FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF AGRICULTURAL MECHANIZATION AND IRRIGATION ENGINEERING.

PROJECT TITLE: DESIGN AND FABRICATION OF ENGINE-DRIVEN MAIZE DE-HUSKING AND THRESHING MACHINE.

FINAL YEAR PROJECT REPORT PREPARED BY;

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A final year project report submitted to the Department of Agricultural Mechanization & Irrigation Engineering in partial fulfillment of the requirements for the award of a Bachelor's degree in Agricultural Mechanization & Irrigation Engineering of Busitema University.

ABSTRACT

Traditionally, maize Dehusking and threshing were done using manual methods, which are time-consuming and tedious, and they continue because of the low incomes of maize growers in Uganda. The mechanical method of using a combine harvester is faster, highly efficient, and increases maize production while reducing maize losses. However, it is very expensive, and few or no medium- and small-scale farmers can afford it in Uganda. To overcome this problem, there was a need to design a simple machine that performs the same purpose but cheaper than the combine harvester. The main objective of this work was to design and fabricate a simple, affordable, engine-powered maize dehusking and threshing machine. The method adopted involved selecting an engine suitable for the operation. Based on the available engine, the mechanical part was fabricated to work with the engine. The maize husks were effectively detached from the maize by two spirals and two rollers in the design, and the kernels were detached by spikes in the shelling unit. Choosing materials that are long-lasting and resistant to hot environments, maintaining food safety, and maximizing mechanical efficiency were important design factors. The research methodologies employed were research design, data collection, the design of a maize de-husking and threshing machine using Solid Works software, engineering textbooks, work preparation, manufacturing fabrication, process, and work testing. Durable, corrosion-resistant materials, such as mild steel with a food-safe coating, wire meshes, a shelling unit, and certain parts that come into direct contact with the seeds, were used during fabrication. Performance evaluation yielded a dehusking efficiency of 82.1% and a threshing efficiency of 94%, with a throughput capacity of 117.14 kg/hour and fuel consumption of 1.5 liters per hour. Financial analysis showed a positive Net Present Value (UGX 35,167,418), a Profitability Index of 17.8, and a payback period of approximately 2 months and 4 days, demonstrating economic viability

DECLARATION.

I, Kimuli Herman, declare that this final year project report was prepared out of my own endless efforts, and it has never been presented to any institution of higher learning for any award.

KIMULI HERMAN, BU/UG/2022/1642

Signature

.................................Kimuli.......................

Date

..........................17·06·2026..............................

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I thank the Almighty Allah for giving me strength, good health, wisdom, and protection throughout the preparation of this work.

I would like to acknowledge Mr. Naguyo Samuel, who helped in the fabrication, the support, and guidance of my supervisor, Dr. Kavuma Chris, for the continual guidance and support given to me, and have been instrumental in the completion of this final year report.

APPROVAL.

This final year project proposal report has been prepared and compiled by Kimuli Herman. It is therefore submitted to the Department of Agricultural Mechanization and Irrigation Engineering to be approved with approval from my supervisor;

Dr. Kavuma Chris

Signature

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Date

……17/06/2026……………………………

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ABBREVIATIONS.

DC……………………………Direct Current
RPM…………... …………………Revolutions per Minute
USA……………………………United States of America
FAW……………………………Fall Army Worm
MSV……………………………Maize Streak Virus
GLS………………………………Gray Leaf Spot
NLB………………………………Northern Leaf Bright
IPM………………………………Integrated Pest Management
MC………………………………Moisture Content
PV……………………………….. Photovoltaic
PC……………………………….. Personal Computer
ASME…………………………American Society of Mechanical Engineers
P.I………………………………………Profitability Index
kW………………………………………kilowatt

CHAPTER ONE: INTRODUCTION

Globally, agriculture is a major economic activity in many countries and is said to be the backbone of many countries. Maize, commonly known as corn (Zea mays), is one of the important cereal crops grown and plays a vital role in the agricultural sector, hence ranked among the world's most important staples alongside wheat and rice (Birje et al., 2025), whole grain maize and its processed flour product are of utmost importance for both human consumption and animal feed production. According to (Bamidele 2024), maize and its processed product, consumed in the form of pudding and flakes, are unquestionable, readily affordable staple foods for low-income earners and economically marginalized.

Maize processing involves key post-harvesting operations such as drying (moisture content of 12-14%),(Manuwa, 2020) de-husking/peeling (removing the outer leafy husk), threshing (separating the kernels from the cob), cleaning, sorting, grading, transportation, and processing(milling), which are essential in both small and medium-scale farming. De-husking and shelling of maize cob are one of the operations carried out after the harvesting operation, either on the farm field or within the storage environment, before prolonged storage in silos or grain barns. Shelling requires the outright removal of maize grains from the cob. This is done either to improve the cleanliness (quality) of grains while in storage, prolong the shelf life, or add value to the produce. The de-husking and shelling operations enhance the processing of the grains into flour. (Nyakuchena, 2020).

Currently, in many regions of the world, maize de-husking and threshing have been labor-intensive processes, with farmers relying on manual techniques such as using bare hands to de-husk maize, which causes swollen hands and body weakness. (Nyakuchena, 2020). Dry maize leaves also cause skin irritation. Also, hand-shelling or breaking cobs into pieces to separate kernels, while low-cost, these methods are inefficient, time-consuming, and physically demanding, often leading to fatigue, inconsistent seed quality, and significant wastage.

In many developed countries, they have improved agriculture by developing machines for deseeding, shelling, and peeling. However, these machines perform one task at a time, which leads to farmers resorting to manual farming methods and thus an increase in post-harvest losses, laborers' wages, costs, and reduced market value of maize at large. Additionally, these machines are reliant on the national grid and escalating costs. (Birje et al., 2025),

In response to these challenges, recent research has focused on developing combined energy-efficient alternatives, such as engine-powered corn de-husking and threshing machines, which aim at providing cost-effectiveness, low-maintenance solutions that minimize labor requirements while ensuring high productivity and safety.

1.1. PROBLEM STATEMENT:

In many developing regions, maize post-harvesting processes such as de-husking and threshing are still performed manually and one at a time. Manual methods are often slow, labor-intensive, and hazardous, contributing to low productivity and high post-harvesting losses. Existing combined harvesters, although faster, are often unaffordable, and threshers do one task at a time, limiting their usefulness to farmers. Currently, affordable combined de-husking and threshing machines are scarce, and commercially available models are either too costly or unsuitable for small-scale farmers. Therefore, there was a need to design and fabricate a low-cost, efficient, engine-powered maize de-husking and threshing machine that reduces labor demand, saves time, improves post-harvest handling processes, and improves accessibility for rural farmers.

1.2.MAIN OBJECTIVE

To design and fabricate a mobile engine-powered maize de-husking and threshing machine.

1.2.1.SPECIFIC OBJECTIVES.

- To design the components of the maize de-husker and thresher.
- To fabricate the designed components of the maize de-husker and thresher.
- To test the performance of the maize de-husker and thresher.
- To carry out a financial analysis of the fabricated maize de-husker and thresher.

1.2.2. RESEARCH QUESTIONS.

- What are the specifications and design parameters required for the engine-powered maize de-husking and threshing machine components?
- What materials, tools, and fabrication techniques are suitable for fabricating the machine components?
- What is the de-husking efficiency, threshing efficiency, throughput capacity, and grain damage level of the fabricated machine?
- Is the machine economically viable for small-scale maize farmers based on Net Present Value (NPV), Profitability Index (PI), and Payback Period?

1.2.3.SCOPE OF THE STUDY

1.2.3.1.Conceptual Scope

This study was limited to the conceptualization, design, prototyping, initial fabrication, testing, and evaluation of a medium and small-scale machine suitable for smallholder farmers, with an emphasis on affordability, portability, and minimal maintenance.

1.2.3.2.Geographical Scope

The scope of this study focused on addressing the challenges in post-harvest processing of maize, particularly in rural and off-grid areas where traditional manual methods of de-husking (removing the outer husk) and threshing (separating grains from cobs) are labour-intensive, time-consuming, and inefficient.

1.2.3.3.Time scope.

The time scope of this study was approximately 3 to 4 months.

1.3.JUSTIFICATION OF THE PROJECT.

Time and Labor Savings: Traditional de-husking and shelling are strenuous, slow, and labor-intensive. Engine-powered systems can achieve a throughput capacity ranging from 300 to over 2000 kg/hour, drastically reducing the time required compared to manual methods. The actual capacity for the designed machine was 117.14kg/hour.

High Efficiency and Performance: This machine achieves a high shelling efficiency, often up to 94% at optimized moisture contents. (Nyakuchena, 2020), and there is reduced Post-Harvest wastage due to reduced kernel breakage compared to manual methods.

Economic Viability and Profitability: While requiring an initial investment, the machine's low operating cost, coupled with high-speed processing, allows the machine to pay for itself in a short period. It helps farmers save on hired labor, particularly during peak seasons and also the engine-powered unit was designed to be mobile, allowing it to be transported from farm to farm or used in areas without electricity.

Combined Operation: The machine handled both removing the sheath (de-husking) and removing the kernel (shelling) in one operation, saving additional steps as well as using a petrol or diesel engine ensures consistent, high-speed operation needed for effective shelling, often using local materials for easy maintenance.

1.3.1.SIGNIFICANCE OF THE PROJECT.

The significance of the design and fabrication of an engine-powered maize de-husking and threshing machine lied in several key benefits, such as addressing the limitations of solar-powered threshers, such as cloudy and rainy days, the distraction of sunlight by garden plants, and changes in the intensity of radiation received in a day.

The design and fabrication involved the use of a petrol engine, which was user-friendly, easy-to-operate machine suitable for small-scale farmers in rural areas.
The machine can handle different maize moisture levels, adjust speed and clearance, and work with various maize sizes.

Increased Operational Efficiency: Mechanized de-huskers and threshers process maize much faster than manual methods**,** enabling large volumes to be handled in a short time, hence saving time during peak hours of the season.

Reduction of Labor: Manual threshing and de-husking are extremely labor-intensive and time-consuming. Historically, de-husking and threshing consume a large share of farm labor, yet a mechanized machine eliminates tedious hand work and reduces physical strain on farmers. This reduces labor requirements and improves processing capacity, enabling faster and more efficient maize peeling and shelling with low grain damage.
It supports sustainable agriculture since two post-harvest handling practices were combined that can improve rural livelihoods, and also reduce dependence on unreliable grid electricity.

CHAPTER TWO: LITERATURE REVIEW

2. Description of maize

Maize (Zea mays L.), also known as corn (Birje et al., 2025), is an important cereal crop globally, with over 1 billion metric tons produced annually, with the top producers being the USA, China, Brazil, and India. It is ranked third in importance after wheat and rice. It is a good source of carbohydrates, fiber, and several essential nutrients like thiamin, folate, and phosphorus, also low in fat and calories, making it a nutritious food option. It also serves as an animal feed and raw material for industries such as starch, oil, and biofuel production. It is grown in various climates and soil types, but it flourishes best in well-drained, well-aerated, deep warm loamy or sandy soils, with adequate moisture, and requires a warm and humid climate with temperatures between 15°-35°C. The ideal soil pH for maize cultivation is between 5.8 and 7.0. Temperatures below 10 °C and above 40 °C result in poor growth and death of the maize plant. Maize prefers rainfall of 500 to 600 mm as the optimal range and well distributed over the growing season. (Manuwa, 2020)

2.1.1. Maize production in Uganda Maize

Originally a New World crop, it was introduced in Uganda in 1861 and by 1900 was already an established crop. The World Bank estimates that there are about 1.3 million ha of land suitable for maize production in Uganda.(Kwikiriza et al., 2021) Maize is an important food and income security crop that supports the livelihood of millions of small-scale farmers in Uganda. Production of maize has increased from 2.8 million MT 6 2015 to 4 million MT in 2017. Maize's importance is associated with increasing demand and a favorable climate that enables two cropping seasons in a year (Birje et al., 2025), it was introduced in Uganda in the mid-19th century. Maize is the third largest crop cultivated in the country as measured by production volume, trailing only plantains and cassava. The production system is dominated by peasant farmers, with 75% of the country's output grown on plots of land that are between 0.2 and 0.5 hectares. In 2020, the maize production for Uganda was 2750 thousand tons. (Manuwa, 2020)

2.1.2. Maize Uses.

Maize is a versatile crop with multiple uses, such as, acting as a staple food in many countries, a major ingredient in animal feed, particularly for poultry and livestock. It is also used to produce ethanol, high-fructose corn syrup, and other industrial products.

2.1.3. Types of Maize

There are several types of maize, including:
Flint Corn which is known for its hard outer layer and soft inner kernel, dent corn which is characterized by the presence of corneous, horny endosperm, soft central core, and floury endo sperm commonly used for livestock feed and industrial products.

Sweet Corn which is harvested when immature and eaten fresh or used in processed foods, popcorn which is a special type of maize that explodes when heated. These are characterized by a corneous, very hard endosperm containing a small portion of soft starch, flour corn which is among the oldest types of corn and is characterized by soft starch. Vitreous endosperm and an opaque kernel that shrinks uniformly when drying.

2.1.4.The physical properties of maize

The physical properties of maize that were considered during the design were; the size of maize, which helped maize not to be trapped in the de-huskers, hence relatively large sizes are preferred and the moisture content of maize where the recommended moisture content, helped in maize not to be stuck between the rollers, hence effective de-husking.

2.1.5. Indicators of mature maize.

Maize stalk system and cob sheath turn brown, lobes begin to drop from the stalk and bend downwards depending on the variety, the grain is hard and has a floury texture when bitten, the grain moisture content is between 18-24 % (determined using moisture meter), grains form a brown layer at kernel tip and this shows maize can be efficiently de-husked without any husks left and without damaging the machine. (Birje et al., 2025)

2.1.6.MAIZE HARVESTING.

There are mainly two methods of harvesting maize ie, Manual harvesting and Mechanical harvesting.

2.1.6.1.Manual harvesting.

This is where harvesting of dried maize from the garden is done by human as shown in Figure 2.1. It is also divided into two categories, either by plucking of cobs or by stalk cutting.

For plucking cobs, the ears are removed from the standing plants, and they are piled to open for twenty-four hours, and they are spread for drying in the sun. In this method, stalks may be used as green fodder, whereas during stalk cutting, the plants are cut and piled up in the shade, and the cobs are removed after two or three days of harvesting. Manual harvesting has merits such as; no use of the machine, hence cheap and also requires no technically skilled labor, however, it also has demerits, which include time wasting.

Figure 2.1 shows manual maize peeling

2.1.6.2.Mechanical harvesting method.

This can be accomplished by using a self-propelled maize combine harvester, which is used for direct harvesting and threshing of the maize crop. It has a specially designed cutter bar for maize. It has a gathering unit to guide the stalks into the machine, and snapping rolls to remove the ears from the stalks (Kwikiriza et al., 2021)

Mechanical method of harvesting maize has merits such as being faster, reducing dependence on labor, and increasing efficiency, reduced grain loss, however, it has demerits, such as the machine's initial costs are expensive for small-scale farmers, the machine creates unemployment for the people, as it reduces the dependence on labor.

2.1.7. Post-harvest operation carried out on maize

Postharvest handling practices are activities carried out immediately after harvesting, and they include drying, peeling, threshing, cleaning, milling, processing, storage, and transportation.

2.1.7.1. Drying

Drying is the systematic reduction of crop moisture down to safe levels for storage. Maize is usually harvested with a moisture content in the range of 18–26%, which is considerably higher than the 12–14% for safe handling. Therefore, drying is very important to reduce the moisture level to accepted level of 13.5% and also reduces the chances of rotting and germination of the grains. (Manuwa, 2020)

2.1.7.2. Drying Method and technologies of drying

Sun Drying: Cobs are dried in open air on tarpaulin, drying yard, collapsible dryer, drying racks, and in cribs, whereas mechanical drying is where hot air is blown into the grain to remove excessive moisture under controlled conditions. Hot air is generated using burning fuel, solar, electricity, and biomass.

2.1.7.3. Maize Peeling (Maize De-Husking)

Maize peeling, also known as corn peeling, is defined as the process of removing the outer layer or husk from maize (corn) kernels to prepare them for threshing, storage, or sale. This can be done manually using hands, often using a knife or a specialized tool, which is not only ineffective but also time-consuming, or mechanically using motorized machines or combine harvesters, depending on the scale and purpose of the peeling. However, for the case of a combine harvester, it is expensive for the small-scale maize growers.

2.1.8. Purposes of Maize Peeling

Improves the appearance and quality of maize for food or feed, enhances the storage life of maize by removing the husk, which can harbor pests or moisture, and prepares maize for further processing, such as milling or grinding.

2.1.8.1. Advantages of Mechanical Maize Peeling

It uses machines designed to remove the husk and sometimes the germ from maize kernels, it is faster and more efficient than manual peeling, often used for large-scale commercial purposes, reduces dependence on labor and increases efficiency, and the machine reduces grain loss.

2.1.8.2. EXISTING TECHNOLOGIES.

An automated maize de-husking machine for Zimbabwe, emphasizing sustainability and low cost. The machine targets small farmers unable to afford combined harvesters. Key features include a husk moisture content analysis (10-20% optimal, determined via oven-drying 18 samples) and stress testing using SolidWorks 2016, confirming structural safety. (Nyakuchena, 2020). The compact 3D prototype processes maize efficiently but not to an optimal level, reducing time loss from manual methods and benefiting developing nations.

An integrated peeling-shelling system was developed which reduced kernel damage, with efficiencies of 91% in compact designs. (Kadam et al., 2008). This is shown in Figure 2.2

A corn chaff peeling machine was developed to address low production rates and kernel damage in traditional methods. (Gorad Naik, 2019). The design uses a screwed shaft arrangement for smooth peeling, with the objectives to optimize guideways, minimize blockages, and ensure portability. It focuses on small farmers, reducing manual effort and improving output without high costs as shown in figure 2.3

A portable electric-operated maize de-husker cum sheller for Chattisgarh farmers was introduced and the design considered engineering properties, achieving 90% de-husking efficiency at 10.63% moisture and 1.91 m/s roller speed. The rectangular frame (610 × 390 × 650 mm) uses a 2.24 kW motor, minimizing stalk cutting and blower loss (1.37%) (Dange *et al.*, 2021)

A compact peeling-shelling combo machine noting reduced human effort and manufacturing costs. (Abhijeet *et al.*, 2016). The design emphasizes simplicity for farmers, integrating peeling to minimize damage and enhance productivity.

Figure 2.2 shows the peeling operation powered by electricity

Figure 2.3 shows a fabricated model of corn peeling

2.1.8.3. Maize Threshing (Shelling)

Threshing (shelling) refers to separating kernels from cobs. Traditionally, maize threshing was done using manual methods, such as rubbing cobs or beating with sticks. Such methods cause up to 10-15% kernel damage. (Birje et al., 2025), thus reducing market value and seed viability. Mechanized threshers improve efficiency but require affordable energy sources. Mechanical shelling is also carried out using a hand operated sheller as shown in figure 2.4. For the machine to perform optimally, the maize should be dry (13-14% MC). It is a low-capacity tool used by farmers who have very low volumes.

Motorized maize shelling involves the use of powered electrical mortars. They can either be stationed or mobile, imported or fabricated within the country. They can shell between 500kg and 1000kg per hour. The mobile maize sheller was designed to ease issues of accessibility. Using motorized shellers reduces postharvest losses and hence results in more returns to the farmers. Use of motorized maize shelling has increased among farmers as a result of individuals, especially youth, adopting the technologies to offer shelling services as a business. (Birje et al., 2025)

2.1.9. EXISTING TECHNOLOGIES.

A solar-operated maize sheller was developed for remote Indian areas. (Ghritalahre, 2020). The machine achieved 174.33 kg/h output. It addresses power shortages, promoting sustainability for marginal farmers.

A solar-powered maize de-husker cum shellers were developed highlighting components like feed hoppers, de-husking units, and cleaning systems.(Karale Sahoo, 2012). Performance metrics include 90-92% efficiency for both operations, with solar PV enabling off-grid use in rural India. The review emphasizes environmental benefits and cost savings.

An evaluation of a solar-powered maize sheller for Nigerian rural farmers was conducted. (Lawal, 2020) .The machine shells 68.25 kg/h with 89.61% efficiency. Direct DC motor coupling simplifies design, making it affordable where grid power is unreliable.

A shelling efficiency of 92 % at 7.35 m/s cylinder speed and 14.12% moisture, with kernel breakage of 1.1% and unshelled grains (1.04%) was reported according to (Dange *et al.*, 2021). Seed germination remained high (91-96%), suitable for seeding.

Figure 2.4 shows a hand-operated maize Sheller with its CATIA design

2.1.10. Grain cleaning

It is the removal of foreign material and non-conforming grains from the normal ones. Several technologies are employed to clean the grain, and they include traditional (winnowers of different shapes and materials are used to clean the grain, taking advantage of the wind) and mechanical cleaners (manual and motorized). Machines that are operated by engines or motors.

2.1.10.1. Maize Processing and Maize Products.

Maize can be processed into various products, including:
Flour: Maize flour is used to make tortillas, bread, and other baked goods. Meal, which is a granular product used to make porridge or as an ingredient in animal feed, and grits, which are a coarsely ground product used to make a breakfast cereal or as an ingredient in other dishes.

2.1.10.2.Maize By-Products

Maize by-products, such as corn cobs and stover, can be used as animal feed or biofuel, and maize germ which can be processed to extract oil, which is used in cooking and industrial applications.

2.1.10.3. Maize Storage and Handling

Storage is the process of keeping grains until an appropriate time of use. The primary aim of storage of grain storage is for quality maintenance, food and nutrition security, seed, and better prices. It should be stored in a cool, dry place with good ventilation to reduce the risk of mold and insect infestation. Due to inadequate storage practices, farmers in the region, including Uganda, lose up to 40% of their harvest to insects, pests, mold, and moisture.

2.1.10.4. Transportation

Maize is transported home or to storage units for other activities to be carried out. Transportation is done on foot, by bicycle, by motorcycle, and by vehicles, depending on the volumes.

2.2. GAPS IN KNOWLEDGE.

According to (Abhijeet *et al.*, 2016), this paper shows that many authors have reported that the corn sheller and peeling design exists for different loading conditions, but with separate mechanisms; hence, there is no single unit that exists consisting of both the mechanisms, thus a need for combined mechanisms.

According to (Jahan *et al.* 2019), the study does not address the long-term durability of the machine components, especially the rubber and spiral rollers, under continuous use. Wear and tear, maintenance frequency, and component lifespan remain unexamined. The study also focused on de-husking only.

According to (Adesokan *et al.*,2019), this study involved the design, construction, and performance evaluation of a low-cost maize de-husker-sheller in Nigeria. This machine was suitable for small/medium-scale maize production in Nigeria; however, further improvements needed to be made on its throughput capacity, which was low, with a maximum of 55.90 kg/h and exhibited considerable grain loss, ranging from 17.16% to 21.20%, which represents a direct economic loss for farmers, thus becoming inefficient for farmers with larger harvests. Enhancing the feeding mechanism through widening the hopper, power transmission, or processing chamber design could address this limitation.

From the literature reviewed (OdediranManuwa, 2020), this paper focused on the design and fabrication of a motorized maize sheller. However, there is a need to fill some gaps by designing and fabricating an improved, engine-powered machine that is at least more affordable, gentle on grains through minimizing damage, and portable and mobile for easy transport.

According to (Nyakuchena, 2020), the scope of the paper was to design an automated maize de-husking machine for the case of Zimbabwe; most of the objectives were met; however, the machine was heavy and difficult to use by one operator. Therefore, there was a need to focus on the design a light weight machines with easy maneuverability.

According to (Bamidele, 2024), this project was focused on the performance evaluation of the Maize De-husker Cum Sheller Machine for Small Scale Maize Processing Farmers in Nigeria, and almost all its objectives were fulfilled as required; however, it was recommended that improved technological design features should be applied to the machine to enhance better output capacity through efficient de-husking and shelling operations as may be required by individual farmers.

Therefore, from the literature review and recommendations from the studied papers, there is a need to design a single machine that combines both the mechanisms of peeling and threshing according to (Abhijeet *et al.*, 2016), increase the throughput efficiency by widening the size of the hopper, reducing the grain loss, and incorporating wheels to enable mobility of the machine.

3. CHAPTER THREE: RESEARCH METHODOLOGY.

This chapter discusses the research methodology, design, instruments, data collection procedure, and the machine design concepts/features

3.1.1. Designing the components of the maize de-husking and threshing machine.

3.1.1.1.Material Selection

Choosing suitable materials was the first and essential step in the design and fabrication of the various components of the machine. The selection process was guided by several important factors following the Pugh Matrix/ method.

Strength**:** Given the mechanical loads that each part was subjected to during operation, materials were selected based on their ability to endure these forces without breaking or deforming. Material Availability: The ease of sourcing materials played a crucial role in the decision-making process. To simplify construction and future maintenance, all materials were chosen based on their local availability and low cost, ease of machining where preference was given to materials that can easily be cut, shaped, and joined using common workshop tools. This helped streamline the fabrication process and ensure compatibility with available machining resources.
Affordability where cost was a key consideration, as the project needed to stay within a limited budget. Only cost-effective materials that still meet the necessary performance requirements were used and corrosion resistance where machine parts must be prevented from moisture to prevent corrosion of the machine. This was achieved by painting the machine parts.

3.1.1.2.The design of the hopper

The hopper is trapezoidal in shape with length L, width W, and height of the hopper H. The feeding hopper was placed at the top of the machine, where maize was fed into from the rotating roller portion. In designing a hopper, the angle of repose, $\boldsymbol{\theta}$ which is obtained from the formula in equation 3.1

$$\boldsymbol{\theta = \tan^{-1}\frac{2H}{D}} \quad \text{……………………….Equation 3.1}$$

Where; H = height, and D = diameter of the pile, which determines the slanting sides to allow the maize to fall under gravity, were considered. The volume, V, of the hopper was obtained by using equation 3.2

$$\boldsymbol{V_h = \frac{h}{3}(A_1 + A_2 + \sqrt{A_1A_2})} \quad \text{………………… Equation 3.2}$$

Where; $\boldsymbol{V_h}$ is the Hopper volume in meters cubed, H is the vertical height in meters, $\boldsymbol{A_1}$The top area is calculated from the top length multiplied by the top width, and $\boldsymbol{A_2}$The bottom area is calculated by multiplying the bottom width by the bottom length.

3.1.1.3.De-Husking Unit (Rollers)

This unit removed husks using rotating rollers and spiral shafts. Formulas focus on speed, length, and power.

3.1.1.4. De-Husking Roller Speed

The de-husking roller speed for effective husk removal was calculated using equation 3.3

$\boldsymbol{V_s} = \frac{\boldsymbol{\pi DN}}{\boldsymbol{60}}$…..……….Equation 3.3 (Khurmi and Gupta).

Where;

$\boldsymbol{V_s}$ = Speed of rollers (m/s),

D = Diameter of the pulley in meters,

N = the Rotational speed (rpm), 60 is the conversion factor, and π is the Mathematical constant.

3.1.1.5. Length of the De-husking Rollers

The length of rollers were determined by using the Winkler formula from equation 3.4 (Jahan *et al.*, 2019)

$\boldsymbol{L_s} = \frac{\boldsymbol{F}}{\boldsymbol{\delta \times n \times k}}$ …………………. Equation 3.4

Where $\boldsymbol{L_s}$ is the roller length, $\boldsymbol{F}$ is the feed rate, and n is the shaft speed, $\boldsymbol{\delta}$ is the material factor k=0.25kg/m

3.1.1.6.Power requirement For De-husking

Power required for de-husking was calculated from equation 3.5 and is the product of the difference in tensions and speed.

$\boldsymbol{P_1} = (\boldsymbol{T_1} - T_2)v$ ………………Equation 3.5

Where; $\boldsymbol{T_1}$ is the tension in the tight side of the belt, $\boldsymbol{T_2}$ is the tension in the slag side of the belt, $\boldsymbol{v}$ is the speed

3.1.1.7. Threshing unit

The number of pegs were determined using equation 3.6

$\mathbf{N_p} = \frac{\mathbf{L_c \times \pi d}}{\mathbf{S_{sr} \times S_{sc}}}$ ………………Equation 3.6

where;

L_c = cylinder length,

$\mathbf{S_{sr}}$ = spacing between spikes in a row,

$\mathbf{S_{sc}}$ = spacing between rows.

3.1.1.8.Power delivered by threshing shaft

Power required for threshing was calculated from equation 3.7 and is the product of the difference in tensions in the belt and speed.

$\boldsymbol{P_2} = (\boldsymbol{T_1} - T_2)v$ ……………………..Equation 3.7

Where; $\boldsymbol{T_1}$ is the tension in the tight side of the belt, $\boldsymbol{T_2}$ is the tension in the slack side of the belt, $\boldsymbol{v}$ is the speed

3.1.1.9. Design of the shaft

The shaft was designed according to the American Society of Mechanical Engineers (ASME) code from equation 3.8 According to this code, the permissible shear stress $\boldsymbol{\tau_{max}}$. The shaft without key ways is taken-as 30% of the yield strength in tension or 18% in the ultimate strength of the material, which is at least the minimum. (Khurmi and Gupta)

$$\boldsymbol{\tau_{max} = \frac{16}{\pi d^3}\sqrt{((K_m \times M_b)^2 + (K_t \times T)^2)}}$$

$$\boldsymbol{d^3 = \frac{16}{\pi \tau_{max}}\sqrt{((K_m \times M_b)^2 + (K_t \times T)^2)}} \text{ ……………………Equation 3.8}$$

$\boldsymbol{\tau_{max} = 0.3s_{yt}}$ or $\boldsymbol{\tau_{max} = 0.18s_{ut}}$

Where:

$\mathrm{M_b}$ = bending moment

T = twisting moment

$\mathrm{K_m}$ = combined shock and fatique factors for bending

$\mathrm{K_t}$ = combined shock and fatique factors for torsion

The values of $\mathrm{K_m}$ and $\mathrm{K_t}$ can be got from Table 3-1.

Table 3-1 Showing the recommended values for Km and Kt.

Nature of load	K_m	K_t
1. Stationary shafts		
(*a*) Gradually applied load	1.0	1.0
(*b*) Suddenly applied load	1.5 to 2.0	1.5 to 2.0
2. Rotating shafts		
(*a*) Gradually applied or steady load	1.5	1.0
(*b*) Suddenly applied load with minor shocks only	1.5 to 2.0	1.5 to 2.0
(*c*) Suddenly applied load with heavy shocks	2.0 to 3.0	1.5 to 3.0

Source:(Khurmi and Gupta)

The torque on the shafts was calculated from equation 3.9

Torque or torsional moment = $\boldsymbol{\frac{P\times 60}{2\pi N}}(Khurmi\ and\ Gupta)$ ………………… *Equation 3.9*

Where:

P is power (KW) transmitted to the shaft,

N is the number of revolutions per minute (RPM)

3.1.1.10.Design of the sieve

The area of the sieve was calculated from equation 3.10

Area = πrL (mm^2)………………….Equation 3.10

Where r = radius and L = length of the sieve

3.1.1.11. Determination of the speed of the pulley.

This is determined using the speed ratio formula shown in equation 3.11

$SR = \frac{nd}{nD} = \frac{Dp}{dp}$ ………………… Equation 3.11

Where;

dp = driven pulley pitch diameter,

Dp = driver pulley diameter

nd = speed of the driven pulley in (rpm) and

nD = driver pulley speed.

3.1.1.12.Belts and pulleys design.

Determination of the length of an open belt drive

According to (Khurmi and Gupta), the length of a belt is determined using the formula in equation 3.12

The belt length will be determined to know the actual dimension to drive the drum. Belt length is important for effective power transmission from components. The following expressions for the length of the belt are to be applied.

$\mathbf{L = 2C + \frac{\pi}{2}(d_1 + d_2) + \frac{1}{4C}(d_2 - d_1)^2}$ ………………… Equation 3.12

Where;

L =Length of the belt,

C= distance between two centripetal forces,

$\mathbf{d_1}$= diameter pulley driver and

$\mathbf{d_2}$= diameter pulley driven.

3.1.1.13. Determining tensions for the V-belt.

When higher belt speeds (more than 10 m/s) are used, the effect of centrifugal tension is considerable and thus has to be taken into account.

Centrifugal tension will be determined using the equation 3.13

$\mathbf{T_c = MV_2}$ ………………… Equation 3.13

Where;

Tc = centrifugal tension,

M = mass of the belt per meter,

V = velocity of the belt

3.1.1.14. The maximum tension in the belt is calculated from

The maximum belt tension was calculated from equation 3.14 which is the product of maximum stress in the belt, width of the belt and thickness of the belt.

$\boldsymbol{T = \delta . b . t}$ ………………… Equation 3.14 (Muhire, 2013)

Where;
$\boldsymbol{\delta}$ = maximum stress.
b = width of the belt.
t = thickness of the belt.

3.1.1.15.The tension in the tight side of the belt is to be calculated from

The tension in the tight side of the belt is the difference between maximum tension and centrifugal tension and was calculated using equation 3.15

$\mathbf{T_1 = T - T_c}$ ………………… Equation 3.15 (Khurmi and Gupta)

Where;
$\mathbf{T_1}$ = tension in the tight side,
$\mathbf{T}$ = maximum tension in the belt
$\mathbf{T_c}$ = centrifugal tension.

3.1.1.16.Tension in the slack side of the belt is determined from the equation below

The tension in the slack side of the tension was calculated using equation 3.16

$\mathbf{2.3\log\left(\frac{T_1}{T_2}\right) = \mu.\theta cosec\beta}$ ………………… Equation 3.16 (Khurmi and Gupta)

Where;
$\mathbf{T_1}$ = tension in the tight side of the belt.
$\mathbf{T_2}$ = tension in the slack side of the belt.
μ = coefficient of friction between the belt and the pulley.
$\boldsymbol{\theta}$ = angle of contact at the smaller pulley.
$\boldsymbol{\beta}$ = groove angle of the pulley.
From;

3.1.1.17.The angle of contact can be calculated as;

Angle of contact was calculated using equation 3.17

$\boldsymbol{\theta = (180^\circ - 2\alpha) * \frac{\pi}{180} rad}$ ………………… Equation 3.17 (Primis, 1976)

where $\alpha = \mathbf{\sin^{-1}\left(\frac{r_1 - r_2}{x}\right)}$ $\mathbf{r_1}$and $\mathbf{r_2}$are the radii of the larger and smaller pulleys, respectively.

3.1.1.18.Determination of speed for the driven pulley

The speed of the driven pulley was calculated from equation 3.18

$\mathbf{N_2 = \frac{N_1 d_1}{d_2}}$ ………………… Equation 3.18

Where;
$\mathbf{d_1}$ = diameter of the driver pulley,
$\mathbf{d_2}$ = diameter of the driven pulley
$\mathbf{N_1}$ = speed of the driver pulley in revolutions per minute,
$\mathbf{N_2}$ **is** The speed of the driven pulley in rpm.

3.1.1.19. Determining the center-to-center distance between two pulleys.

The center-to-center distance between two pulleys was calculated using the formula in equation 3.19

$\mathbf{X} = \frac{\left(\frac{\mathbf{d_2}}{\mathbf{d_1}}\right)}{\mathbf{2}} + \mathbf{d_1}$ ………………… Equation 3.19 (Baroroh *et al.*, 2023)

Where;

X = center-to-center distance between two pulleys,

$\mathbf{d_1}$= diameter of the larger pulley,

$\mathbf{d_2}$ = diameter of the smaller pulley.

3.1.1.20.Design of the frame.

Equation 3.20 below was used to determine the compressive stress on the frame stand.

$\boldsymbol{\sigma_c} = \frac{\mathbf{F_t}}{\mathbf{n \times A}}$ ………………… Equation 3.20(Primis, 1976)

Where;

$\boldsymbol{\sigma_c}$ = compressive stress on the column,

$\boldsymbol{F_t}$ = total force supported by the frame,

n = number of stands on the frame, and

A = cross-sectional area of the column.

3.1.1.21. Factor of safety

The Factor of safety was calculated using equation 3.21

$Factor\ of\ safety = \frac{Yield\ strength}{Working\ stress}$………………… Equation 3.21

Where the working stress is the compressive stress on the column, and the yield strength is for the material of the frame.

3.1.2. POWER TRANSMITTED BY THE BELT.

The power transmitted by the belt was calculated using the formula in equqtion 3.22

$\mathbf{P_3} = (\mathbf{T_1} - \mathbf{T_2})\mathbf{v} \times \mathbf{n}$ ……………..Equation 3.22(Khurmi and Gupta)

Where; $\boldsymbol{P_3}$ = the power

$\boldsymbol{T_1}$= tension in the tight of the belt.

$\boldsymbol{T_2}$= tension in the slack side of the belt.

v = speed of the belt/velocity.

n = the number of belts.

3.1.2.1.Determination of the angular velocity of the pulley

The angular velocity of the pulley is the rate at which the pulley rotates or spins around a central point and was calculated from equation 3.23

$\boldsymbol{\omega} = \frac{\boldsymbol{V}}{\boldsymbol{r}}$ ……………………… Equation 3.23 (Khurmi and Gupta)

Where;

$\boldsymbol{\omega} =$ angular velocity

r = radius and **V** = speed

3.1.2.2.The design of gears

Gears are toothed cylindrical wheels used for transmitting mechanical power from one rotating shaft to another. A simple gear train is one in which each shaft with one gear is connected to the center shaft so that the gear can drive the simple gear train to drive each roller attached to it.

3.1.2.3.Determination of gear Velocity

The peripheral speed of the gear was calculated using equation 3.24

$\boldsymbol{V} = r\,\boldsymbol{\omega}$ ………………… Equation 3.24 (Khurmi and Gupta)

Where;

$\boldsymbol{\omega}$ = the angular velocity

r = pitch radius

V = pitch line velocity

3.1.2.4. The speed of gears

The speed of the gear was determined by using the gear ratio formula shown in equation 3.25

$\frac{n_1}{n_2} = \frac{N_2}{N_1}$ where; ………………… Equation 3.25

n_1 = teeth of the driver gear

n_2 = teeth of the driven gear

N_1 = speed of driver gear

N_2 = speed of driven gear.

3.1.2.5.The power developed by the gear

The power developed by the gear arrangement was calculated using equation 3.26

$P = \frac{2\pi NT}{60}$ ………………… Equation 3.26 (Khurmi and Gupta)

Where $P = is\ the\ power,$

N = rotational speed and T = torque developed

The instruments used in the design and fabrication of a maize de-husker and thresher were SolidWorks, a calculator/spreadsheet, and the outcomes were technical drawings with dimensions and a bill of materials.

3.2. To fabricate and assemble the different components of the machine.

The fabrication and assembly of the machine was based on material selection as shown in table 3-2.

Table 3-2: Different material selections for the fabrication of the machine.

S/N	Machine Component	Selection criteria	Possible Materials to be selected
1.	The hopper	Strength, rigidity, weight, cost, and availability	Mild steel, stainless steel
2.	Supportive frame	Strength, rigidity, weight, cost, availability, simplicity in design	Mild steel L-shaped angle bar
3.	Belt	Strength, high coefficient of friction	Reinforce rubber
4.	Spiral rollers	Strength, resistance to wear	Galvanized Iron
5.	Shafts	Wear resistance, machinability, strength, and resistance to both torsional and bending stresses.	Mild steel Alloy steel,
6.	Pulleys	Machinability, wear resistance, good casting properties, high compressive strength, and cost	Cast iron, Aluminium
7.	Bolts and nuts	Strength, Reliability, ease of fitting, and availability	Mild steel
8.	Bearings	Strength to withstand axial and radial forces, durability, cost, and availability	Cast iron/stainless steel
9.	Wheels	Strength and toughness to withstand the machine's weight	Steel and fabric

10.	Grain sieve	Strength, rigidity, weight, cost, availability, hardness, and corrosion resistance.	Stainless steel.
11.	Rollers	High coefficient of friction, strength	Galvanized Iron
13.	Body cover	Strength, rigidity,	Mild steel, aluminum, stainless steel
14.	Gears	Strength, machinability	Steel, aluminum, cast iron
15.	Threshing shaft	High wear resistance, strength, and corrosion resistance	Galvanized steel,
16.	Petrol Engine	Matches power requirement, cost-effective	

The instruments used to achieve specific objective two were cutting tools, such as grinders and cutting discs. Drilling machine, welding machine, lathe machine, measuring tools, spanners, and paint were other instruments used. The outcomes were fully fabricated components, a properly assembled machine, and Painted and rust-protected -Safety guards and labels in place. Ready for performance testing

3.3. To evaluate the performance of the machine.

A systematic approach that covers operational efficiency, power utilization, throughput capacity, and quality of output was evaluated, the tools used during the design of the prototype were Solid works, Books and pens, and rulers

3.3.1.Procedures that were followed when testing the machine.

The machine is started to run at constant speed, and a given number of maize was poured into the de-husking unit, say N. The machine is stopped, and the number of de-husked maize say $N1$ is got.

The number of unhusked maize say $N2$ is obtained, and the number of damaged maize is also obtained, say $N3$. The above experiments were repeated over time, and the average numbers were obtained.

The efficiency of the de-husking unit. This is the percentage of maize cobs that have had their outer leafy husks completely removed by the machine, relative to the total number of maize cobs fed into the de-husking unit, and was determined from equation 3.27

$$\boldsymbol{Efficiency} = \frac{Number\ of\ maize\ de\text{-}husked}{\boldsymbol{Number\ of\ maize\ fed\ in\ for\ de\text{-}husking}} \times \mathbf{100}\% \text{ .... Equation 3.27}$$

For Threshing, the percentage of maize kernels that are successfully separated or shelled from the cob by the machine, relative to the total number of kernels that were available on the cobs fed into the threshing unit, was determined from equation 3.28

$$\boldsymbol{Efficiency} = \frac{Number\ of\ maize\ threshed}{Number\ of\ maize\ falling\ in\ for\ threshing} \times \mathbf{100}\% \text{ .... Equation 3.28}$$

3.4.CARRYING OUT FINANCIAL ANALYSIS OF THE MACHINE.

This project's goal was to make it easier for farmers to de-husk and thresh their maize so they can gain from farming. Therefore, the initial cost of the prototype to the farmer and the benefits (net annual cash flows) that the farmer will produce when the machine is in operation for five years was the basis for the cost-benefit analysis of this project. The costs of buying materials for the prototype's construction, hiring workers for it, and transporting it were included in the overall capital outlay. The amount of money earned from selling maize for a season and from renting the equipment to other farmers are two examples of the yearly revenue inflows that the farmer produced. The yearly financial outflows that the farmer would experience while operating the prototype were identified. These outflows included charges for maintenance and repairs. The prototype underwent a thorough cost-benefit analysis from the perspective of the farmer using the following techniques. (Commonwealth of Australia, 2006)

3.4.1.Net Present Value (NPV)

The project's cost of capital was applied to the net yearly cash flows, reducing them to their present value. The original capital investment was subtracted. The necessary minimum rate of return serves as the interest rate for discounting. Choosing to accept a project with a positive net present value was a criterion. (that is, NPV > 0)The Net Present Value was calculated using the equation 3.29

$NPV = \left[\sum_i^n \frac{Cf}{(1+r)^n}\right] - i_0$ .... Equation 3.29(*Lecture 7: the Feasibility Study*, 2004)

Where;

$\frac{\mathbf{1}}{(\mathbf{1}+\boldsymbol{r})^{\boldsymbol{n}}}$ is the discount factor

$\boldsymbol{i_0}$ is the initial cost of investment

$\boldsymbol{Cf}$ Is the net annual cash flow

r is the discount rate

n is the period.

3.4.2. The Profitability Index, P. I

Profitability index rule is a decision-making tool that aids in determining whether or not to move forward with the project.

The profitability index was determined using the formula in equation 3.30 below;

$\mathrm{P.I} = \frac{\textbf{Present Value of Net Annual Cashflows}}{\textbf{Initial Cost of Investment}}$ .... Equation 3.30

If the$P.I > 1$, it indicates that the project should proceed, whereas in the case of $P.I < 1$. This indicates that the project should be abandoned.

3.4.3. The payback period.

Payback period is the time it would take for an investor to earn the project's initial investment. It is a rapid and simple method of evaluating risk and investment opportunities. Years are used to represent the repayment period. An investment would be more appealing if the payback period were shorter because it would take less time to break even.

The payback period was calculated using the formula in equation 3.31 below;

$\text{Payback period} = \frac{\text{Initial Cost of Investment}}{\text{Net Annual Cashflows}}$ …………………………….. Equation 3.31(*Lecture 7: the Feasibility Study*, 2004)

3.4.4.Depreciation

Machines always depreciate over time, and depreciation includes in-use related costs. It was calculated from the formula in equation 3.32 below.

$\text{Depreciation} = \frac{\boldsymbol{purchase\ cost - salvage\ value}}{\boldsymbol{number\ of\ years}}$ …………………………………………. Equation 3.32

Instruments used included a spreadsheet, a calculator, and a market survey.

CHAPTER THREE: RESULTS AND DISCUSSIONS.

4. To design the different components of the maize de-husking and peeling machine.

4.1.1.Design of the hopper

Volume of the hopper was obtained from equation 3.2

$$A_1 = \frac{1}{2} \times (0.15 + 0.35)0.105$$
$$A_1 = 0.02625m^2$$
$$A_2 = 0.15 \times 0.15 = 0.0225m^2$$
$$h = 0.115m$$
$$V_h = \frac{0.115}{3} \times (0.02625 \times 0.0225) + \sqrt{0.02625 \times 0.0225}$$
$$V_h = 0.0243m^3$$

4.1.2.The length of the roller was designed using the Winkler equation.

This was calculated from equation 3.4

$\boldsymbol{L_s} = \frac{1.01}{\mathbf{0.25}\times 9\times\mathbf{0.67}}$

$$\boldsymbol{L_s} = 0.67m$$
$$\boldsymbol{L_s} = 0.67 \times 1.5 = 1.005m = 1005mm \sim 1000mm$$

Where; $\boldsymbol{L_s}$ is the roller length, n is the shaft speed in rps, $\boldsymbol{\delta}$ is the material factor, 0.67, k=0.25kg/m, and 1.5 is the factor of safety

4.1.3.Number of spikes/pegs

This was calculated from equation 3.6

$$\mathbf{N_p} = \frac{610 \times 102\boldsymbol{\pi}}{80 \times 81}$$
$$\mathbf{N_p} = 30$$

4.1.4.Design of the shafts.

Design of the rollers and the spiral shafts.

During a study of the morphological characteristics of the whole maize cob, it was found that the cob was surrounded by layers of 6 to 20 sheaths attached to the stalk. It was assumed maximum number of sheaths should be de-husked from the de-husking unit. The following design considerations were undertaken for designing the de-husker roller: Maximum number of sheaths per cob = 20

4.1.5.Design of the de-husker main shaft.

According to the maximum shear stress theory (Guest theory), the equivalent twisting moment for a shaft subjected to torsion loading and bending moment in combination is calculated from equation 3.8

$$J = \frac{\pi}{32}(D^4 - d^4)$$

$$\frac{T}{J} = \frac{\tau}{R}$$

$$T = \frac{\pi(D^4 - d^4)\tau}{16D}$$

$$\tau max = 75MPa$$

$$T = \frac{\pi D^3 \tau(1 - k^4)}{16}$$

Where $k = \frac{d}{D}$And for GI pipe, take $k = 0.87$

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

$\omega = 376.99rad/s$

$\frac{P}{\omega} = T$

$T = \frac{2484}{376.99}$

$T = 6.589Nm$

$$6.589 = \frac{\pi \times D^3 \times 75(1 - 0.87^4)}{16}$$

$$D^3 = 1.0476$$

$$D = 0.1015m$$

$$D = 101.56mm$$

The chosen diameter was a 3-inch diameter since it's the recommended diameter for de-husking.

Therefore, $D = 3inch = 76.2mm$

From, $0.87 = \frac{d}{76.2}$, $d = 66.294mm$

Therefore, the internal diameter is 66mm.

4.1.5.1.Calculating Shear stress on the shaft.

The figure 4.1 below shows the forces acting on the de-husking shaft, shear force diagram and the bending moment diagram where 20N is the weight of the pulley, 30N is the weight of the roller linings and 15N is the weight of the bushings.

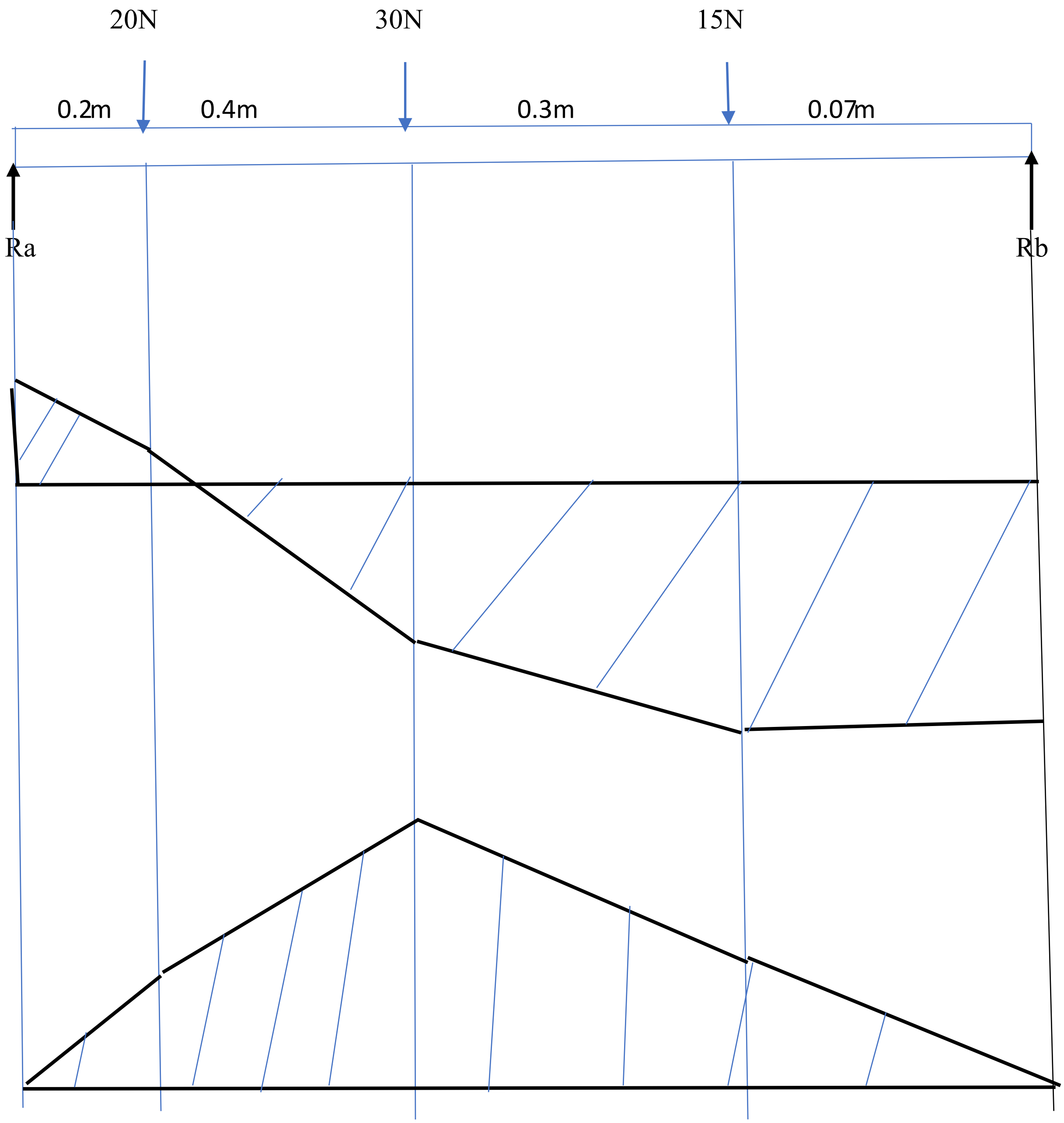


Figure 4.1 shows shear force and bending moment diagrams for a dehusking roller

Taking a moment at point Rb

$$(R_a \times 0.97) - (20 \times 0.77) - (30 \times 0.37) - (15 \times 0.07) = 0$$

$$R_a = 28.40N$$

Considering vertical forces

$$28.40 + R_b = (20 + 30 + 15)$$

$$R_b = 36.60N$$

Shear forces at different points

S.F at start $= 28.40N$

S.F $= 28.40 - 20 = 8.40N$

S.F $= 8.40 - 30 = -21.60N$

S.F $= -21.60 - 15 = -36.60N$

S.F $= -36.60 + 36.60 = 0.00N$

Bending moment at different points

B.M at start $= 28.40 \times .2 = 5.68Nm$

B.M $= (28.40 \times .6) - (20 \times 0.4) = 9.04Nm$

B.M $= (28.40 \times .9) - (20 \times 0.7) - (30 \times .3) = 2.56Nm$

B.M = 0.0Nm

$$\tau = \frac{Tr}{J} = \frac{Tr}{\frac{\pi}{32}(D^4 - d^4)} = \frac{32 \times 6.589 \times 33 \times 10^{-3}}{\pi((76.2 \times 10^{-3})^4 - (66 \times 10^{-3})^4)} = 0.1503MN/m^2$$

Shear stress on the peeling rollers $= 0.1503MN/m^2$

Bending stress

$$\delta = \frac{MR}{I} = \frac{MR}{\frac{\pi}{64}(D^4 - d^4)}$$

$$\frac{64 \times 9.04 \times 38.1 \times 10^{-3}}{\pi((76.2 \times 10^{-3})^4 - (66 \times 10^{-3})^4)}$$

$$= 476020.6N/m^2$$

4.1.6. Design of the Threshing Shaft.

Design of shaft diameter.

Considering;

Shaft length, $L = 610mm$

Speed, $N = 3600rpm$

Material Galvanized Iron

Assumption: Yield strength $S_{yt} = 250\ MPa$

Ultimate strength $S_{ut} = 400MPa$

For $\tau_{max} = \min(0.3S_{yt}, 0.18S_{ut})$

$$\tau_{max} = (0.3 \times 250) = 75MPa$$

$\tau_{max} = (0.18 \times 400) = 72MPa$If the material is mild steel.

We consider the minimal maximum shear stress because minor shocks are applied.

Torque calculation;

From equation 3.25

$$T = \frac{5.6 \times 60}{2\pi \times 3600}$$

$$T = 14.85Nm$$

Forces acting on the shaft.

Forces acting at the center of the shaft; $(F_1) = (weight\ of\ the\ spikes + weight\ of\ dry\ maize)$

$$(F_1) = M_{spikes} + M_{maize})xg$$

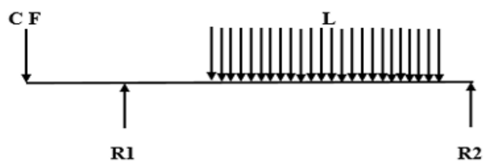
$$(F_1) = (3.996 + 0.03073)x9.81$$

$$(F_1) = 39.5N$$

Total vertical load acting on the shaft $F_2 = weight\ of\ pulleys$

$$F_2 = 2.5x9.81$$

$$F_2 = 24.525N$$



The figure shows Representation of the forces: CF- centrifugal force due to the pulley L-force exerted by cobs of maize and the spikes on the cylinder, R1 and R2-reactions from the two bearings.

The uniformly distributed loads L are turned into a point load.

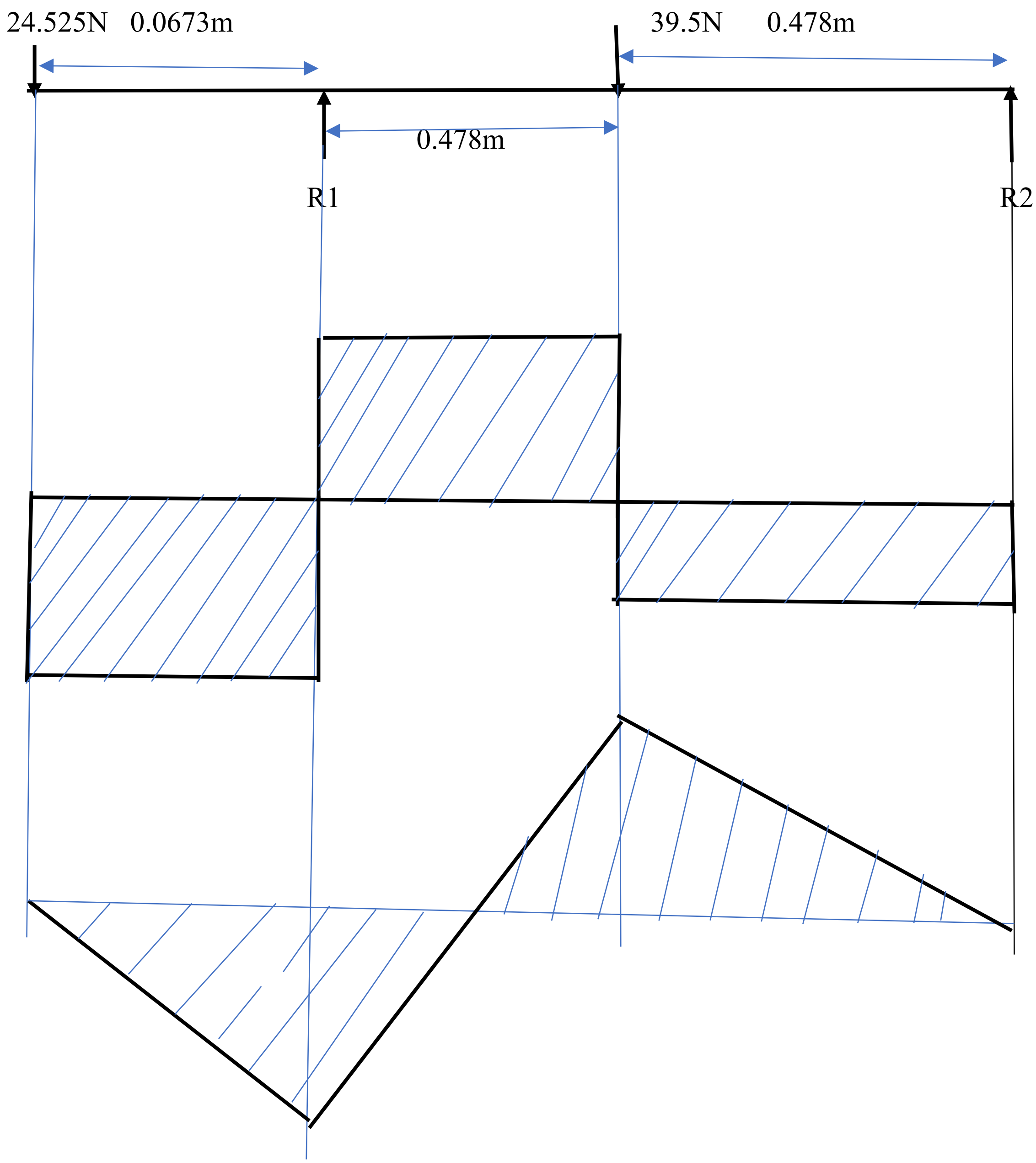


Figure 4.2 shows shear force and bending moment diagrams for a threshing shaft

Taking a moment at point 1

$$(R_2 \times 0.956) + (24.525 \times 0.0673) = (39.5 \times 0.478)$$

$$R_2 = 18.02N$$

Considering vertical forces

$$18.02 + R_1 = (24.525 + 39.5)$$

$$R_1 = 46.01N$$

Shear forces at different points

S.F at start = $-24.525N$

S.F at R1 = $-24.52 + 46.01 = 21.49N$

S.F at 39.5N = $21.49 - 39.5 = -18.02N$

S.F at R2 = $-18.02 + 18.02 = 0.0N$

Bending moment at different points

B.M at 24.525N force = 0

B.M at R1 = $-(24.525 \times 0.0673) = -1.651Nm$

B.M at 39.5N force = $-24.525(0.0673 + 0.478) + (46.01 \times 0.478) = 8.619Nm$

B.M at R2 = $-(24.525 \times 1.0233) + (46.01 \times 0.956) - (39.5 \times 0.478) = \ 0.008Nm$

B.M at R2= 0.

From:

$$J = \frac{\pi}{32}(D^4 - d^4)$$

$$\frac{T}{J} = \frac{\tau}{R}$$

$$T = \frac{\pi(D^4 - d^4)\tau}{16D}$$

$$\tau max = 75MPa$$

$$T = \frac{\pi D^3 \tau (1 - k^4)}{16}$$

Where $k =, and$ for GI pipe, take $k = 0.87$

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

$\omega = 376.99 rad/s$

$\frac{P}{\omega} = T$

$T = \frac{2484}{376.99}$

$T = 6.589 Nm$

$$6.589 = \frac{\pi \times D^3 \times 75(1 - 0.87^4)}{16}$$

$$D^3 = 1.0476$$

$$D = 0.1015 m$$

$$D = 101.56 mm$$

The chosen diameter was 4 inches.

Therefore, $D = 4 inch = 101.6 mm$

From, $0.87 = \frac{d}{101.6}$

$$d = 88.4 mm$$

Therefore, the internal diameter is 88.4mm

4.1.7.Design of the sieve

Area of the sieve of the sieve was calculated from equation 3.10

$$\text{Area} = \pi \text{rL} \ (mm^2)$$

Where r = radius and L = length of the sieve

$$\text{Area} = \pi \times 80 \times 788 \ (mm^2)$$

$$\text{Area} = 198046 \ (mm^2) = 0.198 \ m^2$$

$$\text{Volume} = \text{Area} \times \text{height}$$

$$\text{Volume} = \pi \times 80 \times 788 \times 120$$

$$\text{Volume} = 0.023766m^3$$

Total area of the holes: Area $= 12 \times 12 \times 468 = 0.067392m^2$

Area under stress= $total\ area - area\ of\ the\ holes$

$$= 0.198 - 0.067392$$

$$0.13061m^2$$

4.1.8.Speed of the pulley on the rollers.

From equation 3.11, the pulley speed on the rollers was calculated.

$$\mathrm{N}_2 = \frac{3600 \times 55}{304.8}$$

$$\mathrm{N}_2 = 649.6\mathrm{rpm}$$

4.1.9.Peripheral speed of the de-husking rollers.

This was calculated from equation 3.23

$$\boldsymbol{V}_r = \frac{\pi \times 0.0762 \times \mathbf{649.6}}{\mathbf{60}}$$

$$V = 2.592m/s$$

Speed of the pulley on the thresher; N_2

From equation 3.18, the speed of the pulley on the thresher was calculated.

$$\mathrm{N}_2 = \frac{254\mathrm{x}649.6}{170}$$

$$\mathrm{N}_2 = 970.6rpm$$

4.1.10.Speed of the threshing shaft.

From equation 3.3, the speed of threshing shaft was calculated.

But D = 101.6mm, n = 970.6 rpm

$$\mathrm{V} = \frac{\pi \times 0.1016 \times 970.6}{60}$$

V = 5.1634m/s

4.1.11. Belt design.

De-husking belt design

$d_1 = 54\text{mm}$

$d_2 = 304.8\text{mm}$

$N_1 = 1500\ \text{rpm}$

Belt length;

Belt length was calculated from equation 3.12

$$L = \pi(152.4 - 27) + 2 \times 670 + \frac{1}{670}(152.4 - 27)^2$$

$$L = 1757.43\text{mm.}$$

Threshing unit

Since the belt is crossed;

From equation 3.12, the belt length was calculated

$$L = \pi(127 + 85) + 2 \times 500 + \frac{1}{500}(127 + 85)^2$$

$$L = 1755.91\text{mm}$$

Tension in the de-husking belt.

Belt tensions;

Assumptions

B- Section V-belt properties

Mass per metre (m) =0.18kg/m

Maximum stress $\sigma_{max} = 2\text{MPa}$

Width (b) = 17mm

Thickness (t) = 11mm

Coefficient of friction $\mu = 0.3$

Groove angle $(\beta) = 40°$

Belt velocity, $v = \frac{\pi d_1 N_1}{60}$

$$v = \frac{\pi x 50.8 x 3600}{60}$$

$$v = 9.57 m/s$$

Centrifugal tension, T_c was calculated from equation 3.13

$$T_c = 16.519N$$

Maximum tension T was calculated from equation 3.14

$$T = 2 \times 10^6 x 0.017 x 0.011$$

$$T = 374N$$

Tension on the tight side, T_1 from equation 3.15

$$T_1 = T - T_c = (374 - 16.519) = 357.481N$$

Angle of contact (θ);

From equation 3.17

$$\sin\alpha = \frac{152.4 - 27}{670} = 0.187$$

$$\alpha = 10.78°$$

$\theta = (180° - 2\alpha)\frac{\pi}{180} = 2.765$ rad

Tension in the slack side, $T_{2,}$ was calculated from equation 3.16

$$T_2 = \frac{357.481}{3.6398} = 98.21N$$

4.1.11.1.Power Transmitted

Power transmitted was calculated from equation 3.5

$P = (357.481 - 98.21)9.58$

$$P_1 = 2.484kW$$

Tension in the threshing belt.

Assumptions

B- Section V-belt properties

Mass per meter (m) =0.18kg/m

Maximum stress $\sigma_{\mathrm{max}} = 2\mathrm{MPa}$

Width (b) = 17mm

Thickness (t) = 11mm

Coefficient of friction $\mu = 0.3$

Groove angle $(\beta) = 40°$

Belt velocity, $v = \frac{\pi d_1 N_1}{60}$

$$v = \frac{\pi x177.8x928}{60}$$

$$v = 8.64 \mathrm{m/s}$$

Centrifugal tension, T_c was calculate from equation 3.12

$$T_c = 0.18x8.64^2$$

$$T_c = 13.434\mathrm{N}$$

Maximum tension T;

This was got from equation 3.14

$$T = 2 \times 10^6 x0.017x0.011$$

$$T = 374\mathrm{N}$$

Tension on the tight side, T_1 was calculated from equation 3.15

$$T_1 = (374 - 13.434) = 360.566\mathrm{N}$$

Angle of contact (θ);

From equation 3.17

$$\sin \alpha = \frac{127 + 88.9}{500} = 0.4318$$

$$\alpha = 25.58°$$

$$\theta = (180° + 2\alpha)\frac{\pi}{180} = 2.25 \text{ rad}$$

Tension in the slack side, T_2 was calculated from equation 3.16

Where $\beta = 36$

$$T_2 = \frac{360.566}{14.0737} = 25.621\text{N}$$

4.1.11.2.Power Transmitted

From equation 3.7, the power was calculated.

$$= (360.566 - 25.62)\ 8.639$$

$$P_2 = 2.894kW$$

$P_{\text{friction}} = \text{frictional load} \times \text{P}$, (assume frictional load = 10%)

$$P_f = 0.1 \times (2.894 + 2.484)$$

$$P_f = 0.538\text{kW}$$

Total power= $(2.894 + 2.484 + 0.538) = 5.916kW$

4.1.12. BELT SELECTION

The selection of V-belts depends on the following factors: Power transmitted, speed of the belt, material of the belt, length of the belt, and service factor.

A guide to V-belt selection is given in following chart.

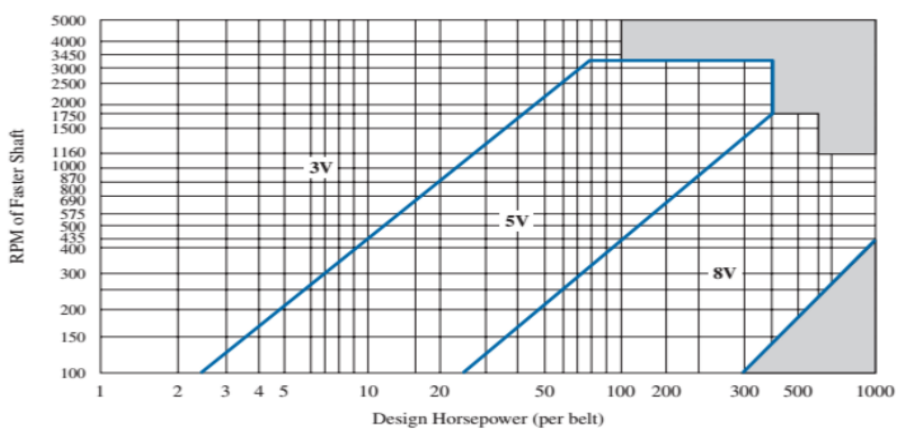


Figure 4.3 Shows a guide to the belt selection
courtesy of *(Khurmi and Gupta, 2005)*
The belt to be selected is 3V according to the engine capacity.

4.1.13.Design of the frame.

The total weight of the machine is 70kg.

Yield strength $S_{yt} = 250\ MPa$

Young's modulus (E) = 200GPa

Safety factor = 5 (For agricultural equipment standard)

Frame configuration = 4 Vertical legs

Load distribution;

$$F_t = Wg$$

$$F_t = 70 \times 9.81$$

$$F_t = 686.7N$$

Force per leg,

$$F_{leg} = \frac{F_t}{4}$$

$$F_{leg} = \frac{686.7}{4}$$

$F_{leg} = 171.675N.$

Required cross-sectional area per leg;

$$\sigma_{allow} = \frac{S_{yt}}{F.O.S}$$

$$\sigma_{allow} = \frac{250}{5}$$

$$\sigma_{allow} = 50MPa$$

$$A_{min} = \frac{F_{leg}}{\sigma_{allow}}$$

$$A_{min} = \frac{171.675}{50}$$

$$A_{min} = 3.43mm^2$$

4.1.14.The gears mechanisms

Four spur gears of the same size were connected to each roller, as they are responsible for driving the rollers.

Determination of the circular pitch

Circular pitch: It is the distance measured on the circumference of the pitch circle from a point of one tooth to the corresponding point on the next tooth

Circular pitch $= \frac{\pi D}{T} = \frac{110\pi}{19} = 18.2mm$

Gear ratio $= \frac{T_2}{T_1} \times \frac{T_3}{T_2} \times \frac{T_4}{T_3}$

$$= \frac{19}{19} \times \frac{19}{19} \times \frac{19}{19} = 1$$

Determination of the angular velocity of the gears

The angular velocity of the gear was determined using the formula from equation 3.23

N =649.6 rpm $\quad \omega = 2 \times \pi \times 649.6$

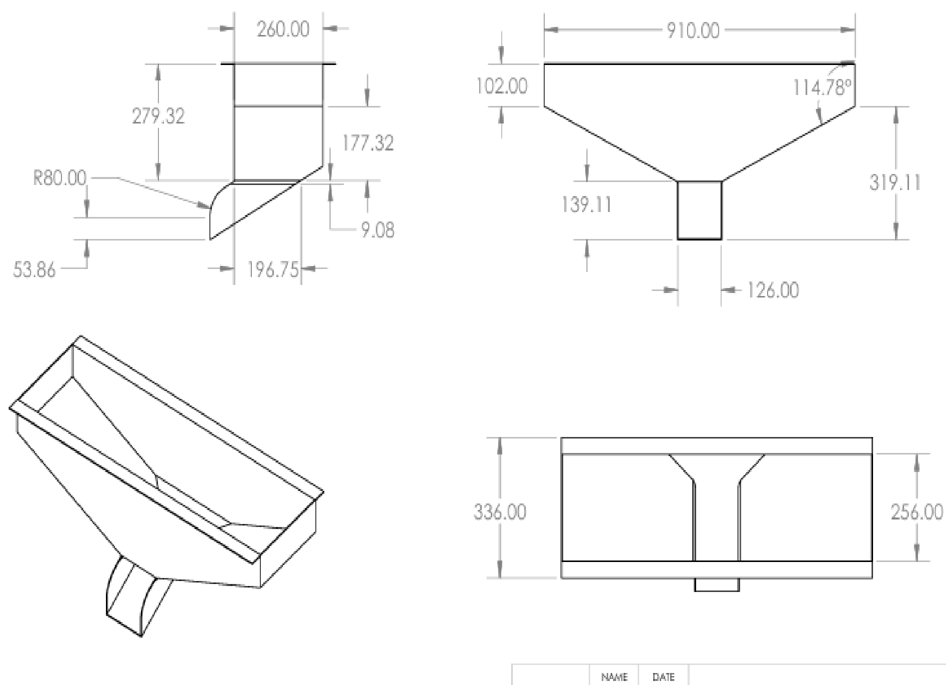
Angular velocity is 68.026rad/s

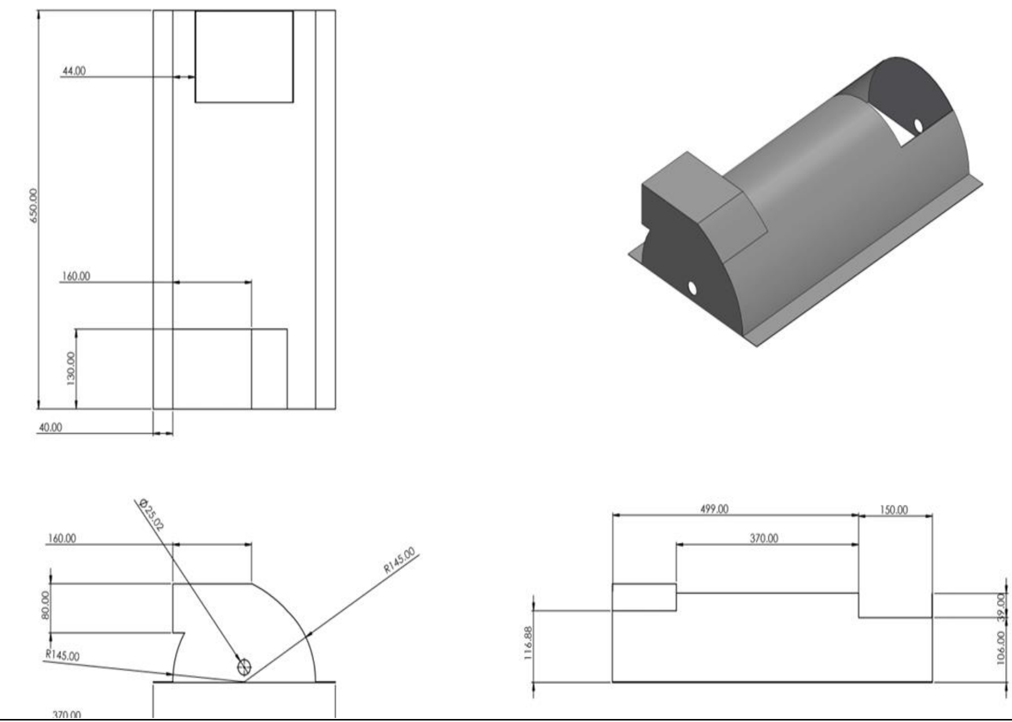
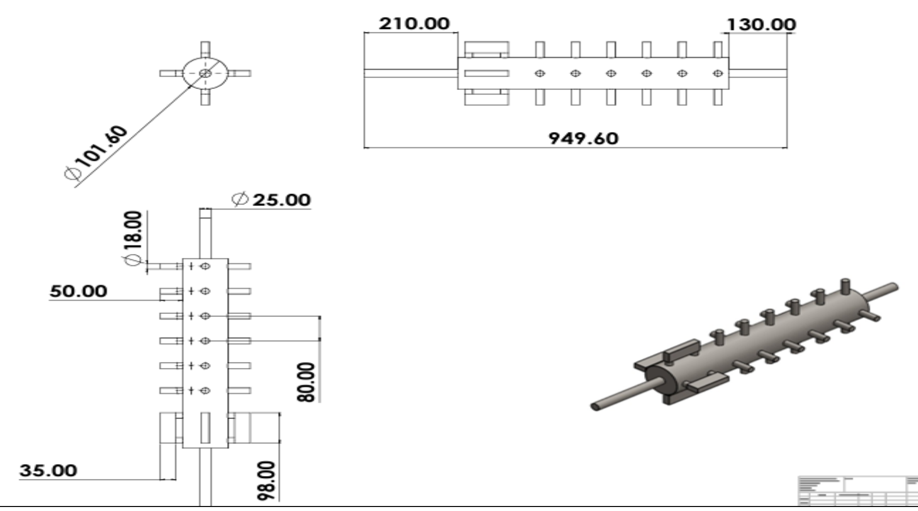
4.2.TO FABRICATION AND ASSEMBLY OF MACHINE COMPONENTS.

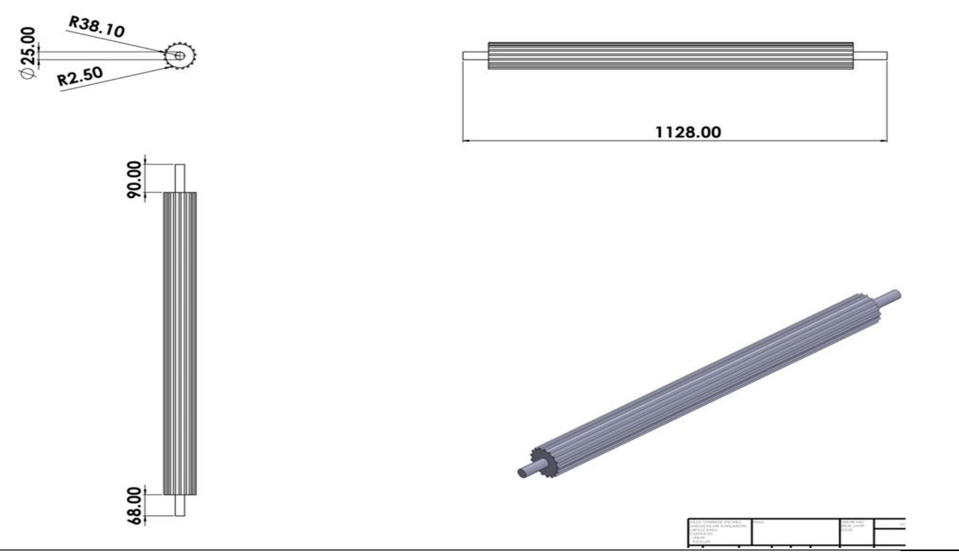
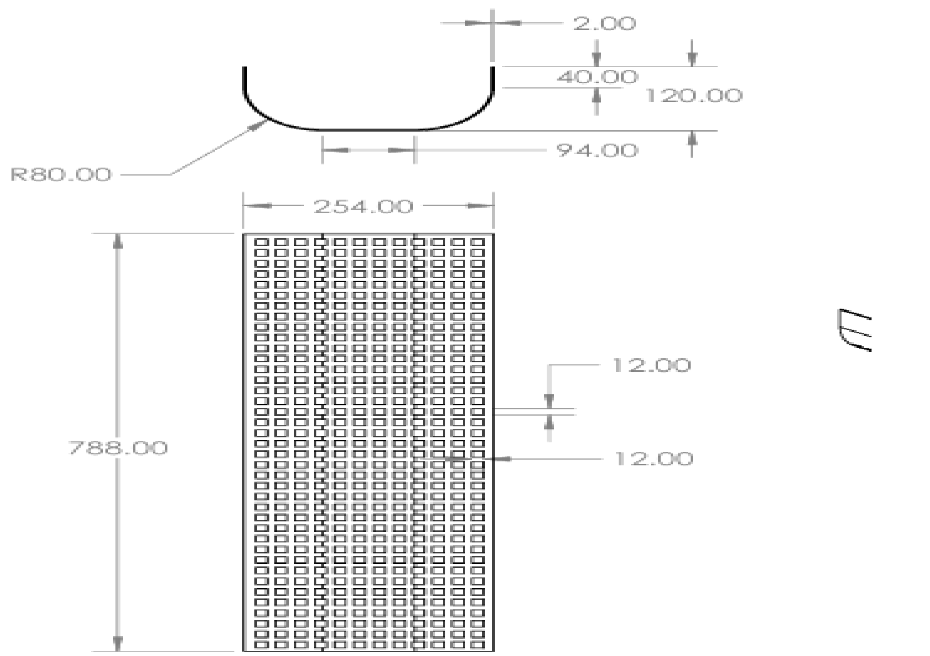
The components that we fabricated include hoppers, top covers, stands, peeling units, and threshing units. After the fabrication, the components were assembled with the help of pulleys, V-belt, bearings, and bushes to form a complete machine for peeling maize. The procedures we followed when fabricating the machine, including the sketch.

The fabricated components such as, the top cover, de-husker rollers, threshing shaft, threshing unit and the sieve are shown in Table 4-1

Table 4-1shows the designed and fabricated components

S/N	Components	Fabrication procedures followed	sketch
1	Threshing unit chamber	This was made from a 1.5 mm mild steel plate	

2	Top covers	The cover was made from a 1.5 mm mild steel plate. The top cover is concave.	
3	The threshing unit	The threshing shaft was made from a hollow shaft and connected to a 25mm solid shaft supported by the bearings.	

4	The peeling units	The four peeling rollers were made from a hollow shaft and connected to a 25mm shaft, which is connected to gears	
5	The sieve	The sieve was made from a plate of 2mm thickness	

4.2.1. The assembled Machine.

All the components were assembled together by welding, to form a full machine as shown in figure 4.4 and the parts list of the machine are shown in figure 4.5.

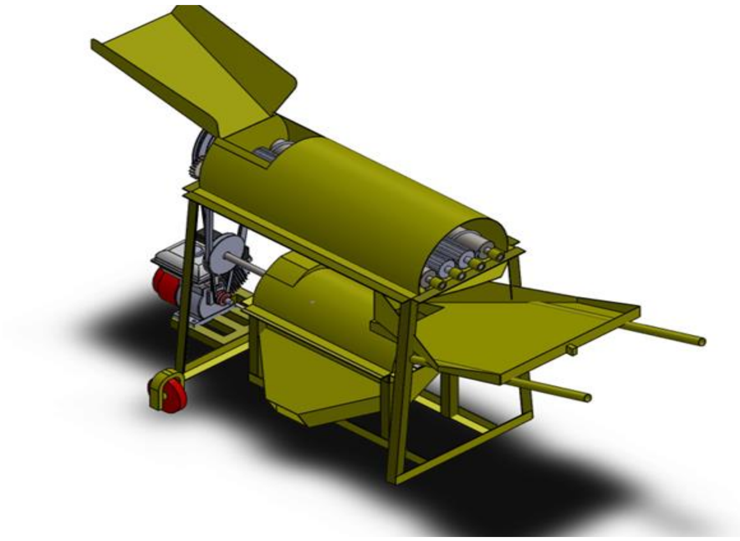
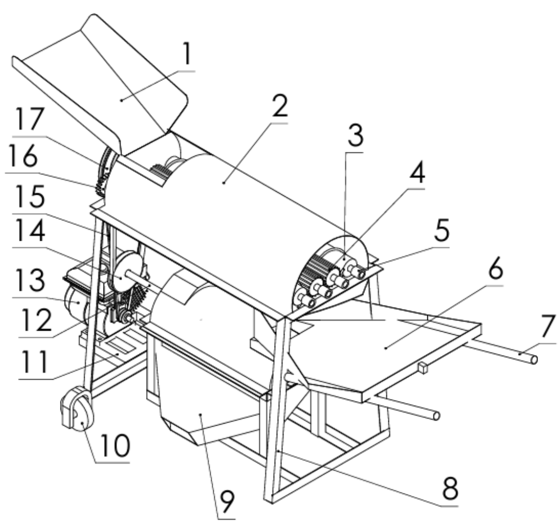


Figure 4.4: shows the fabricated and assembled components



ASSEMBLY COMPONENTS

1 Sliding Plate
2 Roller and Spiral cover
3 Spiral Shaft
4 Roller
5 Bushing
6 Hopper
7 Handle
8 Frame
9 Kernel output
10 Wheels
11 Engine Base
12 Threshing Shaft
13 Engine
14 Threshing pulley
15 De-husking belt
16 Gears
17 Driven pulley(1st)

Figure 4.5: shows machine parts list

4.3.To evaluate the performance of the machine.

The machine was tested after fabrication and figures 4.6 and 4.7, shows the husks and kernels obtained after machine testing and the results of testing were tabulated in Table 4-2

Figure 4.6: shows husks after machine testing

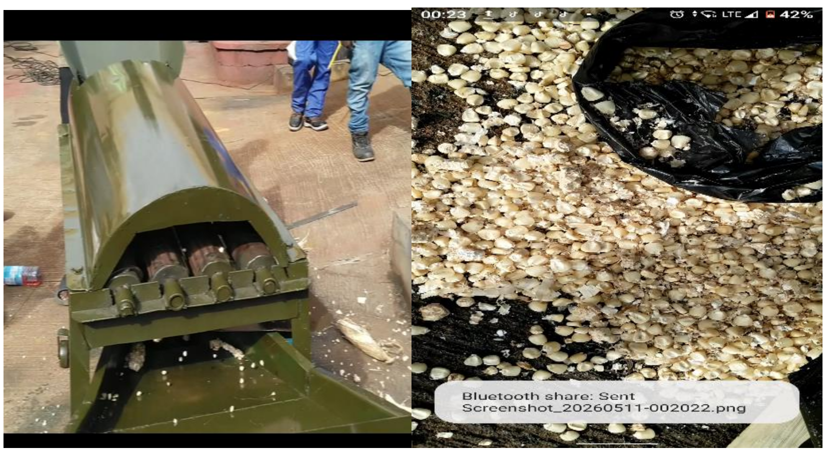


Figure 4.7: shows kernel after machine testing.

Table 4-2: Results obtained from the testing process

Test	Number of maize fed in for de-husking	Number of maize effectively de-husked	Number of maize falling into the threshing unit	Number of maize effectively threshed	Time taken to de-husk and thresh (seconds)
1	13	10	7	7	49
2	5	5	4	4	30
3	10	8	6	5	39

4.3.1. Fuel consumption rate

Fuel rate, $F_r = \frac{Fuel\ liters}{time\ in\ hours}$

Fuel rate, $F_r = \frac{1.5}{1} = 1.5l/hr$

4.3.2. De-husking efficiency

This was calculated from equation 3.27

$$Eff = \frac{(10+5+8)}{(13+5+10)} \times 100\%$$

$$Eff = 82.1\%$$

4.3.3. Threshing efficiency

This was calculated from equation 3.28

$$Eff = \frac{(7+4+5)}{(7+4+6)} \times 100\%$$

$$Eff = 94\%$$

The machine achieved a de-husking efficiency of 82.1%, and this is slightly close to 85% de-husking efficiency reported by Dange *et al.*, 2021)

The machine achieved a threshing efficiency of 94%, which is very competitive compared to 92% shelling efficiency reported by (Dange *et al.*, 2021) and 89.61% reported by (Lawal, 2020)

4.4.To perform the economic analysis of the machine.

This was done with the help of the budget I used, and the cost of items were tabulated in Table 4-3

Table 4-3: The budget that I used

S/N	ITEMS	SPECIFICATIONS	ANTITY	UNIT PRICE	AMOUNT
1	Gasoline engine	7.0Hp	1	400000	400000
2	Gears		4	25000	100000
3	Mild steel shaft	25mm	1	50000	50000
4	Mild steel angle bar	$(40 * 40 * 3)mm$	1	50000	50000
5	Cutting disc		1	10000	10000
6	Welding rod	Gauge 10	1 packet	15000	15000
7	Paints		2 litres	16000	32000
8	Airtime and Data			20000	20000
9	Mild steel plate	1.5mm	1	200000	200000
10	Aluminium pulley		1	45000	90000
11	Belts		2	15000	30000
12	Iron rod	18mm	13ft	920	11960
13	Small rods			20000	20000
14	Bearings	25mm	3	45000	135000
15	Hollow shaft	5mm thickness		25000	100000
16	Sample and Transport				145000
17	Cost of designing				115500
18	Labour				300000
19	Miscellaneous				150000
	GRAND TOTAL				1974460

Table 4-3: shows considerations to aid in economic analysis.

Initial Investment Cost (I_0)	UGX 1,974,460
Life of Machine	5 years
Salvage Value	UGX 0
Discount Rate (r)	15% per annum
Seasons per Year	2 seasons
Farmer's Own Harvested Area	1.5 hectares per season
Other Farmers' Total Area	4 hectares per season
Total Area Processed per Season	5.5 hectares
Average Maize Yield	800 kg per hectare
Selling Price of Maize	UGX 1,500 per kg
Labor Cost (2 workers @ UGX 10,000/day each)	UGX 20,000 per day total
Working Hours per Day	8 hours
Labor Cost per Hour (2 workers total)	UGX 2,500 per hour
Machine Operating Days per Season	5 days
Fuel Consumption Rate	1.5 liters per hour
Fuel Cost (Petrol)	UGX 6,000 per liter
Maintenance & Repair Cost	10% of annual revenue

OPERATING HOURS

Hours per day	8 hours	8 hours
Days per season	5 days	5 days
Hours per season	8 × 5	40 hours
Hours per year (2 seasons)	40 × 2	80 hours

Revenue per season.

Total maize processed = 5.5 hectares × 800 kg/ha = 4,400 kg

Revenue per season = 5,500 kg × UGX 1,500/kg = UGX 6,600,000

Annual Revenue = UGX 6,600,000 × 2 = UGX 13,200,000

4.4.1.OPERATING COSTS

Labor Cost (2 workers @ UGX 10,000/day each = UGX 20,000/day total)

Period	Hours	Rate (per hour)	Cost
Per season	40	UGX 2,500	UGX 100,000
Per year	80	UGX 2,500	UGX 200,000

Fuel Cost

Period	Hours	Consumption (L/hr)	Total Fuel (L)	Cost at UGX 6,000/L
Per season	40	1.5	60	UGX 300,000
Per year	80	1.5	120	UGX 600,000

Maintenance & Repair Cost (10% of annual revenue)

Annual Maintenance = 10% × UGX 13,200,000 = UGX 1,320,000

Total Annual Operating Cost

Cost Component	Amount (UGX)
Labor (2 workers, 80 hours/year)	200,000
Fuel (120 liters/year)	600,000
Maintenance & Repairs	1,320,000
Total Annual Operating Cost	UGX 2,120,000

4.4.2.NET ANNUAL CASH FLOW

Description	Amount (UGX)
Annual Revenue	13,200,000
Total Annual Operating Cost	2,120,000
Net Annual Cash Flow	UGX 11,080,000

4.4.3.NET PRESENT VALUE (NPV) CALCULATION

Net Present Value was calculated from equation 3.29

Where:

Cf = UGX 11,080,000per year

r = 15% = 0.15

I_0 = UGX 1,974,460

Discounted Cash Flows:

Year	Cash Flow (UGX)	Present Value (UGX)
1	11,080,000	9,634,783
2	11,080,000	8,378,072
3	11,080,000	7,285,279
4	11,080,000	6,335,026
5	11,080,000	5,508,718
Total Present Value of Cash Flows		37,141,878

NPV=37,141,878−1,974,460 =35,167,418

Since the NPV is **positive (UGX 35,167,418 > 0)**, the project is **financially viable and acceptable**.

4.4.4.PROFITABILITY INDEX (PI)

Profitability Index was calculated from equation 3.30

$$\mathrm{P.I} = \frac{35{,}167{,}418}{1{,}974{,}460}$$

$\mathrm{P.I} = 17.8$ This means, for every **UGX 1** invested in the machine, the farmer receives **UGX 17.8** in present value benefits over the 5 years.

4.4.5. PAYBACK PERIOD

This was calculated from equation 3.31

$$\text{Payback period} = \frac{1{,}974{,}460}{11{,}080{,}000} = 0.1782\text{years}$$

Payback period is approximately 2 months and 4 days. The farmer will recover the full initial investment of **UGX 1,974,460** in just over **2 months** and 4 days of operation.

4.4.6.DEPRECIATION

This was calculated from equation 3.32

Depreciation $= \frac{1,974,460}{5} = 394,892$

The machine loses **UGX 394,892** in value each year due to wear, tear, and usage, and after **5 years**, the machine has a book value of **UGX 0** (fully depreciated). This depreciation is a **non-cash expense** but can be used to reduce taxable income if the farmer is paying taxes.

From market research conducted, imported standalone maize threshing machines cost between UGX 2,100,000 and UGX 2,500,000, yet locally available machines (single operation) are UGX 1,950,000 to UGX 2,000,000. The fabricated machine is way cheaper than locally available alternatives and performs two operations (de-husking + threshing) in one pass, making it more cost-effective for small-scale farmers.

5. CONCLUSION AND RECOMMENDATIONS

This chapter presents the conclusion, challenges encountered during the implementation of the project, and recommendations for the improvement of the project for future designs.

5.1.Conclusion.

A single unit or machine that de-husks and threshes maize was designed and fabricated.
The de-husking efficiency and threshing efficiencies were 82.1% and 94%, respectively.
The result of the performance evaluation of the maize de-husker unit revealed that moisture content, speed of rollers, and feeding rate at various levels of operation affect the de-husking efficiency of the machine.
Machine de-husking capacity increases with an increase in feeding rate and roller speed, and grain loss also increases with an increase in roller speed and the moisture content.
Financial analysis shows that the machine is affordable to farmers, and the payback period is 2months and 4days

5.2.Recommendations.

The use of modern technology, where sensors detect maize after being de-husked and then released, increasing the number of spiral rollers and de-husking rollers, manufacturing of the machine to be used in countries farming maize, adding a blower to blow away the husks, putting guards near the moving machine parts to protect the users. The design must switch to food-grade materials for processing components and also to consider the minimization of vibration stresses.

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