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FACULTY OF ENGINEERING

DEPARTMENT OF AGRICULTURAL MECHANISATION AND IRRIGATION ENGINEERING

DESIGN AND CONSTRUCTION OF A WATER MELLON SEED SHELLING MACHINE USING LOCALLY AVAILABLE MATERIALS

BY

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A final year project submitted in partial fulfillment for the award of a Bachelors' Degree in Agricultural Mechanization and Irrigation engineering

ABSTRACT

Watermelon is one of the most common economic and productive fruits grown in the eastern part of Uganda. Water Melon processing in the industry generates large quantities of by-products that are usually discarded (Mansouri, Mirzabe and Ráufi, 2017). Within those by-products, melon seeds account for 10% of total melon weight.

Thus to increase the economic value of watermelon, the best use of this discarded has been studied in this literature. Since watermelon seed shelling is still carried out manually in most countries thus making the process slow, labour intensive, arduous in nature, and low productivity.

This work therefore focused on: design; construction; performance evaluation; economic analysis of a motor operated watermelon shelling machine which can shell a variety of watermelon seeds. A motor operated watermelon seed shelling machine was designed, fabricated and tested.

This watermelon seed shelling machine consists of an electric motor onto which a belt is attached which transfers motion to the pulley that is attached on the Shelling disk.

The shelling disk consists of a shaft which turns to drive the shelling disk; where

The seeds are hit against the stationary drum. During testing, 12 kg of watermelon seeds were shelled per hour with a shelling efficiency of 68.7%.

The machine had an investment cost of 1,200,000UGX, NPV of 8,763,840.48UGX and salvage value UGX 8,486.01UGX after five years. The results obtained showed that slight increase in the amount of seeds increases the shelling efficiency.

DECLARATION

I **MUSANA DEOGRACIOUS** hereby declare to the best of my knowledge that this is my true and original piece of work and has never been submitted to any university or institution of higher Learning by anybody for any academic award.

Signature………………………..

Date ……………………………….

APPROVAL

This final year project report has been submitted to the Faculty of Engineering for examination with approval of my supervisor.

SUPERVISOR: **ENG. GODFREY SSAJJA SSALI**

SIGNATURE: ……………………………………………………………………..

DATE: …………/……………/………….

ACKNOWLEDGEMENT

I extend sincere gratitude to my Aunt, Madam **KASEA FLORANCE** for the continued support she has rendered to my academic journey.

Special thanks goes to my Supervisor, **ENG. GODFREY SSAJJA SSALI** for the technical guidance in writing this project report.

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Lastly my sincere thanks go to all my friends and the AMI class of 2017 for their good peer and Academic support throughout the project developing process.

DEDICATION

This report is dedicated to **ZIKUSOOKA** family, most especially my aunt madam **KASEA FLORANCE** in appreciation for their selfless care and parental support provided to me since childhood, and for the mentorship of hard work and determination delivered to me, which attributes I have cherished with firmness and which have transformed me to this level

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1. CHAPTER ONE

1.1 INTRODUCTION

This chapter includes the following; back ground to the study, statement of the problem, purpose of the study, objectives of the study, scope of the study which includes the conceptual scope, geographical scope and time scope and finally the significance of the study.

1.2 BACKGROUND

Watermelon (Citrullus lantatus) belongs to the family Cucurbitaceae which includes squash, pumpkin and cucumber to (Raji *et al.*, 2020). It is a popular dessert vegetable; with year-round availability the fruit is generally eaten raw. The fruit is known to be a good source of lycopene and carotenoid. It helps quench the free radicals that contribute to conditions like asthma, atherosclerosis, diabetes, colon cancer and arthritis (Dube, Ddamulira and Maphosa, 2020).

Globally, melon production has continuously risen in the last decade, reaching the current annual production of about 31.2×10^6 tons.(Rabadán *et al.*, 2020)

Presently, Asia accounts for more than 80% of worldwide watermelon production. China being the number one producer accounting for 67.6% worldwide

In Africa, in 2017, watermelon accounted for 5.4% of the harvested area devoted to vegetable production, contributing 5% to world watermelon production. Algeria is the leading watermelon producer in the continent (1.87 million units per year), sixth in the world, contributing 1.6% to worldwide production(Dube, Ddamulira and Maphosa, 2020).

Currently, Africa, as a whole, is the third producer of watermelon in the world (Anonymous, 2019).

In Uganda, the main melon growing areas include; Luweero, Mpigi, Kayunga, Bugerere, Mayuge, Masaka, Mubende, Masindi and Bushenyi, obtaining about 8×10^3 watermelons per acre The main melon species found in Uganda are Sugar baby, Sukari F1, Zuri F1, Galia F1, Charleston Gray, Early Scarlet F1, Crimson Sweet. The sugar baby has large brown seed with black edges thickened towards the apex, about 16 x 9.5mm. The 100 seed weight is about 14g, while Galia F1 seed are smooth, light brown, with a light whitish edge that is not thickened, about 15 x 9mm in dimension. They are mainly found in the Eastern part of Uganda.(Knowledgeable and Watermelons, no date).

The 100 seed weight is about 12g and seed yield ranges between 131 to 1005kg /ha. (Amali, Kortse and Vange, 2013).

Water Melon processing in the industry generates large quantities of by-products that are usually discarded (Mansouri, Mirzabe and Ráufi, 2017). Within those by-products, melon seeds account for 10% of total melon weight.

However, melon seeds are not considered as waste in all regions of the world. In some Arabian countries, they are roasted and directly consumed, and in India they are dried and used to add flavor to traditional dishes and desserts.

The melon seed can be grounded into thick paste for making soup or stew as well as serving as a raw material in the production of margarine, salad, “robo cake”, baby food, livestock feeds, local pomade, soap and its shells can be used as poultry litter. (Asibeluo Imonifewo Stephen and Abu Lukman A., 2015)

Melon seeds are found to be a rich source of proteins (14.9–27.4%), lipids (25.7–30.8%), fiber (19.0–25.3%), carbohydrates (20.8–24.8%), and ashes (3.2–4.8%). Within proteins, melon seeds contain essential amino acids such as phenylalanine, isoleucine, and leucine. The seeds also contain appreciable minerals (Ca, P, Mg, Na, K and Zn).

Despite the large productivity and nutritional potentials of this crop, there has been a hindrance to the use of melon for large scale production of oil and protein sources. This is as a result of inability to shell melon seeds to meet the capacity required for industrial purposes.

One can obtain melon seed oil between values 16.95 and 29.90 g per 100 g (Rabadán *et al.*, 2020) . Significant amounts of tocopherols are reported to be in melon-seed oils. Tocopherols and tocotrienols are part of vitamin E, a potent antioxidant that is reported to protect against cancer and bone, cardiovascular, eye, nephrological, and neurological diseases. the average total tocopherol content in melon-seed oils is variable, with amounts between 270 and 720 mg/kg. (‘• PRODUCTION GUIDELINES • (Citrullus lanatus) agriculture ’, no date).

Oil from the seeds is also used in cooking and incorporated into the production of cosmetics.

In order to increase the economic value of watermelon in Uganda by making good use of the discarded seeds, designing melon seed shelling machine was done basing on the principle of impact force from spinning disc in order to address the problem associated with melon shelling.

In Uganda, Farmers and other users of water melon where to perform melon shelling through cumbersome and wasteful manual methods. The traditional method of shelling which is the oldest method of shelling was in use in the village or rural areas today. Hurling the melon shell can be done with bare hands. These methods appear to be too slow, time consuming, tedious, inefficient and involved drudgery, thus will limit the availability of the product in the market. This has given concern to scientist and researchers in the recent past particularly, since women are the major processors of melon especially at shelling stage. Therefore, taking a careful look at the usefulness of melon seeds, there is a need of efficient means of processing it, so as to increase its economic value, improve the quality of its products and so encourage more farmers to be involved in its growth and production. Processing of melon seeds included; fermentation, washing, drying, shelling and oil extraction.

The aim of this work was to design a melon shelling machine which can effectively shell almost all the species of water melon found in Uganda, with little or no technical skill required for its operation and at a cheap affordable price.

This research therefore was to seek to offer assistance to the teaming population of local melon farmers or traders and medium scale industries involved in the melon business in the quest for a convenient, available and easy method of shelling their melon which in most cases is still being done manually due to either very high cost or unavailability of shelling machines.

1.3 PROBLEM STATEMENT

Farmers and other users of water melon usually perform melon seed shelling through cumbersome and wasteful manual methods. The traditional method of shelling which is the oldest method of shelling will still be in use in the village or rural areas. Hurling the melon shell is done with bare hands. These methods appear to be too slow, time consuming, tedious, inefficient and involved drudgery, thus limiting the availability of the product in the market, hence there is a need of efficient means of processing it, so as to increase its productivity, improve the quality of its products and so encourage more farmers to be involved in its growth and production through The Design and Construction of a Melon Shelling Machine using Locally Available Materials.

1.4 OBJECTIVES

1.4.1 MAIN OBJECTIVE.

To Design and Construct a Melon seed Shelling Machine using Locally Available Materials of a capacity 300gm weight of dry seed to be shelled

1.4.2 SPECIFIC OBJECTIVES.

- ✓ To design different components of Melon Shelling Machine.
- ✓ To fabricate and assemble the different components of a machine.
- ✓ To test for the performance of the prototype.
- ✓ To evaluate the economic analysis of the machine.

1.5 JUSTIFICATION

This proposed project seeks to offer assistance to the teaming population of local melon farmers or traders and medium scale industries involved in the melon business in a quest for a Design and Construction of a simple and efficient Melon Shelling Machine, for shelling their melon. Thus, safeguarding against food insecurity which is in line with the achievement of the second SDG of zero hunger (end hunger, achieve food security and promote sustainable agriculture) (Webintern,2015).

The project was also aimed at reducing too much time consumption, tediousness as well as drudgery in the melon industry hence increasing the farmers earnings from the sale of high-quality shelled melon seeds.

This achieved the first SDG goal of no poverty as well as Uganda’s vision of 2040.

1.6 THE SCOPE AND LIMITATION OF STUDY

1.6.1 Geographical scope

This study was carried out in Masindi district.

1.6.2 Conceptual scope

This project was limited to the Design and Construction of a Melon seed Shelling Machine using Locally Available Materials in Masindi district.

1.6.3 Time scope

The study was carried out for a period of seven months

2 CHAPTER TWO

2.1 LITERATURE REVIEW

This chapter takes into account the important literature related to the description of watermelon and melon seeds, Watermelon production in Uganda, relevant facts about melon seeds (Physical properties and mathematical modeling of melon seeds and kernels), methods employed in shelling melon seeds in the world and different existing melon seed shelling machines.

2.1.1 Description of watermelon and melon seeds.

Watermelon (Citrullus lanatus) is a warm, long-season crop. Watermelons can be grown on a wide range of soil types, Sandy loam rich in organic matter with good drainage is most ideal. Cultivation in heavy textured soils results in a slower crop development and cracked fruits. Soil should have a pH of 6 to 7. Apply lime if soil pH is too low('• PRODUCTION GUIDELINES • (Citrullus lanatus) agriculture ', no date).

Individual plants produce both male and female flowers and fruit size varies from 2 to 14 kg, depending on variety. However, seedless varieties will require pollinators. Watermelon grows as a vine that sends out long runners along the ground. According to (Manual and Beginners, 2015), Watermelons require long, warm growing periods. Bright, hot days (27 – 35°C) and warm nights (16-21°C). Cooler temperatures and excessive rainfall slow growth, maturity and can cause growth abnormalities, poor fruit setting and hollow fruit. High humidity at the time of vegetative growth renders the crop susceptible to various fungal diseases.

The world-wide production is around 19,000,000 tons and by continents the production of melons and other types is as seen below.

TABLE 1: THE WORLD PRODUCTION OF WATER MELON

Continent	Thousand tons	%
Africa	1031	5
Asia	12790	66
Europe	2845	15
North America	2296	12
Oceania	74	-

South America	403	2
Total	19439	100

However the current Global melon production has continuously risen in the last decade, reaching the annual production of about 31.2 × 106 tons.(Rabadán *et al.*, 2020)

The melon seed, generally, has a spherical or anelongate shape with a grayish white hard shell with a white inner kernel, which is soft and oval in shape. These melon seeds, on a dry weight basis, consist of 52.3% of Testa and 47.7% of kernel and moisture content in melon seeds is 54.5%.

According to (Adebayo, 2014),The melon seed is an important source of edible oil, vitamin E, protein, potassium, calcium magnesium, iron and sodium. Its soft cotyledon could have its edible oil extracted (44 to 50% oil content in seed), ground and used for sauces' (36 to 60% protein content in seed), roasted or boiled and eaten.

According to (Milovanovic and Picuric-Jovanovic, 2005) Watermelon seed oil, rich in linoleic acid (~64.5%), is used for frying and cooking in some African and Middle Eastern American countries owning to its unique flavor (Ak o h , C.C, and C.V. N w o s u , 1992).

The analysis of the mineral constituents of the ash showed a significant Mineral Constituents of Melon Seeds.

TABLE 2: THE SIGNIFICANT MINERAL CONSTITUENTS OF MELON SEEDS

Mineral Constituents	Amount (Parts per million-mg/kg)
Iron	42
Calcium	1035
Zinc	39
Copper	17.8
Phosphorus	5200
Magnesium	2100
Potassium	7700

2.1.1 Common varieties of watermelon grown in Uganda.

There are many watermelon varieties all over the world but the major ones in Uganda are:

Sugar baby

Features of the sugar baby watermelon variety:

- Round in shape
- Dark green in color;
- The flesh is red;
- Very sweet
- Average weight is 4 to 5kg per fruit
- Maturity time is 75-85 day

Sukari F1:

Medium to early maturity (90 days) hybrid with good fruit setting ability. Fruits are oblong in shape with an average fruit weight of 7-8 kg - some may grow to up to 12 kg. Rind is light green with dark green stripes. Flesh is deep crimson with good granular texture and high sugar content (12-13%). Has good transport and keeping qualities. Yield up to 20-25 tons/acre. (Knowledgeable and Watermelons, no date),

Zuri F1:

It takes about 90 days after planting. Round fruits weighing up to 12 kg. Strong rind with an attractive fade resistant dark green colour. Bright red flesh with small seeds. Flesh is crispy, sweet solid and delicious. Has good transport and keeping qualities. Yields up to 25-30 tons/acre(Knowledgeable and Watermelons, no date),

Galia F1:

A very popular green-fleshed hybrid which is in great demand in the export market, especially in Europe.

- Resistant to powdery mildew.
- The fruit is round with a small cavity and weighs about 1-1.2 kg.
- The rind is yellow - orange with medium net,

- The flesh is light green, very sweet, aromatic and excellent taste.
- Good shelf life.

Charleston Gray

- This variety has an average weight of 9kg.
- It is late maturing (85-110days)
- It is also the best drought resistant variety.

Early Scarlet F1:

- It is early maturing (about 85 days),
- Weighs up to 12 kg and can yield up to 60 tons per acre.
- It has deep-red flesh and a dark-green striped outer rind

2.1.2 Common Watermelon Growing Areas in Uganda

The fruit is grown in most parts of the country however. it's mostly grown in the following areas.

Luweero, Mpigi, Kayunga, Bugerere, Mayuge, Masaka, Mubende, Masindi, Bushen

2.1.3 Physical properties of seed and kernel for seeds

1. Bulk and real densities of seed and kernel:

The real density is defined as the ratio of a given mass of sample to its real volume which is measured as the increase in 5 ml sodium nitrate solution subjected in a small graduate cylinder of 5 cm3 with accuracy of 0.1 cm3 when the particle was put in the solution (El-Raie et al., 1996). The bulk and real densities of seed and kernel are evaluated as a function of moisture contents(Shieshaa, Kholief and Meseery, 2007). The bulk density is calculated by dividing the mass of bulk of seeds by its volume, which is measured by using a constant volume cylinder as shown in equation 2.0.

$P_b = \frac{M_b}{V_b}$………………………………… (2.0)

Where:

P_b = the bulk density of seed, g/cm3

M_b = mass of the certain quantity of seeds, g

V_b = volume of the same quantity of seeds, cm3

2. Porosity of seed and kernel:

The porosity (ε) of the bulk is the ratio of the volume of internal pores in the particle to its bulk volume and is determined as,

$\varepsilon = (1 - {}^{P_b}/_{P_r})100$

Where:

ε = the porosity of seed melon seeds, % and

P_r = real density of seed melon seeds, g/cm3.

2.1.4 Mechanical properties of seed and kernel:

1. Terminal velocity:

The terminal velocities of melon seed kernel at different moisture contents can be measured using the terminal velocity apparatus. According to Awady and El-Sayed (1994). The air flowed upwards in the tube from the bottom to top and the air velocity at which the major fraction of sample remained suspended was recorded by using an anemometer. Ten replicates were undertaken for each sample.

2. Static friction coefficient and angle of repose:

The static friction coefficient in terms of the repose angle is examined by using the digital apparatus that, designed and fabricated at the Rice Mechanization, Center.

The static friction coefficient (SFC) for seed and kernel is calculated by the equation 2.1.

SFC =tan θ ……….........………...... (2.1)

Where:

SFC = static friction coefficient.

θ = repose angle, degree.

3. Hardness of seed and kernel:

This is the maximum amount of force a sesame seed can withstand without cracking, breaking and bruising. This is helpful in the design of threshing and shelling components.

The hardness of seed and kernel is tested using rigidity tester.

2.1.5 The existing seed melon shelling methods

According to *(Princewill and Ikechukwu, 2018)*,Shelling can be done both manually and mechanically. Here the corresponding techniques of each method are analyzed for strength and weakness in effectively performing the shelling of melon seeds. The factors that limit the wide adoption of the improved methods is also included.

2.1.5.1 Manual method**.**

This is a traditional means of shelling, it does not encourage higher productivity, as it is time and energy consuming.

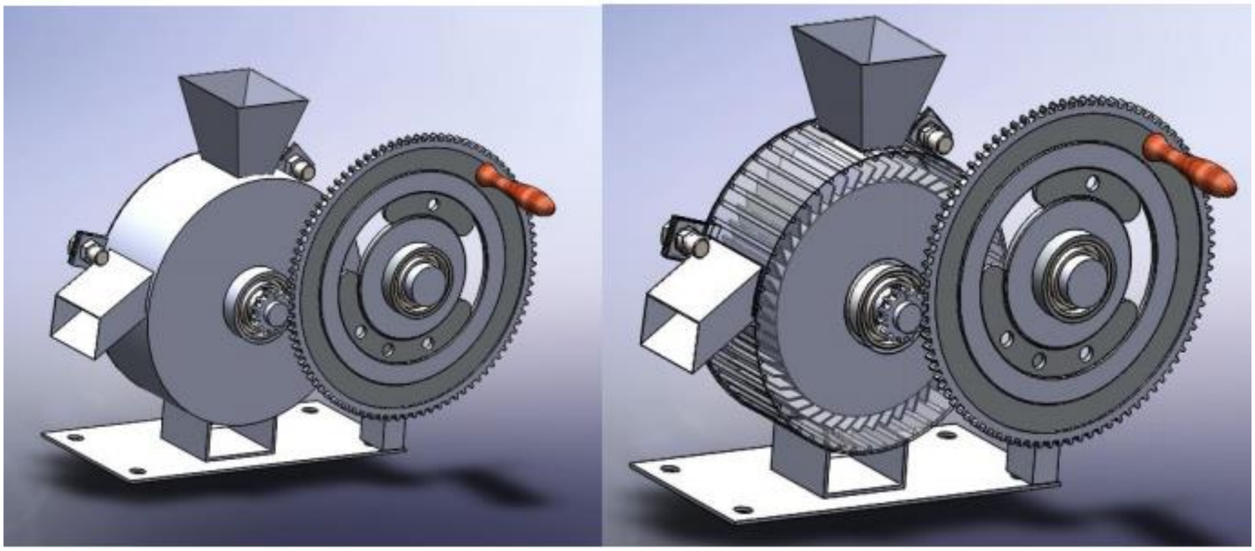
2.1.5.1.1 Manual methods can be by;

- Picking and shelling.
- Bagging and shelling.
- Manually operated melon Sheller.

2.1.5.1.2 Manually operated melon seed shelling machine.

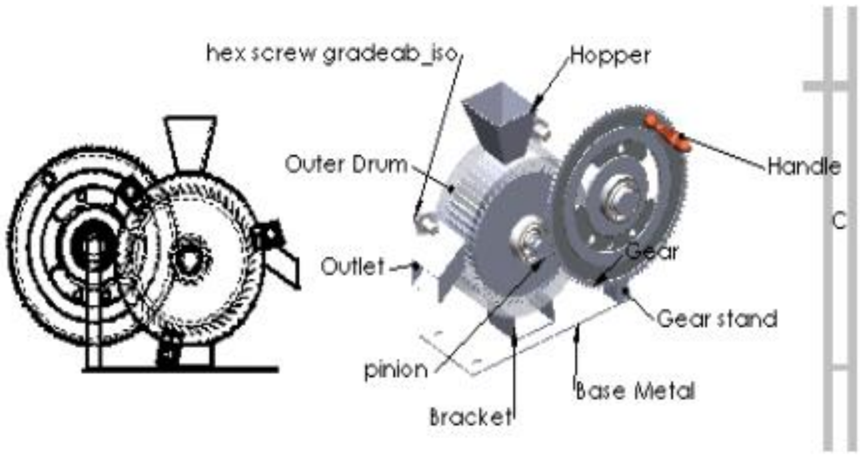
The melon shelling machine consists of three sections, the hopper, the shelling chamber which is made up of the Inner shelling drum and Outer drum and the shaft, the gear system and Base as shown in fig 1. The Inner drum is a cylindrical device which revolves inside the outer drum thereby producing the collision needed for shelling, its surface is lined with fins inclined at an angle of 30 degrees to the surface. It has a detachable shaft fixed at the center, which provides drive for the drum through the drive shaft. Lastly is the chute, where the mixture of melon seed and shell are discharged from.

FIGURE 1:DETAILED DRAWING OF MANUALLY OPERATED MELON SHELLER



Principle of Operation, This Machine has these component parts which are: Hopper, Shelling Unit, Discharge Unit, and Power Source Unit. The working principle of the melon Sheller is hinged on the principle of energy absorption by a seed due to impact (collision) between the seed and a stationary wall which results in the cracking and separation of the seed from its coat. The melon Sheller contains a rotating inner drum moving at a certain speed received from the gear drive sufficient enough to generate a force whose magnitude is high enough to shell the melon seeds. The unshelled melon seeds that are free from dirt, are fed consistently through the hopper into the shelling chamber where the seeds move between a rotating inner drum and a fixed cylindrical ring that encloses the drum. The unshelled seeds which absorb initial velocity coming from the vanes of the rotating drum which rotates anticlockwise. This is to improve the collision of the unshelled seeds with the rough body of the shelling unit (lined with rod weldments), then causing the breakage of the shell and the removal of cotyledon from the coat before getting down the outlet point. These labelled parts are as presented in fig. 2.

FIGURE 2: LABELLED PARTS OF THE MANUAL MELON SHELLER.



Challenges facing manual melon seed shelling machine.

- Manual shelling of melon seeds is labor intensive
- High costs are involved since many people are required
- High post-harvest loses are experienced during the manual shelling and cleaning
- It is an unhygienic form of shelling since it passes through many hands
- It is time consuming.

2.1.5.2 Mechanical (motorized) methods.

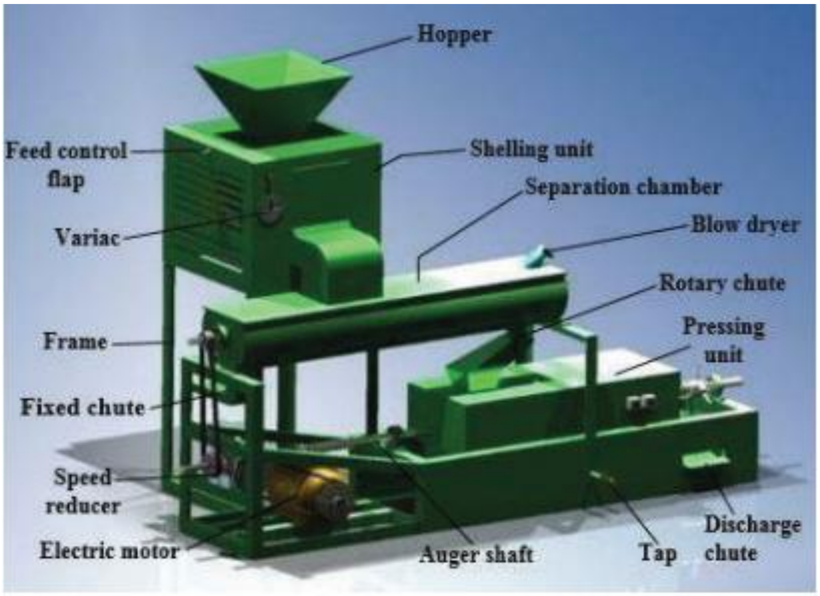
According to *(Asibeluo Imonifewo Stephen and Abu Lukman A., 2015*),several research efforts have been made in designing melon shelling machines. Some of these efforts are reported as follows;

- A melon seed shelling machine which works on the principle of bending by feeding seeds through a set of rollers having ridges on their surfaces
- An impact melon seeds shelling machine that works on the principle of impact force from spinning disc.
- A machine based on principle of friction between a rotating disc and a stationary disc positioned to be parallel to the rotating disc,
- A melon shelling using the principle of extrusion.

2.1.5.2.1 An Integrated Melon Processing Machine.

The integrated melon processing machine shown below comprises of three major units- shelling/dehusking, separating, and pressing units.

FIGURE 3: INTEGRATED MELON PROCESSING MACHINE.



Advantages.

- It has high capacity (kg/hr.).According to to(Onwuka and Nwankwojike, Nduka, 2015),Its melon kernel, flour and oil extraction capacities are 94.4kg/hr., 10.42kg/hr. and 4.67kg/hr. respectively while 93%. 89.3% and 91.5% constitute the respective melon seed shelling, kernel/shell separation and oil extraction efficiencies of the integrated machine.
- it has reduced seed breakage during shelling,
- it has improved hygiene (as human contact with the product during processing is reduced)
- it has also improved on energy saving.
- It has reduced the set-up cost
- It has reduced drudgery
- It has encouraged just in time production in the sector.

Limitation

It is bulky, very expensive and not suitable for small scale production

2.1.6 The extraction process of oil from the melon seeds

- The watermelon seeds are procured from local fruit vendor.
- Seeds are dehulled, winnowed, screened, cleaned and grinded. Crushing the seeds before extraction makes the oil extraction easier and efficient. This process ruptures the cell wall which helps in easy oil release.
- The grinded seeds are then heated in oven for 2 hours at 105 °C until the colour of seeds is off white and to a moisture content of between 7%-9%. Heat treatment also offers the easy oil release by driving moisture out of the seeds. According to *(Athar et al., 2020)*, It can be concluded that the pretreatment of seeds prior to solvent extraction increases the surface area and makes solvent penetration easier which results in effective oil extraction.
- After pretreatment and heat treatment solvent extraction assembly is set up. Benzene, n-hexane and mixed solvent system are utilized for oil extraction.
- The solid to solvent ratio is kept at 1:5. The solvent extraction is done by Soxhlet apparatus.
- Miscella is allowed to cool at room temperature.
- Then distillation of mixture is carried out in order to separate oil and solvent.
- The recovered solvent is measured and is used for next batch whereas; oil obtained after distillation is filtered and weighed

3 CHAPTER THREE

3.1 Methodology

This chapter shows the engineering methods that was used in designing of the various machine components of the melon shelling machine, how the different machine components were selected, fabricated, assembled and operated.

3.1.1 Proposed description of a melon shelling machine**.**

The melon shelling machine worked on the principle of energy absorbed beyond the elastic limit of the melon seeds as a result of impact force experienced during collision between the seeds and the stationery wall which results in the cracking and removal of the seeds shells. Unshelled melon seeds was fed into the machine through the hopper which was opened directly into the shelling unit.

The shelling vanes were welded at an angle of 45° to the shelling disc in order to increase the speed and rate of collision of the unshelled seeds with the rough body of the shelling unit, thereby leading to the breakage and subsequent removal of the melon shells from the cotyledon. The unshelled seeds and the peeled shells were blown out of the shelling vanes through the conveyor chute under gravity and thus separate the cotyledon from the unshelled seeds and peeled shells.

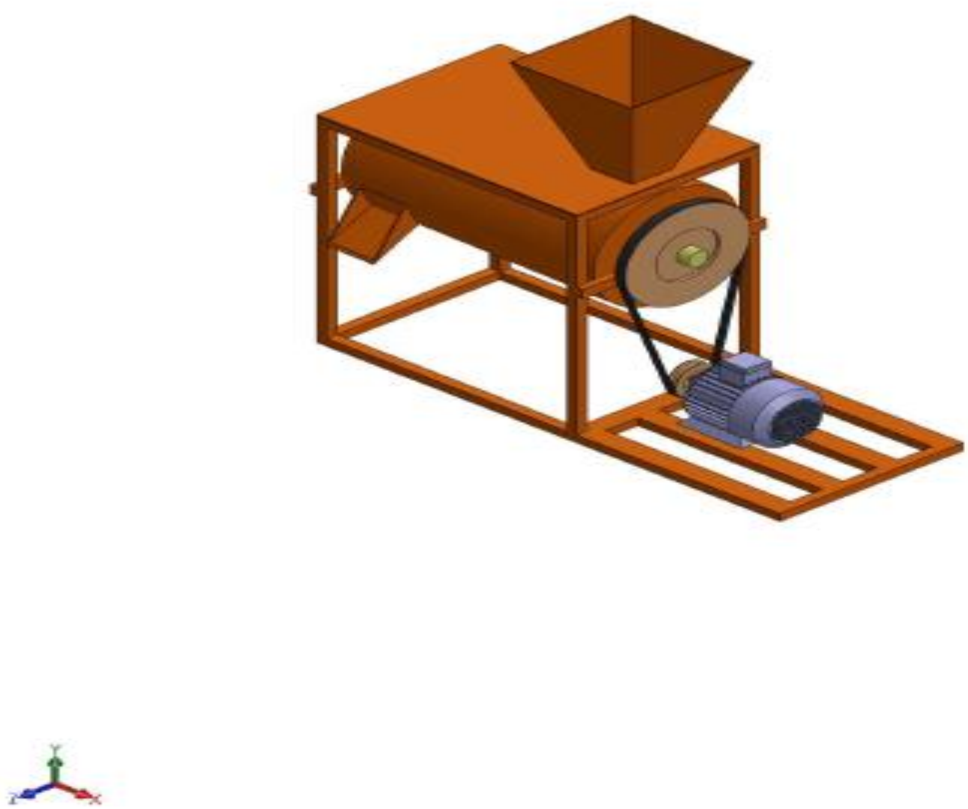
The shelling vanes were welded at an angle of 45° to the shelling disc connected to a shaft powered by an electric motor of one horse power (2hp) which rotates at 1400 r.p.m.

A ball bearing housing and hanger was designed to stabilize the rotary shaft and reduce vibration, thereby preventing collision of the rotating shelling disc with the stationery wall of the shelling drum and in turn reduce the amount of crushed melon seeds.

The machine was designed using locally available materials to meet the low-cost expectation of the farmers. The design was based on considerations of the chemical, mechanical and physical properties of water melon seeds grown in Uganda

3.1.2 Conception diagram of the water melon seed shelling machine

FIGURE 4: CONCEPTION DIAGRAM OF MELON SEED SHELLING MACHINE



3.1.3 Determination of machine capacity**.**

One single feed involved 1000 grams of melon seeds for every 3 minutes,

3.1.4 Criteria for selection of materials.

The following criteria was considered in section of materials in the design and fabrication of a melon shelling machine.

TABLE 3: SHOWING CRITERIA FOR SELECTION OF MATERIALS.

S/N	***MACHINE COMPONENT***	***CRITERIA FOR MATERIAL SELECTION***	***MATERIAL SELECTED***	***REASONS***

1	Hopper and housing	Corrosion resistance, workability, rigidity and lightness	Mild steel	High strength and hardness, easy weldability, ductility, cheaply available
2	Shaft	Machinability, toughness, hardness	Mild steel	Easy of machinability, readily available, cheap
3	Frame	Corrosion resistance, workability and compression and tensile Strength, rigidity	Mild steel	High strength and cost effectiveness
4	Bearing	Axial loading and radial loading	High speed steel	Accommodate both axial and radial loading
5	Pulley	compression forces, Availability	Cast aluminum	Ease of cast, cheap and readily available
6	Belt	Tensile Strength, flexibility	Rubber	Flexibility and strength
7	Shelling chamber (Shelling drum, vanes and disc)	Corrosion resistance, workability and	Mild steel	High strength and hardness, easy weldability, ductility, cheaply

		rigidity		available

3.1.5 Design considerations and assumptions.

In the acquisition of the various materials employed in the fabrication of a Melon shelling machine, the following considerations among others were given attention;

- ✓ Strength: Each component was selected based on its ability to withstand the loads/stresses, torques and frictional forces, it would experience during Melon shelling operation.
- ✓ Ergonomics: The ease with which a machine can be used by different categories of people is a very important consideration in the design of the machine. The Melon shelling machine was designed to aid self-feeding and at a suitable height such that it can be used by people of different heights and gender.
- ✓ physical and aerodynamic properties of melon seeds and the chaff as a falling body was consider`
- ✓ Corrosion resistance: Since the melon seeds that are to be used were moist and wet, corrosion resistance materials were considered.
- ✓ Impact force resistance of melon seeds**.** This was to help in determining the correct torque to apply during the application of impact force on the melon seeds. The impact force resistance of the melon seeds must be must be at least equal to impact force provided by the shelling disc.
- ✓ Economic considerations: This involves cost of the entire machine in terms of the materials of construction, welding, the power requirements, maintenance cost. The machine was designed with minimum power requirements and was be easily disassembled for easy maintenance
- ✓ Availability of materials**:** During designing, the materials from which the machine was constructed was highly considered. The most important material consideration is the availability of the materials in Uganda, thus using materials that are readily available in that environment is an important consideration. The durability of the machine versus the ease of use was considered in the selection of the materials to be used in the in the fabrication of the Melon shelling machine.

3.2 Specific object one.

3.2.1 Design and analysis of the machine components.

3.2.2 The Shelling Chamber.

3.2.2.1 The feed hopper

This was trapezoidal in shape and made of mild steel which was designed in such a way that it was slanting at an angle to allow self-feed (gravity) of pineapples leaves into the shelling discs. The seeds were fed only from the top position.

3.2.2.1.1 Volume of the hopper

$$Volume = \frac{1}{2}[(a+b) \times l] \times H \qquad (3.1)$$

Where;

a and b Are hopper width, l- length of the hopper and H- height of the hopper

3.2.2.2 Shelling drum

The shelling drum was stationary, made from mild steel and the inner part of the drum was lined with rods to make the surface rough hence facilitating breaking of the melon seeds

3.2.2.2.1 Design of the shelling drum.

The shelling drum was designed in a cylindrical format and provide housing for the shelling disc. The shelling drum was subjected to impact forces during the cracking of the melon seeds

3.2.2.2.2 Diameter of the shelling drum.

This was obtained from;

$$d_1 = 2 \times \left(\sqrt[\frac{1}{2}]{h^2 + 2\frac{A}{\pi}} - \frac{h}{2}\right) \qquad (3.2)$$

Were,

d_1 = Diameter of shelling drum

h = length of the shelling drum

A = surface area of the shelling drum.

3.2.2.3 Shelling vanes and shelling disc

The shelling disc was made from mild steel having vanes slots at the edges. The shelling vanes are made from mild steel. They were arranged side by side at an angle of 120° to each other and welded to the shelling disc at an angle of 45°

3.2.2.3.1 Design of the shelling disc

The shelling disc was designed in a cylindrical format to rotate about the axis and it was to utilize the power transferred from the pulleys. The shelling discs was subjected to centrifugal force due to rotation, bending force due to force impact of the melon seeds hence great care should be taken in the design for optimum result.

3.2.2.3.2 Diameter of the shelling disc.

This was obtained from;

$$d_2 = 2 \times \left(\sqrt[\frac{1}{2}]{h^2 + 2\frac{A}{\pi} - \frac{h}{2}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.4)}$$

Were,

d_2 = Diameter of shelling disc

h = length of the shelling drum

A = surface area of the shelling drum.

3.2.2.4 Volumetric capacity of the shelling chamber.

The volumetric capacity of the shelling chamber was determined according to the equation adopted from **Onwualu et al. (2006).**

$$Q_{VC} = \frac{Q}{\rho_m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.5)}$$

Where: Q_{VC} - volumetric capacity of the shelling chamber

ρ_m– density of the melon seeds (kg/m^3)

Q- Capacity of the shelling chamber (kg/h).

3.2.2.5 The rotational force that was to act on the shelling disc.

The rotational force that was acting on the shelling discs was calculated according to the equations adopted fromInvalid source specified.

From $P = 2\pi TN$ …………………….. (3.6)

$$T = \frac{P}{2\pi N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.7)}$$

Where: P- Power required by the shelling chamber (Kw)
T-Torque (Nm), and N- disc speed (rpm)

3.2.2.6 Force required by the shelling chamber

The force required by the shelling chamber was adopted according to the equation from **(Lito, 2012)**

$$F = \frac{T}{R} \qquad (3.8)$$

Where:

F-Force required by the crushing unit s

R-shelling disc radius

T- Torque (Nm)

3.2.3 Design of the shaft.

According to(Natarajan, 2000), a shaft is a circular cross section rotating machine element that transmits power from one machine component to another. This design consists of shelling disc shaft. This shaft was subjected to combined axial load in addition to twisting moment and bending moment hence, it was designed according to the maximum shear stress theorem considering that the shaft was of a ductile material (mild steel).

3.2.3.1 Determination of the Minimum Diameter of the shaft.

The shaft was subjected to combined axial load in addition to combined torsion and bending

To safeguard against bending, axial load and torsion; the minimum diameter of the shaft was calculated according to the equations given from (Khurmi, 2005)

$$d^3 = \frac{16}{\tau_{max}\pi}\sqrt{M^2 + T^2} \qquad (3.9)$$

Where, d = Required diameter of the shaft in m

τ_{max} = maximum shear stress on the shaft(Mpa)

M - Bending moment and T -Torsion

3.2.3.2 Shaft speed.

The speed was found according to the equation adopted from **Gupta and Khurmi, (2005)**

$\frac{D_1}{D_2} = \frac{N_2}{N_1}$ ………………………………………………………… (3.10)

Where: N1 - revolution of the driver pulley (rpm),

N2 = revolution of the driven pulley (rpm),

D_1 =Diameter of driver pulley (m) and D_2 =diameter of driven pulley (m).

3.2.3.3 Power transmitted by the shaft

The power transmitted by the shaft in watts was determined from the following equation according to **Gupta and Khurmi, (2005)**

$Power\ (P) = T\omega = \frac{2\pi NT}{60}$ ……………………… (3.12)

Where: T - Torque transmitted in (Nm), and

ω - Angular speed in (rad/s).

3.2.3.4 Determination of power that was delivered by the Shaft

Power is obtained from the product of force and velocity.

Therefore; $P = Fv = F\omega r$ … … … … … … … ….……… (3.13)

Where $v = \omega r$ ………………………………… (3.14)

$F = force\ (N)$

$\omega = angular\ velocity\ (m/s)$

$r = radius\ of\ the\ pulley\ (m)$

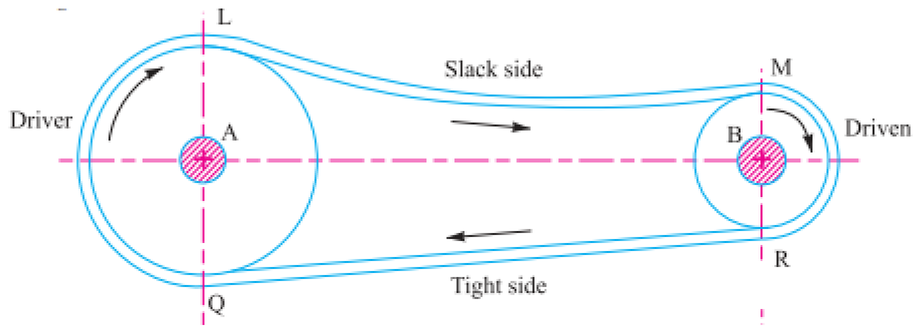
3.2.4 The driving mechanism

These are mechanisms which formed the basic components for operation of the various moveable parts of the machine. These include; pulley-belt, sprocket-chain and gear drive mechanisms do differ in application according to the speed and torque to be transmitted **(Khurmi and Gupta, 2005)**. For this design, a pulley belt drive mechanism of V-type belt mechanism was used

3.2.4.1 The pulley system

This was used to transmit power from the electric motor to the solid shaft connected to the shelling vane.

FIGURE 5: THE ARRANGEMENT OF THE PULLEY AND BELT SYSTEM



Driver Pulley: The horse power rating is given at a maximum pitch diameter of pulleys and the corresponding speeds. The horse power rating of the study was used to determine the diameter of the driver pulley in accordance to **Khurmi and Gupta, (2005)** thus;

3.2.4.2 Diameter of driver and driven pulley

This was determined from the velocity ratio between the driver and the driven pulley as expressed below according to **(Khurmi and Gupta, 2005).**

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \qquad (3.15)$$

Where; N_2 = Speed of the driven pulley (rpm)

N_1 = speed of the driver pulley (rpm)

D_1 = Diameter of the driver pulley (m)

D_2 = Diameter of the driven pulley (m).

Center distance between the pulleys.

This was determined by the following equation as given by (Khurmi and Gupta, 2005)

$$C = \frac{\left(\frac{D_2}{D_1}\right)}{2} + D_1 \qquad (3.16)$$

Where;

C = center distance between the two pulleys

D_1 = Diameter of the driver pulley

D_2 = Diameter of the driven pulley.

And hence the weight of the driven pulley was determined as follows.

$$W = \frac{\pi}{4} D_1^2 t\rho \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (3.17)}$$

3.2.4.3 Speed of the belt.

The belt speed was calculated according to the following formula as stated by (Serate, 2012)

$$V = \frac{\pi D_1 N_1}{60} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (3.18)}$$

Where, V = Belt speed.

D_1- Diameter of the belt (m)

N_1- Speed of rotation of the belt (rpm)

3.2.4.4 Length of the belt

According to **(khurmi et al, 2005),** taking the length to be 1.5% less to sustain the initial tension and is defined as a function of the pulley diameters and the center distance between them. This was calculated using the equation below adopted from (**Khurmi and Gupta, 2005)**.

$$L = \left[\left(\frac{\pi}{2}\right)(D_2 + D_1)\right] + 2C + \frac{[(D_2 - D_1)^2]}{4C} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (3.19)}$$

Where: L- length of the belt.

3.2.4.5 Tension in the belt

This was obtained according to the equation from **Khurmi and Gupta, (2009)** as shown below.

$$2.3 \log \frac{T_1}{T_2} = \mu\theta \operatorname{cosec} \beta \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (3.20)}$$

Where: T_1 - Tension in the tight side of the belt

T_2 - Tension in the slack side of the belt

μ- Coefficient of friction between the pulley and the belt.

Assume the grove angle of the pulley to be $2\beta = 34^0$

Angle of wrap. This was obtained according to the equation adopted from **(deck,1992)**

$$\theta = \left\{180 - 2\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right)\right\} \times \left(\frac{\pi}{180}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.21)$$

3.2.4.6 Torque at the main shaft and power transmitted by the belt

$T = (T_1 - T_2)\ R$ …………………… (3.22)

P= $(T_1\text{-}T_2)$ V …………………… (3.23)

R= Radius of the larger pulley; T1 and T2 is the tension in the tight and slack side respectively.

The power requirement

The power required to drive the machine was calculated using an equation adapted from **Onwualu et al. (2006)** as

$P = \frac{QLg\rho_d}{3.6}$ …………………………………………… (3.24)

Were,

P- Is the power required to drive the machine (W)

L- Is the shaft length in m

ρ_d- is the density of melon seeds in kg/m^3,

g -is the acceleration due to gravity in m/s^2

And the power of the electric motor to drive the system was obtained according to the equation adopted from **Onwualu et al. (2006);**

$P_m = \frac{P}{\eta}$ …………………… (3.26)

Where,

Pm is the power of electric motor in W

η is the efficiency of the motor in decimal.

P is the power required to drive the machine

3.2.5 Bearing selection

Bearing dimension selection was based on the operating load and the bearing's life expectancy requirements(Kharagpur, 2012). The selection of pulley bearings was dependent upon the following factors:

1. The load-carrying capacity and the nature of the load
2. The speed of shafts in revolutions per minute
3. The conditions under which they it operated, such as temperature, dustiness, and acidity.
4. The anticipated life of the bearing
5. Magnitude and direction of loads

3.2.6 Machine frame and supports

The frame and supports of the melon shelling machine was made of mild steel angle bars. They hold the machine, drive and driven assemblies in position and provide points of attachment and stabilizes the system during operation. The machine had four stands made of the same material. It was subjected to the direct weight or load of other members of the machine and also torque and vibration from the impacting force and motor. The desired material for the frame exhibited hardness, adequate toughness and high rigidity.

Then let the weights of shaft, shelling vane, feed hopper, motor, bearings, pulleys, shelling drum, housing, be $W_{sh}, W_{sv}, W_{fh}, W_m, W_b, W_p, W_{sd}, W_h$ respectively.

Assuming each column supports an equal weight, the weight to be supported by one column and compressive stress was determined as shown below according to Khurmi and Gupta(2005).

$F = \frac{total\ weight}{4}$ ……………………………………… (3.27)

Thus; $compressive\ stress, \sigma = \frac{Force\ (F)}{cross\ sectional\ area\ (A)} N/m^2$ ……………………. (3.28)

3.2.7 Design of the Key

A key as a machine element which is used to connect the transmission shaft to rotating machine (Bhandari *et al*., 2007), Keys are made from plain carbon steels in order to withstand shear and compressive stresses resulting from transmission of torque. Flat keys were selected due to their stability as compared to the square keys. For flat, the thumb-rule dimensions are as follows:

$b = \frac{d}{4}$…………………………………… (3.29)

b=width of key (mm)

$h = \frac{2b}{3} = \frac{d}{6}$…………………………… (3.30)

h=height of thickness (mm)

d=diameter of shaft (mm)

$l = 1.5d$…………………………….....…… (3.31)

l = length of the key (mm)

3.3 SPECIFIC OBJECTIVE TWO:

3.3.1 Fabrication and assembly of a melon seed shelling machine.

The fabrication of the machine was done by measuring, marking out, cutting, drilling, machining, welding, assembling, bending, fastening, grinding and painting. These was used for producing the desired components. The materials used for fabrication were selected based on their strength, cost, durability, availability and suitability of the material for the working conditions in service. They were also selected basing on the type of force acting on them, and their chemical and mechanical properties.

3.3.2 Tools and equipment

The different methods employed were accomplished by using various tools and equipment as shown below.

- ❖ Bolts and nuts; they were used in mechanical fastening of separable components.
- ❖ Square, Tape measures or meter rules; they were used to take measures of the materials for specified dimensions especially before cutting.
- ❖ Grinders and cutting disc; they were used to grind and surface finish the welded joints of the components and also for cutting the sheet metal and other parts.
- ❖ Drilling machine; it was used for drilling holes where bolts and nuts were to be fixed.
- ❖ Welding equipment; Involved the use of the welding transformer and welding electrodes corresponding to the material used.
- ❖ Weighing scale to determine the weight of unshelled melon seeds and shelled melon seeds
- ❖ After these processes, the machine was assembled according to the design drawing.

3.4 SPECIFIC OBJECTIVE THREE:

3.4.1 Testing the performance of a melon seed shelling machine

During the testing exercise, the following equipment and materials were used;

- Un-shelled melon seeds, weighing scale, stop clock, collecting basin.
- Data recording instruments (pen and note book).

3.4.1.1 Feed rate *f*.

This was the grams of seeds fed into the hopper in a given period of time. For machine evaluation, the feed rate shall be varied for at least three different levels (f_1, f_2 and f_3)

3.4.1.2 Shelling efficiency, SE (%)

$$SE\ (\%) = \frac{G_T - G_U}{G_T} x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.32)$$

Abubakar and Abdulkadir, (2012)

Where; Gu = Weight of unshelled seeds kg, $G_{T=}$ Weight of unshelled seeds fed into the machine, kg**.**

3.4.1.3 Percentage of damaged seeds, Pb

$$Pb = \frac{Td}{(Td + Tu)} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.33)$$

(PHILIP YAMBA, ATEL., (2017).

Where; Td = weight of cracked and damaged seeds (kg), Tu = weight of uncracked and undamaged seeds (kg)

3.5 SPECIFIC OBJECTIVE FOUR:

3.5.1 Economic analysis of the melon seed shelling machine.

3.5.1.1 Net Present Value (NPV)

Net present value is the sum of the present values of incoming and outgoing cash flows over a period of time. Incoming and outgoing cash flows can also be described as benefit and cost cash flows respectively, discounted at the project's cost of capital and deducting the initial outlay. Decision criteria are to accept a project with a positive net present value.

Net Present Value (NPV) Method evaluates new investments based on discounted cash flows mathematically as the sum of annual cash flows at their present value less the initial outlay amount.

$$NPV = \left[\sum_i^n \frac{cf_i}{(n+1)^i}\right] - i_o \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.34)$$

$$P.I = \frac{NPV}{i_0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.35)$$

Were

NPV = net present value

$\frac{1}{n+1}$ = discount rate

cf_i= future cash flow

n = number of periods

i_0= initial capital investment

$P.I$= Profit index.

Advantages and disadvantages of net present value.

TABLE 4:ADVANTAGES AND DISADVANTAGES OF NET PRESENT VALUE.

Advantages	**Disadvantages**
Takes size of benefit in to account	Needs a decision on the discount rate.
Takes inflation in to account.	Complicated calculations than payback and other method.
Takes project lifetime in to account.	

3.5.2 Expected results

- Well-designed system components for the PALF extracting machine
- Fully fabricated and assembled system components of the prototype
- Results from testing performance of the prototype constructed were obtained
- The economic evaluation results of the prototype wasobtained

4.0 CHAPTER FOUR

4.1 DESIGN CALCULATIONS FOR THE MACHINE COMPONENTS.

Various aspects of design and all the necessary assumptions were made in order to determine the desired dimensions and features of the machine components as presented in the sections that follow.

4.1.1 Hopper

The volume of the hopper was determined by given formula below by

V = 0.5 [(a+b) *h] *L……………………………….(4-1)

V = 0.5[0.34(0.1+0.3)] 0.1

= $6\times 10^{-3} m^3$

4.1.2 Determination of the shelling disc and shelling drum diameter

Watermelon seeds are of irregular shape and usually come in different sizes, shapes and thickness. The maximum watermelon seed length of 10.2 mm, width of 4.80 mm and thickness of 2.94 (Koocheki *et al.*, 2007) were used to determine the space/gap between the shelling drum and shelling discs that constitutes the shelling space so as to enable the watermelon seeds to fit in the shelling space.

Consequently, the shelling disc diameter was selected to be 300 mm and the shelling drum diameter 350 mm with length of 580 mm and 640 mm respectively in order to obtain the shelling.

4.1.3 Weight of the shelling drum.

The shelling drum considered as a cylindrical shape thus its volume is given as:

$V_o =$ [(volume of the cylinder) + (volume of the two circular end plates)]

$V_o = (\pi D_o L_o t_o) + 2\left(t_p \frac{\pi D_p^2}{4}\right)$…………………………….... (4-2)

Where,

$V_o =$ Volume of the shelling drum

$D_o =$ Diameter of the shelling drum, $D_o = 0.35$m,

$L_o =$ Length of the shelling drum, $L_o = 0.64$m,

t_o =The thickness of the shelling drum and abrasive surface, $t_o =$ 0.004m

t_p =Thickness of the two circular end plates of the shelling drum, t_p = 0.002m

From equation (4-2), the volume of the shelling drum (cylinder);

$$V_o = (\pi \times 0.35 \times 0.64 \times 0.004) + 2\left(0.002\,\frac{\pi 0.35^2}{4}\right)$$

$$V_o = 0.0032m^3$$

And thus, the weight of the shelling drum was determined using the formula of weight below;

$W_o = V_o\ \rho_d$g.......................................(4-3)

Where,

W_o - Weight of the empty shelling drum (N)

ρ_d - Density of the material used to shelling drum, ρ_d= 7850kg/m^3

Density of mild steel sheet used to construct the shelling drum; ρ_d= 7850kg/m^3(Khurmi, 2005)

g - Acceleration due to gravity, 9.81 m/s^2

From equation (4-3), Weight of the shelling drum was,

W_o= 0.0032×7850×9.81

W_o= 246.43 N

4.1.4 Weight of the shelling disc.

Since the shelling disc was considered as a cylindrical shape and of mild steel, thus its volume is given as:

$V_i = (\pi D_i L_i t_i) + 2\left(t_p\,\frac{\pi D_i^2}{4}\right)$.. (4-4)

Where

V_i = Volume of the shelling disc

D_i = Diameter of the shelling disc,D_i =0.3m,

L_i =Length of the shelling disc, L_i = 0.58m,

t_i = The thickness of the shelling disc and abrasive surface, t_i = 0.004m

t_p =Thickness of the two circular end plates of the shelling disc, t_p =0.002m

From equation (4-4), the volume of the shelling disc (cylinder);

$$V_i = (\pi \times 0.3 \times 0.58 \times 0.004) + 2\left(0.002\,\frac{\pi 0.3^2}{4}\right)$$

$$V_i = 0.0025\ m^3$$

Thus, the weight of the shelling disc is estimated by;

$W_i = V_i\ \rho_d$g.......................................(4-5)

Where,

W_i - Weight of the shelling disc (N)

ρ_d - Density of the material used to shelling disc, ρ_d= 7850kg/m^3

g - Acceleration due to gravity, 9.81 m/s^2

From equation (4-5), Weight of the shelling disc was,

$$W_i = 0.0025 \times 7850 \times 9.81$$

$$W_i = 192.52 \text{ N}$$

4.1.5 Volume of the space for shelling.

This was estimated by;

V_s = (Solid shelling drum) – (solid shelling disc)

$V_s = \left[L_o \frac{\pi(D_o - t_o)^2}{4}\right] - \left[L_i \frac{\pi(D_i - t_i)^2}{4}\right]$.. (4-6)

$$V_s = \left[0.64\,\frac{\pi(0.35-0.004)^2}{4}\right] - \left[0.58\,\frac{\pi(0.3-0.004)^2}{4}\right]$$

$$V_s = 0.02\ m^3$$

4.1.6 Weight of the watermelon seeds.

Volume of watermelon seeds V_m to be shelled per kg is assumed to be 80% of the volume of the space left between the shelling disc and the shelling drum.

$V_m = 0.8V_s$...(4-7)

From equation (4-7), the volume of seeds to be peeled is;

$$V_m = 0.8\times 0.02$$

$$V_m = 0.016\, m^3$$

And thus, the weight of watermelon seeds was estimated using the equation below;

$$W_m = V_m\, \rho_m \text{g} \text{..(4-8)}$$

Where,

W_m-is the weight of one kg of melon seeds (N)

V_m - Volume of melon seeds in the shelling disc (m^3)

ρ_m -Bulky density of melon seeds in the drum (kg/m^3) From(Koocheki *et al.*, 2007), the bulky density of dry watermelon seeds is 446.4 kg/m^3

Thus, the weight of seeds to be shelled was determined as from equation (4-8)

$$W_m = 0.016 \times 446.4 \times 9.81$$

$$W_m = 70.07 \text{ N}$$

4.1.7 Weight of the shaft.

This is made of Mild steel material and cylindrical Shape, thus from equation below;

$$V_{ss} = \pi \times r^2 \times h_{ss} \text{ .... (4-9)}$$

$$V_{ss} = \pi \times 0.015^2 \times 0.70$$

$$V_{ss} = 0.00049 m^3$$

$$M_{ss} = 0.00049 \times 7800 = 3.8\text{kg}$$

And hence weight W_{ss} =37.28 N

4.1.8 Weight of shelling vanes..

These are made mild steel Material and are rectangular in Shape thus from the equation below;

$$V_V = \text{L}\times W \times H \text{ .... (4-10)}$$

$V_V = 0.3 \times 0.002 \times 0.02 = 0.000012 m^3$

but there are 25 blades, hence $V_V = 0.0003 m^3$

$M_V = 0.0003 \times 7800 = 2.34$kg, Hence,

$W_V = 2.34 \times 9.81 = 22.96$N

4.1.9 Total weight of the shelling chamber (W_c).

Thus The total weight of the shelling chamber and all its content (watermelon seeds, the shelling drum , shelling disc, shelling vanes and the shaft) is determined by;

$W_c = (W_o + W_m + W_i + W_v + W_{ss})$ .... (4-11)

Where;

W_c– Total weight of the shelling drum and its content

Hence from equation (4-11), the total weight of the shelling chamber is

$W_c = (246.43 + 70.07 + 192.52 + 22.96 + 37.28)$

$W_c = 569.26$ N

Neglecting the weight of the shaft, the total weight acting on the shaft (W_T) is determined by

$W_T = (W_m + W_i + W_v)$ .... (4-12)

This implies that the total weight (W_T) of the shelling disc and all its content (seeds) is the force acting on the shaft that drives the whole unit. This was determined by equation (4-12)

$W_T = (246.43 + 70.07 + 22.96)$

$W_T = 531.98$N.

4.1.10 Power required

From; $power = torque \times velocity$.

$power = F \times r \times V$ .... (4-13)

Where,

r- Radius of shelling disc, r =0.15

N - Is the number of revolutions per minute of the shelling disc with shaft = 400 rpm

$V_{shelling\ disc\ with\ shaft} = \frac{2\pi rN}{60}\ m/s$

Thus, V = 12.56 m/s

Thus, from equation (4-12)

$power = 531.98 \times 0.15 \times 12.56$

$power = 1002.25\text{W} \cong 1.002K\text{w}$

Using a power factor of 1.5, power required is 1.5 kw, therefore an electric motor of 2 Hp is selected to power the shelling disc with shaft and shell the seeds

4.1.11 Pulley design and selection

Let:

N_1=Revolution per minutes of Driving pulley (N_1 = 1400 rpm as seen on 2Hp electric motor)

N_2= Revolution per minutes of Driven pulley

D_1 =Diameter of driving pulley

D_2= Diameter of Driven pulley

V_1= Speed in (m/s) of driving pulley

V_2= Speed in (m/s) of Driven pulley

The diameter of driving pulley selected, D_1 = 30mm(Khurmi and Gupta, 2005)

The ratio of the driven pulley outer diameter to that of the driving pulley outer diameter is 3.5:1

Thus, from the equation;

$N_1 D_1 = N_2 D_2$ ………………………………... (4-14)

N_2= 400 rpm

$D_2 = \frac{N_1 D_1}{N_2} = \frac{1400 \times 30}{400}$ = 105 mm = 0.105m

To Obtain Speed of Driving and Driven Pulley

$V_1 = \frac{\pi N_1 D_1}{6O} = \frac{\pi \times 1400 \times 0.03}{60} = 2.199 m/s$

$V_2 = \frac{\pi N_2 D_2}{6O} = \frac{\pi \times 400 \times 0.105}{60} = 2.199 m/s$

Since there is no slip,

$V_1 = V_2 = 2.199 m/s$

4.1.12 Design and selection of the belts.

4.1.12.1 Calculating the center distance between pulleys

The minimum center distance according to(Khurmi and Gupta, 2005)

From, X = $\frac{(D_1 + D_2)}{2}$ + 30mm to 50mm…………………………………... (4-15)

Hence from equation (4-14), the center distance is determined as,

X = $\frac{(30+105)}{2} + 40$ = 107.5mm

Hence, the length of the belt was determined by,

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

L = $\frac{(30+105)\pi}{2} + 2 \times 107.5 + \frac{(105-30)^2}{4 \times 107.5}$

L = 440.14mm

4.1.12.2 Determination of tensions in the belt.

For an open belt,

$sin\ \alpha = \frac{R - r}{x}$………………………………………… (4-16)

Hence from equation (4-16), angle of contact (α) was determined by

$sin\ \alpha = \frac{52.5-15}{107.5}$ = 0.3488

$\alpha = \sin^{-1}(0.3488)$

Thus, the angle of contact

$\alpha = 20.4°$

4.1.12.3 Calculating the wrap angle (θ)

$\theta = 180° - 2\sin^{-1}\left(\frac{52.5-15}{107.5}\right)$

$\theta = 180° - 2×20.4°$

$\theta = 139.2°\ = 2.43$rads

4.1.12.4 Tensions

From equation below

$P = (T_1 - T_2\ )V$

$T_1 - T_2 = 66.072N$…………………………………………….... (4-17)

Also, from the belt tension ratio of an open belt,

$\frac{T_1}{T_2} = e^{\theta\mu}$, $\mu = coeficient\ of\ friction\ between\ belt\ and\ cast\ iro$n pulley=0.3

Thus, $\frac{T_1}{T_2} = e^{2.3×0.3}, \frac{T_1}{T_2} = 1.993$

$T_1 = 1.993\ T_2$ ………………………………………………………… (4-18)

From equation (4-16) and (4-17),

$T_2 = 66.4$N

$T_1 = 132.6$N

4.1.12.5 Force (F) on the shaft due to the tensions in the belts

$F_1 = T_1 cos\ \alpha = 132.6×\ 0.917$

$F_1 = 121.6$N (downwards)

$F_2 = T_2 cos\ \alpha = 66.4×\ 0.917$

$F_2 = 60.9$N (upwards)

$Resultant\ force,$

$F = F_1 - F_2 = 60.7\boldsymbol{N}\ (\boldsymbol{downwards})$

4.1.12.6 Belt selection

According to (Khurmi and Gupta, 2005), selection of v-belts depends on the following factors power transmitted

i) Speed of the belt.

ii) Material of the belt

iii) Length of the belt

iv) Service factor

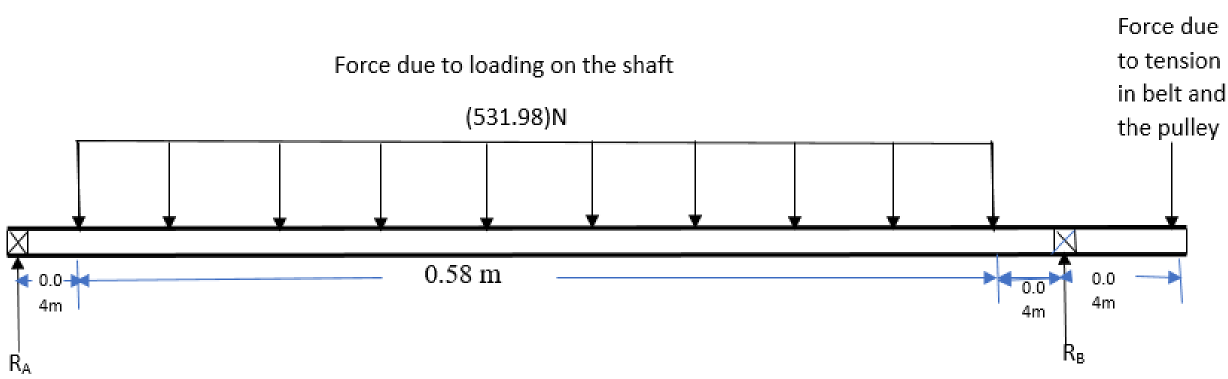
4.1.13 The shaft

The shaft is a round solid made of mild steel of ASME code of 40C8. Deflection is typically the design limiting issue. The theory according to(Khurmi, 2005) is appropriate for shafts subjected to combined bending and twisting moments. The shaft used in the machine is made of mild steel because they are ductile with high strength (shear stress).

4.1.12.2 Determination of forces acting on the shaft.

It is estimated that the total weight of the shelling disc and the seeds calculated above to be the force acting on the shaft. Considering that it is a uniformly distributed load as from the drawing

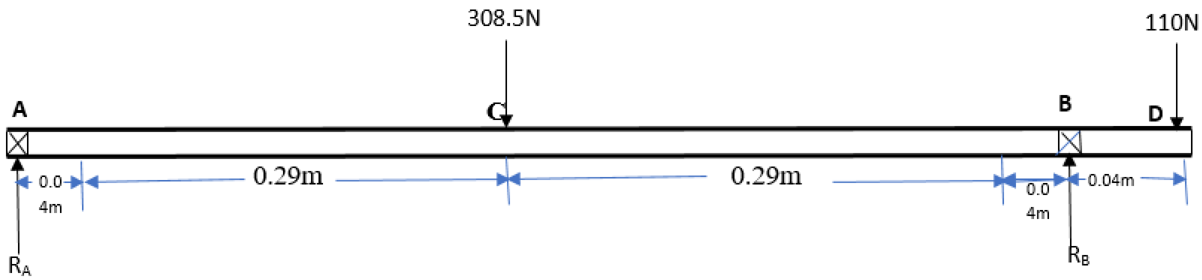
a) Loading conditions of the shaft



b) Free body diagram of the shaft

Assumptions taken.

1. Weight of the shaft is considered negligible.
2. All UDLs were made point loads at their centres of action



4.1.12.3 Determination of maximum bending moments

Solving for the vertical components of the bearings

$+\uparrow \Sigma F_y = 0$

$R_A + R_B = (308.5 + 110)$ ………………………………………….. (1)

Taking moments about bearing A

$M_{RA} = 0$

$0.33 \times 308.5 + 110 \times 0.7 = R_B \times 0.66$…………………………………………………... (2)

Thus, from equation (1) and (2),

$R_B = 270.9N$

$R_A = 147.6N$

Taking –ve for downward and +ve for upward moments

$M_A = 0$

$M_B = 0$

$M_C = 147.6 \times 0.33$

$M_C = 48.71$Nm (Upwards)

$M_D = 147.6 \times 0.70 - 308.5 \times 0.37 + 270.9 \times 0.04$

$M_D = 0.025$ Nm (downwards)

Therefore, maximum bending moment is 48.71 Nm at point C

4.1.12.4 Torque transmitted to the shaft

Torque transmitted to the shaft is given by;

Torque= $\frac{P60}{2\pi N}$ .... (4-19)

Where;

P – Power of the motor

N – Number of revolutions of the shaft

From equation (4-19); the maximum torque to be transmitted to the shaft is determined as;

Torque= $\frac{1002.25 \times 60}{2\pi \times 400}$

Torque=23.93Nm

4.1.12.5 Estimated shear stress in the shaft

This was determined using the formula

$\tau_{max} = \frac{S_{yc}}{fos} = \frac{0.5S_{yt}}{fos}$ ....(4-20)

Where;

τ_{max} – Maximum shear stress (N/m^2)

S_{yc} - Compressive yield strength of the shaft (N/m^2)

S_{yt} - Yield strength of the shaft (N/m^2)

fos - Factor of safety

From equation (4-20) and according to (Khurmi, 2005) a shaft of mild steel 40C8 has yield strength of S_{yt} 400N/mm^2 and factor of safety 2 to 4. Taking an average of 3,

The maximum shear stress was calculated as;

$\tau_{max} = \frac{S_{yc}}{fos} = \frac{0.5 \times 400}{3}$

$\tau_{max} = \frac{66.67\text{N}}{mm^2}$.

4.1.12.6 The shaft diameter

This was determined by;

$D_s^3 = \frac{16}{\pi \tau_{max}} \sqrt{(M^2 + T^2)}$..(4-21)

Where,

D_s = Diameter of the shaft (m)

τ_{max} = Maximum Shear stress (N/m^2)

M = Maximum bending moments (Nm)

T= Maximum Torque (Nm)

Thus, from equation (4-21),

$$D_s = \left(\frac{16}{\pi \times 66.67 \times 10^6} \sqrt{(48.71^2 + 23.93^2)}\right)^{\frac{1}{3}}$$

$$D_s = 0.02\text{m}$$

But the standard value that was used is 0.03m as shaft diameter since they range from 0.025 and 1m (Kharagpur, no date)

4.1.12.7 Design of the appropriate length (L) of Keys in the shafts

$\boldsymbol{l} = \frac{\pi d}{2}$ =1.57d…………………………………………………... (4-22)

$\boldsymbol{l} =$ 0.04m, = 4cm

4.1.13 Design for the main support frame.

4.1.14.1 $\boldsymbol{F}orce\ (F) on\ each\ support$

From the equation;

$$F = \frac{(\text{total weight on the frame}(W_T))}{(\text{Number of supports(n)})}$$ ……………………………………………………… (4-23)

$n = 4$ and

$W_T = (W_o + W_m + W_i + W_{ss} + W_v + W_{bearing} + W_{pulley})$

W_T = (246.43+70.07+192.52+37.28+22.96+ 5.886+49.05)

W_T = 624.2N

Thus, from equation (4-22),

$\boldsymbol{F}orce\ (F)$ on $each\ support = \frac{624.2}{4}$ =156.05 N

4.1.14.2 $Cross\ sectional\ area\ of\ the\ support$

A = L× W…………………………………………………… (4-24)

$A = \left(\frac{5}{1000}\right) \times \left(\frac{5}{1000}\right) = 0.000025m^2$

4.1.14.3 $Compressive\ stress.$

$$\sigma = \frac{\text{Force (F)}}{\text{Cross sectional area (A)}}$$ ………………………………………………………… (4-25)

$\sigma = \frac{111.35}{0.000025} = 4.454 MN/m^2$

4.2 Fabrication and assembling of the Prototype

Basing on the design details of the components and the selected materials, the prototype was fabricated using various methods; say welding, cutting using hacksaw, machining, etc. Each component of the machine was fabricated separately before they are joined or welded together as the case may be. The components that were fabricated include; the hopper, the shelling chamber and the supporting base.

The following are the expected procedures of fabrication of each component of the machine and the final assembly;

4.2.1 Fabrication of the Hopper

The hopper is made up of four welded mild steel metal sheet slanting toward the smaller opening.

The following procedures were carried out to come up with the hopper;

i. The mild steel metal sheet was measured and marked out with the aid of tape measure, set square, steel rule and scriber.
ii. An allowance of 10mm was given on all edges of the sheet to cater for hemming.
iii. Cutting was done with a shearing machine, chisel and hammer.
iv. The cut-out sheet was later folded and thereafter welded using manual arc welding machine. See fig1b.
v. Grinding was done to remove the sharp edges of the cut metallic parts and for smoothening the welded surfaces preparing them for painting.

4.2.2 Fabrication of the Shelling Chamber

The shelling chamber consists of the shelling drum, the shelling vanes and shelling disc.

4.2.2.1 The shelling drum.

The shelling drum was made from mild steel which was;

i. Measured and marked out with the aid of tape measure, set square, steel rule and scriber.
ii. Given an allowance of 10mm on all edges of the sheet to cater for hemming.
iii. Cutting was done with a shearing machine, chisel and hammer.
iv. The cut-out sheet was later folded and thereafter welded using manual arc welding machine.
v. The inner part of the drum is lined with ¼ inch rods.

vi. Grinding was done to remove the sharp edges of the cut metallic parts and for smoothening the welded surfaces preparing them for painting.

4.2.2.2 The shelling disc

The shelling disc was made from mild steel and with vanes slots at the edges. And the following procedure was carried out during the fabrication;

i. The mild steel metal sheet was measured and marked out with the aid of tape measure, set square, steel rule and scriber.
ii. An allowance of 5mm was given on all edges of the sheet to cater for hemming.
iii. Cutting was done with a shearing machine, chisel and hammer.
iv. The cut-out sheet was later folded and thereafter welded using manual arc welding machine.
v. Grinding was done to remove the sharp edges of the cut metallic parts and for smoothening the welded surfaces preparing them for painting.

4.2.2.3 The shelling vanes

This are made from mild steel. They are arranged side by side at an angle of 120° to each other and welded to the shelling disc at an angle of 45°. The following procedure was carried during the fabrication process;

i. The mild steel metal sheet was measured and marked out with the aid of tape measure, set square, steel rule and scriber.
ii. An allowance of 1mm was given on all edges of the sheet to cater for hemming.
iii. Cutting was done with a shearing machine, chisel and hammer.
iv. The cut-out sheet was later folded and thereafter welded using manual arc welding machine.
v. Grinding was done to remove the sharp edges of the cut metallic parts and for smoothening the welded surfaces preparing them for painting.

The shelling chamber incorporates an opening at the bottom part which serves as an outlet for the shelled melon seeds.

4.2.3 The shaft

A shaft of diameter 3 cm was measured and cut out from a solid mild steel shaft

4.2.4 Electric Motor

The electric motor is used to transmit power or rotational motion to the shelling disc through its protruding shaft with the aid of a key that fastened them together. The power rating of the electric motor is 1hp. The electric motor was bought already made from the market.

4.2.5 Fabrication of the Frame and Supporting Base

The frame is the structure that holds all the components together. It was constructed with 25mm square hollow pipe with 2mm thickness and metal plate of 450mm by 375mm with 3mm thickness. The metal plate was welded to the frame after measurement and cutting it to size.

The base is the structure that supports the electric motor and the shelling chamber to the frame. The base was constructed with flat bars of 35.5mm with 3mm thickness. 12mm rods of different length were used to braze the shelling drum and the electric motor to the frame to reduce vibration and enhance rigidity.

4.2.6 Assembling Of Parts

After all the components have been fabricated, the following steps were taken to assemble the machine.

i. The electric motor with a protruding shaft at one end was installed on the base by the use of clamps
ii. The next step was to fix the shelling drum on the base. This was achieved by using the appropriate welding electrodes and welding shield/helmet to weld the shelling drum to the base. The shelling drum houses the shelling disc with a shaft fastened to the electric motor by the help of the key, pulleys and bearings. The bearings are attached to the frame by the help bolts and nuts after the drilling process
iii. Using manually operated arc welding machine, the hopper was welded to the shelling pot in such a manner that permits smooth flow of unshelled melon seeds into the shelling chamber.
iv. Polishing was done to clear off the roughness on the surface of the machine using sand paper to create a fine finish.

v. Painting was done after polishing and was aimed at making machine look good and attractive as well increasing the machines life span.

4.3 Testing of the machine

The fabricated machine was tested to know how much can be shelled within a given period of time, so as to examine the machine performance.

During testing, the following procedure was followed.

i. The seeds to be shelled were weighed and total weight was recorded for each trial.
ii. The machine was then set to run.
iii. The seeds were then loaded in the shelling drum through the hopper.
iv. In each machine trial after thorough shelling, the seeds were then reweighed and recorded separately basing on the following,
    - Weight of dry seeds to be shelled (gm)
    - Weight of completely shelled seeds (gm)
    - Weight of unshelled seeds (gm)
    - Weight of partially shelled and broken seeds (gm)
    - Weight of crushed seeds (gm)
v. The results obtained from the three trials were then tabulated in the table below

TABLE 5: RESULT OF SHELLING TEST OPERATION

S/N	Weight of dry seeds to be shelled (gm)	Weight of completely shelled seeds(gm)	Weight of unshelled seeds(gm)	Weight of partially shelled and Broken seeds (gm)	Weight of crushed seeds (gm)	Efficiency (%)
1	125	63	30	25	7	50.4
2	190	134	28	23	5	70.5
3	250	205	21	19	5	82

Average percentage performance $= \frac{50.4+70.5+82}{3} \quad = 67.6\%$

4.4 Economic analysis.

4.4.1 The project budget

TABLE 6: THE PROJECT BUDGET

S/N	PARTICULARS	TYPE	QUANTITY	UNIT COST	AMOUNT(Shs)
DATA COLLECTION					
1	Transport				200,000
	Subtotal 1				**200,000**
CONSTRUCTION AND ASSEMBLY OF DIFFERENT MACHINE PARTS					
2	Belt	Rubber	1		20,000
3	Bearings		2	15,000	30,000
4	Welding rods	Gauge 10	2kgs	30,000	60,000
5	Angle bars	40*40*2mm	6	30000	180,000
6	Hiring a motor		1		75,000
7	Shaft	Mild steel	1	50,000	50,000
8	Paint		1	15,000	15,000
9	Pulley keys		1	10000	10,000
10.	Mild steel plates		1	220,000	220,000
11	Bolts and nuts		1kg	10,000	10,000
12	Hiring labor			150,000	150,000

	Subtotal 2				820000
TESTING THE PERFORMANCE OF THE MACHINE					
13	Unit testing				30000
14	Whole system testing				40000
	Subtotal 3				**70,000**
PROJECT REPORT PREPARETION					
15	Printing and binding of document				60,000
16	Communication(airtime)				20,000
17	Internet.				30,000
	Subtotal 4				**110,000**
	Grand total.				**1,200,000**

4.4.2 Determination of variable costs

Total initial investment = 1,200,000***UGX***

Operating costs

- **Electric power consumed**

- 0.69177kwh is to be used by the shelling machine
- The shelling machine is to be operated for 8 hours working days

1kwh of power costs 750.9UGX

0.69177kw of power costs 519.45UGX

Cost of electric power consumed in 8 hours = (8×519.45) = 4,155UGX

Cost of electric power consumed in a week = (5×4155) = 20,778UGX

Cost of electric power consumed in a month = $(20{,}778 \times 4)$ = 83,112UGX

Cost of electric power consumed in a year = (83,112×12) = 997,344UGX

Cost of electric power consumed in 5 years = (997,344×5) = 4,986,720UGX

Determining labor costs

Assuming 10000 per hour and that 3 people are employed**.**

Labor costs in 8 hours = (8$\times$ 3×1000) = 240,000UGX

Labor costs in a month = (240,000$\times$ 20) =4,800,000UGX

Labor costs in a year = (4,800,000$\times$ 12) =57,600,000UGX

Labor costs in 5 years = (57,600,000$\times$ 5) =288,000,000UGX

4.4.3 Determining savings.

Each kg of shelled watermelon seeds costs 11,737.7UGX.

24kg can be shelled in one day (each kg is shelled for 20minutes) =281,704.8UGX

In one month = (20$\times$ 281704.8) = 5,634,096UGX

In one year = (5,634,096$\times$ 12) = 67,609,152UGX

Savings

Savings per month = 5,634,096 – (83,112+4,800,000) = 750,984UGX

Savings per year = 67,609,152 - (997,344 +57,600,000+120,000) = 8,891,808UGX

Savings after 5 years = (8,891,808×5) = 44,459,040UGX

Maintenance costs

This includes all the activities and actions carried out on the melon seed shelling machine to maintain it in proper working conditions. Taking the maintenance costs to be 10% of the initial investment per year

$Maintenance\ cost\ in\ the\ first\ year$= ($\frac{10}{100} \times 1{,}200{,}000$) =120,000UGX.

Taking $interest\ rate,\ i$ to be 4% for five years, to calculate the future maintenance costs as in the table

$$FV = PV(1+i)^n$$

TABLE 7: CALCULATION OF THE FUTURE MAINTENANCE COST

Maintenance	Present maintenance value(PV)	Future maintenance value(FV)

1	120,000	124,800
2	124,800	134,983.68
3	134,983.68	151,838.28
4	151,838.28	177,629.31
5	177,629.31	216,113.22

4.4.4 Calculating the salvage value

The system is assumed to be depreciating at a rate of 25% per annum, and the table below indicates the salvage value after 5 years.

TABLE 8: CALCULATION OF THE SALVAGE VALUE

Year	Historical cost	Depreciation	Netbook worth
0	1,200,000	0	1,200,000
1	1,200,000	300,000	900,000
2	900,000	225,000	675,000
3	675,000	168,750	506,250
4	506,250	126,562.5	379,687.5
5	379687.5	94,921.9	284,765.6

Salvage value=UGX 284,765.6

4.4.5 Calculating NPV

The cash flows (CFs) calculated in the previous section are given as;

1. Initial investment = 1,200,000 UGX

2. Electricity, labor and maintenance costs = (4,986,720+ 288,000,000 +216113.22) = 34,002,833.22UGX.

3. Savings = 44,459,040 UGX.

4. Salvage value = 284,765.6 UGX.

Present value= $CF * Discounting\ factor = CF \times (\frac{1+i)^n-1}{i(1+i)^n})$, for cumulative PVF (series cash flow).

Present worth (PW) of salvage value = $CF \times PVF = \times CF \times (\frac{1}{(1+i)^n})$

Interest rate, i=4% f=2.05%

I = $\frac{(1+i)}{(1+f)} = \frac{(1+0.04)}{(1+0.0205)} = 1.019\%$

TABLE 9: CALCULATION OF THE NPV

Year	Narrative	CF(UGX)	DF	PV
1	Initial investment	1,200,000	1	1,200,000
1-5	Savings	44,459,040	0.9521	42,329,451.98
1-5	Costs	34,002,833.22	0.9521	32,374,097.51
5	Salvage value	284,765.6	0.0298	8,486.01
NPV				8,763,840.48

4.4.6 Profitability index (P.I).

This was used to indicate the rate of return of the project on every investment.

$$P.I = \frac{Net\ present\ value}{initial\ investment}$$

$$= \frac{8{,}763{,}840.48}{1{,}200{,}000}$$

$$= 7.30$$

4.4.7 Payback period

$$\text{Simple payback} = \frac{\text{Project investment cost}}{\text{Total annual saving}}$$

$$= \frac{1{,}200{,}000}{8{,}891{,}808}$$

$$= 0.135 \text{ years}$$

Therefore, the time required to recover our original investment through the annual savings realized is approximately 2 months.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

- A simple and affordable melon seed shelling machine was designed, constructed and tested to examine its performance.
- The machine was able to attain a shelling efficiency of 68.7% after testing it at the different trials.
- The overall performance of the machine was moderately effective compared to existing manual methods of peeling.
- The cost of production and maintenance is relatively cheap; hence, the machine could be welcomed by local processors given its performance

5.2 RECOMMENDATIONS

- At the end of this project work and research, some loopholes were discovered which anybody interested would improve for more efficiency.
- It is recommended that a proper clearance is obtained to ensure that the seeds are impacted on the drum so as to achieve a better efficiency.
- It is recommended that the inside abrasive surface of the outer drum is made rough so as to help in the breaking of seeds.
- A separation mechanism of the chaff from the cotyledon should be incorporated to reduce on the labour costs.
- Due to time constraints and finances, it was not possible to make further research on the other types of seeds (white small ones). It is recommended that further research work be encourage towards this line since the small white melon seeds are very common as compared to the big black ones.

6 References

'• PRODUCTION GUIDELINES • (Citrullus lanatus) agriculture ', (no date).

Adebayo, A. (2014) 'The Design , Construction and Testing of Water Mellon Sheller THE DESIGN , CONSTRUCTION AND', (November).

Amali, E. P., Kortse, P. A. and Vange, T. (2013) 'Matsum and Nakai seeds derived from fruits harvested at different growth stages and at different positions on the mother plant', *International Journal of Scientific and Research Publications*, 3(4), pp. 1–7.

Asibeluo Imonifewo Stephen and Abu Lukman A. (2015) 'The Design and Construction of a Melon Shelling Machine using Locally Available Materials', *International Journal of Engineering Research and*, V4(03), pp. 311–316. doi: 10.17577/ijertv4is030375.

Athar, S. *et al.* (2020) 'Watermelon Seed Oil : Its Extraction , Analytical studies , Modification and Utilization in Cosmetic Industries', *International Research Journal of Engineering and Technology*, pp. 2862–2865. Available at: www.irjet.net.

Dube, J., Ddamulira, G. and Maphosa, M. (2020) 'Watermelon production in Africa : challenges and opportunities Watermelon production in Africa : challenges and opportunities', *International Journal of Vegetable Science*, 00(00), pp. 1–9. doi: 10.1080/19315260.2020.1716128.

Kharagpur, I. I. T. (no date) 'bearings Lesson'.

Khurmi, R. et al (2005) *Khurmi, R. et al.; Theory of Machines , 14th ed.; S. Chand & Co. Ltd., New Dehli 2005; ISBN 9788121925242*.

Knowledgeable, B. and Watermelons, A. (no date) 'A Farmer's Guide To Permits', pp. 1–18.

Mansouri, A., Mirzabe, A. H. and Ráufi, A. (2017) 'Physical properties and mathematical modeling of melon (Cucumis melo L.) seeds and kernels', *Journal of the Saudi Society of Agricultural Sciences*, 16(3), pp. 218–226. doi: 10.1016/j.jssas.2015.07.001.

Manual, W. and Beginners, F. O. R. (2015) 'Watermelon manual for beginners'.

Milovanovic, M. and Picuric-Jovanovic, K. (2005) 'Characteristics and composition of melon seed oil', *Journal of Agricultural Sciences, Belgrade*, 50(1), pp. 41–47. doi: 10.2298/jas0501041m.

Natarajan, R. N. (2000) 'Machine design', *Handbook of Machinery Dynamics*, (I), pp. 11–28.

doi: 10.1038/042171a0.

Onwuka, O. S. and Nwankwojike, Nduka, B. (2015) ‘Design and Development of Integrated Melon Processing Machine’, *Innovative Systems Design and Engineering*, 6(12), pp. 41–52. Available at: www.iiste.org%0ADesign.

Prince, N. C. and Ikechukwu, M. K. (2018) ‘Design and Performance Evaluation of Manually-Operated Melon Sheller Available online www.jsaer.com Journal of Scientific and Engineering Research , 2018 , 5 (1): 70-78 Design and Performance Evaluation of Manually-Operated Melon Sheller’, (July).

Rabadán, A. *et al.* (2020) ‘From by-product to the food chain: Melon (cucumis melo l.) seeds as potential source for oils’, *Foods*, 9(10), pp. 1–11. doi: 10.3390/foods9101341.

Raji, O. *et al.* (2020) ‘THE FEDERAL POLYTECHNIC ILARO SCHOOL OF ENGINEERING 4TH NATIONAL CONFERENCE’, (October).

Shieshaa, R. A., Kholief, R. and Meseery, A. A. El (2007) ‘A study of some physical and mechanical properties of seed melon seed’, 24(July), pp. 575–592.

7 APPENDICES

FIGURE 6: ASSEMBLING OF THE SHELLING CHAMBER

FIGURE 7: INSTALLATION OF PULLEY BELT

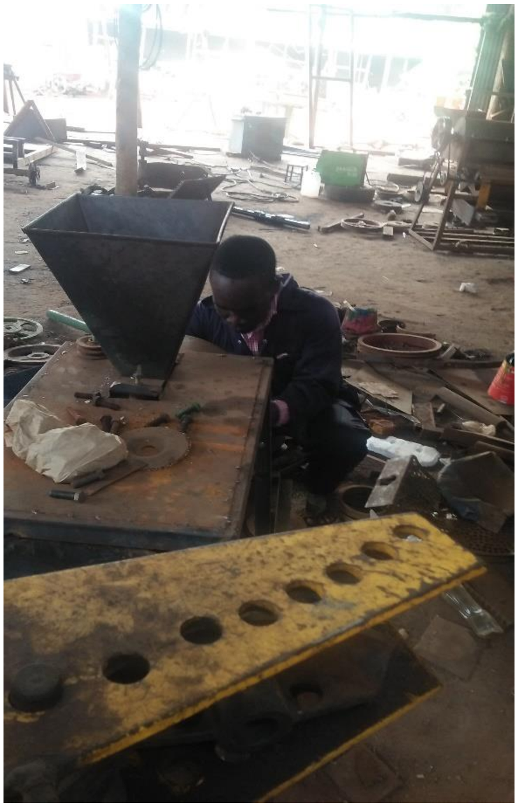
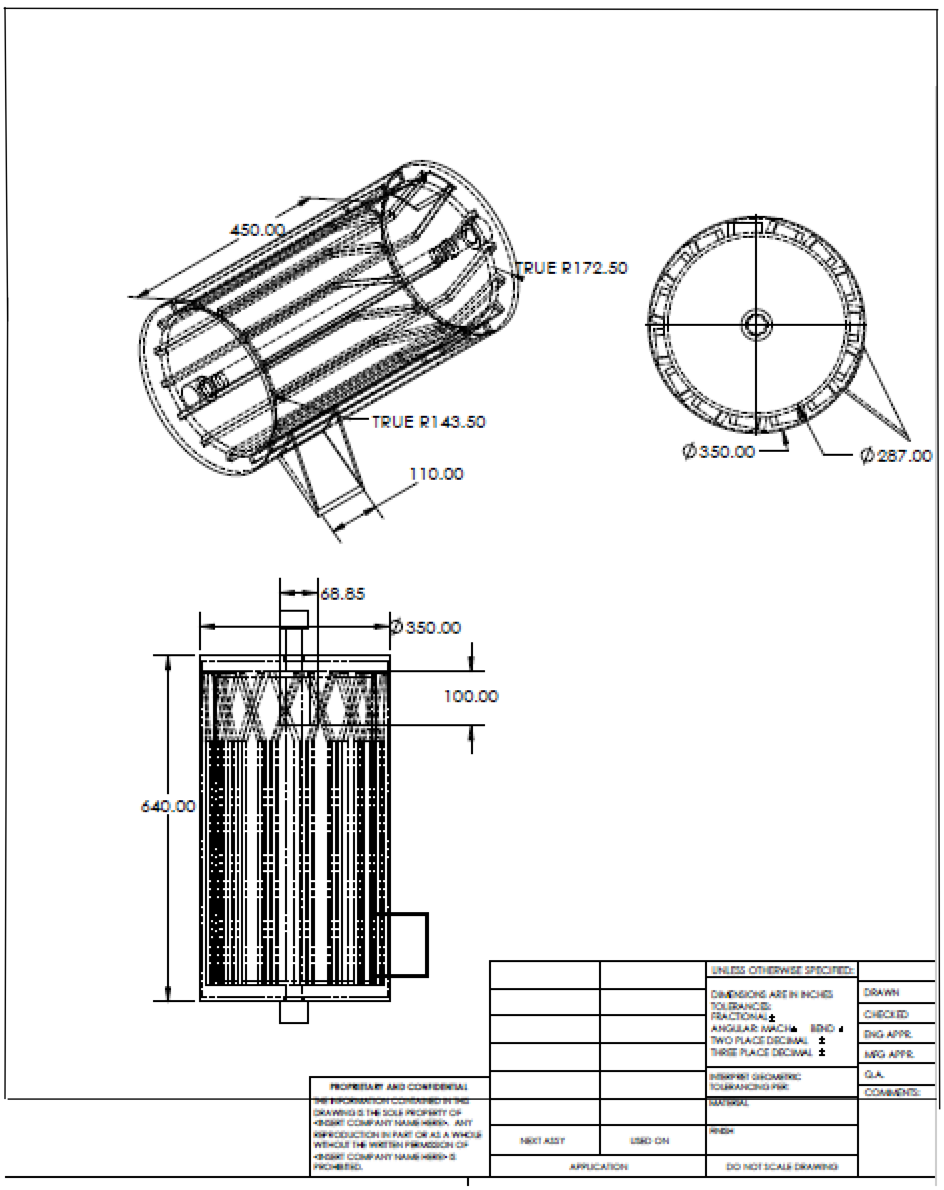
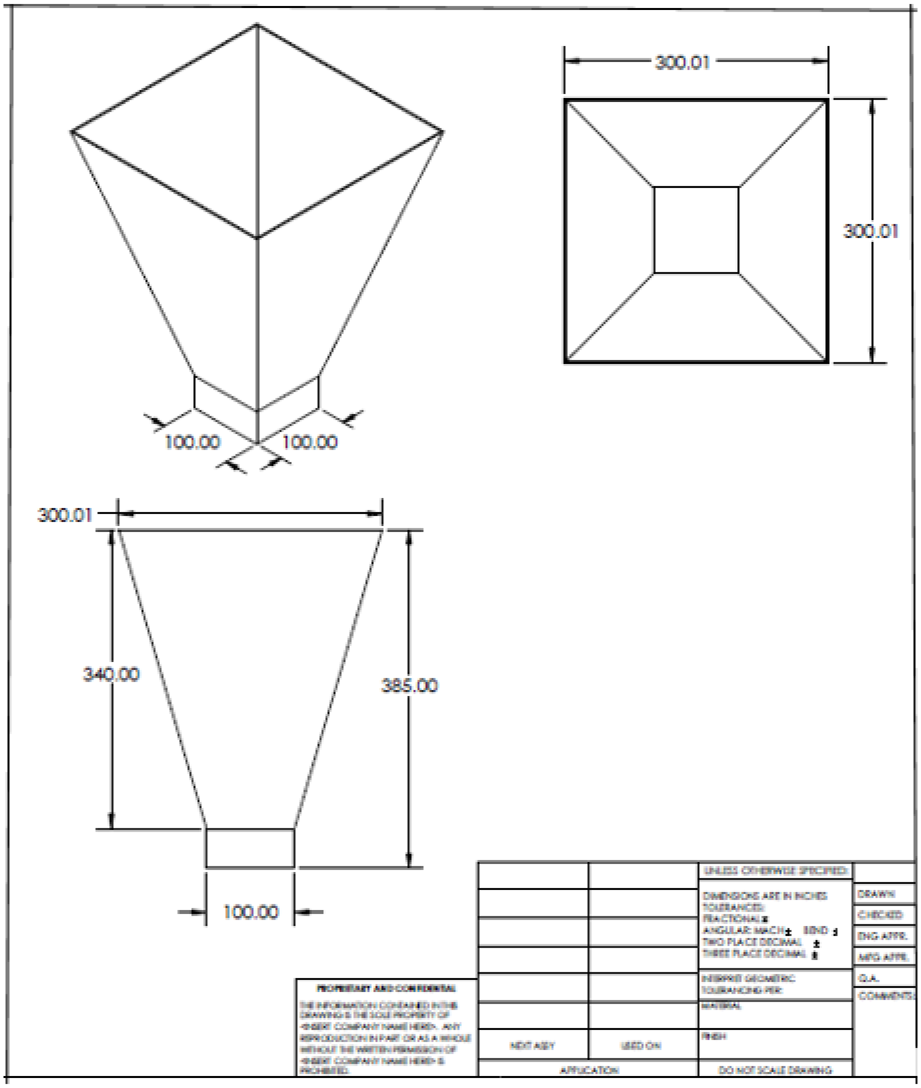


FIGURE 8: ENGINEERING DRAWING OF THE SHELLING CHAMBER





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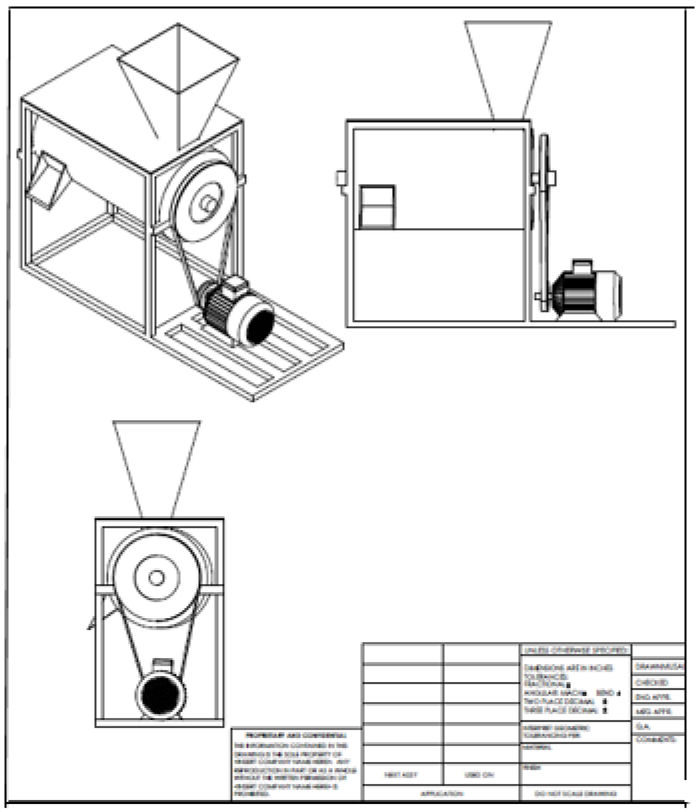
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APPLICATION
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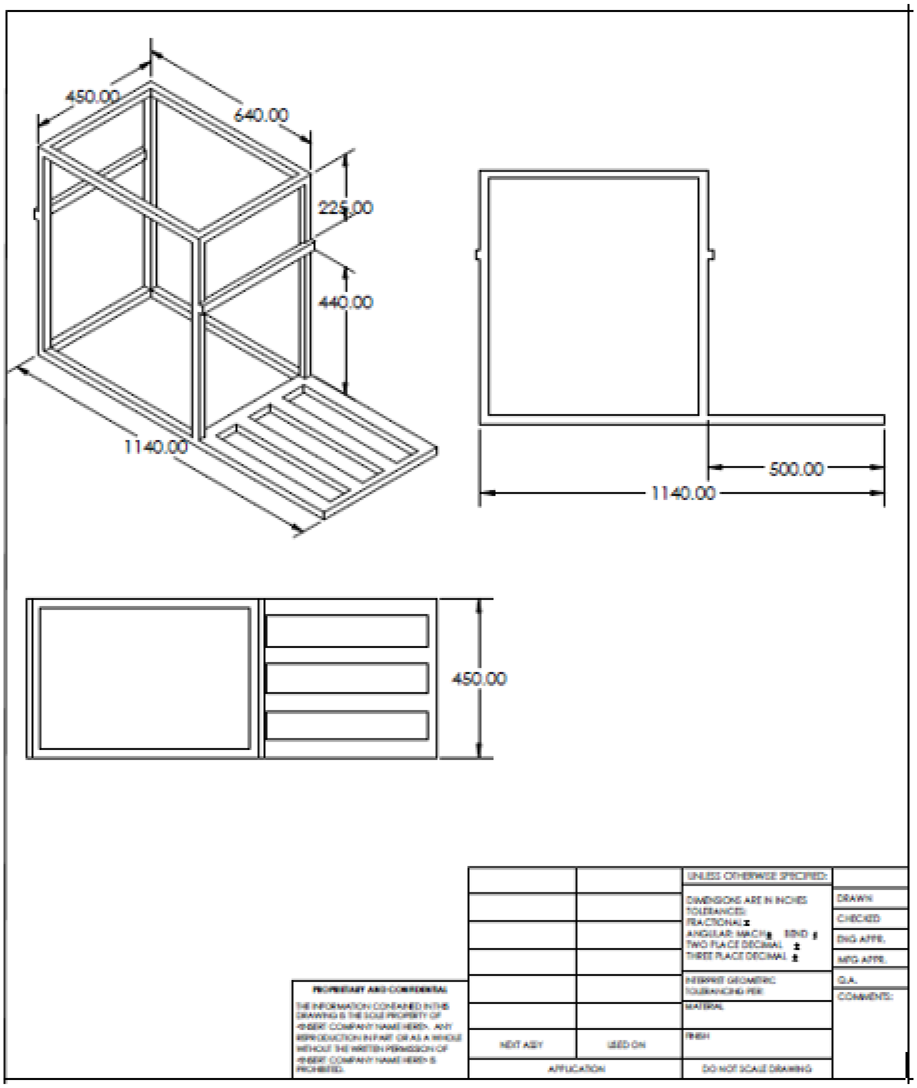
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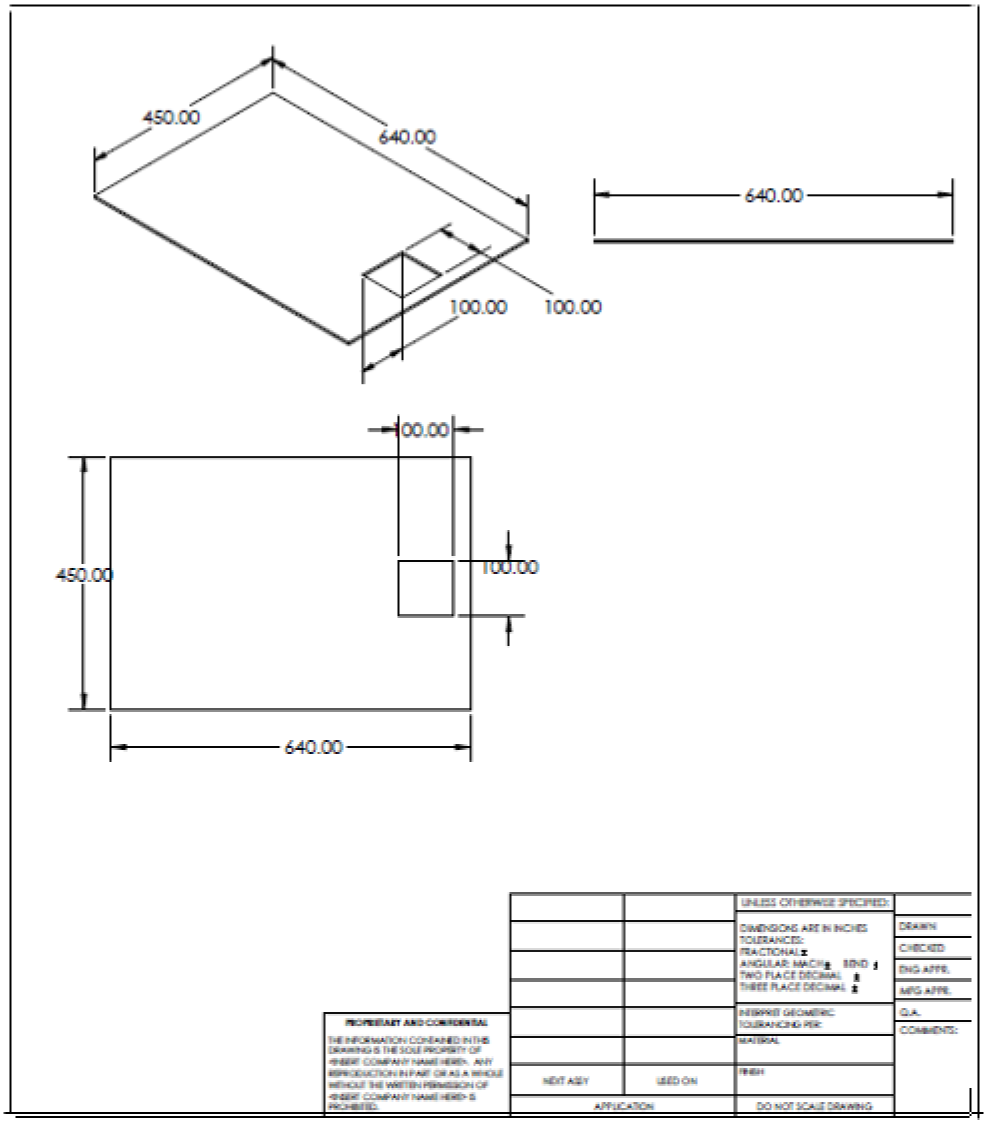
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL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