DESIGN AND FABRICATION OF A MILLET THRESHER

BY

SUBERU, MATTHEW AMOTO

MATRIC No. 2006/25761EA

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

FEBRUARY, 2012

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

29/02/2012.

Suberu, Matthew Amoto

Date

CERTIFICATION

This is to certify that the project entitled "Design and Fabrication of a Millet Thresher" by Suberu, Matthew Amoto 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.

______________________	28/02/2012
Engr. Dr. Agidi Gbabo	Date
Supervisor	
______________________	29/02/2012
Engr. Dr. Peter. A. Idah	Date
Head of Department	
______________________	22-02-2012
External Examiner	Date

DEDICATION

This project work is dedicated to God Almighty, my biological parent; Chief & Mrs. E.A. Suberu, my Siblings, Friends and Well-wishers.

ACKNOWLEDGEMENTS

I give all thanks and praises to the immortal, invisible and the only wise God for the gift of life and the immeasurable grace given me to see this day.

To my project supervisor, Engr. Dr. Agidi Gbabo, for your advice and instructions through all the period of our contact. God bless you sir.

To the entire school of Engineering, most especially, to the department of Agricultural and Bio-resources Engineering under the leadership of Engr. Dr. P.A. Idah, the departmental project coordinator Engr. Dr. O. Chukwu, my amiable level adviser Engr. Mrs. B.A. Orhevba. I will also say a big thank you to the other lecturers; Engr. Prof. I.N. Itodo, Engr. Prof. B.A. Alabadan, Engr. Prof. M.G. Yisa, Engr. Dr. Ahaneku, Engr. Dr. Mrs. Z.D. Osounde, Engr. Dr. A.A. Balami, Engr. Dr. D. Adgidzi, Engr. Dr. N. Egharevba, Engr. Dr. M.Y. Otache and the company of other academic and non-academic staffs without whose commitment and contributions, my study would not have been a success.

This project work would not be complete without acknowledging my ever loving and caring parent Chief &. Mrs. E.A. Suberu who for by Gods grace made me who I am today. For the gift of my beautiful sisters, Blessing and Favour and to my brothers, Joseph, Gabriel, Elijah and Elisha. Finally, I devote my gratitude to my friends, relatives and those who remain unnamed but who were a source of encouragement and support throughout the duration of my programme. May God bless you all!

ABSTRACT

The millet thresher consist of a hopper, threshing cylinder, concave, screen (sieve) and a winnowing system. The entire system was powered by 22.371KW electric motor. The performance of the machine was evaluated for moisture content of pearl millet panicle and threshing speed of the threshing cylinder. It is expected of the machine to work optimally at a rate of 252kg/hr. The test shows that the maximum efficiencies of the millet thresher on the average are 57.67% threshing efficiency and 51.40% cleaning efficiency. These were obtained at 13% moisture content (wet basis) of pearl millet panicle and 800rpm threshing cylinder speed.

TABLE OF CONTENTS

HAPTER THREE

LIST OF TABLES

LIST OF PLATES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Millet is one of the oldest human foods and believed to be the first domesticated cereal grain. Though difficult to know the exact origin, it is widely accepted that millet was domesticated and cultivated simultaneously in Asia and Africa over 7000 years ago during Neolithic Era and then spread through the world as staple food.

Millets are a group of small seeded species of cereal crops or grains belonging to the family **Gramineae** and widely grown around the world for food and fodder. The most widely cultivated species in order of worldwide production are pearl millet (*Pennisetum glaucum*), Foxtail millet (*Setaria italica*), Proso millet (*Panicum miliaceum*) and Finger millet (*Eleusine coracana*). (Crawford and Lee, 2003) Ikwelle *et al.* (1993) ranked pearl millet as the most important cereal in the southern Sudan and the northern guinea.

In the Northern area of Nigeria Millet is known as GERO, OKA BABA in Yoruba land. There are two major types of recommended and local varieties of millet in Northern Nigeria namely, Ex-Borno with a yield potential of 2,000 -3,000 kg/ha and the improved SOSAT variety with a yield potential of 2,500 - 3,500 kg/ha (LCRI, 1997).

Millets are principally food sources in arid and semi-arid regions of the world. It is the staple food of millions of people in drier parts of tropical Africa. It has been reported that air – dried grains contain approximately 12.4% water, 11.6% protein, 5% fat, 67.1%

carbohydrate, 1.2% fibre and 2.7% ash. However, its protein is low in methionine (Onwueeme and Sinha, 1991).

Millet are good sources of minerals e.g. calcium, iron, zinc, copper and manganese (Hulse *et al.*, 1980). Products from millet vary depending on people's taste and cultural preference. One of the common traditional products made from millet in Nigeria is 'kunu', a non alcoholic beverage. It is of low viscosity and has a sweet-sour taste, milky cream appearance and is popular with people of northern Nigeria (Adeyemi and Umar, 1994). The most important characteristic of millet is their unique ability to tolerate and survive under adverse condition of continuous or intermittent drought as compared to most other cereals like maize and sorghum (LCRI, 1997).

At present, Nigeria is the third leading millet producing country in the world after India and China with production capacity of about 4 million tonnes which is about 13.4% of total world production (FAO, 1991). The production of millet in Nigeria comes with a lot of human labour because of the local and crude method of production. Due to this strenuous and crude method of production, the design and fabrication of millet threshing and cleaning machine is considered to make a great impact to farmers.

1.2 Statement of the Problem

The traditional method of threshing and cleaning millet is done manually through the use of hand beating of the panicles to dislodge the seeds. The threshed materials are thrown into the air and on their way coming down the lighter materials are blown away by the natural convection (air) leaving the heavier ones. This method is tedious and time consuming therefore the drudgery and constraints associated with the threshing and cleaning of millet is seriously limiting the production and consumption of these grains due to the use of rudimentary equipments and low production output. Thus, the need for an improved technology to thresh millet becomes very imperative.

1.3 Objectives of the Study

The objectives of this project include the following:

- To design and fabricate a machine that is capable of threshing and cleaning millet efficiently
- To carry out performance test on the machine

1.4 Justification of the Study

In the past, despite the availability and improvement in technological advancement, post-harvest processes for millet rely heavily on labour-intensive manual operations in most production regions in Africa. This process is slow and energy consuming. Often this local method of processing the crop leads to low quality product due to the presence of impurities like stones, dust and chaff. Threshing and separation of the grain from these impurities, requires modern technology. This work (design and fabrication of millet thresher) is therefore set out to achieve a better threshing and separation of millet efficiently so as to encourage more production acceptable for commercial purpose

1.5 Scope of the Study

The scope of this project is to design, fabricate and test a millet thresher that will reduce the drudgery associated with millet production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Historical Background

The millets (small seeds) represent a diverse group of cereal crops that typically produce small seeds. They comprise about a dozen crop species, belonging to different genera that originated, were domesticated, and are cultivated by small farmers in Africa and Asia. Distinctive attributes of the millets are their adaptability to adverse agro ecological conditions, requirement of minimal inputs, and good nutritional properties. It does well in most soil except in pure sand and clay soil. The crop is successfully grown in well drained soil ranging in pH from 5.5 to 8.5. Rainfall amount of about 60-120 cm^3 and a temperature of about 27 °C will be favorable for the crop (Gama and Shemington, 1977). It can be stored for 6 months without any significant spoilage. In areas and cases where grains have been stored for more than 12 months without any treatments, losses of 15-20% have been reported (Gama and Shemington, 1977).

Millets represent critical plant genetic resources for the agriculture and food security of poor farmers that inhabit arid, infertile, and marginal lands. Africa is home to important centre of origin; diversity and cultivation of millets. The genuinely African millets comprise the two global millets (pearl millet and finger millet), which are widely cultivated in Africa and elsewhere, and three West African millets (fonio, black fonio and guinea millet), which are characteristic of West African dry lands. African farmers are custodians to an enormous genetic diversity of these millets, including many cultivars adapted to adverse agro ecological conditions. In Sub-Saharan Africa, millet biodiversity constitutes both a unique ecological heritage and a critical food security component among millions of small-scale farmers. In particular, pearl millet and the West African millets have a superior adaptation to drought and poor soils, providing a reliable harvest under such conditions, growing where no other crops succeed, requiring minimal inputs, and providing good nutritional sources. Although the African millet agriculture requires minimal material inputs, it relies on extensive cultural dynamics, including indigenous knowledge, customary genetic resource management system and local food habits. Accordingly, the maintenance of millet biodiversity depends on agricultural, food and livelihood dynamics at the farmer level, since every community holds local cultivars to address their agro ecological conditions, farming practices, livelihood concerns, and food needs. As it matters nutritional aspects, the African millets are not just a good source of energy, as cereals typically are, but surpass most cereal and grain crops in protein quality and in some key micronutrients. They are thus a nutritionally valuable crop group. Millets represent a unique biodiversity component in the agriculture and food security systems of millions of poor farmers in Sub-Saharan Africa. However, they suffer large neglect in science, agricultural programmes, and policies, despite the increasing global awareness on plant genetic resource conservation and the concerns on local food security. Millets are principally food sources in arid and semi-arid regions of the world. Nkama (1998) outlined the uses and traditional food preparations of pearl millet in Nigeria. The grain serves as food for the majority of people of Africa who utilize it in the form of porridge produced from flour called 'tuwo', refreshing drink 'kunu', dessert 'dan wake' and palp 'ogi', millet beer in Cameroon , millet flour called ' Bajari' in western India.

Millet can be the sole grain source if maximum gains of 2 pounds a day are desired. Limit millet to approximately 50 percent of the ration if gains of 2.7 to 3 pounds are desired. In

India and Africa, cereals products comprise 80% or more of the average diet, 50% in central and Western Europe and between 20-25% in the U.S. (Onwueeme and Sinha, 1991).

2.2 Millet Production in Africa

Millet is grown by millions of resource-poor, subsistence level farmers (IFAD, 1999). The percentage of millet used for domestic consumption is rising steadily in Africa (World Bank, 1996). It is the third major crop in sub-Saharan Africa, with estimated 26 million hectares cultivated for millet production primarily for human consumption (Andrews and Kumar, 1992). Millet production increased from 26 million tonnes in 1981 to 31 million tonnes in 1990 with the major producing countries being Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritania and Senegal in the west; Sudan and Uganda in the east. In Southern Africa, maize has partially or completely displaced millet because of the predominance of commercial farming. In Africa, five climatic factors are of particular importance to millet production: rainfall, air and soil temperatures, day length (photoperiod), radiation and wind. The impact of these variables is dependent on the developmental stage of the crop (World Bank, 1999)

Millet, are used as food for man and animals. The seeds of the millet are used to make drink called 'pito' in Ghana. In the southern part of Nigeria, the Yorubas used the sprouting seed of the red seeded variety of millet for brewing local beer. In the northern area, the Hausa people used them to make 'kunu' and 'burukutu' (Hobbs *et al,* 1978) In Africa, millets are extremely important in the semi-arid and sub-humid zones as staples and ethno-botanical crops. Produced in18.50 million ha and yielding total of 11.36 million tonnes mainly at subsistence level by 28 countries, the millets cover 30% in the semi-arid tropical areas of the continent in diverse agro ecologies. Nigeria produces 40% (nearly half) of the millets grown in Africa; and West Africa has largest hectarage (13.63 million ha) accounting for 74% of total area. The cereal crop is mostly produced in mixtures (intercropped, double-cropped or relay-cropped) with other semi-arid tropical cereals like sorghum, legumes and oil crops like groundnuts, cowpeas, pigeon peas and sesame, and root crops mostly cassava. There are nine species of millets cultivated worldwide; their relative importance across the continents show four to be important in Africa, and only two (not grown in Africa mainly prosso millet and foxtail millet) in other areas. The four most important millets cultivated in Africa are: Pearl millet- *Pennisetum glaucum* (accounting for 76% of total production), finger millet – *Eleusine coracana* (19%), Teff – *Eragrostis teff* (1.8%), and Fonio – *Digitaria exilis* and *Digitoria iburua* (0.8%).(Obilana and Manyasa, 2002). These four species of millets are spread out in their cultivation across several countries in the three sub-regions of Africa. Pearl millet is grown in all 28 countries. Finger millet is cultivated mostly in Eastern, Southern and Central Africa in Uganda, Western Kenya, Sudan and Eritrea; Zimbabwe, Zambia, Malawi and Madagascar; Rwanda, and Burundi. Fonio is only cultivated in West Africa mostly in Mali, Burkina Faso, Guinea Canakry and Nigeria. Teff is grown only in the dry mid-highlands of Ethiopia (FAO, 1996).

Table 2.1: African Countries and Regions with Largest Areas for Millets Production.

Region / Country	Area (million ha)	production (million tons)
West Africa	**13.63**	**8.70**
Nigeria	5.10	4.53
Niger	4.87	1.86
Burkina Faso	1.23	0.78
Mali	1.14	0.69
East Africa	**2.45**	**0.77**
Sudan	1.92(2.50)	0.54(0.63)
Tanzania	0.22	0.16
Southern Africa	**0.39**	**0.09**
South Africa	0.21	0.04
Zimbabwe	0.18	0.05

Source: FAO, 1996

2.3 Nutritional and Technological Properties of Millet

Millet ranks intermediately as an energy source among cereal grains. It has many of the nutritional characteristics, including deficiencies, common to other grains such as the amino acid methionine. Seed density and fiber content are issues to consider (Hulse *et al.*, 1980). Millets are high energy, nutritious foods recommended for the health and well-being of infants, lactating mothers, elderly and convalescents. However, the foods produced from them traditionally and industrially, at present, have short keeping qualities due to the presence of high fat content in the millet flours (Belton and Taylor, 2002). This constraint to extended utilization and properties of millet foods is being responded to through research and development in improved processing. Their good nutritional values including high levels of quality protein, ash, calcium, iron and zinc, which make millet nutritionally superior than most cereals, are now being enhanced through biofortification and micronutrient research. Tables 2.2-2.4 show the major nutrients, minerals, and essential amino acids of the four important millets in Africa, relative to two other cereals wheat and sorghum.

Table 2.2: Major Nutrients of the Four Important Millets in Africa Relative to other Selected Cereals.

	Millet				other cereals	
Major nutrients ($g100g^{-1}$)	**pearl**	**finger**	**teff**	**fonio**	**wheat**	**sorghum**
Protein	11.0	7.3	9.6	9.7	7.8	7.9
Carbohydrate	70.0	74.0	73.0	75.0	71.0	73.0
Fat	4.8	1.3	2.0	1.8	1.1	2.8
Crude fibre	2.3	3.6	3.0	3.3	2.0	2.3
Ash	1.9	2.6	2.9	3.4	1.6	1.6
Food energy (KJ)	1483	1403	1411	1541	1105	1142

Table 2.3: Mineral Composition of the Four Important Millet in Africa

	Millets				other cereals	
Minerals ($mg100g^{-1}$)	**pearl**	**finger**	**teff**	**fonio**	**wheat**	**sorghum**
Calcium	37	344	159	44	30	27
Copper	9.8	0.5	0.7	-	1.1	2.4
Iron	114	9.9	5.8	8.5	4.0	6.6
Manganese	190	140	170	-	120	180
Magnesium	0.8	1.9	6.4	-	3.6	2.9
Phosphorus	339	250	378	177	400	520
Potassium	418	314	401	-	330	440
Sodium	15	49	47	-	16	14
Zinc	2.0	1.5	20.0	-	3.5	4.4
Chlorine	43	84	13	-	-	-

Table 2.4: Essential Amino Acids in Important Millets in Africa

Amino acids ($g16g^{-1}N$)	Pearl Millet	Finger Millet	Teff Millet	Fonio Millet
Cystine	1.6 – 1.8	1.7	1.9	2.2 – 2.5
Isoleucine	3.9 – 4.6	4.0	3.2	4.0 – 4.5
Leucine	9.5 – 12.4	7.8	6.0	10.5-11.8
Lysine	2.8 – 3.2	2.5	2.3	1.9 – 2.5
Methionine	1.8 – 2.6	2.9	2.1	3.0 – 4.5
Phenylalamine	4.1	4.1	4.0	5.7 – 6.8
Threomine	3.3 – 4.1	3.1	2.8	3.3 – 3.7
Tryptophan	1.4 – 1.5	1.3	1.2	1.6
Tyrosine	3.0	4.1	1.7	3.5
Valine	4.9 – 6.0	6.4	4.1	5.2 – 5.5

Sources: FAO, 1996

2.4 Method of Planting Millet

Millets are generally suited to less fertile soils and poorer growing conditions, such as intense heat and low rainfall. In addition, they require shorter growing seasons. Millets are generally planted in much the same manner as small grains, using drills with 6-8" row spacing, as wider-spaced drills may allow weed competition. Soil preparation should follow recommendations for producing small grains or sorghum. A fairly level, loose, and mellow seedbed is recommended, and soils should be weed free prior to planting. Millets may be seeded at any time that will allow 60-70 days growing season until frost; yields are reduced if seeding is delayed beyond 60-70 days prior to frost. Millets do not germinate in cool, wet soil, so it is necessary to delay planting until soils are thoroughly warmed. Regular grain drills set to deliver seed from the small side are generally used for seeding. Seeding depth should not exceed 1/2-1". Generally, when producing millet for seed crops, seeding rates should be reduced by half and millet should be planted in rows to allow cultivation. Higher seeding rates are recommended when forage or hay crops are desired (Baker, 1998).

2.5 Millet Species Information

Millets include five genera, *Panicum, Setaria, Echinochloa, Pennisetum,* and *Paspalum,* all of the tribe Paniceae; one genus, *Eleusine,* in the tribe Chlorideae; and one genus, *Eragrostis,* in the tribe Festuceae. The most important cultivated species of millet are foxtail (*Setaria italica*), pearl or cattail millet (*Pennisetum glaucum*), proso (*Panicum miliaceum*), Japanese barnyard millet (*Echinochola crusgalli*), finger millet (*Eleusine coracana*), browntop millet (*Panicum ramosum*), koda or ditch millet (*Paspalum scrobiculatum*), and teff millet (*Eragrostis teff*) (Baker, 1998).

Foxtail Millet: One of the oldest cultivated crops, foxtail millet has generally been displaced by Sudan grasses as late-sown hay crops. Foxtail millet requires warm weather and matures quickly in the hot summer months. Generally grown in semi-arid regions, it has a low water requirement, though it does not recover well from drought conditions because it has a shallow root system. Successful production is due almost entirely to its short growing season: millet hay crops will mature in 65-70 days; grain varieties mature in 75-90 days. Foxtail millet can be planted when it is too late to plant most other crops. An annual grass, foxtail millet forms slender, erect, leafy stems varying in height from 1-5 ft. Seeds are borne in a spike-like, compressed panicle resembling yellow foxtail, green foxtail, or giant foxtail. Its small convex seeds are enclosed in colored hulls, with color depending on variety. Only about 10 or more varieties of foxtail millet are grown in the U.S. Principal use of foxtail millet include hay or forage. Although other hay crops are superior in quality, foxtail millet makes good hay for cattle and sheep. Foxtail millet is also used as a grain crop and for birdseed. Some diseases affecting foxtail millet include mildew, bacterial blight, and leaf spots. Kernel smut is also a problem in some cases; it can be controlled with seed treatments at planting (Baker, 1998).

Pearl Millet: Pearl millet is generally used as a temporary summer pasture crop or in some areas as a food crop. It is a tall, erect, annual bunchgrass growing from 6-15 ft in height. It is particularly well adapted to nutrient-poor, sandy soils in low rainfall areas. Stems are pithy and leaves are long-pointed with finely serrated margins. The plant tillers freely and produces an inflorescence with a dense spike-like panicle l4" long and 1" or less in diameter. The mature panicle is brownish in color, and spikelets are borne in fascicles of two, surrounded by a cluster of bristles. Each spikelet has two florets, one of which is generally staminate. The upper floret is fertile, with the caryopsis (seed) being enclosed by the lemma and palea from which it threshes free during harvest. Pearl millets are generally cross-pollinated. Several varieties and hybrids have been developed. Uses of pearl millet include hay, pasture, silage, seed crops, and food. There appear to be few or no disease problems associated with pearl millet (Baker, 1998).

Proso Millet: Proso millet is grown as a grain crop for human food and is adapted to regions where spring-sown small grains are successful. A short-season crop, it often requires only 60-75 days from seeding to maturity and is generally grown as a late-seeded, short-season summer catch crop. Moderately warm weather is necessary for good plant growth. Proso millet has the lowest water requirement of any grain crop; it is also subject to drought injury because of its shallow root system. It does not grow well on coarse sandy soil. The inflorescence of proso millet is a large open panicle with coarse, woody stems 12-48" high. The large erect stems and leaves are covered with hair. Seed are enclosed in the inner chaff or hull, and they are larger than those found on foxtail millet. Hulls can vary from white to black, with reds, browns, and grays. Most seeds are self-fertilized, but some cross-pollination does occur. Varieties of proso millet are divided into three groups based on the shape of the panicle: (1) spreading, (2) loose and one-sided, and (3) compact and erect. Proso millet can be planted following most other crops. It is generally used as a late-seeded, short-season summer catch crop. Diseases are not prevalent on proso millets, but some diseases warrant mention, especially bacterial stripe disease and head smut. Both diseases are considered to be seed-borne: a producer should only buy registered or certified seed for planting to ensure disease-free seed (Baker, 1998).

Japanese Millet: Japanese millet is grown principally as a forage grass. It resembles barnyard grass (considered a weed in many places) and probably originated from it. Japanese millet is usually grown as a late-season green feed in temperate climates with humid or sub-humid conditions. It makes the most rapid growth of all millets under favorable weather conditions, occasionally producing ripe grain in 45 days after seeding. The growth habit of this annual grass is an erect plant 2-4 ft tall with a panicle inflorescence made up of 5-15 sessile erect branches. Spikelets are brownish to purple and are borne on one side of each branch. Seeds are slightly longer than wide and are larger than those of barnyard grass. Japanese millet makes its best growth on good soils. It is not subject to major fungal diseases; it is susceptible to several species of head smuts. Another related species of Japanese millet is jungle rice, *E. colonum*, which is considered a weed in most places. The mature Japanese millet plant is difficult to cure for hay because of the thick stems; thus it makes a more palatable hay when cut before heading (Baker, 1998).

Finger Millet: Finger millet is generally grown as a food crop in areas where rice is grown, in contrast to other millets grown in arid or semiarid conditions. Finger millet grows best in moist climates in almost any type of soil. It does not do well in areas of heavy rains, but prefers damp conditions. This annual millet generally grows 3-4 ft tall and tillers freely. Helminthosporium diseases can cause leaf spots, seedling blight, and head blight in finger millet. Grain smut has also been reported (Baker, 1998).

Browntop Millet: Browntop millet is grown for hay and pasture in the southeastern U.S. It provides an excellent source of food for game birds. It is a quick-growing annual 2-4 ft tall with an open panicle 2-6" long. Its forage yields are less than that of pearl millet, but it has a shorter growing season and finer stems that allow easier curing for hay. Brown top millet seed shatters easily and reseeding is natural, making this millet a weedy pest in some places (Baker, 1998).

Koda or Ditch Millet: These millets resemble certain forage grasses from the genus *Paspalum*. They are closely related to Dallas grass, Vasey grass, and Bahia grass and are primarily grown for forage (Baker, 1998).

Teff Millet: Teff millet is grown for food in many countries. This millet has a high iron content nearly double that of other food grains and calcium content almost 20 times more than other grains. These two nutrient levels provide a more favorable nutritional value for teff over other millets (Baker, 1998).

2.6 Processing and Utilization of Millet

Millets (together with sorghum) provide 75% of total caloric intake for the poor people living in the semi-arid tropical and sub-humid drought-prone areas. Millets alone provide 13.40 kg/yr per capita food use. Across Africa several indigenous foods and drinks are made from flour/meal and malt of the millets. They are nutritionally equivalent or superior to other cereals. They generally contain high protein (up to 9.5 g/100g for teff and fonio), ash, calcium (up to 344 mg/100g for finger millet), phosphorus and potassium (up to 250 mg/100 g and 314 mg/100 g respectively for finger millet), iron and zinc levels. The high levels of methionine and good digestibility make the millets valuable food for humans and other monogastric animals (Obilana and Manyasa, 2002). About 80% of the world's millet is used as food, with the remaining being used for stock feed (2%), beers (local and industrial), other uses (15%) and bird seed (FAO, 1996). Foods prepared from millets are several and differ from country to country and occasionally from region to region. In West Africa, the main food dishes from pearl millet vary by country. The stiff or thick porridges (Tuwo or Tộ) are the most popular, commonly consumed in all the Sahelian countries across the region. The steam-cooked product 'Couscous' is more commonly consumed in the Francophone countries including Senegal, Mali, Guinea, Burkina Faso, Niger and Chad. The thin porridge 'bouillie' is also popular in these countries. Three countries among others have unique foods from pearl millet specific to them. In Nigeria and Niger the thin porridge 'Fourra' is very popular while 'Soungouf; 'Sankhal' and 'Araw' are very popular in Senegal. Animal feed as forage, grain and residue is still insignificant, with about 7% (< 2 million tons) of total production going into stock feed. Malting and breeding local beers using millets is significant in Uganda, Zimbabwe, Zambia and Namibia. Non-alcoholic local beverages are commonly made from millets in West Africa. The stalks of the long season, late maturing pearl millet types called Maiwa in Nigeria are used in roofing, fencing and as firewood. Millets have good grain qualities suitable for processing. Processing of the grain for many end uses involves primary (wetting, dehulling and milling) and secondary (fermentation, malting, extrusion, glaking, popping and roasting) operations. Being a staple and consumed at household levels, processing must be considered at both traditional and industrial levels, involving small, medium and large-scale entrepreneurs.

Dehulling, which is not favorable to millets due to their small grain sizes and which causes high dehulling losses, is followed by milling. All the millets can be milled by hand grinding (household level) or machine milling (cottage, small-to-medium scale service and large scale industrial). The milling process affects the nutritional status of millet and prepared products. Generally, flour products from mechanically milled processes are acceptable and have improved shelf life, whereas the traditionally milled products retain more nutrients

(Belton and Taylor, 2002). There is need to balance these process outcomes to have longer shelf life with adequate nutritional status. This should be achievable through product development and testing research. Pearl millet is relatively more amenable to milling process as it has relatively largest grains of the millets. However, modified mini mills for millets processing would minimize milling losses if used. Malting and fermentation processes result in malted and brewed products which are non-alcoholic and alcoholic depending on the desired needs. Malted pearl millet and finger millet are used in the brewing of traditional opaque African beer in southern and eastern Africa. Finger millet makes the best quality malt used in both brewing industry and making of digestible nutritious foods. Pearl millet has been shown to have similar dietetic power similar to sorghum and makes just as good beer brewing with good quality malts (Pelembe, 2001). He also showed the potential of pearl millet, like sorghum in the brewing of clear lager beer. Teff and fonio are mostly for food (porridges and flat breads); they possess low malting potential, because of very high malting losses (Obilana and Manyasa, 2002). Fermentation of sprouted (germinated) millets results in significant increases in protein and starch digestibility (Nzelibe and Nwasike, 1995). Fermented thick porridges are popular in Niger, Sudan and Southern Africa, while fermented thin porridges are commonly consumed in West Africa especially Nigeria and Ghana (ogi, koko, akamu, kunu) and East Africa mostly in Kenya and Uganda (uji) where souring (with lemon) is used instead of fermentation. In Nigeria and Ghana, stiff or thick porridges (tuwo) are not fermented, as done in francophone West African countries.

2.7 Commercialization and Trading of Millet

The greatest constraint in the realization of importance of millets is in their handling and limited use by the producers, processors and consumers. The harvesting, threshing and processing for food is mainly done by women at the household level. Processing and brewing for malts and drinks are however done at both communal (taking 70% share) and medium- large scale industrial levels by breweries (taking 10% share mostly in southern Africa). The brewing process and activities form the bulk of commercialization in millets and account for 80% of the informal trading of the crop. The remaining 20% are in form of thin and thick porridges (in west, east and southern Africa) and flat breads (mainly in Ethiopia using teff, and Sudan using pearl millet). The reverse is however true for food use at household levels to satisfy food security. In most instances, for these foods, drinks and local beer, millets composited with other cereals, like sorghum and maize, are used. For millets, commercialization and trade need to be put in proper perspective for better and appropriate response to their enhancement and up scaling through value addition. Commercially, there is a slow and emerging trend in the industrial use of millets at the national and regional levels. Because of its nature and ecology of production areas, the mainly cultural and household processing and consumption pattern is yielding to more and more cottage, medium and large scale practices. Pearl millet, for instance, ranks first as the major staple in human consumption in the West African semi-arid tropics. A survey conducted by the West and Central African Millet Research Network (WCAMRN) on 522 consumers in four countries revealed that millet is the most preferred staple in the semi-arid tropics of the region (Ndjeunga and Nelson, 2001). It is consumed at breakfast, lunch and supper, and its product demand is very high; 62-84% eating it in form of thin (bouillie and furra) and thick (tuwo/tộ); porridges up to 80% consuming it as couscous in Senegal. Similar levels can be found for teff in Ethiopia, as flat bread (injera). In southern Africa, commercialization of millets products is more advanced than in West Africa. In eastern, central and southern Africa traditional beer brewing from finger millet and pearl millet has long been a large-scale commercial enterprise; used in the form of malt and unmalted adjunct. In Zimbabwe, small quantities of pearl millet and finger millet are used in commercial opaque beer brewing. In Kenya, finished millets products in form of 'Uji Mixes' are processed in large and small scale private firms; and demand for these products are high. International trade in millets is estimated to range between 200,000 – 300,000 tonnes, representing approximately 0.1% of world trade in cereals or 1.0% of world millet production (FAO, 1996). Africa has no participation in this official trade figures. However, what is important in Africa is internal national and regional trading of millets. Substantial quantities of millets are traded within African countries and sub-regions. Grains move from surplus to deficit areas, along and across boundaries. Two broad types of grain marketing are identified in West Africa (Akintayo and Sedgo, 2001). These include the long distance from grain involving more than one country in the Western Africa sub-market (Senegal, Mali, Niger and Nigeria); and short distance trading which is usually an internal country grain marketing system. Grain trade in this sub-sector is estimated at 15-20% of domestically produced grains, with the rest consumed locally in the areas in which they are produced. At the regional level, in the Sahelian countries of West Africa, countries that generate surplus millet (mainly pearl millet) are net exporters. Because of the informal nature of trading in this sub-region, trading volumes are usually not well recorded. However, based on surplus/deficit from production data in good rainfall years, Mali and Burkina Faso are potential millet grain exporters to Mauritania, Senegal, Guinea and Niger, by large-scale traders, producers and wholesalers (Debrah, 1993). Another significant net exporter of millet in West Africa is Nigeria, through cross-border trading principally to Niger and also Chad, Cameroon, Ghana and Burkina Faso. A survey of such cross-border grain trade shows Niger as net importer, with 11% of total grains imported (100,000 tonnes) from Nigeria being pearl millet. This quantity could increase significantly following droughts, an indication of Nigeria's significance in pearl millet trading in the West African sub-region.

2.8 Improved Processing Technology for Millet

In order to increase the production rate and for Africa to realize proper commercialization and International trade for millet, it is thus necessary to modernize the production techniques and optimize the processing conditions as these apply to be the only way that will guarantee an improved and consistent flavor, increased shelf life, enhanced shorter processing time and improved quality of the product obtained from millet (Ogunlowo and Adesuyi, 1999). Women are primarily responsible for the labour and time-intensive post-harvest processing operations. Traditionally, millet panicles are broken apart by mortar and pestle action in a hollowed out log or threshed out on the ground. The grain is separated from the chaff in a winnowing area. Development of simple technologies to facilitate grain threshing, winnowing, and grinding would have a significant impact in freeing women's time to pursue alternative family or entrepreneurial activities, and would provide cost savings to existing grain processors and convenience food manufacturers. The characteristics of millet require special consideration in developing these technologies. A panicle consists of seed-bearing spikelets arranged around a central rachis. Manipulations often break the spikelets off of the rachis. The grain must be dislodged and then separated from the spikelet and other plant debris. If grains are broken during the process, oxidation of the unsaturated fatty acids in millet can result in rancidity and off-flavors. On April 7-8, 2008, Compatible Technology International conducted a review of prototype and advanced devices for post-harvest solutions for millet processing. Criteria of importance in the assessment included:

- Low cost and simplicity of construction and operation
- Options for convertibility between hand-power or motorization
- Potential for scalability for increased capacity and
- Ability to result in clean, unbroken grain.

2.9 Consideration for Threshing Machine

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

2.9.1 Traditional Threshing

The traditional threshing of millet is generally done by hand: bunches of panicles are beaten against a hard element (e.g. a wooden bar log, bamboo table, or stone). In many countries in Asia and Africa, and in Madagascar, the crop is threshed by being trodden underfoot (by humans or animals); this method often results in some losses due to the grain being broken or buried in the earth (Food Agency Organization 1995).

2.9.2 Mechanized Threshing

Two main types of stationary threshing machines have been developed. The machine of Western design is known as "through-flow" thresher, because stalks and ears pass through the machine. It consists of a threshing device with pegs, teeth or loops, and (in more complex models) a cleaning-winnowing mechanism based upon shakers, sieves and centrifugal fan. In the 70s, IRRI developed an axial flow thresher which has been widely manufactured at local level (Saxena, *et al.* 1971). More recently, a small mobile thresher provided with either one or two threshers was developed. This machine has been widely adopted in many millet-growing areas (Policarpio and Mannamy 1978). The simple design and work rates of these machines seem to meet the requirements of rural communities (Food Agency Organization 1995). The main disadvantages of these machines are their fragility.

2.10 Separation Operations

Cleaning and grading are the first and most important post-harvest operations undertaken to remove foreign and undesirable material from the threshed grains to separate the grains into various fractions. The comparative commercial value of agricultural product is dependent on their grade factor. This grade factors further depends on;

- Physical characteristics like size, shape, moisture content, colour etc.
- Chemical characteristics like odour, free-fatty acid content and
- Biological factor like germination, insect damage etc.

The separation of a mixture of seeds can be done based on difference in length, width/thickness, specific gravity, surface texture, drag in moving air, colour, shape, electrical conductivity and magnetic properties. Cleaning which is actually the operation carried out before grading in agricultural processing generally means removal of foreign and undesirable matter from the desired grains. This may be accomplished by washing, screening, handpicking etc. Sorting refers to the separation of cleaned product into various quality fractions that may be defined on the basis of size, shape, density, texture and colour. The term scalping refers to the removal of few large particles in an initial process. Screens are the most widely used device in cleaning and grading operation. When grains are drop over a screen, the smaller particles of grains smaller than the size of screen opening pass through it, whereas larger particles of grains are retained over the screen or sieve. According to Singh and Kashyab (1987), the basic purpose of any screen is to separate the feed consisting of a mixture of particles of different sizes into two distinct fractions. Those fractions are;

- The underflow: - the particles which pass through the screen, and
- The overflow or oversize: - the materials that are retained over the screen.

A screen can be termed as ideal screen when it separates the feed in such a way that the largest particle of underflow is just smaller than screen opening, while the smallest particle of overflow is just larger than the screen opening. But in practice no screen gives perfect separation as stated above, and is called actual screen. The underflow may contain material coarser than screen size, whereas the overflow may contain smaller particles than screen size.

An effective cleaning operation of grain must:

- Separate the contaminants effectively
- Remove the cleaned surfaces in the desired condition and
- Limit recontamination of the cleaned grains.

Inefficient removal and disposal of the contaminants once separated from the grain, results in product recontamination. The operation of separation such as cleaning grading and sorting of products is performed by exploiting the differences in engineering properties of the materials. Various forms of cleaning and grading equipments have been designed and developed on the basis of properties of the product to be handled. Thus, these equipments can be classified based on the characteristics of the materials namely; size, shape, specific gravity or weight and aerodynamics properties (Kaul, 1967).

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.

3.1.3 Human Height Consideration

Since human being is to operate the machine and not a robot, the feeding of the millet panicle into the hopper is thus necessary to be considered with respect to human height. The overall height of the machine has been chosen from within acceptable limits of 1.5 m as this was assumed to be the average height of human being.

3.1.4 Affordability

In order to facilitate easy maintenance, the machine is made from locally available raw materials making it to be cheap hence affordable by the small, medium, and large scale stock millet processors.

3.2 Material Selection

Basically, selection of materials for a particular work in any given engineering design has to be adequately considered. From the economic point of view, such material has to be cheap and at the same time meet the specific purpose for which it was designed for. In the fabrication of machine for the threshing and cleaning of millet grains from its panicle, the following factors were considered.

I. Availability of the materials

II. Durability of the materials

III. Cost of the materials

IV. Ease of construction in order to achieve the desired objectives.

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 22.371KW 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/s^2

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

$$C_{vph} = \frac{4.38 \times 10^{-3} \times 60}{1} = 0.2628m^3/hr$$

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

$= 0.1108m$

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

$$\mathrm{W} = mg$$

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, $\mathrm{W} = 37.8213 \times 9.81 = 371.03N$

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

3.4.4 Power Required to Thresh Grain from 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)

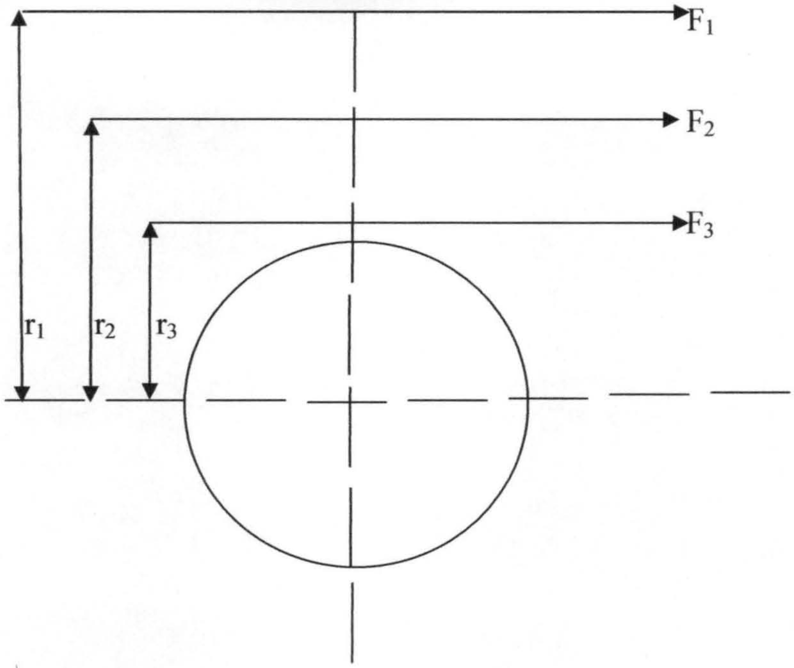


Fig.3.1 Cross Section of pegs on rotating drum.

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) = $F_1 r_1 + F_2 r_2 + \ldots\ldots + F_i r_i$

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

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

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

$P = 22.5 \times 83.776 = 1884.96W$

3.5 Design of the Pulley and the Belt

3.5.1 Motor-Threshing Drum Belt Length

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

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + [\frac{(D_2 - D_1)^2}{4C}]$$ (Khurmi and Gupta, 2005)

Where; D_1- diameter of the Motor Pulley (60mm)

D_2 - diameter of the Threshing Drum Pulley

But; $D_2 = \frac{N_1 D_1}{N_2}$ (Khurmi and Gupta, 2005)

Where; N_1 - speed of the motor Pulley (1500rpm)

N_2 - speed of the Threshing Drum Pulley = 800rpm (Ndirika 1997).

Therefore $D_2 = \frac{1500 \times 60}{800} = 112.5mm$

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

$C = (\frac{D_2 + D_1}{2}) + D_1$ (Khurmi and Gupta, 2005)

$C = (\frac{112.5 + 60}{2}) + 60$

$= 146.25mm$

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) = $2 \times 146.25 + \frac{\pi}{2}(60 + 112.5) + \frac{(112.5-60)^2}{4 \times 146.25}$

$$= 292.5 + 270.96 + 4.712$$

$$= 568.172\text{mm}$$

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 ($9.81 m/s^2$)

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

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)

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

$= 225$mm

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;

$$L = 2C + \frac{\pi}{2}(D_{3i} + D_4) + [\frac{(D_4 - D_{3i})^2}{4C}]$$ (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) = $2 \times 178.78 + \frac{\pi}{2}(80 + 117.55) + \frac{(117.55-80)^2}{4\times178.78}$

$$= 357.56 + 310.35 + 1.97$$

$$= 669.88mm$$

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;

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

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

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-$radius\ of\ the\ fan\ pulley(58.775mm)$

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

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

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

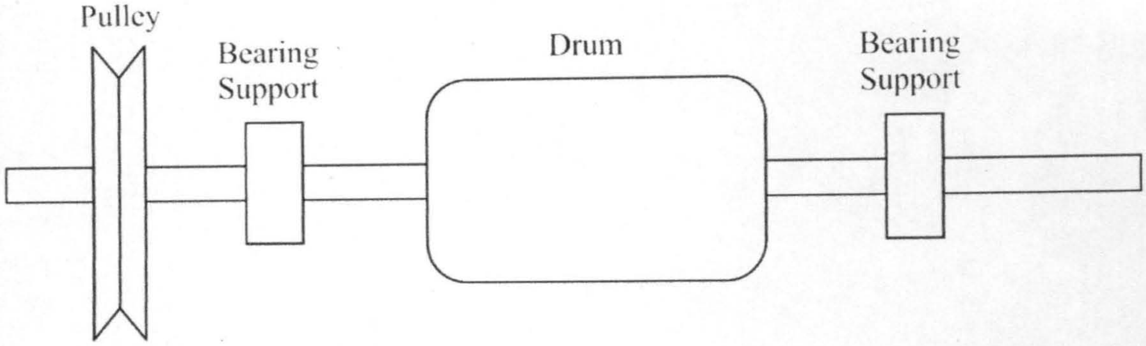


Fig 3.2: Loading System of Drum Shaft

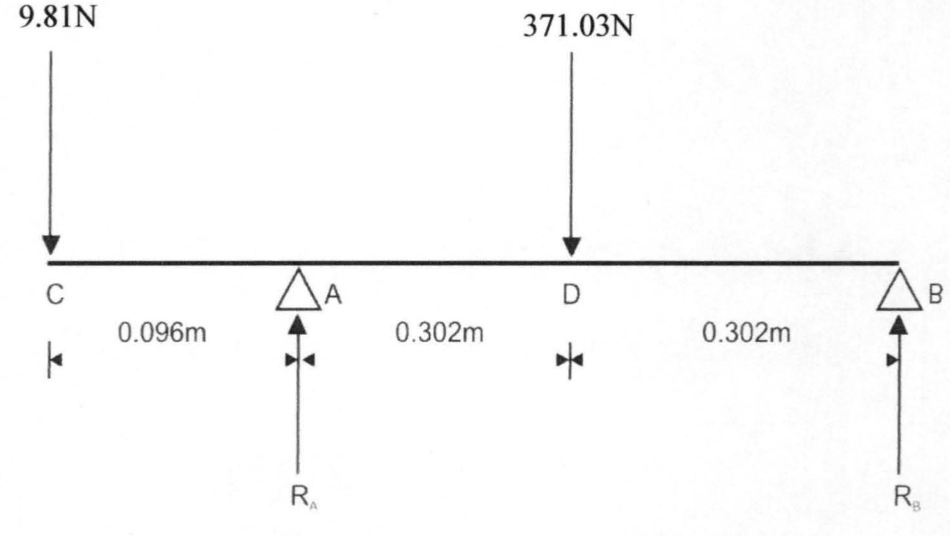


Fig 3.3: Free-body Diagram of Drum Shaft Loading System

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, $F_v = 9.81cos25 = 8.89N$

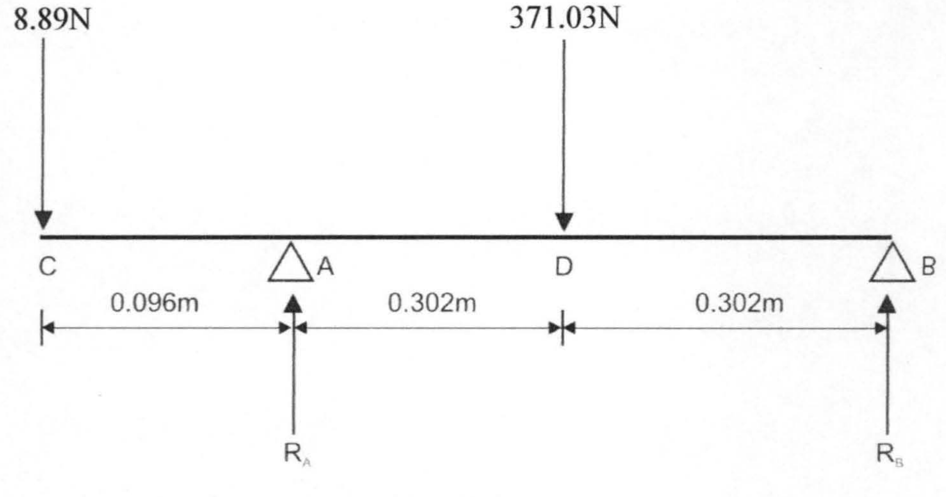


Fig 3.4: Vertical Force Loading

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

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

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

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

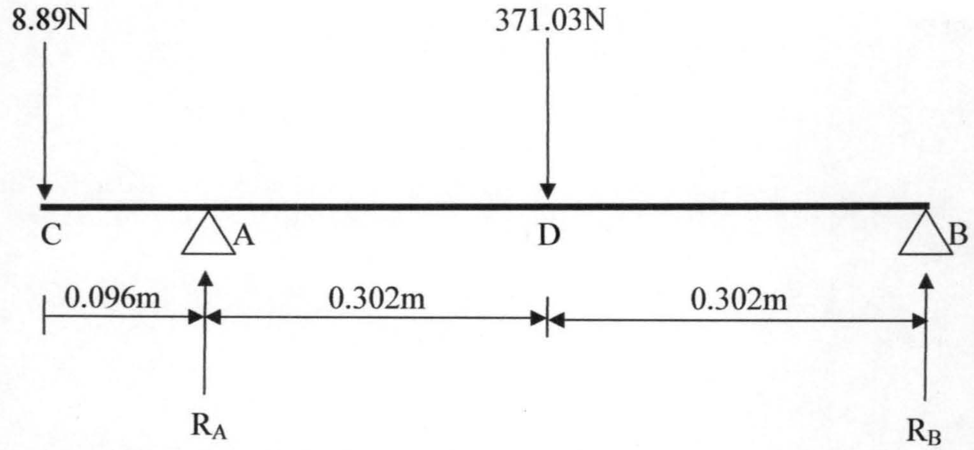
$$F_{VB} = -184.102 + 184.102 = 0\ for\ 0 \leq x \leq 0.7$$

To determine the vertical bending moment diagram

$$M_C = M_B = 0$$

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

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



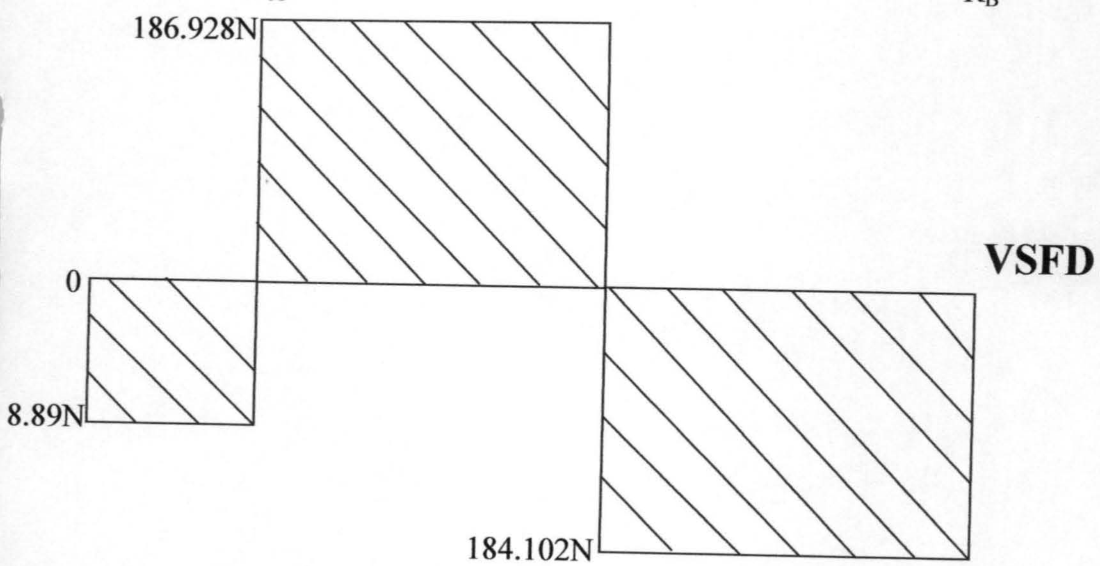


Fig 3.5a: Vertical Shear Force Diagram

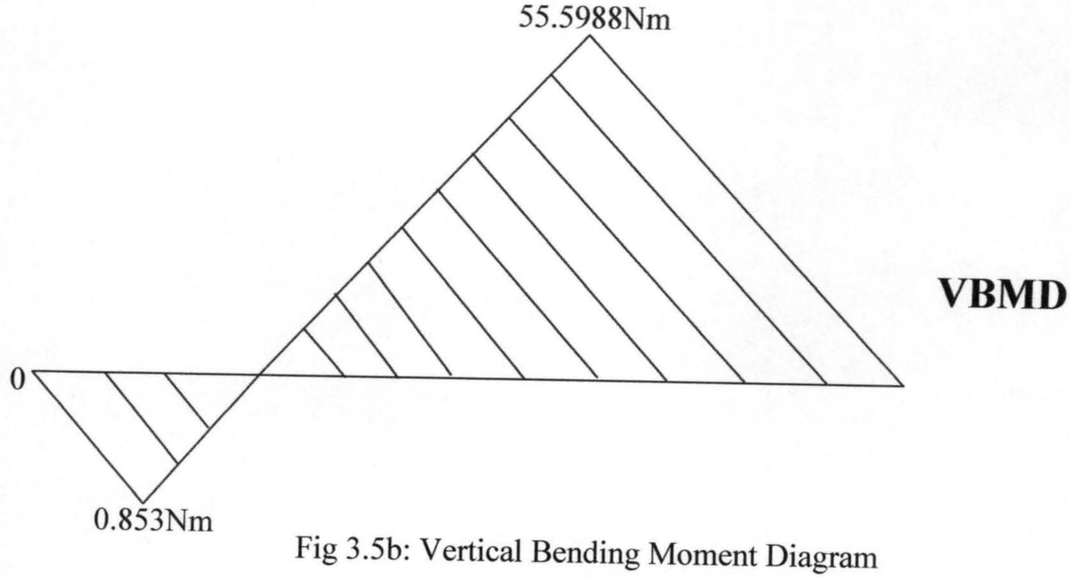


Fig 3.5b: Vertical Bending Moment Diagram

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, $F_H = 9.81sin25 = 4.15N$

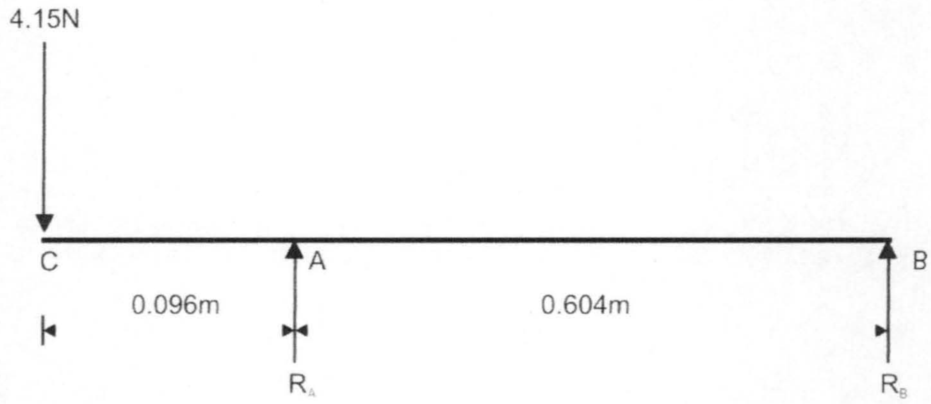


Fig 3.6: Horizontal Force Loading

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

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

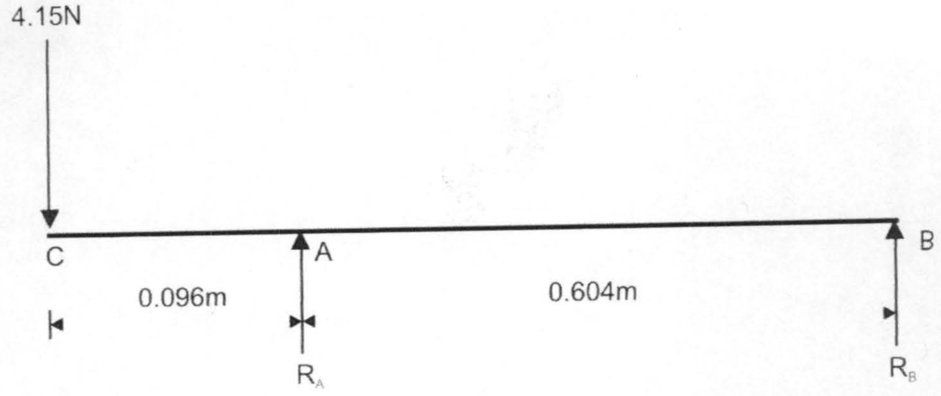
$$F_{HA} = -4.15 + 4.81 = 0.66N \; for \; 0 \leq x \leq 0.906$$

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

To determine the horizontal bending moment diagram

$$M_C = M_B = 0$$

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



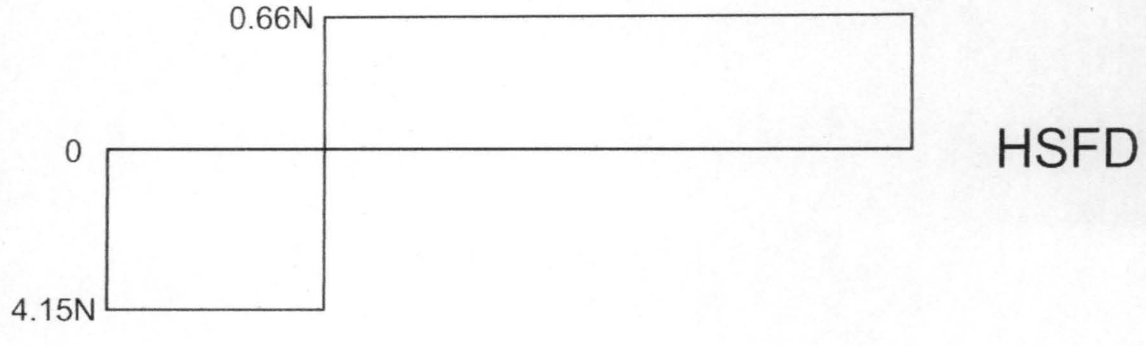


Fig 3.7a: Horizontal Shear Force Diagram

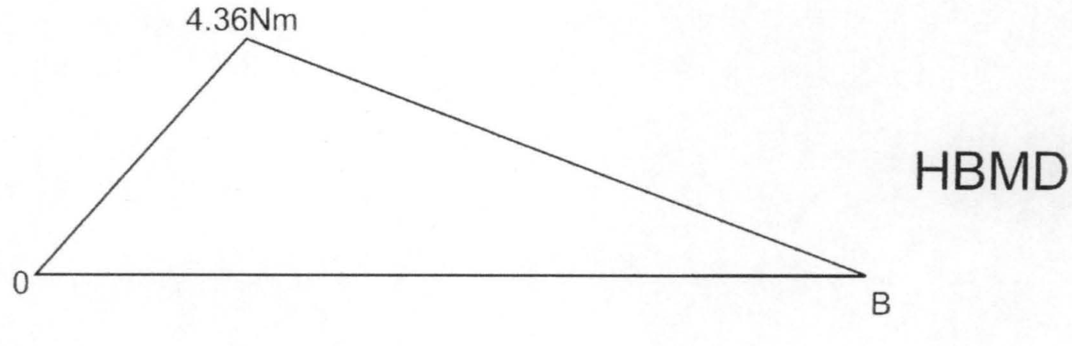


Fig 3.7b: Horizontal Bending Moment Diagram

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

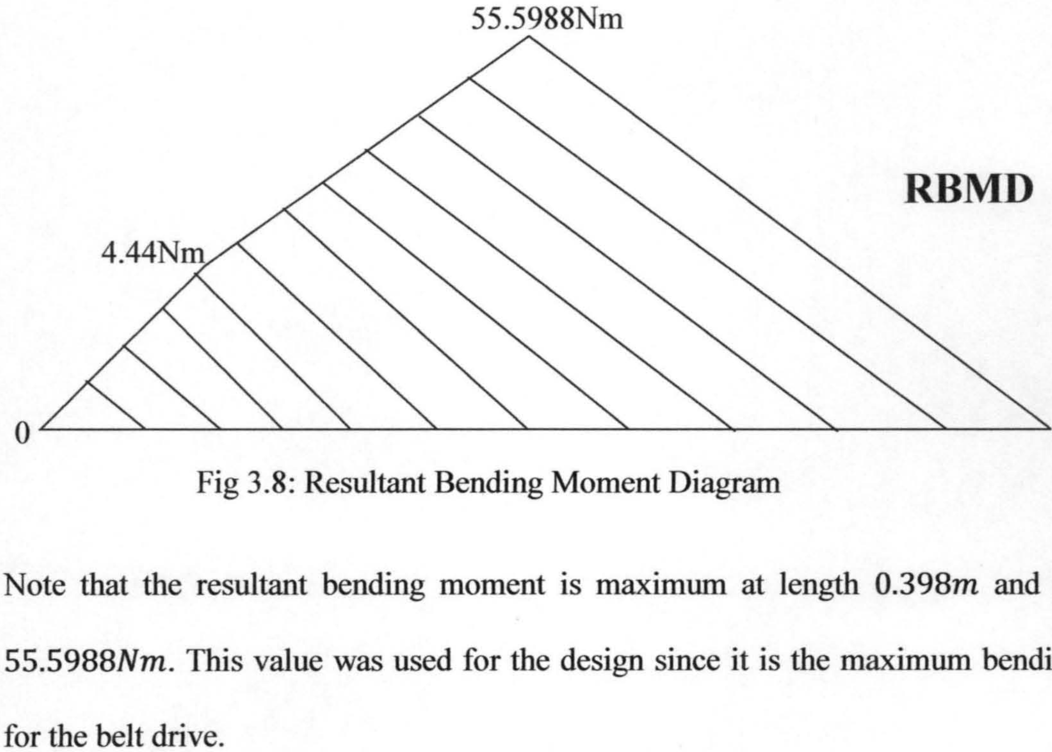


Fig 3.8: Resultant Bending Moment Diagram

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,

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

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

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 expression 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

r- radius of the fan pulley $(0.056m)$

But, mass of the cleaning unit= $mass\ of\ the\ sieves +$ mass of the metal sheet plate used for the housing of the sieves

Where, mass of the sieves $= 3.8kg$

And, mass of the metal sheet plate used for the hosing of the sieves= volume of the metal sheet $\times$ $density\ of\ the\ material$

Also, volume of the metal sheet $= length \times breadth \times thickness$

$$= 0.6m \times 0.337m \times 0.004m = 8.088 \times 10^{-4} m^3$$

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

Therefore, mass of the metal sheet plate used for the housing of the sieves

$$= 8.088 \times 10^{-4} \times 7850 = 6.3491kg$$

Hence, mass of the cleaning unit= $3.8 + 6.3491 = 10.1491kg$

But $\quad \omega = \frac{v}{r}$

$$= \frac{4.712}{0.056} = 84.143rad/sec$$

Therefore, $F_v = 10.1491 \times (84.143^2) \times 0.056 = 4023.9404N$

And $W = mg$

Where, g- acceleration due to gravity

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, RESULTS, DISCUSSION OF RESULTS AND COST ANALYSIS

4.1 Fabrication

As shown in the Plate 4.1 and Plate 4.2, all other part of the millet thresher 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.

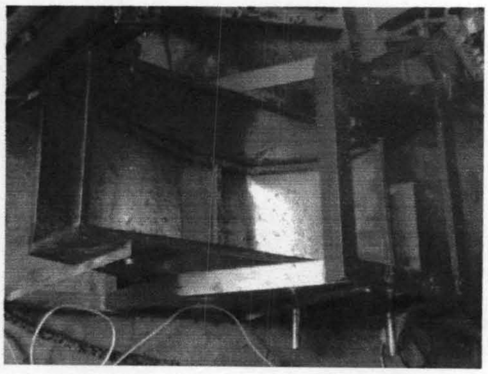


Plate 4.1 Construction in progress (Threshing drum frame with cleaning unit).

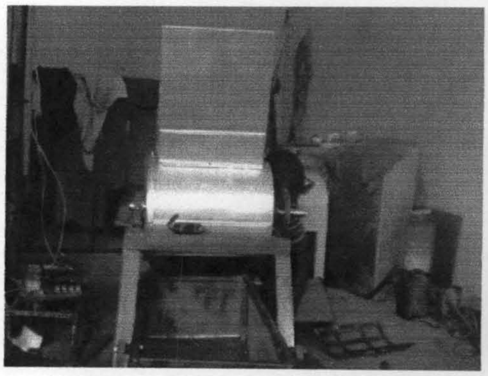


Plate 4.2 Construction in progress (Hopper with threshing drum).

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

As shown in Plate 4.3 and 4.4, the machine was first run under no load condition using an electric motor of 22.371KW 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.

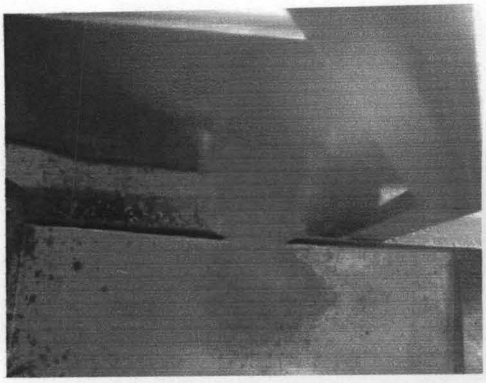


Plate 4.4 Threshing in progress.

4.3 Results

4.3.1 Computation of the Results

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

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

$$Cleaning\ efficiency = \frac{w_c}{w_o + w_c} \times 100$$

Where,

w_c – is the mass of clean millet grains

w_o – is the mass of chaff

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

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,

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

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

$$percentage\ loss = \frac{184}{5oo} \times 100 = 36.80\%$$

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,

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

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

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

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 to 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(G16)	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 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The millet thresher was designed, fabricated and tested. Conclusively, it can be presented that the millet thresher works more efficiently as the moisture content decreases and the threshing drum speed increases. On the average, the threshing and the cleaning efficiencies are 57.67% and 51.40% respectively. The optimum operating parameters that are responsible for the result above are; 13% moisture content (wet basis) of pearl millet panicle and 800 rpm threshing drum speed.

5.2 Recommendations

- The number of pegs should be increased in order to increase the chances of threshing more grains from the panicle.
- In the rural areas where there is no access to the use of electricity, the machine could use diesel or petrol engine as an alternative source of power.
- The grain sieve should be replaced with a smaller diameter of sieve aperture in order to have a better cleaning efficiency.
- The RPM of the fan should be increase by separately having a high speed electric motor that will run the fan.
- Useful criticisms are welcome that would lead to improvement in the threshing efficiency, cleaning efficiency as well as cost reduction of this work.

REFERENCES

Abu, O.O., (2006). Design and development of a rice threshing machine. Unpublished B.eng Thesis Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna. p. 11.

Adeyemi, I.A., and Umar, S. (1994). *Effect of method of manufacture on quality characteristics of kunu zaki, a millet- based beverage.* Nig. Food J., 12, 34-41.

Andrews, D.J., and Kumar, K.A. (1992). Pearl millet for food, feed, and forage. Adv. Agron.48, 89-139.

Baker, R.D., (1998). Millet production. Cooperative extension service college of agriculture and home economics. Guide A-414

Crawford, G.W., and Lee, G.A. (2003). Agricultural origins in the Korean Peninsula, Antiquity, 77 (295), 87-95.

Debrah, S.K. (1993). The competitiveness of sorghum and millet in the food system of West Africa. In Sorghum and millet marketing and utilization in Tanzania: National workshop on S/M marketing and utilization for food security and development. IDRC. Arusha International Conference Center 3-5 May 1993.

Epapala,O.L. (1998). Performance testing and modification of a multipurpose winnower. Unpublished B.eng Thesis Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna. p. 39.

Food and Agriculture Organization. (1995). Rice post harvest technology. Ministry of Agriculture, Forestry and Fisheries, Tokyo, Japan, pp. 167-179.

Food and Agriculture Organization. (1996). The world sorghum and millet economies: facts, trends and outlook. FAO Document Repository W1808/E.

Gama, P.M., and Shemington, K.B. (1977). *The science of food.* An Introduction to Food Science Nutrition and Microbiology. 1st Edn., Pergamon Press oxford.

Gupta, J.K., and Khurmi, R.S. (2005). *Machine design (14^{th} ed.).* S .Chand & Company Ltd., Ram Nagar, New Delhi-110055, pp.434-960.

Hall, A.S, Hollwen, K.O.A, and Laughum, H. (1980). *Schaum's outline of theory and Problem of machine design.* Metric selection. McGrac-Hill Books Company. New York, USA.

Hulse, J.H., Laong, E.M., and Pearson, O.E. (1980). *Sorghum and millet. Their Composition and Nutritive Value,* New York, Academic Press, p. 997.

IFAD. (1999). Farmer participatory testing of technologies to increase sorghum and pearl millet production in the Sahel. www.ifad.org/grants

Ikwelle, M.C., Lube, D.A., and Nwasike, C.C. (1993). Millet production in Nigeria, Constraints and prospects. In Proceedings of the regional pearl millet improv. W/shop (Youm, O., & Kumar, K.A.), (Eds). ISC, Niger.

Joseph, E., and Charles, R. (2001). *Mechanical engineering designs (4th ed.).* McGraw-Hill Book Company, New York.

Kaul, R.N., (1967). *Physical characteristics of agricultural material affecting cleaning and separation process.* Bulleting of grain technology. Vol. 5(2), 109-114

LCRI (1997). Lake Chad Research Institute Extension Guide No. 8 on the production of millet.

Ndirika, V. I. O. (1997). Modeling the perfomance of selected stationary grain threshers. Ph.D. Degree Thesis. Departmenl of Agricultural Engineering, Ahmadu Bello University,Zaria, Nigeria.

Ndjeunga, J., and Nelson, C.H. Prospects for a pearl millet and sorghum food processing industry in West African Semi-Arid Tropics. In 'Towards sustainable sorghum production, utilization and commercialization in West and Central Africa' (I. Akintayo and J. Sedgo, eds), WCASRN/ROCARS Bamako, Mali, and ICRISAT, Andhra Pradesh, India (2001), pp. 178-216.

Nkama, I. (1998). Traditional food preparations of pearl millet in Nigeria. In: Pearl millet in Nigeria Agriculture: Production, utilization and research priorities. Proc. of the pre-season national coordination and planning meeting of NCRP for pearl millet (Emechebe, A.M., Ikwelle, M.C., Ajayi, O., Kano, M.A., & Anaso, A.B. (Eds) LCRI Maiduguri, Pp.179 – 208.

Nzelibe, H.C., and Nwasike, C.C. (1995). *The brewing potential of acha (Digitaria exilis) malt compared with pearl millet (Pennisetum typhoides) malts and sorghum (Sorghum bicolor) malts.* J Inst. Brew 101 (1995) 345-350.

Obilana, A.B., and Manyasa, E. (2002). Millets. In 'Pseudocereals and less common cereals: grain properties and utilization potential' (P.S. Belton and J.R.N. Taylor eds), Springer-Verlag, Berlin Heidelberg New York, pp. 177-217.

Ogunlowo, A.S. and Adesuyi, A.S. (1999). Design and construction of a rice destoner agricultural mechanisation . Asia, Africa & Latin America 30(1), 20-24.

Olanrewaju, V.J. (2005). Design and construction of a conical screen centrifugal filter for groundnut oil slurry. Unpublished M.eng Thesis Department of Mechanical Engineering, Federal University of Technology, Minna.

Onwueeme, I.C. and Sinha, T.D. (1991). Field crop production in tropical Africa, Micheal Health Ltd. Reigate Survey RH2 9EL, Technical centre for agricultural and rural cooperation, CTA. Pp, 190-192.

Pelembe, L.A.M. (2001) Pearl millet malting: factors affecting product quality. PhD dissertation. University of Pretoria, Department of Food Science, p. 175.

Policarpio, J.S., and Mannamy, J.A. (1978). The development of the IRRI portable thresher, a product of rational planning, pp. 56-65. AMA Spring.

Sexena, J.B., Sirohi, B.S., and Sharma, A.K. (1971*). Power requirements of Ludhiana type threshers.* J. Agric. Engin. 8, 35-43.

Shigley, J.E. (1986). *Mechanical engineering designs (2nd Ed.)* M.C. Graw-Hill Book Company New York, p. 119.

Singh, K.K. and Kashyap, M.M. (1987). *Performance of flat screen grain pre-cleaner, I.E (1)* Journal- agric. Vol. 67, 65-68.