Drum Shaft

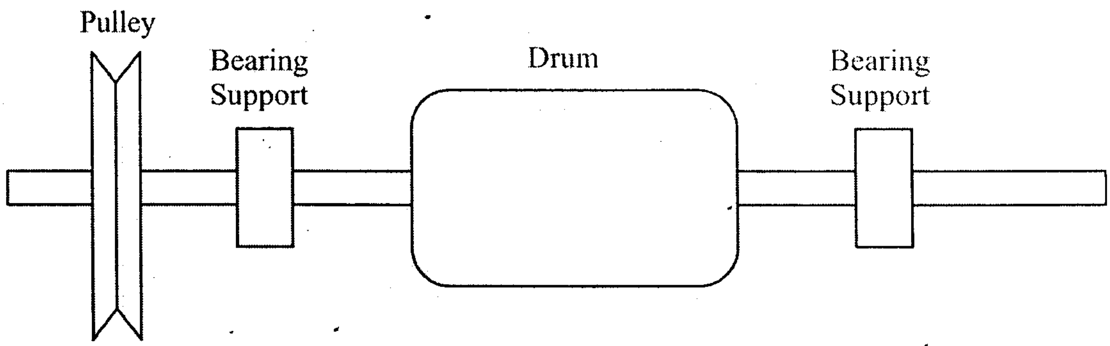

Fig 3.2: Loading System of Drum Shaft

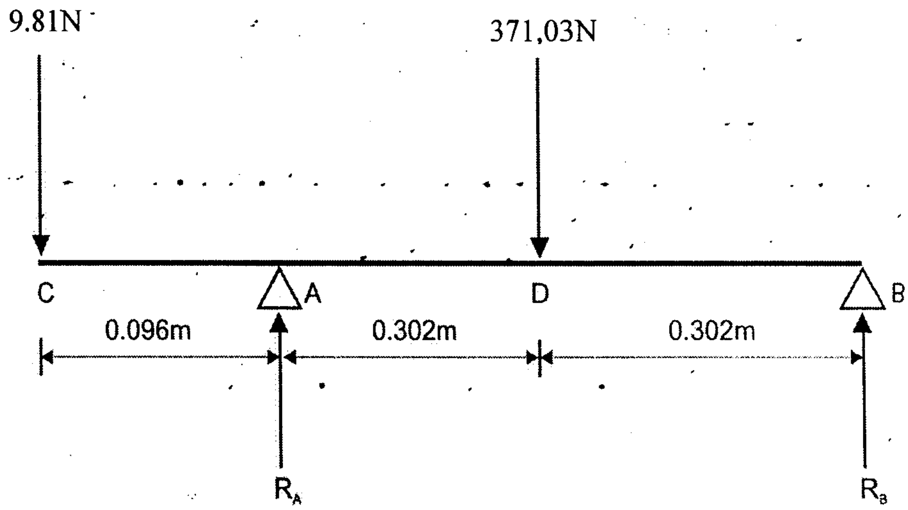

Fig 3.3: Free-body Diagram of Drum Shaft Loading System

While the machine is operating, there is combine bending and tensional stresses acting on the solid shaft driving the threshing mechanism, therefore the need to calculate shear force bending moment and resultant bending moment of the shaft in order to determine the shaft diameter that will withstand the applied loads.

3.6.2 Vertical Resolution of Forces

Resolving forces acting on the shaft vertically, using the relationship below;

$$F_v = W\cos\theta$$

Where, F_v- is vertical force

W- is the weight of pulley $= 9.81N$

θ- is the angle of inclination of the belt to the pulley

For this design θ is taken to be 25^0.

Therefore, $F_v = 9.81\cos 25 = 8.89N$

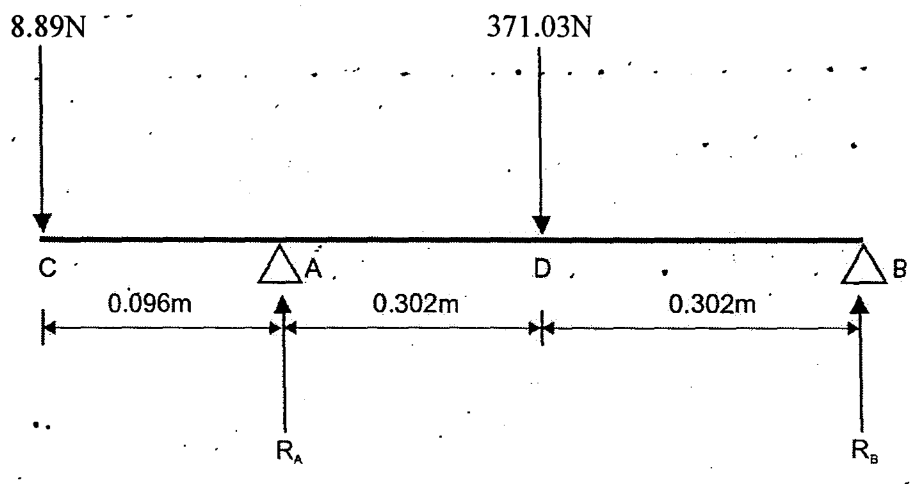

Fig 3.4: Vertical Force Loading

From the figure 3.4, the summation of vertical forces is equal to zero(0)

$$+\uparrow \sum V = 0$$

$$-8.89 + R_A - 371.03 + R_B = 0$$

$$R_A = 379.92 - R_B$$

Taking moment about the point A

$$+\uparrow \sum M_A = 0$$

$$-8.89 \times 0.096 - R_B \times 0.604 + 371.03 \times 0.302 = 0$$

$$R_B = \frac{112.05106 - 0.85344}{0.604} = 184.1020N$$

Hence, $$R_A = 379.92 - 184.1020 = 195.818N$$

To determine the vertical shear force diagram

$$F_{VC} = -8.89N \; for \; 0 \le x$$

$$F_{VA} = -8.89 + 195.818 = 186.928N \; for \; 0 \le x \le 0.096$$

$$F_{VD} = 186.928 - 371.03 = -184.102N \; for \; 0 \le x \le 0.398$$

$$F_{VB} = -184.102 + 184.102 = 0 \; for \; 0 \le x \le 0.7$$

To determine the vertical bending moment diagram

$$M_C = M_B = 0$$

$$M_A = -8.89 \times 0.096 = -0.853Nm$$

$$M_D = -8.89 \times 0.398 + 195.818 \times 0.302 = 55.5988Nm$$

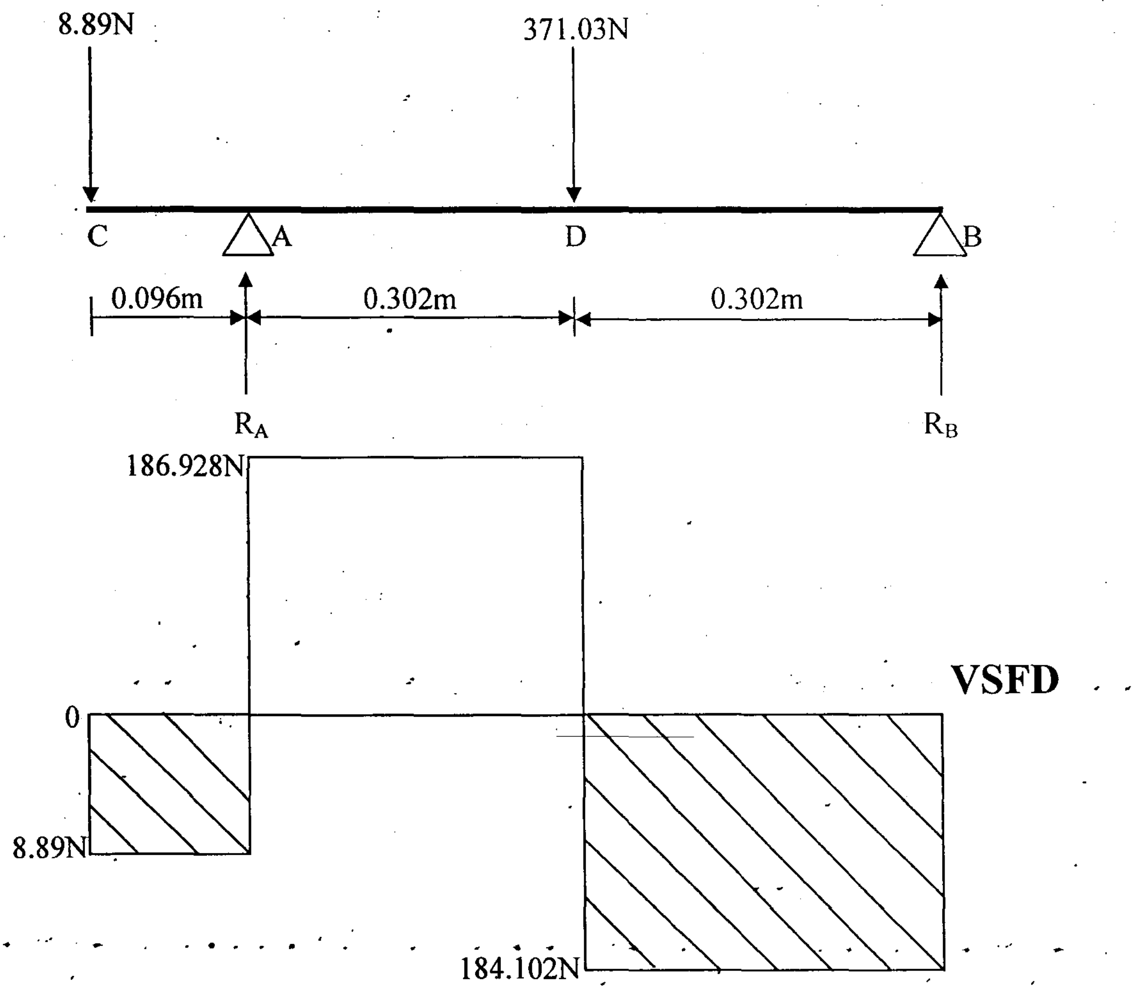

Fig 3.5a: Vertical Shear Force Diagram

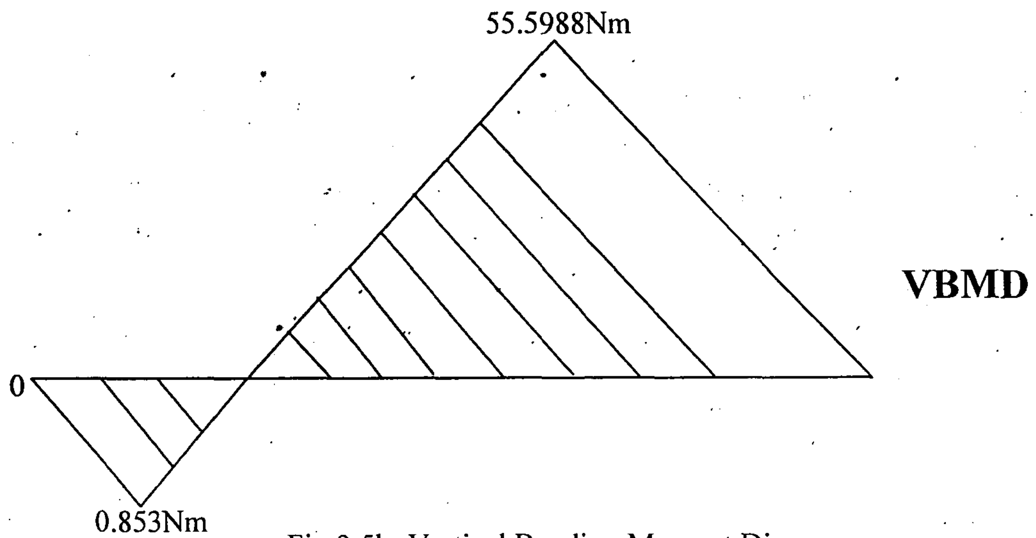

Fig 3.5b: Vertical Bending Moment Diagram

3.6.3 Horizontal Resolution of Forces

Resolving forces acting on shaft horizontally using the relationship below

$$F_H = Wsin\theta$$

Where, F_H- is the horizontal force

W- is the weight of the pulley = $9.81N$

θ- is the angle of inclination of belt to the pulley

For this design θ is taken to be 25^0

Therefore, $F_H = 9.81sin25 = 4.15N$

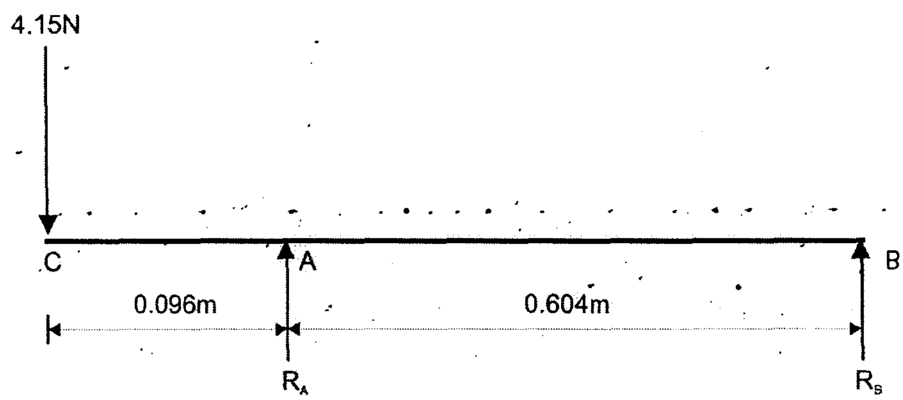

Fig 3.6: Horizontal Force Loading

From the figure 3.6, the summation of the horizontal forces is equal to zero (0)

$$+\uparrow \sum H = 0$$

$$-4.15 + R_A + R_B = 0$$

$$R_A + R_B = 4.15$$

Taking moment about point B

$$+\uparrow \sum M_B = 0$$

$$-4.15 \times 0.7 + R_A \times 0.604 = 0$$

$$R_A = \frac{2.905}{0.604} = 4.81N$$

Hence, $$R_B = 4.15 - 4.81 = -0.66N$$

To determine horizontal shear force diagram

$$F_{HC} = -4.15N \; for \; 0 \leq x$$

$$F_{HA} = -4.15 + 4.81 = 0.66N \; for \; 0 \leq x \leq 0.906$$

$$F_{HD} = 0.66 - 0.66 = 0 \; for \; 0 \leq x \leq 0.7$$

To determine the horizontal bending moment diagram

$$M_C = M_B = 0$$

$$M_A = 4.81 \times 0.906 = 4.36Nm$$

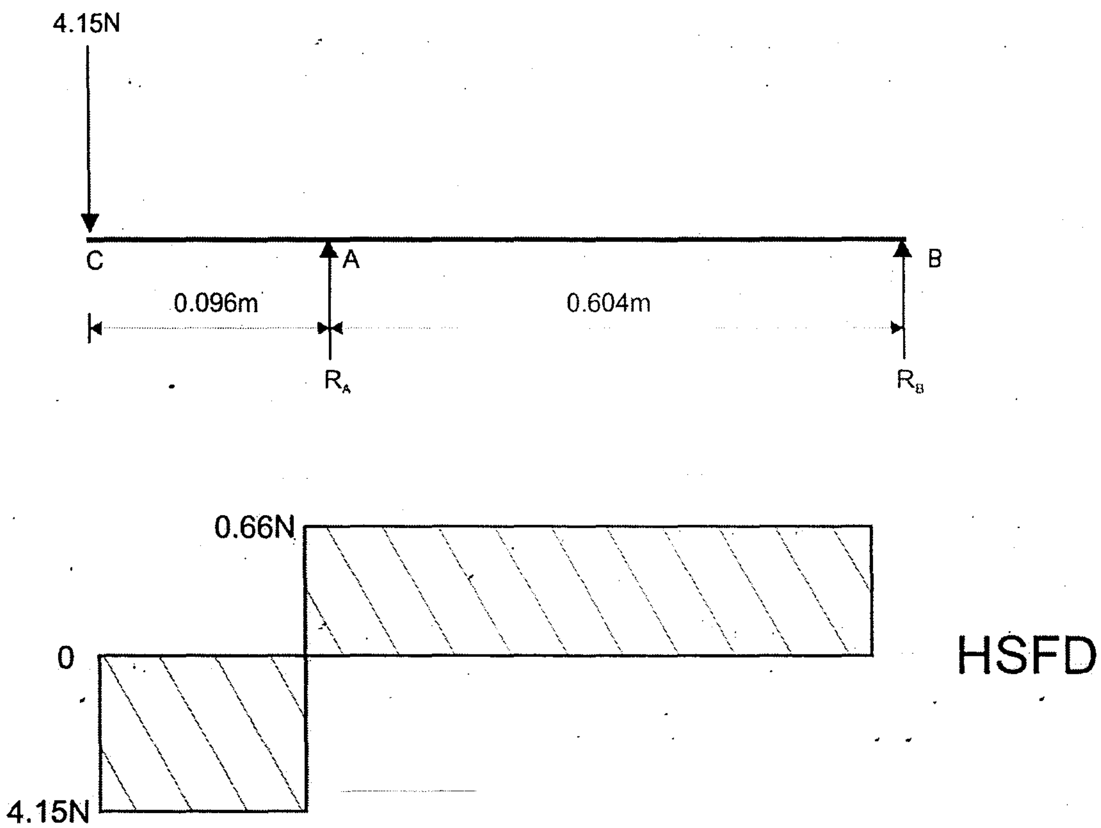

Fig 3.7a: Horizontal Shear Force Diagram

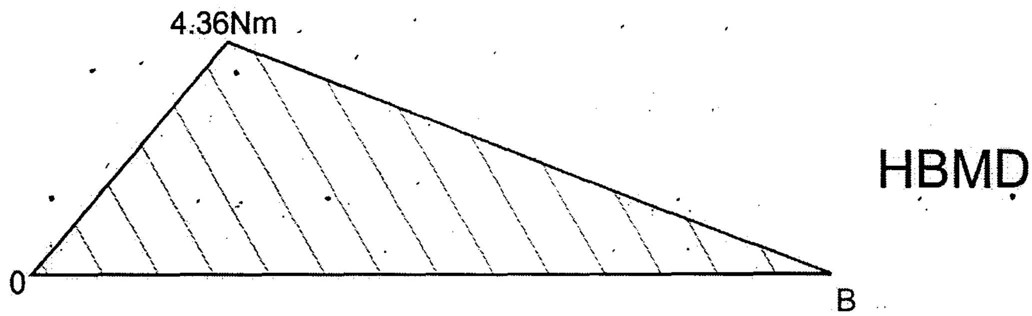

Fig 3.7b: Horizontal Bending Moment Diagram

3.6.4 Resultant Bending Moment

The resultant bending moment was determined using;

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

At $x = 0, M_{BR_C} = 0$

At $x = 0.096m, M_{BR_A} = \sqrt{-0.853^2 + 4.36^2} = 4.44Nm$

At $x = 0.398m, M_{BR_D} = \sqrt{55.5988^2 + 0^2} = 55.5988Nm$

At $x = 0.7m, M_{BR_B} = \sqrt{0^2 + 0^2} = 0$

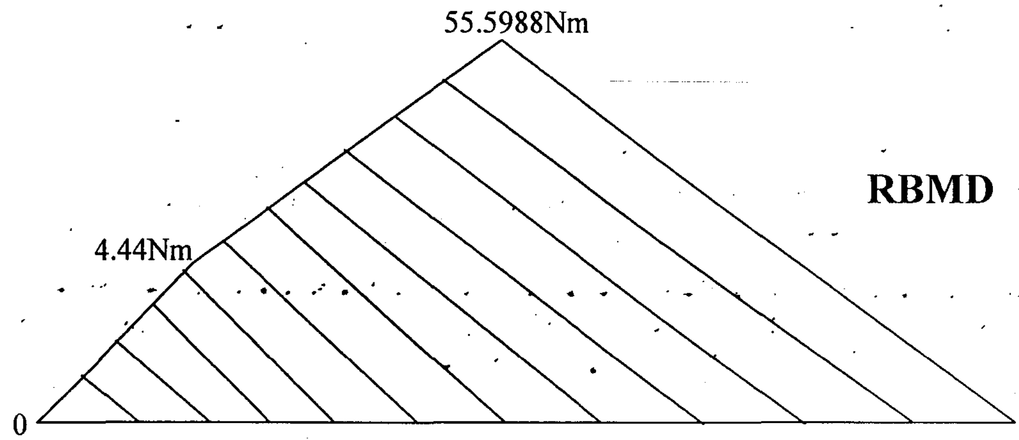

Fig 3.8: Resultant Bending Moment Diagram

Note that the resultant bending moment is maximum at length $0.398m$ and is equal to $55.5988Nm$. This value was used for the design since it is the maximum bending moment for the belt drive.

3.6.5 Determination of Threshing Drum Shaft Diameter

This was determined to know the size of the shaft diameter that will withstand the applied loads.

For a solid shaft with little or no axial load, the diameter of the shaft is determined using;

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

Where,

d- is the diameter of the shaft

S_s- is the allowable stress $= 40 \times 10^6 Nm^{-2}$ (Hall *et al.,* 1980)

K_b- is the combine shock and fatigue factor applied to bending moment $= 1.5$ (Hall *et al.,* 1980)

M_b- is the bending moment $= 55.5988Nm$

K_t- is the combine shock and fatigue factor applied to torsional moment $= 3.0$

M_t- is the torsional moment $= 22.5Nm$

Therefore,

$$d^3 = \frac{16}{\pi \times 40 \times 10^6} \times \sqrt{(1.5 \times 55.5988)^2 + (3 \times 22.5)^2}$$

$$= 1.273 \times 10^{-7} \times \sqrt{6955.2598 + 4556.25}$$

$$= 1.273 \times 10^{-7} \times \sqrt{11511.5098} = 1.3658 \times 10^{-5}$$

$$d = \sqrt[3]{1.3658 \times 10^{-5}} = 0.0239m$$

From the table of standard size of shafting 25mm diameter of shaft is used against the calculated value.

3.6.6 Determination of Angle of Twist

The angle of twist helps to know whether the diameter of the shaft is safe to carry the applied load. According to Hall *et al.*, 1980 the amount of twist permissible depends on particular application and varies about 0.3 degree per meter for a machine tool shaft and about 3 degree per meter for line shafting.

Therefore, angle of twist (θ); for solid shaft is given as follow:

$$\theta = \frac{584 M_t L}{G d^4}$$

Where

L- is the length of shaft = $0.7m$

M_t- is the torsional moment = $22.5Nm$

G- is the torsional modulus = $8 \times 10^9 Nm^2$

d- is the diameter of the shaft = $0.025m$

Hence,

$$\theta = \frac{584 \times 22.5 \times 0.7}{8 \times 10^9 \times (0.025)^4}$$

$$= \frac{9198}{3125} = 2.94^0/m\ twist$$

Therefore, $W = 10.1491 \times 9.81 = 99.5628N$

Hence, $P_v = (4023.9404 + 99.5628) \times 4.712 = 19429.9471W$

3.7.2 Power Required by the Fan

This was determined by the expression below;

$$P_f = \frac{2\pi \times N \times T_f}{60}$$

Where, P_f - power required by the fan

N - speed of the fan ($544.44rpm$)

T_f - torque of the fan which is expressed as;

T_f - $(T_1 - T_2)\, R$

Where, T_1 - tension of belt on the tight side ($263.27N$)

T_2 - tension of belt on the slack side ($114.02N$)

R - radius of the fan pulley ($0.059m$)

Therefore, $T_f = (263.27 - 114.02) \times 0.059 = 8.81Nm$

Hence, $P_f = \frac{2 \times 3.142 \times 544.44 \times 8.81}{60} = 502.04W$

The total power required by the machine is calculated as,

$$P_T = P + P_v + P_f$$

Where, P_T - total power required by the machine.

P - power required for threshing the grain from panicle ($1884.96W$)

Therefore, $P_T = 1884.96 + 19429.9471 + 502.04 = 21816.9371W = 21.82KW$

As a result of losses due to friction, creeping and slipping of the belt drive, $30hp$ electric motor equivalent to $22.371KW$ power is therefore selected for this machine.

CHAPTER FOUR

4.0 FABRICATION, TESTING, DISCUSSION OF RESULT AND COST ANALYSIS

4.1 Fabrication

As shown in the Plate 4.1 and Plate 4.2, all other part of the millet thresher and cleaner were fabricated using mild steel material except for the hopper and the threshing drum which are fabricated using galvanized steel. Mild steel is selected for the fabrication of the majority of the parts in order to provide the adequate strength and rigidity needed by the machine. The choice of galvanized steel for the hopper and the threshing drum is to present the food material in clean and hygienic conditions due to its high resistance to rusting and corrosion.

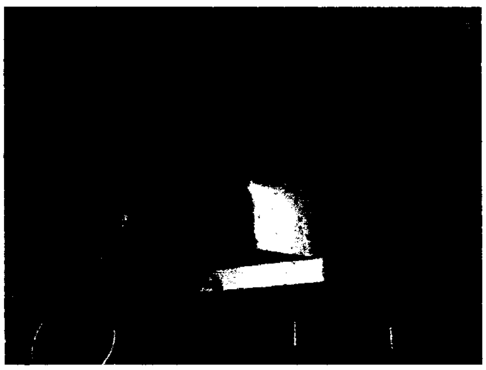

Plate 4.1 Construction in progress (Threshing drum frame with cleaning Unit)

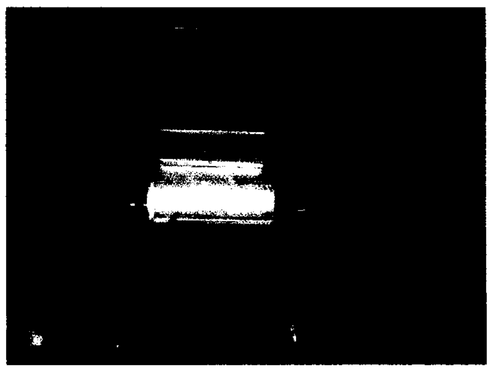

Plate 4.2 Construction in progress (Hopper with threshing drum)

4.2 Testing Procedure of the Machine

After the fabrication the performance test was carried out in order to fulfill the second objective of this study and to make an improvement where necessary.

4.2.1 Material Preparation

5kg of pearl millet panicle was obtained from the farmers' field in Dabarako village bida LGA, Niger state. The pearl millet panicle was divided into three samples, each sample weigh 1.5kg which was then subjected to oven drying in order to obtain three different moisture contents (13%, 15% and 17% wet basis) of pearl millet panicle. Instant moisture meter was used to determine their moisture content.

4.2.2 Testing of the Machine

The machine was first run under no load condition using an electric motor of 5 hp with speed rating of 1500 rpm whereas the threshing drum was running at a speed of 800 rpm under no load condition. This was done in order to ascertain the smoothness of operation for the machines rotating parts. The testing of the machine was targeted at evaluating its threshing efficiency, cleaning efficiency and the percentage losses based on the following parameters; the moisture content and the speed of rotation of the threshing drum. The overall effects of these parameters were investigated majorly on the threshing and cleaning efficiencies. For running the test, 4.5kg of millet panicle was used in the whole testing. The 4.5kg sample of the millet panicle comprises of 1.5kg each of 13%, 15% and17% moisture content. The performance test was conducted at 800 rpm, 700rpm and 600rpm running speed of the threshing drum. The results obtained are presented in table 4.1 to 4.3.

Plate 4.3 Completed millet thresher and cleaner.

Plate 4.4 Threshing in progress.

4.3 Computation of Result

The formulae used in computing the threshing efficiency, cleaning efficiency and the percentage loss is stated as follows,

$$Threshing\ efficiency = \frac{mass\ of\ the\ threshed\ millet}{total\ mass\ of\ millet\ panicle} \times 100 \quad \text{Equation 4.1}$$

$$Cleaning\ efficiency = \frac{w_c}{w_o + w_c} \times 100 \quad \text{Equation 4.2}$$

Where,

w_c – *is the mass of clean millet grains*

w_o – *is the mass of chaff*

$$percentage\ loss = \frac{mass\ of\ losses}{total\ mass\ of\ millet\ panicle} \times 100 \quad \text{Equation 4.3}$$

Where,

$$Mass\ of\ losses = unthreshed\ loss + separation\ loss + scattering\ loss + blower\ loss$$

At the 13% moisture content and 800 rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 176.96g

Mass of chaff = 139.04g

Mass of threshed millet = (176.96 + 139.04) g = 316g

Mass of losses = (53 + 48 + 47 + 38) g = 184g

Therefore,

$$threshing\ efficiency = \frac{316}{500} \times 100 = 63.20\%$$

$$cleaning\ efficiency = \frac{176.96}{139.04+176.96} \times 100 = 56.00\%$$

$$percentage\ loss = \frac{184}{500} \times 100 = 36.80\%$$

At 15% moisture content and 800rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 162.98g

Mass of chaff = 144.53g

Mass of threshed millet = (162.98 + 144.53) g = 307.51g

Mass of losses = (56 + 49 + 48 + 45.5) g = 192.5g

Therefore,

$$threshing\ efficiency = \frac{307.51}{500} \times 100 = 61.50\%$$

$$cleaning\ efficiency = \frac{162.98}{144.53+162.98} \times 100 = 53.00\%$$

$$percentage\ loss = \frac{192.5}{500} \times 100 = 38.5\%$$

At the 17% moisture content and 800 rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 151.32g

Mass of chaff = 139.68g

Mass of threshed millet = (151.32 + 139.68) g = 291g

Mass of losses = (62 + 51 + 49 + 47) g = 209g

Therefore,

$$threshing\ efficiency = \frac{291}{500} \times 100 = 58.20\%$$

$$cleaning\ efficiency = \frac{151.32}{139.68+151.32} \times 100 = 52.00\%$$

$$percentage\ loss = \frac{209}{500} \times 100 = 41.80\%$$

At the 13% moisture content and 700 rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 143.56g

Mass of chaff = 143.44g

Mass of threshed millet = (143.56 + 143.44) g = 287g

Mass of losses = (68 + 53 + 51 + 41) g = 213g

Therefore,

$$threshing\ efficiency = \frac{287}{500} \times 100 = 57.40\%$$

$$cleaning\ efficiency = \frac{143.56}{143.44+143.56} \times 100 = 50.02\%$$

$$percentage\ loss = \frac{213}{500} \times 100 = 42.60\%$$

At the 15% moisture content and 700 rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 123.51g

Mass of chaff = 144.99g

Mass of threshed millet = (123.51 + 144.99) g = 268.5g

Mass of losses = (68 + 53 + 51 + 41) g = 213g

Therefore,

$$threshing\ efficiency = \frac{268.5}{500} \times 100 = 53.70\%$$

$$cleaning\ efficiency = \frac{123.51}{144.99+123.51} \times 100 = 46.00\%$$

$$percentage\ loss = \frac{231.5}{500} \times 100 = 46.30\%$$

At the 17% moisture content and 700 rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 105.94g

Mass of chaff = 146.66g

Mass of threshed millet = (105.94 + 146.66) g = 252.60g

Mass of losses = (81 + 68 + 57.05 + 41.35) g = 247.40g

Therefore,

$$threshing\ efficiency = \frac{252.60}{500} \times 100 = 50.52\%$$

$$cleaning\ efficiency = \frac{105.94}{146.66+105.94} \times 100 = 41.94\%$$

$$percentage\ loss = \frac{247.4}{500} \times 100 = 49.48\%$$

At the 13% moisture content and 600 rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 126.26g

Mass of chaff = 135.74g

Mass of threshed millet = (126.26 + 135.74) g = 262g

Mass of losses = (78 + 52 + 61 + 47) g = 238g

Therefore,

$$threshing\ efficiency = \frac{262}{500} \times 100 = 52.40\%$$

$$cleaning\ efficiency = \frac{126.26}{135.74+126.26} \times 100 = 48.19\%$$

$$percentage\ loss = \frac{238}{500} \times 100 = 47.60\%$$

At the 15% moisture content and 600 rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 108.72g

Mass of chaff = 143.88g

Mass of threshed millet = (108.72 + 143.88) g = 252.60g

Mass of losses = (82.34 + 75 + 63 + 27.06) g = 247.40g

Therefore,

$$threshing\ efficiency = \frac{252.60}{500} \times 100 = 57.40\%$$

$$cleaning\ efficiency = \frac{108.72}{143.88+108.72} \times 100 = 43.04\%$$

$$percentage\ loss = \frac{247.40}{500} \times 100 = 49.48\%$$

At the 17% moisture content and 600 rpm the following results were obtained

Total mass of millet panicle = 500g

Mass of cleaned millet grains = 98.28g

Mass of chaff = 143.32g

Mass of threshed millet = (98.28 + 143.32) g = 241.60g

Mass of losses = (85.2 + 76.2 + 68 + 29.0) g = 258.40g

Therefore,

$$threshing\ efficiency = \frac{241.60}{500} \times 100 = 48.32\%$$

$$cleaning\ efficiency = \frac{98.28}{143.32+98.28} \times 100 = 40.68\%$$

$$percentage\ loss = \frac{258.40}{500} \times 100 = 51.68\%$$

4.3 .1 Results

4.3.2 Presentation of Results

Table 4.1 Summary of Result Obtained at 800 rpm Running Speed of Threshing Drum

Parameters	Moisture Content of Pearl Millet		
	13%	15%	17%
Mass of millet grain Panicle (g)	500.00	500.00	500.00
Threshing Efficiency (%)	63.20	61.50	58.20
Cleaning Efficiency (%)	56.00	53.00	52.00
Percentage loss (%)	36.80	38.50	41.80

Table 4.2 Summary of Result Obtained at 700 rpm Running Speed of Threshing Drum

Parameters	Moisture Content of Pearl Millet		
	13%	15%	17%
Mass of millet grain Panicle (g)	500.00	500.00	500.00
Threshing Efficiency (%)	57.40	53.70	50.52
Cleaning Efficiency (%)	50.02	46.00	41.94
Percentage loss (%)	42.60	46.30	49.48

Table 4.3 Summary of Result Obtained at 600 rpm Running Speed of Threshing drum

Parameters	Moisture Content of Pearl Millet		
	13%	15%	17%
Mass of millet grain Panicle (g)	500.00	500.00	500.00
Threshing Efficiency (%)	52.40	50.52	48.32
Cleaning Efficiency (%)	48.19	43.04	40.68
Percentage loss (%)	47.60	49.48	51.68

4.4 Discussion of Results

The results of the test carried out to determine the effect of moisture content and threshing speed on the threshing, cleaning efficiencies and percentage loss of the machine shows that; the 13% moisture content of millet panicle threshed at 800 rpm threshing speed, the results obtained for the threshing, the cleaning efficiencies and the percentage loss are 63.20%, 56% and 36.80% respectively. The 15% moisture content of millet panicle threshed at 800 rpm threshing speed, the results obtained are 61.50%, 53% and 38.50% for the threshing, the cleaning efficiencies and the percentage loss respectively. The 17% moisture content of millet panicle threshed at 800 rpm, the results obtained for the threshing, the cleaning efficiencies and the percentage loss are 58.20%, 52% and 41.80% respectively. The 13% moisture content of millet panicle threshed at 700 rpm, the results obtained for the threshing, the cleaning efficiencies and the percentage loss are 57.40%, 50.02% and 42.60% respectively. The 15% moisture content of millet panicle threshed at 700 rpm, the results obtained for the threshing, the cleaning efficiencies and the percentage loss are 53.70%, 46% and 46.30% respectively. The 17% moisture content of millet panicle threshed at 700 rpm, the results obtained for the threshing, the cleaning efficiencies and the percentage loss are 50.52%, 41.94% and 49.48% respectively. The 13% moisture content of millet panicle threshed at 600 rpm, the results obtained for the threshing, the cleaning efficiencies and the percentage loss are 52.40%, 48.19% and 47.60% respectively. The 15% moisture content of millet panicle threshed at 600 rpm, the results obtained for the threshing, the cleaning efficiencies and the percentage loss are 50.52%, 43.04% and 49.48% respectively. The 17% moisture content of millet panicle threshed at 600 rpm, the results obtained for the threshing, the cleaning efficiencies and the percentage loss are 48.32%, 40.68% and 51.68% respectively.

4.5 Cost Analysis

As rightly stated under the selection of material for the design of this machine that such material has tó be cheap and at the same time meet the specific purpose for which it was intended for. Due to this reason and couple with the fact that, a product is incomplete unless the cost of designing and fabricating it were rightly evaluated, the cost analysis is thus computed as follows under the following groups.

I. Material cost

II. Labour cost

III. Overhead cost

IV. Total cost

Material Cost: - This is the cost of the materials used in the fabrication of the millet thresher and cleaner. The table below shows the detail of the quantity prices of material used for the fabrication.

Table 4.4 Material Cost Analysis Table

S/N	Component	Material	Specifications	Quantity	Unit Price (#)	Quantity price (#)
1	Angle iron	Mild steel	50 by 50 mm	2	2500	5000
2	Shaft	Mild steel	25 by 700 mm	3	1000	3000
3	Metal sheet	Galvanized steel	4 by 4 ft	$\frac{1}{2}$	8000	4000
4	Metal sheet	Mild steel (G16)	8 by 8 ft	1	6000	6000
5	Bearing	Carbon steel	509	6	500	3000
6	Bearing housing	Mild steel	50 mm	6	400	2400
7	Pulley	Mild steel	F 125 mm	1	500	500
			F 125 mm	1	500	500
			F 450 mm	1	500	500
			F 450 mm	1	500	500
			F 60 mm	1	300	300
8	Bolt and Nut	Mild steel	M 13	30	20	600
9	Rivet	Aluminum	4 mm	100	5	500
10	Electrode		Gauge 12	1 packet	1400	1400
11	Paint and thinner		Auto base	1 litre	1500	1500
12	Belt	Rubber	A 56	1	200	200
			A 58	1	200	200
			9.5 by 775 cm	1	150	150
13	Millet panicle	Bio-material		5 kg	1000	5000
14	Screen (sieve)	Mild steel	3 by 35 by 800 mm		800	800
			6 by 35 by 800 mm		800	800
15	Flat bar	Mild steel	20 by 5795mm	1	500	500
16	Iron rod	Mild steel	10 by 11590mm	1	1200	1200
17	Cutter rod	Mild steel	2 by 1000 mm	1	200	200
18	Square pipe	Mild steel	$\frac{3}{4}$ *inch.*	2	550	1100
19	**Total**					**39,850**

Labour Cost: - This is the cost of all the services rendered by human being during the construction of the machine. Direct labour cost is taking as 25% of the material cost. (Olanrewaju, 2005)

Labour cost = $\frac{25}{100} \times material\ cost = 0.25 \times 39850 = \#9{,}962.50$

Overhead Cost: - This comprises the cost of feeding, transportation and other miscellaneous expenses involved during the construction of the machine. Overhead cost is taking as 30% of the material cost.

Overhead cost = $\frac{30}{100} \times material\ cost = 0.3 \times 39850 = \#11{,}955$

Total Cost: - is the summation of all the cost aforementioned earlier. (i.e. material cost + labour cost + overhead cost).

Total cost = # (39,850 + 9,962.50 + 11,955) = # 61,767.50.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the data collected on millet varieties grown in Nigeria and some information from literature, a millet thresher was designed, fabricated and test for its performance to meet the commercial needs of Nigerian farmers.

The test performance at recommended moisture content of 13%, cylinder and fan speed of 800 rpm and 544.44 rpm respectively indicated a threshing efficiency of 63.20%, percentage loss of 36.80 and cleaning efficiency of 56.00%. Also a millet threshing plant based on this technology could provide employment and at the same time make available quality millet grains at low cost for domestic use and for millet processing industry.

5.2 Recommendations

1 Further investigative study and research should be carried out for more efficient, less cost millet thresher.

2 Computer program should be design and develop to assess the effects of machine variables and crop parameters on the performance of a stationary millet thresher.

3 Private entrepreneurs should be to undertake mass production of millet threshing machine.

4 The neck of the hopper should be bend to prevent millet panicles jumping out of the hopper.

5 The speed of the fan in revolution per minute (rpm) should be increase to ensure a more sufficient cleaning of millets from its chaff.

6 A smaller diameter grains sieve should be use to avoid some chaff passing through the grains sieve.

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Since the calculated angle of twist falls within the permissible amount of twist for line shafting therefore, the shaft is safe and suitable for use.

3.7 Determination of the Power Requirement of the Machine

The power requirement for the millet threshing machine can be divided into three (3) parts

- Power required to vibrate the cleaning unit
- Power required by the fan
- Power required for threshing grain from the panicle.

3.7.1 Power Required to Vibrate the Cleaning Unit

This was determined ~~by the exp~~ression below;

$$P_v = (F_v + W)V$$

Where, P_v- power required for vibrating the cleaning unit.

F_v- Vibration force

W- Weight of cleaning unit

V- Linear velocity of the cleaning unit ($4.712m/s$)

The vibration of the cleaning unit is a result of force (F_v) applied by means of camshaft.

Therefore, $F_v = m\omega^2 r$

Where, m- mass of cleaning unit

ω- Angular velocity

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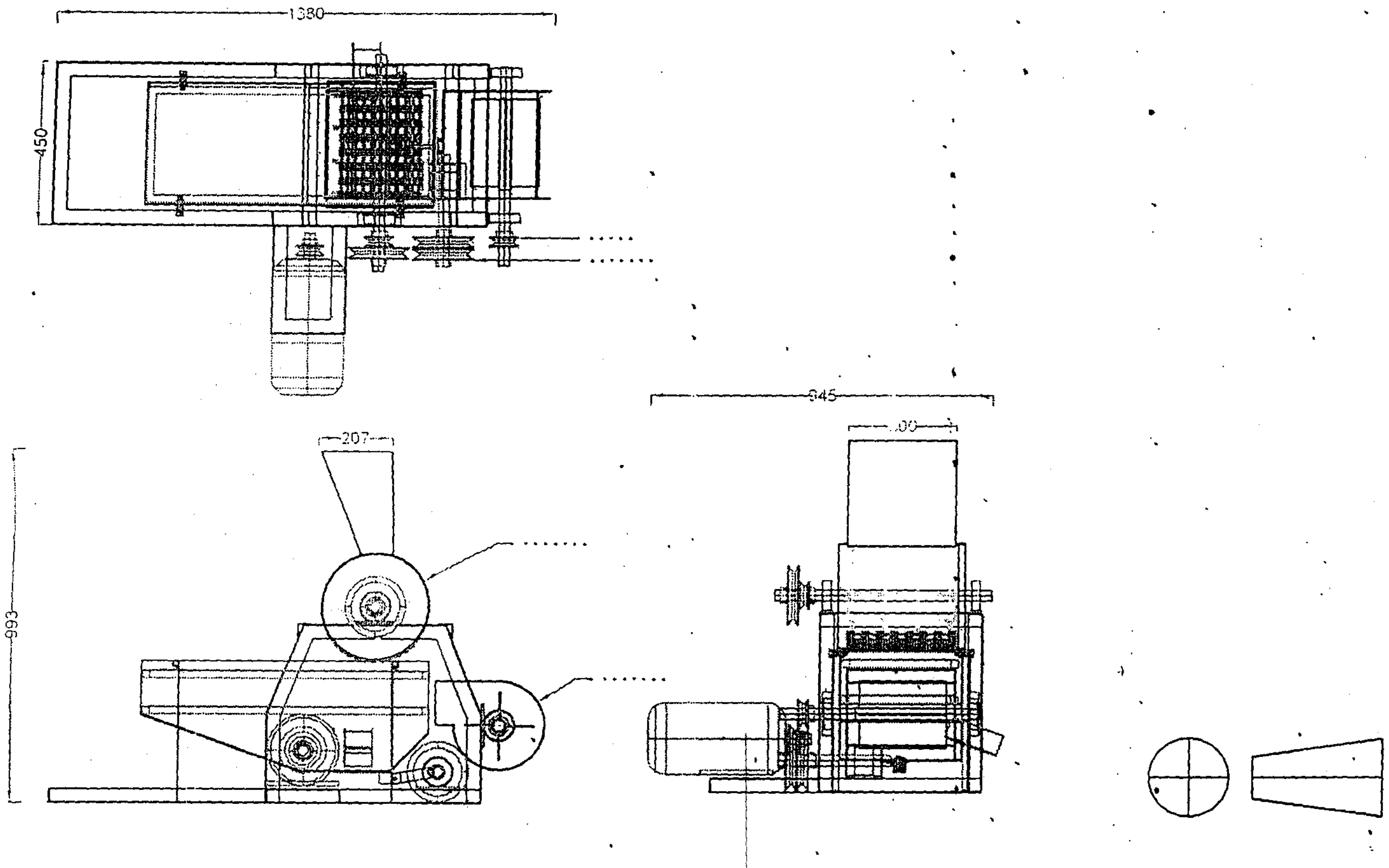

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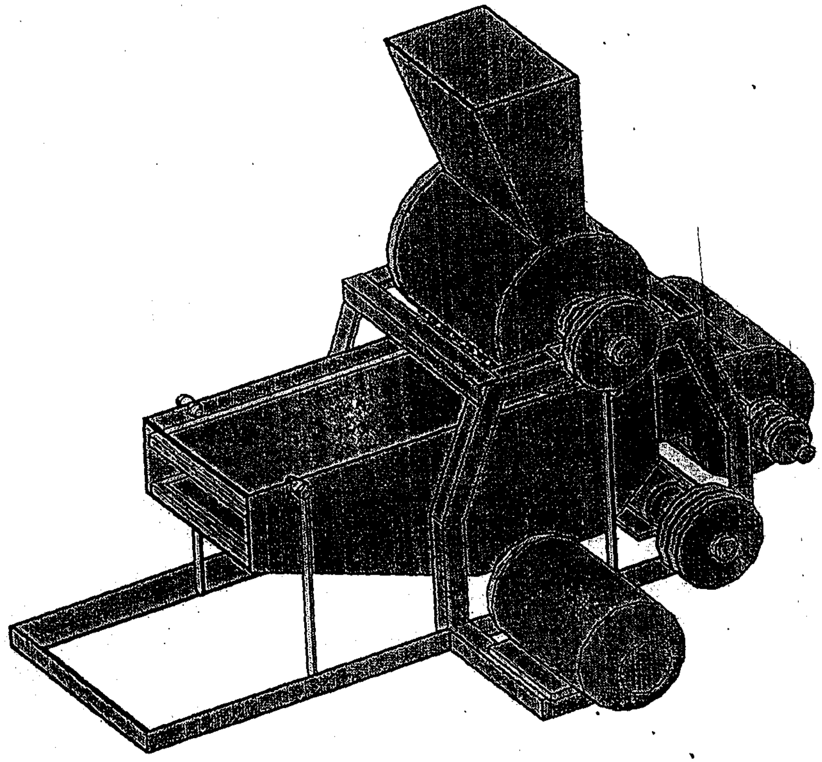
FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE			
AGRICULTURAL AND BIORESOURCES ENGINEERING DEPARTMENT			
NAME:	YUSUF MOHAMMED BELLO	MAT. NO. :	2006/24134EA
TITLE	ORTHOGRAPHIC VIEW OF A MILLET THRESHER AND CLEANER MACHINE		
DRAWN BY	YUSUF MOHAMMED BELLO	SCALE :	1: 1
SUPERVISED BY	ENGR. DR. AGIDI GBABO	SIGNED BY:	
APPROVED BY	ENGR. DR. AGIDI GBABO	SIGNED BY:	



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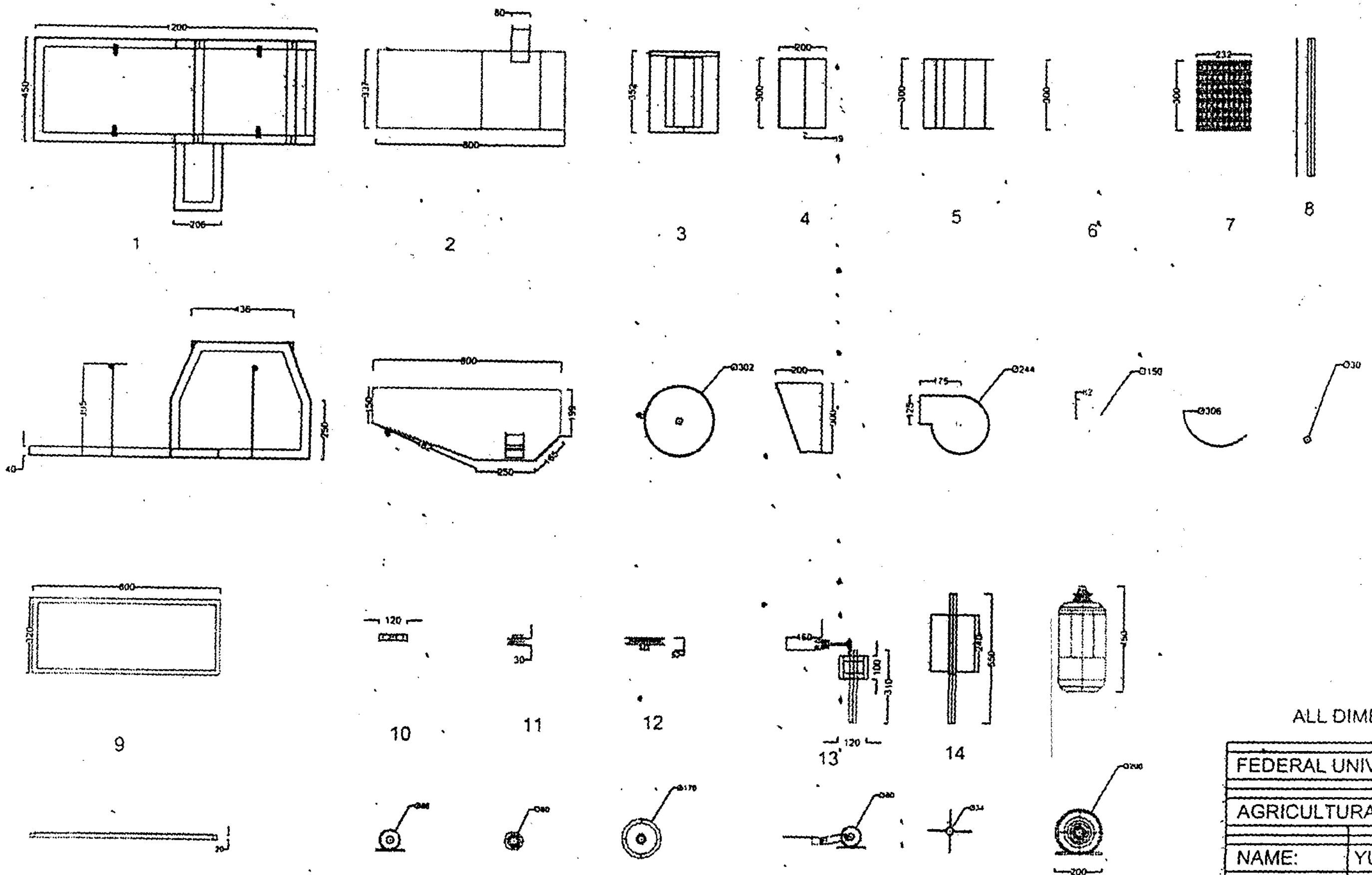
TITLE	ISOMETRIC VIEW OF A MILLET THRESHER AND CLEANER MACHINE		
DRAWN BY	YUSUF MOHAMMED BELLO	SCALE :	1: 1
SUPERVISED BY	ENGR. DR. AGIDI GBABO	SIGNED BY:	
APPROVED BY:	ENGR. DR. AGIDI GBABO	SIGNED BY:	



S/No	PART	MATERIAL
1	MAIN FRAME	MILD STEEL
2	SEPARATOR CHAMBER	MILD STEEL
3	THRESHING CHAMBER	MILD STEEL
4	HOPPER	GALVANIZED STEEL
5	BLOWER HOUSING	MILD STEEL
6	THRESHING DRUM	GALVANIZED STEEL
7	CONCAVE	MILD STEEL
8	THRESHING DRUM SHAFT	STEEL
9	SIEVE	GALVANISED STEEL
10	BEARING	CARBON STEEL
11	SMALL PULLEY	MILD STEEL
12	LARGE PULLEY	MILD STEEL
13	CRANK MECHANISM	MILD STEEL
14	BLOWER BLADES	MILD STEEL
15	ELECTRIC MOTOR	COMPOSITE

ALL DIMENSIONS IN MM

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AGRICULTURAL AND BIORESOURCES ENGINEERING DEPARTMENT			
NAME:	YUSUF MOHAMMED BELLO	MAT. NO.:	2006/24134EA
TITLE	COMPONENTS OF A MILLET THRESHER AND CLEANER MACHINE		
DRAWN BY:	YUSUF MOHAMMED BELLO	SCALE:	1:1
SUPERVISED BY	ENGR. DR. AGI		