Design, Development and Performance Evaluations of Engine Operated Groundnut Sheller

Jebessa Gemechu Sima

A Thesis submitted to

Department of Mechanical Engineering

School of Mechanical, Chemical and Materials Engineering.

Presented in Partial Fulfillment of the Requirement for the Degree of

Master of Science in Agricultural Machinery Engineering.

Office of Graduate Studies

Adama Science and Technology University

May, 2022

Adama, Ethiopia

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By: Jebessa Gemechu Sima

Advisor: Amana Wako Koroso (Ph.D.)

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DECLARATION OF STUDENT

I hereby declare that this MSc Thesis entitled "Design, Development and Performance Evaluations of Engine Operated Groundnut Sheller" is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Design, Development and Performance Evaluations of Engine Operated Groundnut Sheller" prepared under my guidance by **Mr. Jebessa Gemechu Sima (Id.No. PGR/19242/12)** submitted in partial fulfillment of the requirements for the degree of Masters of Science in Agricultural Machinery Engineering, the Graduate Program of the Department of Mechanical Engineering.

Therefore, I recommend the submission of a revised version of the thesis to the department following the applicable procedures.

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I, the advisors of the thesis entitled "Design, Development and Performance Evaluations of Engine Operated Groundnut Sheller" and developed by **Mr. Jebessa Gemechu Sima,** hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by **Mr. Jebessa Gemechu Sima** have read and evaluated the thesis entitled "Design, Development and Performance Evaluations of Engine Operated Groundnut Sheller " and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Agricultural Machinery Engineering.

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ACRONYMS

ASME	American Society of Mechanical Engineering
RCBD	Randomized complete block design
MARIC	Melkassa Agricultural Research Center
SSA	Sub-Saharan Africa
ASME	American Society of Mechanical Engineering
LSD	Least Significant Difference

ABSTRACT

Groundnut is one of the largely produced oilseed crops in Ethiopia. It generates significant financial income for various householders in Ethiopia, as well as foreign exchange. Even though, groundnut is the source of income and its capacity to generate household income is constrained due to the lack of appropriate shelling machine. Groundnut shelling is a fundamental process in post-harvest management. Traditionally farmers shell the groundnut with their hands and separate the pods from its kernels. This method of shelling groundnut pods requires high man-hour, drudgery to workers, has low output and it does not fulfill the market demand. To address these problems an engine operated groundnut sheller was developed. The main components of the machine are, the hopper, frame, shelling cylinder, concave, bellowers, kernels outlet, and power train components. Machine parts design was done with CATIA V5. The shelling operation is achieved by rotational motion of drum fitted with beaters flat belt in its periphery above the stationary concave grid which results in removal of kernel from pods. Some physical and mechanical properties of the pods and kernels, relevant to the design of the sheller, were studied. A randomized complete block design was used to evaluate the machine's performance at three levels of drum speeds and three levels of concave clearance with three replications, while grain moisture content was kept constant. The collected data were analyzed using SPSS 25 statistical software. The performance results revealed that as the cylinder speed increased, the shelling efficiency, shelling capacity, and scatter loss increased but the unshelled pod's percentage reduced. As cylinder speed and blower speed increased the cleaning efficiency and the blower loss increased. The optimum operating condition for the sheller was found to be at 170 rpm cylinder speed and 892 rpm blower speed, with total shelling efficiency of 96.25% and 94.44%, cleaning efficiency of 94.80% and 93.01%, grain loss of 0.15% and 0.20%, the throughput capacity of 308kg/hr and 282.61kg/hr for Burree and Babile varieties respectively, at 16 mm concave clearance and moisture content of 7.2% (d.b). The developed machine has good performance in all aspects with easy operation and comfort in the working environment. From the performance indices of the shelling machine, the sheller is recommended for groundnut producers and industries for both Burree and Babile groundnut variety.

Keywords: Groundnut, Shelling efficiency, Shelling machine and Machine capacity

CHAPTER ONE

1. INTRODUCTION

1.1. Background and Justification

The groundnut (*Arachis hypogaea* L.) is the world's sixth most significant oil crop (FAOSTAT, 2015). It's a valuable source of edible oil (43-55%) and protein (25-28%) for humans, as well as fodder for livestock (Issn & Gowda, 2018). Groundnuts were first grown in southern Bolivia and northern Argentina, then spread over the world. Groundnut, popularly known as peanut (Arachis hypogaea L.), is an important oilseed crop in the Leguminosae family. It is an essential crop in both subsistence and commercial farming systems throughout the world's arid and semi-arid regions (Mohammed *et al.,* 2018).

India, China, Nigeria, Senegal, Sudan, Burma, and the United States of America are the top groundnut producers, with a global average yield of more than 10 million tons per year (Bano & Negi, 2017). Developing countries account for 97% of world land area and 94% of global crop production. Africa contributes about 24.4% of the world's groundnuts (FAOSTAT, 2013). Small-scale farmers in Sub-Saharan Africa (SSA) grow the crop for direct use as food and as a cash crop in various countries (Mohammed *et al.,* 2018).

In Ethiopia groundnut is one of the five widely cultivated oilseed crops (Gelgelo, 2016). Ethiopian groundnut production is currently at a subsistence level. According to Ethiopia's Central Statistical Agency CSA (2011), 240,570 farmers planted groundnut on 49,602.97 ha of land, producing 71,6,06.84 tons and 1.44 (ton/ha) yield in 2010/2011. According to CSA (2021), report that groundnuts were planted on 113,514.95 hectares of land since 2020/21, with a total production of 205,068.65 tons and 1.81 (ton/ha) yield. Within ten years, the overall yield was increased by 96.29%, and the rate of production per hectare was improved by 20%.

Northwestern Ethiopia, the Benshangul Gumuz region (Metekel, Kemashi, and Asossa zones), Oromia (Wellega, Eastern Harergie, near Awash), Gambella, SNNP, Amhara (Gojjam), Afar (Werer), and other comparable areas of the country were among the primary growth areas of groundnut (CSA, 2015).

Due to its high market value and drought resistance, groundnut production is increasing. It generates significant financial income for various small-scale producers in Ethiopia, as well as foreign exchange earnings through export (Gelgelo, 2016). Even though groundnut is the fifth most produced oilseed in Ethiopia, the potential and prospect as a source of income and its capacity to generate household income are constrained due to the lack of appropriate shelling machines.

Shelling is the first major postharvest operation, which involves breaking pods and releasing kernels using mechanical forces. It constitutes about 38% of postharvest expenses (Mohammed *et al.,* 2018). The applied forces fall at random on the pods, breaking them stochastically and releasing the enclosed kernels. Breakage of the pods, which is dependent on the intensity of the applied force, pod orientation, moisture content, freedom of kernel from the pods, and passage of the kernels and broken pods through the concave openings are all physical phenomena involved in groundnut shelling.

Shelling operations differ from country to country and even within developing countries. It ranges from the traditional method of hand-shelling to the more modern use of power shellers. Smallholder and marginal farmers shell their crops manually using mortar and pestle. There are also variations in the plant's peeling pods. Crops of the bunch kind, for example, are heaped in piles with the pod end visible after harvest. After a week or so, the pegs grow brittle, and the pods are laboriously pulled off the vines. This technique is more difficult because the peg to pod attachment is stronger, however drying the plants for a few days makes it easier (Indiarto & Rezaharsamto, 2020).

Shelling enables groundnut for the use of the kernels and hull, as well as other postharvest technologies like oil extraction (Gitau *et al.*, 2013). Despite the large output of groundnuts, the problem of shelling or stripping has yet to be solved in all areas due to the lack of modern technology in developing nations such as Ethiopia.

In Ethiopia, shelling is traditionally done by a group of family members (dabo) who break off the pods and release the kernels by rubbing the pod between their thumb and finger. This technique is inefficient, time consuming, and wastes a lot of energy, and therefore failed to fulfill market demand. In addition, the output per man hour is very low. The rate of production is reduced and the number of workers is increased because one person can shell 2 to 4 kg of groundnut per hour using the hand-shelling method. As a result, groundnut pod shelling has become a key barrier to small and medium-scale groundnut cultivation and processing in Ethiopia.

According to report Gelgelo (2016), farmers lose a substantial amount of the kernel produced during harvesting, shelling, transporting, and storage due to the use of obsolete practices. The total loss has been estimated at about 20-40% of the total production. Out of the total estimated loss, 20-30% is due to poor land preparation, 30-40% is due to weeding infestation, 20-25% is due harvesting and 20-30% is during postharvest operation.

According to Paramawati *et al.* (2016), rapid postharvest management could reduce aflatoxin contamination on groundnuts. When using groundnuts as kernels, the shelling procedure must be completed quickly. They further claimed that using machines in postharvest handling and groundnut processing ensures that the nuts are free of aflatoxin contamination.

The development of engine-powered shellers has a good scope for the shelling of groundnut at the farm level and small-scale processing level. Therefore, this study has been undertaken to develop a suitable engine-driven groundnut sheller for farm-level and industrial uses. The machine was designed to have high shelling capacity and efficiency with minimum grain loss and less kernel damage.

1.2. Statements of the Problem

Groundnut is a major source of vegetable oil and contains a concentrated amount of minerals, proteins, and vitamins. In Ethiopia, groundnuts are highly demanded for oil production, peanut butter, peanut tea, and direct consumption as food. Mostly it serves as a cash crop and for foreign exchange, which increases the country's GDP. Currently, the industry is growing to a high level in Ethiopia, therefore the need for groundnut is increased as input for oil production in the industry. Even though the need for groundnut increased, there are constrained in production due to the absence of efficient shelling machine. The groundnut pods are stripped, dried, shelled, stored, and processed after they have been harvested. Shelling is an essential in groundnut production that requires a machine that can help to produce high-quality and quantity products in a short period of time with low labor costs.

Traditionally farmers shell groundnut with their hands and separate the kernels from their pods. In most of the cases the postharvest manual shelling operation of groundnut is done by women in rural area (Hoque *et al.,* 2018). In most rural farmer, shelling is performed by crushing the nuts in a mortar using a pestle and this results in a lot of kernel breakages. The pods are separated from the kernel by exposing it to the wind (Gelgelo (2016). These methods of shelling and cleanings are inefficient, time-consuming, labor-intensive, and drudgery for farmers. The existing manually operated groundnut shellers were labor intensive and drudgery for operators and the cleaning operations are performed separately, required 5 minutes rest after every 10-15 minutes operation (Hoque *et al.,* 2018).

The existing engine operated groundnut sheller developed by Gelgelo (2016), the beater was made up of flat belts bolted on straight flat bars and the concave was made up of 8 mm round bar. The flat belts bolted on straight flat bars and the concave made from straight arrangement, leads to impact action rather than shearing action which resulted in minimum shelling capacity and shelling efficiency. The concave is fixed stationery, which is not suitable for different varieties of groundnut and difficult to adjust the optimum point of the machine. Therefore, this parameter leads to minimize the shelling capacity and efficiency of the machine and increase the kernel mechanical damage.

The groundnut sheller machine designed and developed by Adenigba & Sedara (2021), having two shelling rollers, rubber beaters, screen and blower unit. Due to its two moving beaters, number of fan blades and screen type concave, leads to low cleaning, shelling efficiency, machine capacity and high mechanical damage.

To solve this problem the concave was made up 8 mm round bar and 4 mm round bars were welded in the interior part of the concave to increase the retention time of unshelled pods, which increases shelling efficiency, and throughput capacity. The beaters were made up of flat belts were helically arranged to beat groundnut by combined shearing and impact action and break the groundnut pods slightly to minimize the kernel mechanical damage. The feeding controller was also designed to control the amount of unshelled groundnut introduced into shelling unit, to optimize the machine shelling capacity and minimize kernel mechanical damage. The concave was adjustable, to adjust the clearance between shelling cylinder and concave by bolt and nut mechanism. Which helps to make the machine to be suitable for different verities of groundnut. This sheller has maximum throughput capacity, shelling, cleaning efficiency and low kernel mechanical damage.

1.3. Objective

1.3.1. General objective

The main objective of this study is to Design, develop and test the performance of engine operated groundnut sheller.

1.3.2. Specific objective

- To design groundnut shelling machine components.
- To manufacture groundnut shelling machine components.
- To assemble groundnut shelling machine components.
- To evaluate the performance of groundnut shelling machine.

1.4. Significance of the Study

The groundnut shelling machines are highly required for groundnut producers and industries. It has high operating efficiency with a low cost of equipment. Due to its adjustable concave clearance and feeding rate controller; it is suitable for different sizes of groundnut seeds. The machine needs less labor, it is easily operated, ergonomically safe to operate, has high efficiency, and has less crop damage. It has a high shelling capacity and production rate. As a result, the farmers can produce their groundnuts with minimum labor cost within a short period of time and can maximize their production. As the production increases the enterprises and industries could fulfill their market demand. The government could be benefited from this research by obtaining foreign exchange and increasing the country's GDP. Therefore, all the producers, enterprises, industries, and governments had benefited from this research.

1.5. Scope of the Study

The scope of this study was limited to the development of a cost-effective groundnut shelling machine powered by an engine, as well as to verify its effectiveness by shelling groundnut kernels. In this study the parts of the machine such as shaft, frame, concave, shelling cylinder, fun, and hopper were designed and constructed. That means including decisions on the size and type of the sheller and its parts.

CHAPTER TWO

2. REVIEW OF LITERATURE

2.1. Groundnut Production and its Importance

Groundnut is one of the world's most popular crops cultivated throughout the tropical and sub-tropical areas where annual precipitation is between 1000 – 1200mm for optimum growth of the crop (Mohammed *et al.,* 2018). It grows best on soils that are well-dried, loosely textured, and well supplied with calcium, potassium, and phosphorous. The production of groundnut is concentrated in Asia and Africa (56% and 40% of the global area and 68% and 25% of the global production, (Aminu *et al.*, 2020).

The general productivity of groundnut in Africa is comparatively low, compare to that of America due to a number of constraints such as biological, undulating climate, socio-economic factors, pests and diseases (Zongo *et al.,* 2019). The average output of groundnut in Africa 90.26ton ha^{-1} is very low comparative to the American output of 3338.14 tons ha^{-1} (FAOSTAT, 2018). The average yield of groundnut in Africa is about ¼ of that of the America's and about ½ of the yield of Asia due to low mechanization, pressure of pest and diseases and low yielding varieties among others (Desmae and Sones, 2017).

Groundnut is planted on every continent, covering 24.6 million hectares and yielding 41.3 million tons (Adenigba and Sedaraid, 2021). It is cultivated on subsistence and commercial bases for food and industrial purposes (Mohammed *et al.,* 2018). According to the Central Statistical Agency (CSA) of Ethiopia (2016), oil crops used to cover about 0.86 million hectares, involving close to four million smallholder producers in Oromia, Amhara, Tigray, and Benishangul- Gumuz Regional States. According to CSA report (2016), groundnut production in Ethiopia was 0.124 million tons. Out of total production, Oromia Region accounts for 60.80% (Gelgelo, 2016).

Groundnut is the thirteenth most important food crop in the world (Jabba, 2020). It is the world's fourth most important source of edible oil and the third most important source of vegetable protein (Sugri, 2020). Over 60% of global groundnut production is crushed for extraction of oil for edible and industrial uses while 40% is consumed for food uses and others such as seeds for sowing in the next season crop. Malnutrition is reduced with the help of groundnuts because it has more energy and proteins. It contains 43-55% oil and 26-28% protein and is a rich source of dietary fiber, minerals, and vitamins (Issn & Gowda, 2018).

2.2.Morphology and Properties of Groundnut

Groundnut plant grows to a height of 30cm to 50cm. The leaves are opposite, pinnate, and pinnate with four leaflets (opposite pairs; no terminal leaflet), each leaflet about 1 to 7 cm long and 1 to 3 cm wide. The flowers are pea-shaped, measuring 2 to 4 cm across, and yellow with reddish veining. The pods mature into a 3 to 7 cm long legume with 1 to 4 seeds per pod after pollination, forcing its way underground to maturity (Karthik, 2018).

The morphology, physical, and mechanical properties of groundnuts, such as cracking stress, moisture content, variety, size dimensions, coefficient of friction, and angle of repose, are the most important in sheller machine design. The physical qualities of seeds are considered crucial parameters to be determined with machine parameters in machine design. They are helpful in resolving a variety of machine design issues as well as in analyzing product behavior throughout agricultural processing. The size and form of the seed are described by dimensions such as geometric mean diameter, arithmetic mean diameter, aspect ratio, and sphericity, which determine its behavior such as flowability (Shukla, 2019).

2.3.Factors Affecting Groundnut Sheller Performance

Machine-based factors (cylinder speed, cylinder-concave clearance, type of cylinder, and fan speed), crop-based factors (crop moisture content, and orientation), and operator-based factors (feed rate, skill, and experience) are the three categories of factors that affect the performance of a sheller (Isaac, 2015).

2.3.1.Crop based factors

Many challenges involving the design or development of a specific machine, or assessing the behavior of the product in handling or grading the material, rely on the physical qualities of any material, such as shape, volume, and surface area. The kernel cleaner uses several ways of separation to clean various pods and kernels, depending on the width, length, thickness, and weight of the grain. The crop's properties must be considered when designing any agricultural machine (Muhammad & Isiaka, 2019).

2.3.1.1.Physical properties of groundnut

The design and building of postharvest processing equipment require knowledge of the physical qualities of pods, kernels, and other agricultural commodities. Moisture content, size, and angle of repose are only a few of the physical and technical attributes of pods and kernels (Wangette *et al.*, 2015).

For the same concave clearance and feed rate, the large-sized types had higher shelling efficiency than their small-sized counterparts (Wangette *et al.*, 2015). The length (L), width (W), and thickness (T) of groundnut pods may be measured by using a Digital Vernier Caliper having the least count of 0.01mm as illustrated in the figure (2.1). The longest dimension in the longitudinal direction is considered as length, while the dorsoventral dimension was measured as width and the third axis lateral dimension was measured as the thickness of the seed (Shukla *et al.*, 2019).

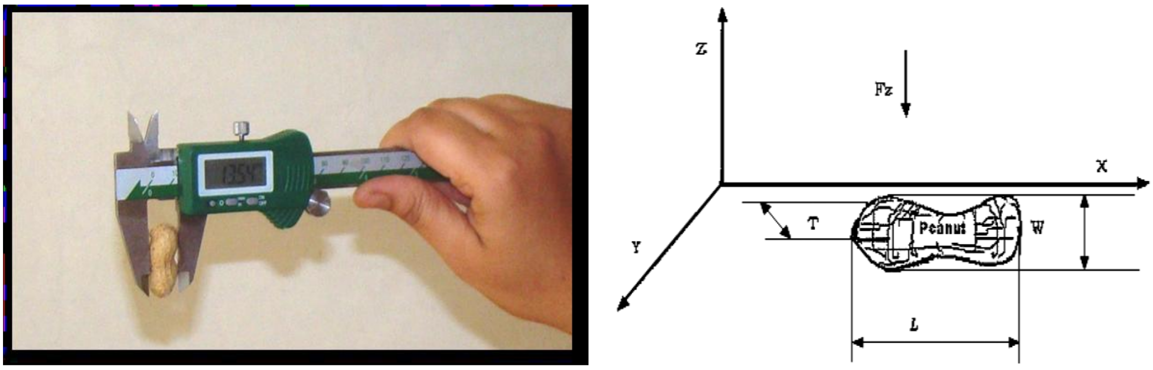


Figure 2.1. Three major axial dimensions of groundnut
Source (Shukla *et al.*, 2019).

The Angle of repose θ was determined by using a wooden box and two plates; fixed and adjustable as shown in Figure (2.2). The wooden box was filled with the groundnut sample and plate on the tilting top of the adjustable plate. The adjustable plate was gradually tilted until the materials start to move along the inclined surface. The angle of inclination was recorded from the adjustable protractor attached to the fixed plate as the angle of repose for the groundnut sample (Muhammad *et al.*, 2015)

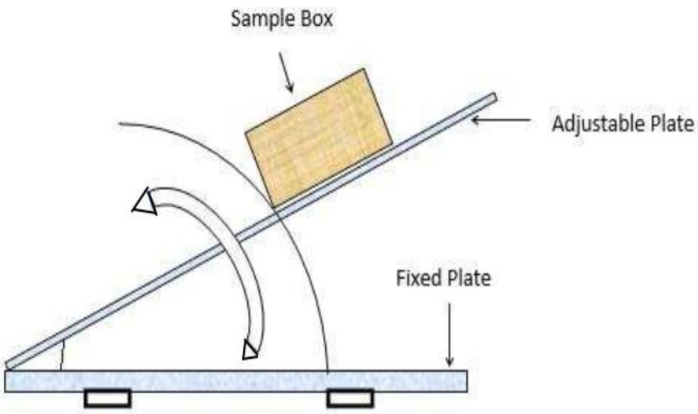


Figure 2.2. Measurement of static angle of repose for pods
Source (Muhammad *et al.*, 2015)

The coefficient of static friction was determined using the method of inclined plane equipment (Shukla *et al.,* 2019). The table was slowly elevated, and the protractor attached to the device was used to determine the angle of inclination to the horizontal at which the sample began to move (Figure 2.3). The coefficient of static friction was calculated using the tangent of the angle.

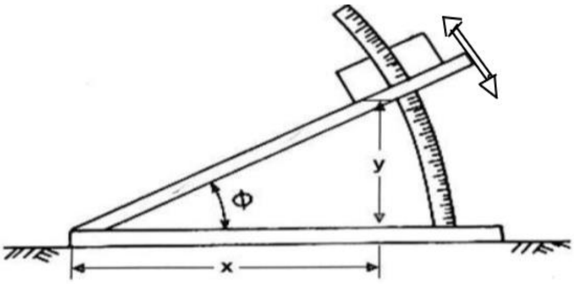


Figure 2.3. Measurement of coefficient of friction
Source (Shukla *et al.,* 2019).

2.3.1.2.Moisture content

The amount of water in a seed is referred to as its moisture content (Amoah, 2012). Too moist cereals and oilseeds, according to Wangette *et al*, (2015), can lead to mold growth, mycotoxin generation, mite infestations, and sprouting. Over-drying grain before or during storage, on the other hand, can result in splitting and cracking, poor quality, and energy waste. As a result, the grain moisture content is one of the most significant factors to consider when determining grain quality and value at the harvesting, storage, processing, and marketing stages (Shukla *et al.,* 2019).

Wangette *et al.* (2015), reported that shelling and winnowing efficiencies decreased while the percentage of partially shelled and unshelled pods increased with an increase in moisture content and feed rate. While the percentage of seed damage increased with an increase in moisture content between 5 and 10% (w.b) to a maximum value of about 38%, and decreased with a further increase in moisture content.

For all peanut cultivars, shelling efficiency rose as moisture content decreased (Gitau *et al.,* 2013). The main, minor, and intermediate diameters of groundnut kernels grow as moisture content rises. Experiments using Bambara nuts revealed that moisture content influenced performance more than feed rate. As a result, the percentage of seed damage rises as moisture content rises, but shelling efficiency falls as moisture content rises (Muhammad *et al.,* 2015).

2.3.2. Machine-based shelling factors

The performance of a groundnut sheller depends on cylinder size, concave clearance, the number of cylinder beaters, operating speed, and fan speed (Muhammad & Isiaka, 2019).

2.3.2.1. Concave to shelling cylinder clearance

Shelling efficiency and kernel damage can both rise when concave clearance decreases. While all studies on the subject noticed the same general tendency, their numbers for concave clearance for optimal shelling were varied. According to Nyaanga *et al.* (2007), the sheller's efficiency rises from 73.6% at 20 mm concave clearance to 79.8% at 30 mm, then drops to 73.2% at 40 mm clearance.

Kittichai (1984), designed a power-operated groundnut sheller, which was improved and tested. When the feed rate was maintained at 400 kg/h and pods were at 13% (d.b) moisture content, the sheller operated best at 180 rpm and 18 mm cylinder concave clearance. The capacity, shelling efficiency, and breakage of the machine were 280 kg/h, 98%, and 45%, respectively. The large impact force applied to the pods was the cause of the increase. Breakage percentages were lowered at all speeds as clearance was increased.

Experiments in Thailand revealed that when clearance increases, shelling efficiency and kernel damage decrease. Shellers with clearances ranging from 7 to 15 mm were used to shell Taina and other Thai peanut species (Isaac, 2015). With an increased clearance, less damage may be achieved, but shelling efficiency would be significantly reduced. As clearance increased from 8 to 12 mm, shelling effectiveness fell, and damage decreased rapidly, then progressively decreased as clearance increased from 12 to 20 mm (Rostami *et al.*, 2009). Helmy *et al.* (2013), discovered that a clearance of 18 mm resulted in a 95.44% shelling efficiency at a feed rate of 80 kg/h.

2.3.2.2. Shelling cylinder operating speed

The effect of machine-related parameters on shelling groundnuts increased shelling efficiency from 74 to 80.6% at a cylinder speed of 1.83 m/s and from 87 to 92.5% at a cylinder speed of 4.58 m/s (Shukla *et al.*, 2019).

A motorized Bambara groundnut sheller was developed by (Simonyan, 2014), and the shelling efficiency, percent damage, and cleaning efficiency of the sheller were all measured. Shelling efficiency (SE) and percent damage (PD) increased with increasing speed, according to the findings.

2.3.2.3.Type of shelling cylinder beaters

Groundnut pods are shelled when they get embedded in the space between shelling beaters and the concave sieve where they are acted upon by shearing, impact, or, frictional forces either singly or in combination with each other. The characteristics of the beaters that most likely affect shelling performance include; their material type, shape, and the number mounted on the cylinder (Isaac, 2015).

Gitau *et al.* (2013), determined that shelling efficiency was higher in steel rod beater shellers than wooden beater shellers. As far as the number of beaters is concerned, Helmy *et al.* (2013), determined that an increase in the number of drum beaters from 4 to 8 increased shelling efficiency and kernel damage. In studies by Kamboj *et al.* (2012), employing L-shaped blades on pea shelling provides maximum rubbing action, resulting in minimum kernel damage compared to that both impact and shearing actions. Centrifugal impellers or rollers rotating in counter directions are utilized in shelling kernels with hard pods or coats such as Bambara nuts (Siebenmorgan *et al.,* 2019).

2.3.3.Operator-based factors of groundnut shelling

Nyaanga *et al.* (2007), determined that feed rate increased with concave clearance. This was explained by the fact that the bigger the opening in the chamber the more pods that can be shelled per revolution. In the case of castor oil, shelling capacity, here referred to as mass flow rate, was found to increase with an increase in cylinder speed.

2.4.Groundnut Shelling Methods

One of the most important factors affecting agricultural productivity is the extent of automation. The amount of automation in a production system has an impact on its efficiency, hence greater levels of mechanization are linked to higher efficiencies. Shelling is the process of removing the husk from groundnut kernels in order to prepare them for storage or consumption. Groundnut shelling, cleaning, and separation labor costs can be considerably reduced using this device. The two most frequent types of shelling processes are manual and motorized. The striping is driven by a motor or an engine (Hoque *et al.,* 2018).

2.4.1.Traditional shelling methods

In developed countries, groundnut processing is highly mechanized but in most developing countries, manual processing is still the norm despite the drudgery and time wastage involved. The groundnut kernels are traditionally rubbed between the palms of the hands by mothers and children. Other legumes, such as sorghum and millet, are de-hulled either by hand smashing tempered grain with a pestle and mortar or mechanically using abrasive de-hullers (Adenigba and Sedara, 2021).

The manual shelling method is achieved by applying pressure to crack pods and releasing the kernel. In most developing countries' smallholder agriculture, it is the most often utilized method. while hand shelling reduces kernel breaking, it is time-consuming and can cause "sore thumb syndrome" when handling big volumes. Crushing or pushing the pods between the thumb and first finger to break off the pods and release the seed is the most common method of groundnut shelling, and it is still extensively employed today. This method has low efficiency, takes a long time, and requires a lot of energy (Gitau, 2013).

According to Jabba (2020), the capacity of hand shelling groundnut is 1-2.5 kg pods per man-hour. Groundnuts for this operation should have a nice physical appearance, with fewer vine-attached pods and fewer contaminants. Most groundnut plants are dried in the fields for 4 to 5 days before being stripped by plucking a handful of pods from the plants in rainfed areas.

Figure 2.4. Shelling by hand
Source (Adenigba and Sedara, 2021).

2.4.2.Mechanized shelling method

The mechanized shelling method could be employed in different ways depending on the type of machinery power source. These could be hand-operated or motorized machinery.

2.4.2.1.Manual operated shelling methods

The mechanized method involved the use of hand-operated machinery, which is primarily separated groundnut seeds from the pods without cleaning. The cleaning or winnowing is done as a separate operation. Small, hand-operated machineries were developed for this purpose, which meets the shelling needs of the farmers for their domestic consumption (Muhammad and Isiaka, 2019).

The operation of a manually operated groundnut sheller was causing human drudgery, necessitating a 5-minute break after every 10-15 minutes of work. The manual-operated sheller couldn't separate the husk from the grain or clean the grain from the unshelled groundnuts (Hoque *et al.,* 2018).

Manual operated groundnut shelling machine has a capacity of up to 118.9kg/hr (Mohamed and Hassan, 2012). When the cropped area is modest and laborers are available, shelling the pods is sometimes done concurrently with harvesting. The pods are dried right after they have been harvested. Manually operated shelling pods are usually accomplished by pounding the plant's pod end against a rough stone or a heavy iron rod (Ghatge *et al.,* 2014).

Figure 2.5. Hand operated machine
Source (Issn & Gowda, 2018).

2.4.2.2.Motorized operated shelling methods

A groundnut shelling machine is a machine used to remove the shell of groundnut to obtain the groundnut kernels. The shelling and cleaning operations are completed in one operation with clean seeds sent to the grain outlet in the motorized shelling technique.

Okegbile *et al.* (2014), constructed and built a groundnut shelling and separating machine that was powered by electricity. The shelling chamber is made up of a fixed concave and a shelling cylinder. The cylinder is operated by the primary mover through a belt and pulleys and features spike teeth as shelling bars. The machine has a shelling capacity of 400kg/hr, a shelling efficiency of 78%, and grain damage of 17.25% with a 1 horsepower motor.

Hoque *et al.* (2018), designed and developed a powered groundnut sheller and winnowing machine, the shelling drum was made from a rubber pad, and the shelling capacities of the sheller were 110 and 115 kg/h for Dhaka-1 and BARI Badam-8, varieties respectively. An average breakage of groundnut kernel was 2% at 7.5% moisture content (w.b). The minimum unshelled pods were about 12.4% and 9.18% for Dhaka -1 and BARI Badam-8, respectively.

The shelling efficiency of the sheller for Dhaka-1 and BARI Badam-8, were 86.6 and 88.82% respectively and the winnowing efficiency of the machine was 99%.

Alonge *et al.* (2016), develop the Bambara groundnut sheller machine and the performance was evaluated. The result revealed that the shelling efficiency, seed damage, partially shelled pods, unshelled pods, and machine capacity was 83.2 %, 17.4 %, 7.8 %, 9 %, and 75000 seeds/hr respectively.

Muhammad & Isiaka (2019), modified the locally constructed groundnut sheller machine. The shelling chamber is made of a rasp bar, a cleaning unit, and a prime mover. The performance test of the modified sheller was carried out using Ex-Dakar groundnut variety with a moisture content of 8%. A feed rate of 300 kg/h and a shelling speed of 180 rpm was used during the test. The modified sheller has an output capacity, shelling efficiency, cleaning efficiency, mechanical damage, and scatter loss of 239.81 kg/h, 98.32%, 50.63%, 4.33 %, and 3.24%, respectively.

Adenigba & Sedara (2021), design, fabrication, and evaluation of the performance of groundnut dehulling and separating machine. A groundnut dehulling machine was developed, having two dehulling rollers, rubber beaters, a screen, blower unit, seed, and chaff outlet. The result obtained after testing the machine shows that at 7.35 mm clearance and 700 rpm of the dehulling roller gave an optimum average dehulling machine capacity of 97.98 kg/hr, efficiency 95.80%, separation efficiency 81.40%, and the least mechanical damage 11.01%.

2.5.Research Gap

Laike (2007), developed a manually operated groundnut sheller machine and tested it with six different groundnut varieties. The results showed that the shelling efficiency ranged from 82.7 % to 94.2 %, the machine throughput capacity ranged from 408 kg/hr to 596.3 kg/hr, and mechanical damage ranged from 9.7 % to 28.1 % depending on the groundnut varieties. The findings revealed that the machine has a high shelling capacity, but low shelling efficiency, it is drudgery for the users due to it operated by manpower and cleaning operation is done separately, which needs additional man power (EIAR annual report, 2007).

Gelgelo (2016), designed an engine-driven groundnut sheller machine, with a maximum shelling capacity of 210.11 kg/hr. Kernel damage of 6.34%, cleaning efficiency was 95.13% and shelling efficiency of 92.07%. The test result reported that the machine has good kernel mechanical damage, but low shelling efficiency and throughput capacity, when compared to the new developed machine.

Adenigba & Sedara (2021), design, fabrication, and evaluation of the performance of groundnut dehulling and separating machine. The test results revealed that the optimum average shelling machine capacity of 97.98 kg/hr, shelling efficiency of 95.80%, cleaning efficiency of 81.40%, and the least mechanical damage 11.01%. The test results show that the machine has good in shelling efficiency, but low throughput capacity and high kernel damage when compared with new developed machine.

Hoque *et al.* (2018), designed a motor-driven groundnut sheller with a shelling capacity of 115 kg/h, kernel breakage was 2% and low shelling efficiency 88.82%. The findings show that good in kernel damage, but shelling efficiency and capacity are low, when compared with performance result of new developed machine.

To solve the gaps mentioned above, the developed machines was operated by an engine to solve the problem of drudgery of the operator facing during manually operated. To address the problem of existing engine operated groundnut sheller machine, 4 mm in diameter round bars were helically welded in interior part of concave. Which was increase the shelling efficiency and throughput capacity by increasing the rotation time of unshelled pods. And four round bars helically welded on three circular plates and flat belts were fastened on the helical round bar to maximize shelling efficiency, minimize kernel mechanical damage and throughput capacity.

CHAPTER THREE

3. MATERIAL AND METHODS

3.1. Study Area Descriptions

The groundnut shelling machine and the performance evaluations were conducted at Melkasa Agricultural Research Center. Which is located in Oromia National Regional State, East Shoa Administrative Zone, near Adama city 17km, and from Addis Ababa 107km. The geographical location of the area is 8° 24' 0" to 8° 30' 12" N latitude and 39° 21' 0" to 39° 35' 14" E longitudes, having an elevation of 1,550 meters above sea level. All the mechanical works such as machining, welding, grinding, drilling and bending, etc. were performed. The performance evaluations were conducted at Melkassa Agricultural Research Center. The Babile variety groundnut kernels with pods sample were purchased from local farmers in the East Arsi Gololcha district and the Burree variety was purchased from local farmers in the East Wollega Sasiga district for performance evaluation.

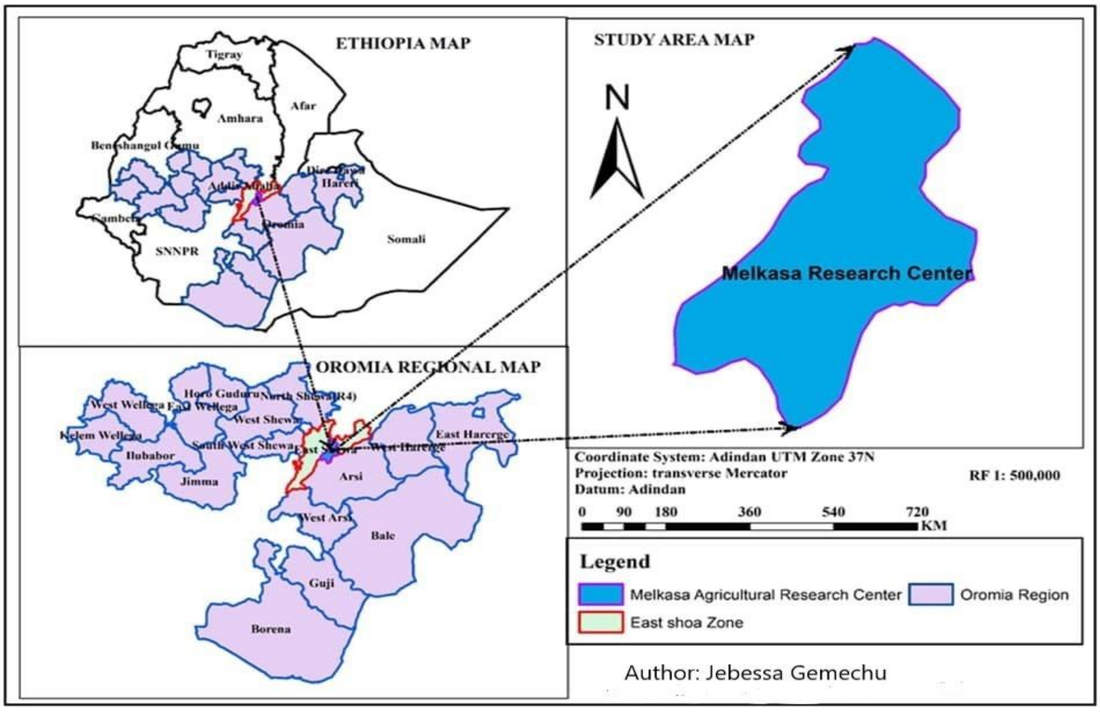


Figure 3.1. Study area descriptions

3.2. Design Considerations

Engineering properties of groundnut pods and kernels were considered during the design and development of the machine, as well as strength of materials, and CATIA V5 software, the theory of machine and mechanism were considered during the design and construction of the machine and its various parts.

Other factors were considered during the design process. The functioning and operational principles, the cost of construction, locally accessible materials and technology for constructing, the machine's power needs, and the manpower required to operate the machine are all instances of such points. The convenience of replacing component parts in the event of damage or failure was also considered in the design. The use of gravity and minimal friction to reduce power requirements. The economy and ergonomics, machine efficiency and product quality, simple operational and maintenance requirements to meet the needs of local farmers, enterprises, and industries, portability, detachability for easy transportation, and low grain damage were all considered during the design process. In addition, capacity, the angle of repose of the groundnut pods, and space are all critical considerations.

3.3. Material Selection

Different part of the machine was made from locally sourced materials. The material selection could be related to the force required to crack the groundnut pods with minimum kernel breakage, to minimize and control the bending and breaking off part of the machine during shelling. During construction, different materials were selected from the store and other related were bought from the market to fulfill the requirements. Consideration for material selection was based on availability, ease of construction, durability, strength, mechanical and chemical properties, and cost.

Table 3.1. Parts of constructed engine driven groundnut shelling machine and its materials

S.N.	Components	Material	Function
1	Frame	Square tubing mild steel	Supporting the shelling unit
2	Shelling drum	Mild steel rod	To support shelling flat belt
		Flat belt	To impact for shell and give out the kernel
3	Hoper	MS sheet.	Holding unshelled groundnut
4	Concave	Mild steel rod	Shelling groundnut pods
5	Pulley	Aluminum	Used to transfer motion to shaft
6	V-belt	Black rubber	Used to connect pulley with a power source
7	Outer cover	Mild steel sheet	To avoid grains spilling out and it has a provision for attaching to hopper.

8	Shaft	Mild steel	It transmits torque and motion from the pulley to turn the shelling drum.
9	Bearing	Mild steel	To allow free movement of the shaft.
10	Stand	Square pipe mild steel	Set for a motor and absorb vibration.

Table 3. 2.Tools and machine for fabrication of machine

S.N.	Tools	Function	Accuracy
1	Digital Vernier caliper	Used to measure the dimension of materials and kernels	0.1mm
2	Oven dry	Used to measure groundnut pods moisture content	
3	Digital balance	Used to determine groundnut and shelled kernel	± 0.05
4	Grain moisture tester	Used to record moisture content of groundnut kernel	± 0.5
5	Digital tachometer	Used to measure the shelling drum speed (rpm)	±0.05
6	Measuring tape	Used for measuring length	± 1mm
7	Stopwatch	Used to record time of operation of the Sheller	____

3.4. Engineering Properties of the Selected Groundnut Varieties

Engineering properties of groundnut pods play an essential role in designing shelling equipment, in order to decide the cylinder speed, concave clearance, sieve sizes, and kernel drop mechanisms. The engineering properties of groundnut varieties were considered for this study. Basic information on these properties such as physical (shape and size, roundness, sphericity, surface area, bulk density, and true density) and frictional (angle of repose and coefficient of friction) were determined and used as design parameters of the sheller.

3.4.1. Physical properties of groundnut pods

Specific knowledge of the physical properties of groundnut pods such as length, width, thickness, thousand pods weight, roundness, geometric mean diameter, arithmetic mean diameter, sphericity, surface area, square mean diameter, equivalent diameter, aspect ratio, bulk density, and the pod-vine ratio is essential for the design of shelling equipment in order to decide the cylinder speed, concave clearance, sieve sizes, and seed drop mechanisms. The size and shape of pods were also important physical properties for the separation of pods from the vine and foreign material. All physical properties were determined under appendix A, and the test results were recorded in table 4.1.

3.4.1.1.Dimensions of the groundnut pods

A hundred pods were randomly selected from the bulk sample in order to determine the size and shape of the pods. For each pod, three principal dimensions, namely length, width, and thickness were measured using a Digital Vernier Caliper with an accuracy of ± 0.01mm.

3.4.1.2. Roundness

Roundness is a measure of the sharpness of the corners of solid materials. A hundred pods of groundnuts were randomly selected from the bulk sample. The groundnut pod grains (100 numbers) are projected on graph paper and traced and calculated by equation (3.1) (Ghosal & Sarangi, 2020).

$$\text{Roundness}=\frac{Ap}{Ac} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Where: Ap = Largest projected area of groundnut grains in natural rest position (mm^2)

Ac = Area of the smallest circumscribing circle (mm^2)

3.4.1.3. Sphericity

Sphericity (Ø) may be defined as the ratio of the diameter of a sphere of the same volume as that of the particle and the diameter of the smallest circumscribing sphere or generally the largest diameter of the particle. This parameter shows the shape characteristics of the particle relative to the sphere having the same volume. To determine the sphericity the average value of length, width and thickness was taken. The degree of sphericity (Ø) was determined using equation (3.2) (Gojiya *et al.,* 2020).

$$\phi=\frac{LxWxT^{\,1/3}}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

Where: L = Length (mm)

W = Width (mm)

T = Thickness (mm)

3.4.1.4. Determination of groundnut kernel shapes

The shapes of the crops were determined from the aforementioned measured dimensions. However, the shapes of the pods and seeds were expressed in terms of roundness (R) and sphericity (Ø) index (Gojiya *et al.,* 2020).

The seeds of groundnut varieties were further classified according to Kara *et al*. (2013), when the ratio of length to width (L/W) falls within the range of 1.51 - 1.71 the variety was classified as Ellipticus which is ellipsoid in shape when the ratio falls within 1.85 - 2.31 the variety was classified Oblongus which is long cylindroids in shape and when the product of length and the ratio of width to thickness (W/T)xL fall within the range of 1.29 - 2.08 the variety was classified Subcompressus which is sub – compressed and long in shape, while for 2.17-3.51 the variety was classified compressus which is more compressed and broad in shape.

3.4.1.5. Arithmetic and geometric mean diameter of grains

Axial dimensions, namely length (L), width (W), and thickness (T) for each variety of groundnut pods were measured with a Digital Vernier Caliper with an accuracy of ±0.01 mm. The average diameter was calculated by using the arithmetic mean and geometer means of the three axial dimensions. The arithmetic mean diameter (Da) and geometric mean diameter (Dg) of the groundnut pods were calculated by using equations (3.3) and (3.4) (Adenigba and Sedara, 2021).

$$Da=\frac{LxWxT}{3} \quad \text{……………………………………………………}(3.3)$$

$$Dg= LxWxT^{1/3} \quad \text{……………………………………………………}(3.4)$$

Where: L = Mean length of groundnut pod (mm)

W = Mean width of groundnut pods (mm)

T = Mean thickness of groundnut pods (mm)

Da = Arithmetic mean diameter of groundnut pods (mm)

Dg = Geometric mean diameter of groundnut pods (mm)

3.4.1.6. Surface area

The surface area of groundnut pods is important to agricultural engineers for the development of farm equipment. The surface area (S) of the groundnut pod was determined by analogy with a sphere of the same geometric mean diameter by equation (3.5) (Kazeem *et al.*, 2015).

$$Sa=\pi\ Dg^{2} \quad \text{……………………………………………………}(3.5)$$

Where: Sa = Surface area (mm^2)

3.4.1.7. Aspect ratio

The aspect ratio (R) was calculated by dividing the width by the length of the groundnut equation (3.6) (Shukla *et al.*, 2019).

$$R=\frac{W}{L} \quad \ldots\ldots (3.6)$$

Where: R = Aspect ratio

W = Width, (mm)

L = Length, (mm)

3.4.1.8. Moisture content

The moisture content of groundnut pods was determined using the oven-dry method and kernels moisture was measured by using a grain moisture meter. The initial weights of samples were recorded using the electronic balance. Triplicate samples were dried in an oven-dry set at a temperature of 105°C and monitored over a period of 24 hours at 6-hour intervals until the weights of the samples were found to be constant (Koushkaki *et al.,* 2017). The moisture content of the groundnut pod and vine was calculated by using equation (3.7).

$$\text{Moisture content} = \frac{W1\text{-}W2}{W1\text{-}W3} \quad \ldots\ldots (3.7)$$

Where: W1 = Weight of the wet sample, (gm)

W2 = Weight of the dry sample, (gm)

W3 = Weight of the moisture cane, (gm)

3.4.1.9. Pod-kernel ratio

Ten samples of groundnut pods with kernel, each weighing about 1 kg were selected randomly from bulk samples and fully matured pods were removed from the vine. The weight of pod and vine were recorded separately using an electronic balance having 0.01g accuracy. The trials were replicated five for two varieties and observations were recorded and average values were reported as the percentage of the mass of the pod to vine ratio (Gojiya *et al.,* 2020).

3.4.2. Frictional properties of groundnut pods

The frictional properties such as angle of repose and coefficient of friction are important in designing hoppers, chutes, pneumatic conveying systems, screw conveyors, forage harvesters, shellers and threshers etc.

3.4.2.1.Angle of repose

The angle of repose is the angle compared to the horizontal at which the material will stand when piled. For measuring the angle of repose, a rectangular box filled with kernels was kept horizontal. The kernels were then allowed to fall on a horizontal circular disc kept below the box. The flow of kernels was stopped after the kernels were fully heaped on the disc. The radius of the base of the heap and height of the heap were measured and the angle of repose was calculated using equation (3.8) (Muhammad *et al.*, 2015).

$$\theta=\tan^{-1}\left(\frac{h_o}{r}\right) \qquad (3.8)$$

Where: θ = Angle of repose (degree)

h_o = Height of heap (m)

r = Radius of the heap (m)

3.4.2.2. Static coefficient of friction

The static coefficient of friction of groundnut samples against to MS sheet was determined. The static coefficient of friction was calculated using the equation (3.9) (Shukla *et al.,* 2019).

$$\mu=\frac{F}{N} \qquad (3.9)$$

Where, μ = Coefficient of friction

F = Friction force (force applied)

N = Normal force (weight of the grain)

3.4.2.3. Terminal velocity

Terminal velocity is the air velocity at which a particle remains in suspended state in a vertical pipe. Five random samples of pods were selected and their terminal velocity was measured using a terminal velocity measurement apparatus.

A particle under a vertical airflow, gravitational force Fg and drag resistance force Fd act on the particle. The drag force and terminal velocity were determined as equation (3.10) and (3.11) (Gojiya *et al.,* 2020).

$$F_d = c_a x \rho_a x A x \left(V_a\text{-}U\right)^2 \qquad (3.10)$$

Where: F_d = Drag resistance force (N)

C_a = Coefficient of the air resistance

ρ_a = Specific density of air (kg/m^3)

A = Projected area (m^2)

V_a = Velocity of air flow (m/s)

V_a -U = Relative velocity between airflow and the particle

The forces Fg and Fd are oppositely directed in vertical airflow. A particle will travel down if Fg>Fd, up if Fg = Fd, and in equilibrium if Fg=Fd when u=0, regardless of the correlation of these forces.

$$Vt = \left(\frac{Fg}{C_a \rho_a A}\right)^{1/2} \quad \text{……………………………………………………………(3.11)}$$

Where: Vt = Terminal velocity (m/s)

3.5. Description of Machine

The machine's driving mechanism comprises a motor and transmission unit that uses a pulley-belt system. Bearings were used to support cylinder drum and blower shafts, which were machined from the same shaft material. Based on the bending and torsional moment, a mild steel rod with diameters 30mm and 20 mm was chosen for both cylinder shaft and fan shafts respectively. Frame, hopper, shelling cylinder, concave, top cover, cylinder shaft, blower shaft, pod outlet, kernel outlet, and diesel motor are among the components of the machine. To make the construction technique easier, each item was constructed and assembled one by one.

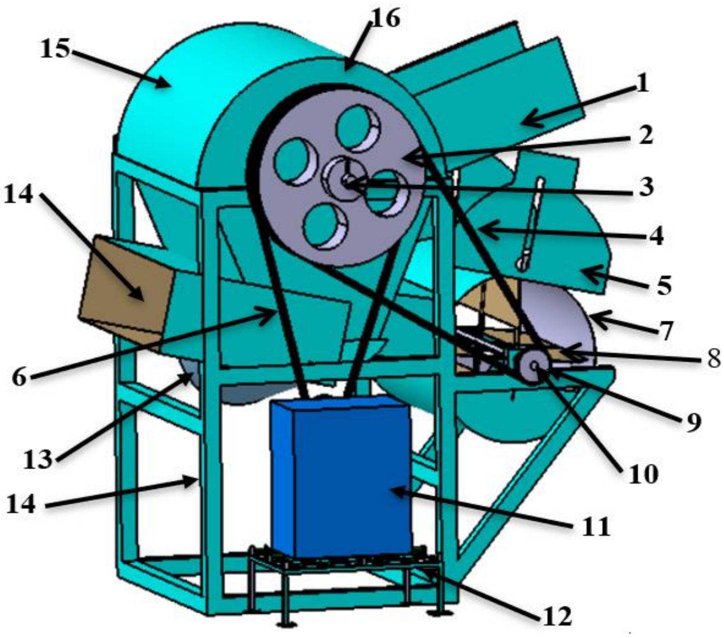


Figure 3. 2. Component parts of engine operated groundnut sheller.

Key component of the machine	
Part No.	Part Name
1	Hopper
2	Cylinder pulley
3	Cylinder shaft
4	Fan belt
5	Air inlet controller
6	Cylinder pulley belt
7	Fan house
8	Fan blades
9	Fan pulley
10	Fan shaft
11	Engine box
12	Motor set
13	Kernel outlet
14	Frame
15	Top cover
16	Shelling unit

Figure 3.3.The constructed groundnut sheller

3.6. Design of Engine Operated Groundnut Sheller Components

The engine-operated groundnut shelling machine comprises the following important components; frame, shelling cylinder, concave, blowing fan, grain outlet, pod outlet, and transmission system.

3.6.1. Frame design

The frame, which supports all the machine components must be rigid enough to withstand the weight of the whole assembly without buckling in order to prevent vibration or collapse of the equipment. Selecting the correct steel sections for the frame construction and analyzing all possible forms of failure that could occur on the frame to ensure the safety of the design. The mainframe was made of mild steel material. The total weights carried by the mainframe are:

- Weight of the hopper
- Weight of top cover
- Weight of shelling cylinder
- Weight of the collector
- Weight of concave
- Weight of shelling shaft
- The weight of the fan and shaft
- The weight of cylinder bearing and pulley.
- Weight of blower pulleys

The following assumptions were considered during the frame design was taken, the frame is fixed, the total load acting on the frame is uniformly distributed, and the frame was fabricated from 40 x 40 x 3mm square pipe bar mild steel. The frame sizes were rectangular in shape and had overall dimensions of 780 mm in length, 630mm in width, and 1000mm in height. The Euler's theory for crippling and buckling load Wcr under various end conditions is determined by equation (3.12) (Khurmi and Gupta, 2007).

$$W_{cr} = \frac{C\pi^2 ExA}{(L_{col}/k)^2} \quad \text{.....(3.12)}$$

Where: Wcr = Crippling load (N)

C= Is the end fixity coefficient, which is 4 for welded and bolted joints; from (Khurmi and Gupta, 2007).

E = Modulus of elasticity for mild steel is $2.1x10^5 N/mm^2$ (Khurmi and Gupta, 2007).

A = Cross-section area ($576mm^2$)

L_{col}= Column's length (1000mm)

K=$\sqrt{I/A}$ the least radius of gyration of the cross-section ($14.78mm^2$)

I = Polar moment of inertia.

$$I=\frac{HB^3}{12}-\frac{hb^3}{12} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.13)$$

$I=125952mm^4$

$$W_{cr}=\frac{4x\pi^2x2.1x10^5x576}{(1000/14.78)^2}=1.04MN$$

Since the frame which supports the shelling unit and bellowers is made from square tubular bar mild steel, it is important to know that the value of the crippling load (Wcr=1.04MN) must be far greater than the total weight (Wt= 1.34KN) of the whole assembly supported by the frame. To achieve this, various dimensions of square pipe bar steel from the manufacturer's specification were used until the desired crippling load was obtained. A dimension that produced a crippling load far greater than the weight of all components assembled to the frame was a 40x40x3mm square tubular bar. The polar moment of inertia of the section is a factor that contributes to the strength of the column.

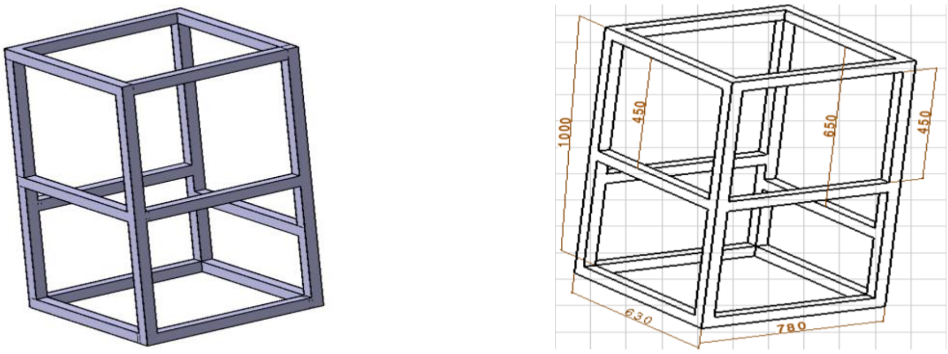


Figure 3.4. Frame

3.6.2.Hopper

The groundnut sheller's maximum capacity was estimated to be 500kg/hr. As a result, the groundnut seed hopper was developed with a rectangular frustum with a face inclined at an angle of 38° degrees to the horizontal to ensure the free flow of groundnuts and to prevent pods from splashing out during shelling. The angle of repose and frictional characteristics of groundnut pods with sheet metal influenced the design and orientation of the hoper (Muhammad & Isiaka, 2019).

The feeding rate was controlled by the controller as the pods to be shelled fell into the shelling mechanism by gravity through the feed table. The angle was chosen to facilitate the unobstructed flow of groundnuts into the cracking chamber, based on the angle of repose of groundnut pods. The hopper's top aperture and base are 400mm x 400mm, and it stands 200mm in height. Sheet metal with a thickness of 1.25mm was used to construct it. The volume of the hopper was estimated to be 0.0032m3. Using the equation (3.14), the hopper was constructed to hold more groundnuts (Muhammad & Isiaka, 2019).

$$Vh = L x W x H \quad \text{……………………………………………………………(3.14)}$$

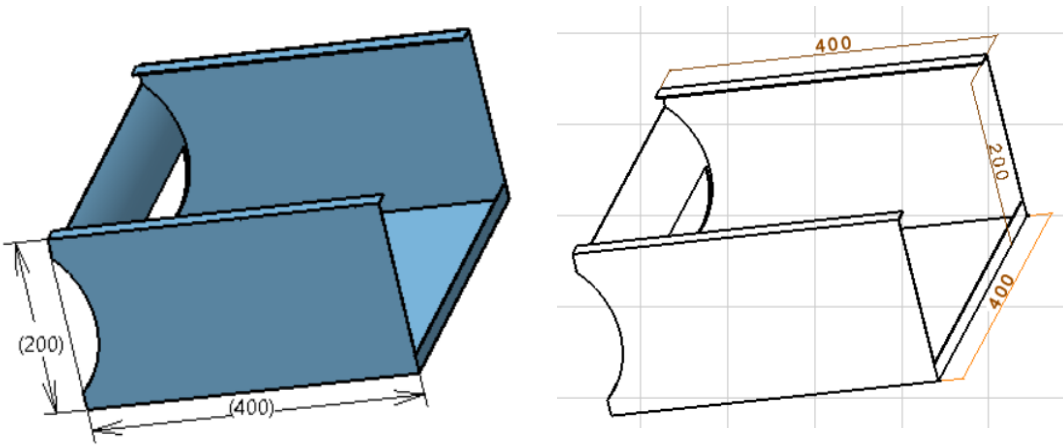
Where: Vh = volume of the hopper (mm^3)

L = Length of the hopper is 60% of drum length = 0.6x664 = (400mm)

W = Width of hopper (400mm)

H = Hopper height (200mm)

$Vh = 0.4x0.4x.02 = 0.0032m^3$



3D view

2D view

Figure 3.5. Hopper

3.6.3. Design of concave

The concave was made up of 8mm reinforcing steel bar welded to four round bars with a diameter of 10mm that were half-circle bent. This machine design used an off cross flow and radial flow shelling mechanism. Groundnut pods pass through the shelling zone between the radial flow shelling cylinder and the concave numerous times, rather than making a single pass in a cross-flow drum, due to rearward movement along the helical path. To extend the retention time of unshelled groundnut, a 4mm diameter round bar was helically welded in the internal part of the concave. Each helically welded round bar is spaced by 50mm.

This feature of the radial flow shelling technique allows for more unshelled pod retention time during continuous feeding. The shelling concave was designed with the diverse engineering properties of the groundnut and grains in mind. To allow free passage of shelled groundnut kernels while retaining unshelled groundnut, the distance between each reinforcement steel bar was 10mm. The radius of curvature was calculated using equation (3.15) (Aremu *et al.*, 2015).

$$R_c = R_d + D_{bd} + D_{bc} + D_{hb} + F_{bl} + C_c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.15)$$

Where: R_c = Concave radius (mm)

R_d = Radius of cylinder drum (180mm)

D_{bc} = Reinforcement steel bar diameter above the concave (8mm)

D_{hb} = Helically welded round bar on reinforcement steel bar (4mm)

D_{bd} = bar diameter above the cylinder (12mm)

F_{bl} = Flat belt above the helically welded bar on cylinder (30mm)

C_c = Concave clearance (16mm)

R_c = 180 + 8 + 4 + 12+ 30 + 16 = 250mm

Concave warp angle was utilized to determine the length of concave equation (3.16) (Bernacki *et al.*, 1976).

$$\text{Warpangle} = \frac{\text{Lenght of concave}}{\text{Radius of concave}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.16)$$

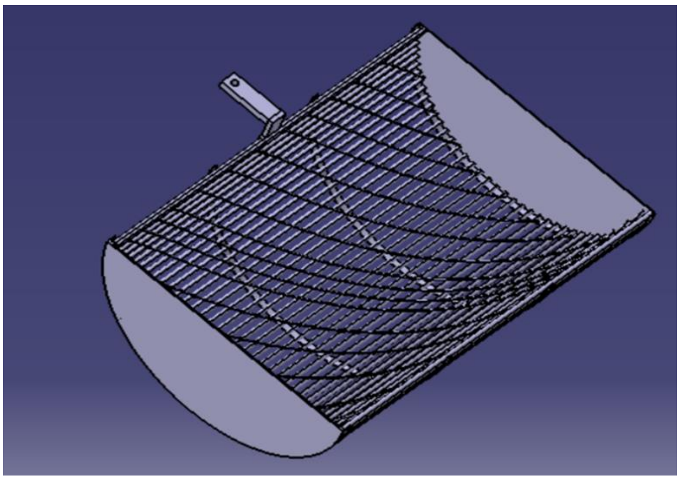
Shelling concave with a maximum warp angle of 120° was taking:

$$120^{o} \text{x} \frac{\pi}{180} = \frac{\text{Leght of concave}}{250}$$

$$\text{Length of concave} = 120^{0} \text{ x } \frac{\pi}{180} \text{ x } 250\text{mm}$$

Length of concave =523.59mm

There for the length of concave 680mm was suggested to have maximum shelling capacity.



Catia V5 design

Experimental work

Figure 3.6. Shelling concave

3.6.4. Mode of concave clearance adjustment

To make shelling different types of crops easier, the shelling machine was developed with a changeable concave clearance. Groundnut properties were used to determine the clearance between the concave and shelling cylinder. By using a bolt and nut system, the clearances were able to be adjusted. The concave was fastened as support at one end and pivoted at the other. The flat iron bent at 90° with 40 mm by 70 mm and 4 mm thickness was fastened with concave and drilled with 14 mm diameter to allow the 14mm diameter bolt to pass through. The 14mm diameter and 100 mm length bolt with the nut was chosen based on the weight to be exerted and the strength of the bolt. The concave could be lifted upward and the clearance between the concave and revolving cylinder was set to a minimum when the nut was loosened, and the clearance increased as the nut was tightened; therefore, the needed concave to cylinder drum clearance was obtained.

The moment of inertia and bolt diameter were determined according to equations (3.17) and (3.18) (Chakrabarty, 2010).

$$I = \frac{L^2 P}{2\pi^2 E} \quad \text{……………………………………………………………………}(3.17)$$

$$D = \left(\frac{64I}{\pi}\right)^{1/4} \quad \text{……………………………………………………………}(3.18)$$

Where: P = Load on concave + weight of concave (696.4N)

I = Moment of inertia (mm^4)

E = Modulus of elasticity for a steel material ($2.1 \times 10^5 N/mm^2$)

L = Concave length (664mm)

$$I = \frac{664^2 x 696.4}{2\pi^2 x 210{,}000} = 74.07mm^4$$

$$D = \left(\frac{64x74.07}{\pi}\right)^{1/4} = 6.23mm$$

The minimum bolt diameter required to carry the load on concave and the weight of concave was found to be 6.23mm. However, 14 mm diameter bolt was selected by considering the dynamic load applied on concave considering and the factor of safety for more rigidity.

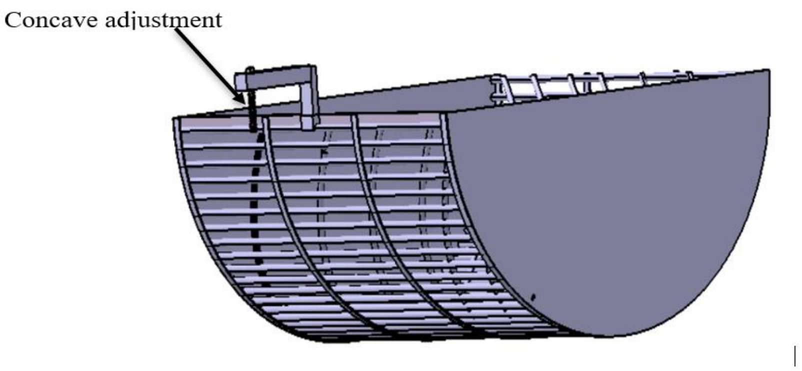


Figure 3.7. Concave with clearance adjustment

3.6.5. Shelling cylinder

The shelling cylinder is responsible for breaking the pod and extracting the kernel from it. The three 360mm diameter and 4mm thick iron sheet metal plates were directly hinged on the drum shaft to receive rotations from the power supply. On the three plates, eight reinforcing steel bars with a 1200mm pitch and a 664mm height were helically welded. The beater was supported by four helically welded bars, while the remaining four were utilized to support the plates. The four helically welded bars were hitched with a flat belt of 40mm width and 4mm thickness to bite the groundnut pods with the concave and release the kernel.

To prevent breakage, the flat belt was used as a beater which was bolted on the helically welded round bar and the distance between each bar was placed in a circular pattern on a flat circular plate at both sides and in the center at 45° angle, with the shaft immediately hinged. The plates were drilled in the middle to accommodate a 30mm diameter shaft. The shelling drum measures 664mm in length. The volume of the shelling chamber was computed based on its cylindrical geometry as equation (3.19) (Bhandari, 2010):

$$V_{sc} = \frac{\pi x D^2_{sc} L_{sc}}{4} \quad \text{...(3.19)}$$

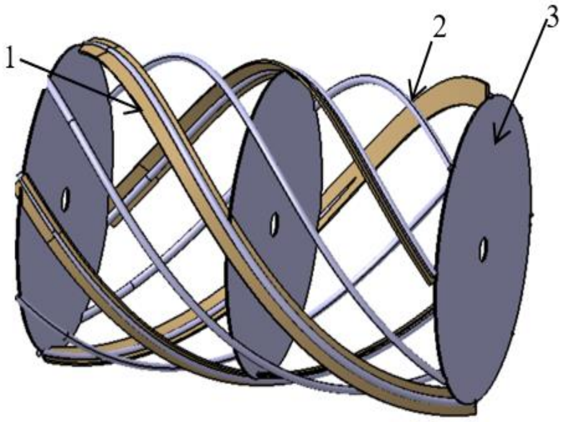
Where: V_{sc} = Volume of shelling chamber (mm^3)

L_{sc} = Length of shelling chamber (664mm)

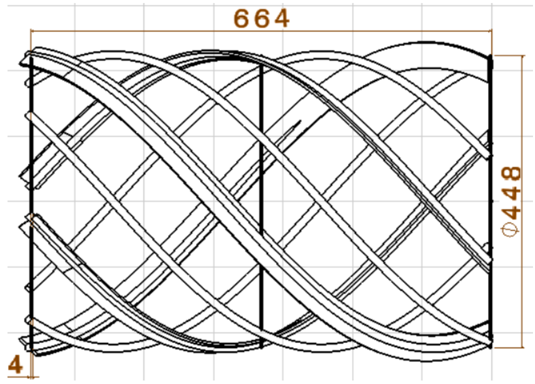
D_{sc} = Diameter of shelling cylinder = Dsc + 2xCc = 448 + 2x14 = (476mm)

C_c = Concave clearance (14mm)

$$V_{sc} = \frac{\pi x 476 x 664}{4} = 248{,}236 mm^3$$



3D view



2D view

Figure 3.8. Shelling cylinder

Where 1- Flat belt 2- Helically welded bar and 3 - Iron sheet metal plates.

3.6.6. Top cover

This was made of 1.5 mm thick mild steel and was 700 mm by 864 mm in dimension. It was rolled into a 580 mm diameter half-cylinder, welded on two sides with 30x30x3 mm angle iron, and holes drilled to facilitate attachment to the frame indicated in figure 3.8. A faceplate was drilled out and cut to a diameter of 56 mm, allowing the shaft to pass through. The shelling drum's upper portion was covered by the outer cover, which also served to support the feed hopper. It was mounted horizontally on the mainframe with a handle extension to make it easy to open whenever needed.

The procedure for making the top concave is detailed below. First, sheet metal is prepared, with all standards and dimensions taken into mind.

- It is measured to be cut from the design stage.
- The sheet metal is then bent to make flanges (in sheet metal bending machine).
- It is subsequently rolled in a hand rolling machine to the predetermined proportions giving the shape of a semi-circle;

The feed hopper and groundnut pod exit were then constructed by forming pockets in a predetermined place on the top cover. The hopper was welded on top cover sheet metal accessories; finally, the item is ground and polished to offer smoother edges.

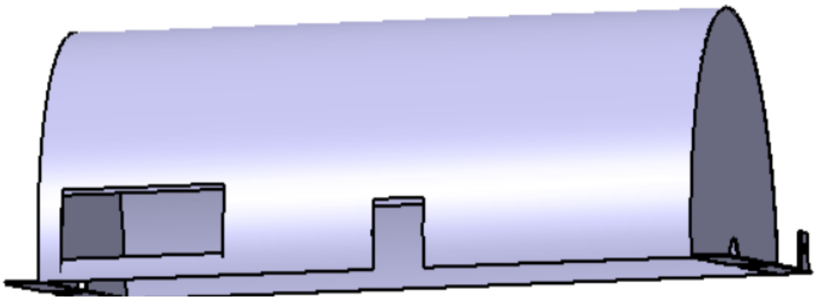


Figure 3.9. Tope cover

3.6.7. Design of kernel outlet

A metal sheet was used to create the outlet, which was put at the bottom of the shelling unit to collect the grains without their shattering outside. The exit was created using the frictional properties of groundnut kernels in conjunction with MS sheet. For gathering grains from the whole side of the cylinder to the center after shelling, a circular shaped 1.5 mm thick MS sheet of 628x820 mm rolled by 200 mm radius was placed at the bottom of the concave at 18^0 angled directions along the drum axis.

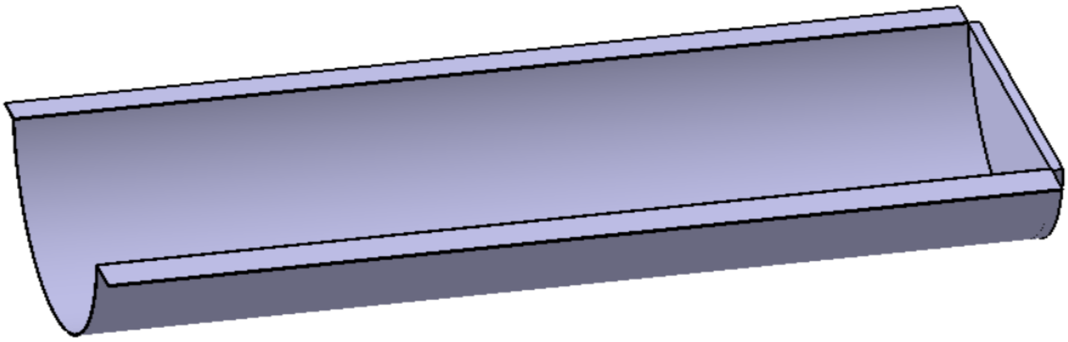


Figure 3. 10. Kernel outlet

3.6.8. Design of pod outlet

A metal sheet was used to create the pod outlet, which was put at the bottom of the concave and parallel to the blower direction. As the blower rotates with 892 rpm the pods were separated from the kernel and the pods below out. The exit was created using the frictional properties of groundnut kernels in conjunction with MS sheet. For removing pods and gathering grains from the whole side of the cylinder to the center after shelling, a rectangular shaped 1.5 mm thick MS sheet of 700 mm width, 650 mm length, and 200 mm height. It was placed at the bottom back of the concave and hinged at 35^o angled upward directions to outside.

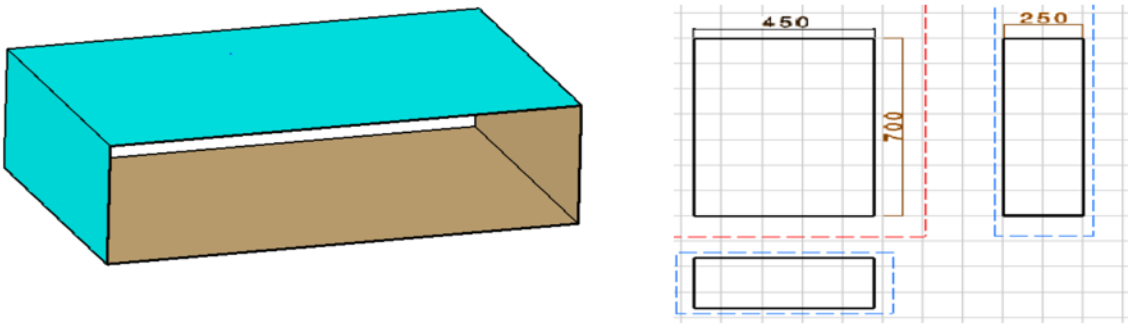


Figure 3. 11. Pod outlet

3.6.9. Power transmission parameters

3.6.9.1. Cylinder pulley diameters and speed ratio relationship

The operation of the groundnut sheller machine necessitates the use of two pulleys. The first pulley is connected to the diesel engine (driver), while the second is connected to the cylinder shaft (driven). The diameter of the pulley was calculated using the equation (3.20) (Muhammad and Isiaka, 2019).

$$N_1D_1=N_2D_2 \qquad (3.20)$$

Where: N_1 = The speed of the engine (892 rpm)

N_2 = The speed of the driven pulley (170 rpm)

D_1 = Diameter of pulley connected to diesel engine = 80 mm

D_2 = Diameter of driven pulley

$$D_2=\frac{80x892}{170}=420mm$$

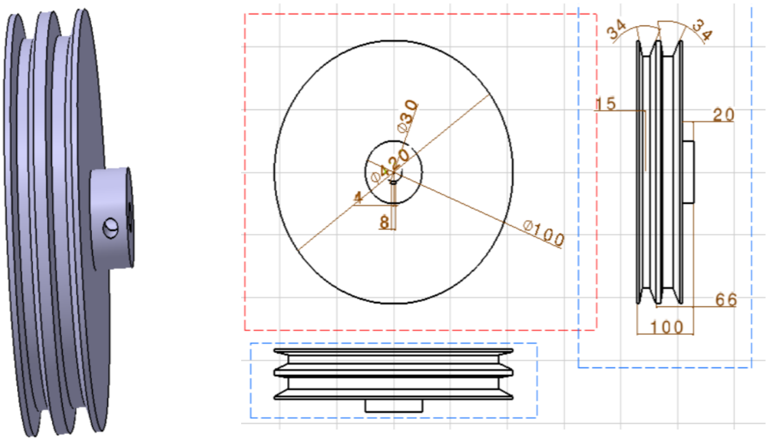


Figure 3.12. Cylinder pulley

3.6.9.2. Blower pulley diameters and speed ratio relationship

The diameter, D_3 of the fan pulley may be determined from equation (3.21):

$$D_2N_2=D_3N_3 \qquad (3.21)$$

Where: D_2 = Diameter of the pulley on cylinder shaft (420 mm)

D_3 = Diameter of the pulley on fan shaft (mm)

N_2 = speed of the cylinder pulley (170 rpm)

N_3 = Speed of fan shaft (892 rpm)

$$D_3 = \frac{170x420}{892} = 80mm$$

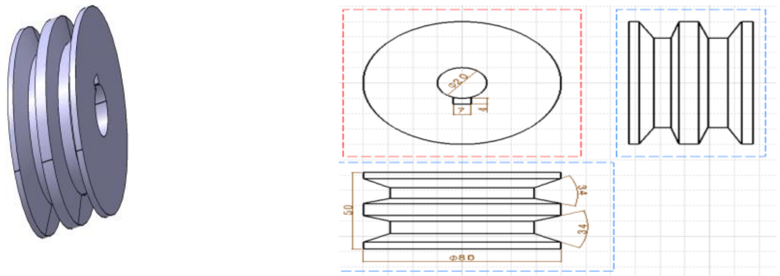


Figure 3.13. Fan pulley

3.6.9.3. Selection of belts

The belt is a device that transfers power from one shaft to another. Belts are typically utilized to reduce the engine's greater rotating speeds to the slower speeds required by mechanical equipment (Khurmi & Gupta, 2005). When the belt connecting two pulleys is stationary, the tensions in the two portions of the belt are equal but when torque is applied to the driving pulley, one portion of the belt is stretched and the other portion becomes slack. The procedure for selecting a V-belt drive is dependent on the motor horsepower and the speed (rpm) rating. The properties of a V-belt of B cross-section such as density, cross-sectional area, and allowable tensile stress (σ) were taken as 1000, 104, and 2.5 MPa. A groove angle (2β) of 35° pulley and 0.3 was considered as the coefficient of friction (μ) between the pulley and belt (Khurmi & Gupta, 2005).

Table 3. 3.V-belt horse power

Cross section	A Load of device (kw)	Recommended Min.pulley pitch diam, d(mm)	Nominal top width, w(mm)	Nominal thickness(mm)	Weight per mater (kg)
A	0.75-5	75	13	8	0.106
B	2-15	125	17	11	0.189

Source: (Khurmi and Gupta, 2005).

3.6.9.4.Determination of center distance

The center to center distance between the driver and driven pulley was estimated using the equation (3.23) (Khurmi & Gupta, 2005).

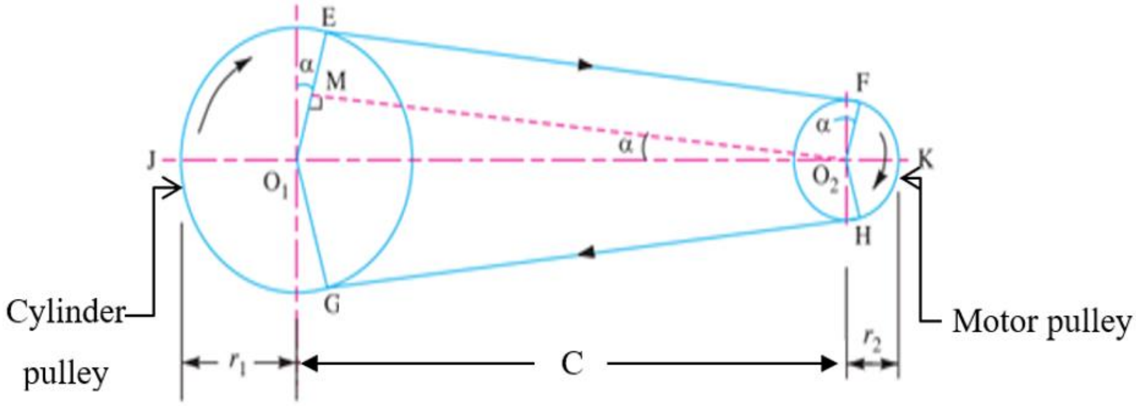


Figure 3.14. Cylinder and motor pulley

The two pulleys must, however, be close to each other. The greatest center distance of the belt in use is specified as and is determined by the size of the two pulleys equation (3.22) (Khurmi and Gupta, 2007).

$$D_2 < X < 3(D_1 + D_2) \quad \text{..(3.22)}$$

The minimum center distance between two pulleys, one being the driver while the other one is the follower, can be determined by using equations (3.23 and 2.24) (Khurmi & Gupta, 2005)

$$C = \left(\frac{D_1 + D_2}{2}\right) + D_1 \quad \text{..(3.23)}$$

$$Cd = \left(\frac{80+420}{2}\right) + 80mm = 330mm$$

$$Cf = \left(\frac{Df+Df}{2}\right) + Df \quad \text{..(3.24)}$$

$$Cf = \left(\frac{420+80}{2}\right) + 420 = 670mm$$

Where: Cd= Center distance for cylinder belt (mm)

Cf= Center distance for fan belt (mm)

Dd1 = Diameter of the driver (80mm)

Dd2 = Diameter of cylinder shaft pulley (420mm)

Df1 = Diameter of the driver (80mm)

Df2 = Diameter of fan shaft pulley (80mm)

C = The minimum center distance between the driving pulley and driven pulley

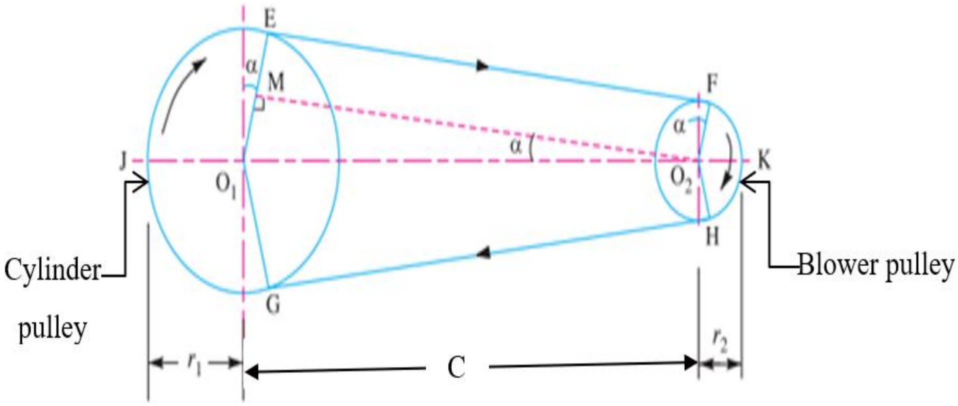


Figure 3.15. Blower and cylinder pulley

As a result, C – the center distance of the driver and driven pulley for dram is 330mm, and C – center distance of the driver and driven pulley for fan is 670mm.

The width of the pulley (face width) 'B' is commonly regarded to be 25% bigger than the width of the belt (b), and the width of the pulley was estimated using equation (3.22) (Budynas *et al.*, 2011). Because the chosen V-belt for power transmission was of the 'B' section and had a width of 13 mm, the width of the sheave was calculated to be 16.25 mm using equation (3.25).

$$B = b + 0.25b = 1.25b \quad \text{……………………………………………………….(3.25)}$$

$$B = 13mm + 0.mm = 16.25mm$$

3.6.9.5. Determination of belt length

The machine design required three pulleys: a prime mover pulley (P1 = 80 mm), a fan pulley (Df2 = 80 mm), and a Cylinder shaft pulley (Dd2 = 420 mm).

The length of the belt required for the shelling drum and blower was computed from equation (3.28) (Muhammad and Isiaka, 2019).

$$L_b = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4C} \quad \text{……………………………………………………..(3.26)}$$

$$L_{bc} = 2x330mm + \frac{\pi}{2}(80mm + 420mm) + \frac{(420mm - 80mm)^2}{4x330mm} = 1524mm = 1.5m$$

$$L_{bf} = 2x760mm + \frac{\pi}{2}(80 + 420) + \frac{(420\text{-}80)}{4x670mm} = 2168mm = 2.2m$$

As a result, the fan belt length (L_{bf}) was calculated to be 2.2 m, whereas the cylinder belt length (L_{bc}) was calculated to be 1.5 m.

3.6.9.6. Determinations of lap angle

The angle of the lap is the angle formed by two different-sized pulleys connected by an open belt. For small and big pulleys, the contact angles 1 and 2 were calculated as equations (2.27, 3.28, 2.39, and 3.30) (Ebunilo *et al.*, 2016).

For driver pulley

$$\alpha_1 = 180° + 2\theta \quad \text{......(3.27)}$$

$$\theta = \sin^{-1}\left(\frac{D2\text{-}D1}{2C}\right) \quad \text{......(3.28)}$$

$$\alpha_1 = 180^o + 2\sin^{-1}\left(\frac{D2\text{-}D1}{2C}\right) \quad \text{......(3.29)}$$

$$\alpha_1 = 180° + 2\sin\left(\frac{420\text{-}80}{2x330}\right) = 242.015° = 4.22rad$$

For driven pulley (open belt)

$$\alpha_2 = 180° - 2\theta\left(\frac{\pi}{180}\right) \quad \text{......(3.30)}$$

$$\alpha_2 = 180° - 2\sin^{-1}\left(\frac{420\text{-}80}{2x330}\right) = 117.98x\left(\frac{\pi}{180}\right) = 2.05rad$$

Where: α_1 = Angle of contact for small pulley

α_2 = Angle of contact for larger pulley

θ = Angle of warp

3.6.9.7. Determination of belt tension for cylinder

$$2.31\log\frac{T1}{T2} = \mu\alpha \quad \text{......(3.31)}$$

$$\frac{T_1}{T_2} = e^{\mu\alpha} \quad \text{......(3.32)}$$

Where: μ = Coefficient of friction between v – belt and pulley (0.3)

T_1 = Tension on the tight side of the belt

T_2 = Tension on the slack side of the belt

From equation (3.31 and 3.32)

$$2.31\log\frac{T_1}{T_2} = 0.3x2.05 = 0.615 \quad \text{......(3.33)}$$

$$\frac{T_1}{T_2} = e^{0.615} = 1.85 \quad \text{......(3.34)}$$

$$T_1 = 1.85T_2 \quad \text{……………………………………………………………………….(3.35)}$$

$$P = (T_1 - T_2)\, V^1 \quad \text{…………………………………………………...……………(3.36)}$$

Where V = Cylinder speed, from equation (3.37) = (3.74m/s)

P = Total power rating

Belt tension was estimated using equations (3.35 and 3.36) and total power rating 1.45 hp (1.08kw) diesel engine.

$$T1\text{-}T2 = \frac{1.08\text{kw}}{3.74\text{m/s}} = 288.77\text{N}$$

T_1 = 288.77N + T_2

1.85T2 = 288.77N +T2

0.85T2 = 288.77N

T2 = 339.93N

T1 = 628.7N

However, the total load to be supported by the cylinder shaft is:

T_{Load} = T1 + T2 = 628.7N + 288.77N = 917.47N

3.6.9.8. Cylinder linear speed determination

Belt speed was estimated using the equation (3.37) (Khurmi & Gupta, 2007)

$$V = \frac{\pi N_2 D_2}{60} \quad \text{…………………………………………………...……………………(3.37)}$$

Where: V = Cylinder linear speed (m/s)

N_2 = Cylinder rotational speed (170 rpm)

D_2 = Diameter of drum (0.42m)

$$V = \frac{\pi x170x0.42}{60} = 3.74\text{m/s}$$

3.6.9.9.Number of belts required for cylinder pulley

The power transmitted per belt was determined by equation (3.36)

P = (628.7 – 339.93) x 3.74 = 1080watt

Number of belts required

$$N_b = \frac{\text{total power transmitted}}{\text{power transmitted per belt}} \quad \text{…………...………………………………………(3.38)}$$

$$Nb = \frac{1{,}286.72\text{watt}}{1080\text{ wat}} = 1.19{:}1$$

3.6.10. Design of key

A key is a machinery component placed at the interface between a shaft and pulley to make sure that the pulley rotates with the shaft while transmitting power and motion. According to maximum shear stress theory, the maximum shear stress on the key was calculated using the equation (3.39) (Richard and Nisbett, 2011).

$$\tau_K = \frac{S_{YK}}{2fs} \quad \text{...}(3.39)$$

$$\tau_k = \frac{352MPa}{6} = 58.9MPa$$

The maximum torque transmitted by the shaft and key was determined by using equation (3.40) (Richard and Nisbett, 2011):

$$T = \frac{\pi\tau_k d^3}{16} \quad \text{...}(3.40)$$

$$T = \frac{\pi x 58.66 x 10^6 x 0.03^3}{16} = 310.82Nm$$

Key failure due to shearing

$$T = F\frac{d}{2} \quad \text{...}(3.41)$$

$$T = LxWx\tau xr \quad \text{...}(3.42)$$

For square key (Khurmi and Gupta, 2007)

$$w = t = \frac{d}{4} \quad \text{...}(3.43)$$

$$L = \frac{T}{wx\tau xr} \quad \text{...}(3.44)$$

Substitute the value of T=310. 82N.m, w=0.008m, τ_k=56.66Mpa and r=0.015m into equation (3.44)

L=44mm

Failure of the key due to crushing

$$T = Lx\frac{t}{2}\sigma xr \quad \text{...}(3.45)$$

$$L = \frac{2T}{tx\sigma xr} \quad \text{...}(3.46)$$

Where: $\sigma_{YK} = \frac{S_{YK}}{2fs}$

$$L = \frac{2Txfs}{txS_{YK}xr} \quad \ldots\ldots(3.47)$$

Substitute the value of T=310. 82Nm, t=0.008m, s_{yk}=352 MPa and r=0.015m into equation (3.47)

L=44mm

Therefore, the design of the key was safe for both shearing and crushing since the key length was equal.

Where: T= shaft torque (Nm)

d= shaft diameter (mm)

S_y= yielding strength of the shaft (N/m^2)

S_{yk}=352 MPa yielding strength of the key (N/m^2) (Richard and Nisbett, 2011):

f_s= 3, the factor of the safety

w=width of key (mm)

l=length of key (mm) and

t=thickness of key (mm).

3.6.11. Selection of bearing

A pillow block bearing was chosen for the groundnut shelling shaft from many series of bearings because it is well suited to the groundnut shelling environment. (Stainless bearing + cast iron housing) constitutes a pillow block bearing. Pillow block bearings are grease-recovery type ball bearings that are standard. Vibration is absorbed and it resists corrosion, fights against corrosion, extends the life of lubricants, and keeps the working environment clean. Its characterized by low torque.

The bearing weight carrying capacity, life expectancy, and reliability were all considered when it was chosen. Equation (3.48) was used to evaluate the relationship between bearing load carrying capacity, basic dynamic rating, and basic rating life (SKF, 2012).

$$C = Px\left(\frac{L}{L_{10}}\right)^{1/K} \quad \ldots\ldots(3.48)$$

Where: P = Equivalent dynamic bearing load (N)

L = Required life of bearing in million revolutions

C = Basic dynamic load rating (N)

K = Exponent for life equation with (k=3.00 for ball bearings and 10/3 for roller bearings)

Because the average bearing life is 10 years at 8 hours per day, the bearing life is measured in hours, and most bearings have a rotational factor of 1, the dynamic equivalent load is equal to the radial load (286.97N).

L_{10} =10 x 8 x 60 = 4,800 hours (Assuming 60 working days per year)

L = 60 x n x L10 = 60 x 170 x 4,800 = 48,960,000 (rev/mill)

$$C=286.97x\left(\frac{48,960,000}{4,800}\right)^{3/10} = 4.57KN$$

Where: n = Revolution speed (rev/min)

From the SKF bearing catalogue, the dynamic capacity of P206 bearing was 15.3 kN, this was greater than the required capacity. As such, this bearing was selected (SKF, 2012).

The P206 bearing, with a diameter of 30mm, and a width of 40mm, was chosen for its load-carrying capability, life expectancy, and fundamental static and dynamic characteristics of various types of radial ball bearings.

3.6.12. Power required for machine

3.6.12.1. Power required for operating machine

The machine's overall power need is equal to the sum of the power necessary to shell groundnut pods, drive the blower, and operate the shelling drum, as shown in equation (3.49) (Muhammad & Isiaka, 2019).

$$P = P_s + P_d + P_f \qquad (3.49)$$

Where: P = Total power required for operating the machine

P_s = Power required to shell groundnut pod

P_d = Power required to drive shelling drum

P_f = Power required to drive blower fan

3.6.12.2. Power required to shell groundnut pod.

According to Tertsegha *et al.* (2021), the power required for shelling groundnut pods is as equation (3.50):

$$E=0.3162xWi\left(\frac{1}{\sqrt{L_2}}-\frac{1}{\sqrt{L_2}}\right) \qquad (3.50)$$

Where: E = Energy required to shell groundnut (J/kg)

Wi = Work index of groundnut pods for crushing groundnut (9-14kWh/ton) (Tertsegha *et al.*, 2021).

L1 = The average length of unshelled groundnut pods (34.39mm)

L2 = Average length of shelled groundnut kernel (15.98mm)

$$E = 0.3162x14kwh/tone\left(\frac{1}{\sqrt{15.98}} - \frac{1}{\sqrt{34.39}}\right) = 0.354KJ/kg$$

Power required to shell groundnut pod is given by:

$$H = 0.3162xScWi\left(\frac{1}{L_2} - \frac{1}{L_1}\right) \quad \text{...(3.51)}$$

Where: H = Powered required to shell groundnut pod (W)

He = Engine power required to shell the groundnut pods (W)

Sc = Shelling capacity of the machine, Assume (0.097kg/s)

Wi = Work index of groundnut pods for crushing groundnut

HTp = Total power required to shell the groundnut pods (W)

$$H = 0.3162x0.097kg/sx14wh/tone\left(\frac{1}{15.98} - \frac{1}{34.39}\right)$$

H = 100.625watt

H = 100.625watt

Considering the power transmission efficiency is 90%, the required engine power is given as:

$$He = \frac{H}{Efficiency} = \frac{100.625}{0.9} = 111.8Watt = 0.15hp$$

Therefore, the total power required to shell groundnut was 111.8W =0.15hp.

3.6.12.3. Power required to drive shelling drum

The power requirement of the machine was determined with the equation (3.52) given by (Oladejo & Oriolowo, 2014)

$$P = \frac{2\pi NT}{60} \quad \text{...(3.52)}$$

Where: p = Engine power (KW)

N = cylinder speed (rpm)

T = Torque of engine (60.69Nm) from equation (3.73)

$$P = \frac{2\pi \text{ x } 170 \text{ x } 60.69}{60} = 1080.42Watt$$

Power required to drive the shaft was 1080.42W =1.08KW = 1.45hp

3.6.12.4. Force required to drive shelling beater

The shelling beaters revolve with the shaft in the threshing cylinder, producing centrifugal and centripetal force were determined as equation (3.53) and (3.55) (Thet *et al.*, 2019).

Centrifugal Force at r.

$$F_f = mx\omega^2 xr \quad \text{(3.53)}$$

$$\omega = \frac{2\pi N}{60} \quad \text{(3.54)}$$

$$F_p = \frac{mv^2}{r} \quad \text{(3.55)}$$

$$V = r\omega \quad \text{(3.56)}$$

Where: F_f = Centrifugal force (N)

F_p = centripetal force (N)

V= Linear speed of cylinder (m/s)

m = Mass of shelling cylinder (kg)

ω = Angular velocity (rad/s)

r = Radius of the cylinder beater (m)

N = Revolution speed of shaft (rpm)

$$\omega = \frac{2x\pi x170}{60} = 17.8\text{rad/s}$$

$$F_f = 7.6\text{kgx}(17.8\text{rda/s})^2\text{x}0.238\text{m} = 573.1\text{N}$$

$$F_p = \frac{7.6\text{kgx}(4.24\text{m/s}^2)^2}{0.238\text{m}} = 573.1\text{N}$$

3.6.12.5. Power to drive the fan,

The power required to drive the fan was obtained from the following equation (3.57) (Negedu *et al.*, 2018).

$$Pf = \frac{QxPs}{\mu} \quad \text{(3.57)}$$

Where: Pf = Power required to derive the fan

Q = Fan flow rate ($0.16m^3/s$)

Ps = Static pressure of the fan ($336N/m^2$)

η = Static efficiency of the fan (85%)

$$Pf = \frac{0.16x336}{0.85} = 63W$$

Pf = 63 W, using the factor of safety of 1.5 gives Pf = 94.5W = 0.13hp

The power required for machine were determined as equation (3.41):

Pt =111.8W +1080.42W + 94.5W = 1,286.72W =1.29KW = 1.73hp

As a result, the machine's total power needed was 1.29KW = 1.73hp. The minimum power required to drive and shell groundnut is 1.73hp.

3.6.13. Determinations of blower parameters

The blower was centrifugal and was constructed from sheet metal of 1.5mm thickness provided housing half-cylinder and opened at both ends. It was mounted on a shaft with a diameter of 20mm and roller bearings was used to support it. The fan features four radial blades on each side, as well as a circular air intake and controller that lets and controls the quantity of air that enters and exits in a direction perpendicular to the fan axis. For agricultural applications, fan speeds are recommended to be between 450 and 1000 rpm (Muhammad & Isiaka, 2019).

3.6.13.1. Air discharge through the blower

A stream of air is blown across the falling grain, eliminating dust and particles and blowing them away. It is designed to rotate at a five-times faster rate than the shelling cylinder. It's mounted to the back of the shelling machine and faces the screen's slope. Based on the air velocity required for cleaning, the depth of the air stream through the duct, and the diameter of the duct, the air discharge by a centrifugal blower (Q) can be simply approximated. Q was determined by using equation (3.60) (Muhammad & Isiaka, 2019).

$$Q=VxA \qquad (3.58)$$

Where, *Q*= air flow rate (m3/s), *V* = velocity of air required for cleaning obtained from literature (m/s) = 9.8 m/s (Ghanem and Shetawy, 2009)

A = Area of air duct (m^2)

A = L x B = 0.68m x 0.14m = 0.095m^2

Q = 9.5m/s x 0.095m^2 = 0.9m^2

3.6.13.2. Determinations of specific speed of blower

The specific speed of the blower was calculated using the equation (3.61) (Oyelami *et al.*, 2008).

$$Ns=\frac{N_1\sqrt{Q}}{H^{3/4}} \qquad (3.59)$$

Where: Ns = Specific speed of the blower

Q = Air discharge in gallons per min (gpm) = 0.95m^3/sx60m^3/minx1127g/m^3

= 64,239gpm

N1 = Prime mover speed (892rpm)

g=Acceleration due to gravity ($9.81 m/s^2$)

H = Total head imparted to the flow by the blower (19.52ft) (Muhammad and Isiaka, 2019).

$$H=\frac{V^2}{2g} \quad \text{(3.60)}$$

$$H=\frac{(9.5)^2}{2x9.81} = 4.6x3.281 = 15.09ft$$

$$\text{Therefore: } Ns = \frac{892x\sqrt{64,239}}{15.09^{3/4}} = 29528.9/min$$

3.6.13.3. Determination of blower outlet diameter

The outlet (D_O) and inlet (Di) diameters of the blower were computed according to equations (3.63) and (3.64) (Gui and Xi, 2010).

$$Do = \sqrt[3]{\frac{240Q}{\pi^2 x \varphi x N_1}} \quad \text{(3.61)}$$

Where: D_o = Outlet diameters of blowers

Di = Inlet diameter of blower

Q = Air discharge ($1.92m^3/s$)

N1 = Prime mover speed (892rpm)

φ = Pressure (0.9) (Muhammad & Isiaka, 2019).

f = 0.51() (Sahay and Singh, 2007).

$$D_O = \sqrt[3]{\frac{240x0.9}{\pi^2 x0.9x892}} = 0.1651m = 165.1mm$$

$$Di = 1.2\phi^{1/3}xDo \quad \text{(3.62)}$$

$$Di = 1.2x0.51^{1/3}x0.1651 = 0.1583m = 158.3mm$$

3.6.13.4. The number of blades required

The number of blades (Nb) was computed according to equation (3.65) (Muhammad & Isiaka, 2019).

$$Nb=\frac{Q}{V} \quad \text{(3.63)}$$

Where: Nb = Number of blades required

V = Volume of air displaced per second (s)

Q = Air follow rate ($^{m^3}/_{s}$)

$$Q=AV \quad (3.64)$$

Where: A = Area of duct inlet for aspirator

$$A=WxD_e \quad (3.65)$$

Where: De = Equivalent diameter of airflow rate (m).

W= Width over which air is required (m)

$$D_e=1.265\sqrt{\frac{(AB)^2}{A+B}} \quad (3.66)$$

A and B are length and width air pods outlet respectively; A = 0.68m, B = 0.55m

$$D_e=1.265\sqrt{\frac{(0.68x0.55)^2}{0.68+0.55}}=0.43m$$

Therefore A = 0.55m x 0.43m = 0.236m^2

According to (Ghanem & Shetawy, 2009), the needed air velocity (V) for groundnut cleaning is between 9.4 and 17.8 m/s.

Also, Ghanem and Shetawy (2009) reported that an air stream of 9.8 - 9.9 m/s was sufficient to separate 98.5 and 96.5 % of shells, fine particles, and dust from the kernels. As a result, 9.5 m/s was chosen for V. Now, substitute 9.5 m/s for the air velocity in equation (3.66).

Q = 0.236m^2 x 9.5m/s = 2.2m^3/s

In order to get the actual flow rate (Qa), 30% efficiency was assumed (Muhammad & Isiaka, 2019).

$$qa=\frac{Q}{0.3} \quad (3.67)$$

$$qa=\frac{2.2}{0.3}=7.3m^3/s$$

The volume of air displaced by the blade, V^1 was computed, according to (Muhammad, 2009) as:

$$V^1=\frac{\pi xWxD_e}{4} \quad (3.68)$$

$$V^1=\frac{\pi x0.55x0.43}{4}=0.2m^3/blade$$

The relationship for blade revolution per sec was determined by using equations (3.66) and (3.71) ((Muhammad & Isiaka, 2019).

$$\text{Blade}\left(\text{rev/s}\right)=\frac{V}{\pi D_e} \quad \text{(3.69)}$$

$$\text{Blade}\left(\text{rev/s}\right)=\frac{9.5}{\pi x 0.43}=7.03\text{rev/s}$$

$$V = \text{blade(rev/s)}xV^1 \quad \text{(3.70)}$$

Where: V = volume of air displaced per sec

$V = 7.6\text{rev/sec} \times 0.2m^3/\text{blade} = 1.7m^3/\text{sec blade}$

$$Nb = \frac{Qa}{V} = \frac{7.3}{1.7} = 4.29 \text{ blade } = 4\text{blade}$$

Therefore: 4 blades were suggested.

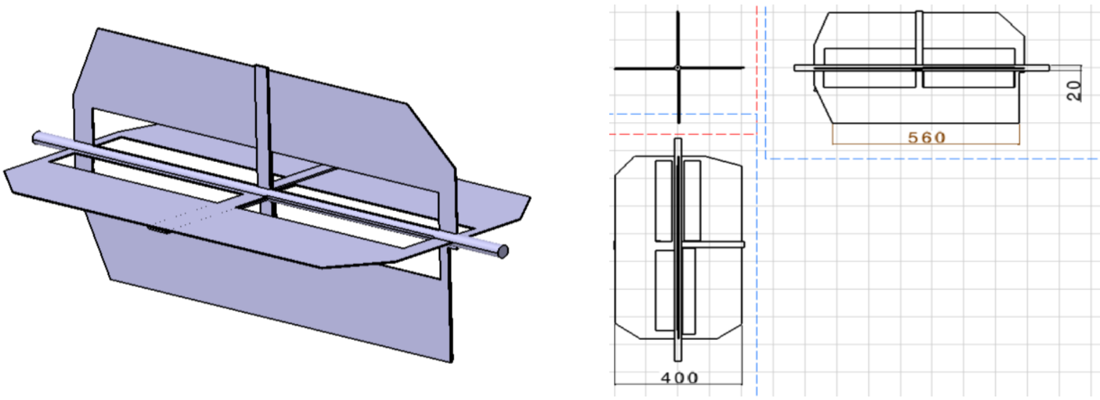


Figure 3. 16. Cleaning fan

3.6.14. Shelling cylinder shaft design

The shaft was designed to be durable, wear-resistant, and strong for optimum performance. For investigation of its combined bending and torsional stresses, a solid round shaft was required. The shaft diameter was calculated using the American Society of Mechanical Engineering (ASME) code equation for solid shafts with little or no axial loadings.

3.6.15. Determination of cylinder shaft torsional moment

The twisting moment (T) for belt drives was calculated using equation (3.71) and found to be 60.69 Nm for cylinder shaft and 6.33Nm for blower shaft, according to (Gupta and Khurmi, 2005).

For cylinder shaft:

$$T_c=\left(T_1-T_2\right)\frac{D_2}{2} \quad \text{(3.71)}$$

$$T=(628.93-339.93)\frac{0.42}{2}=60.69Nm$$

For blower shaft:

$$T_b=(344.64-186.29)\frac{0.08}{2}=6.33Nm$$

The twisted moment for the cylinder and blower shaft is 60.69Nm and 6.33Nm respectively.

Where: T_c = Torque on the cylinder shaft (Nm)

T_b = Torque on the blower shaft (Nm)

T_1 = Tension on tight side (N)

T_2 = Tension on the slack side (N)

D_2 = Diameter of driven pulley (m)

3.6.16. Force acting on cylinder shaft

The weight of the driven pulley and the weight of the shelling device cylinder act as a force on the drum shaft. At point C, the vertical forces applied by the shelling drum and pulley are illustrated in figure 3.18. The load on the shaft is uniformly distributed from point C to point B, i.e., 84.45N over the 640mm length of the drum. The force applied at point D was estimated using the equation (3.74) (Khurmi and Gupta, 2005).

$$W_d = T_1+T_2+W_p \quad \text{……………………………………………………………(3.72)}$$

Where: We = The force applied at drum shaft pulley (N)

T_1 = Tension at tight side (N)

T_2 = Tension at slack tight side (N)

W_p = Weight of pulley (N)

The weight of the cylinder and blower pulley was measured (physical measure) 2.1kg (20.6N) and 0.54kg (5.29N) respectively.

3.6.17. Bending moment calculation for cylinder shaft

The bending moment (Mb) was calculated based on the lateral loadings on the shaft. The loads were the weight of the driven pulleys, the weight of the shelling cylinder, and belt tensions. The force acting on the drum shaft is the weight of the driven pulley and the weight of the shelling device (cylinder) the vertical forces applied by the shelling cylinder and pulley are represented at points C and D respectively. Point C is considered as a uniformly distributed load on the shaft i.e., 84.45N over the 664mm length of the drum. The force applied at point D is calculated by equation (3.74) (Khurmi and Gupta, 2005).

T2 = 288.77N

T1 = 628.7N

Wp =20.6N

Wd = 628.7N + 288.77N + 20.6 = 938.07N

Where: W_d = Weight applied at point D.

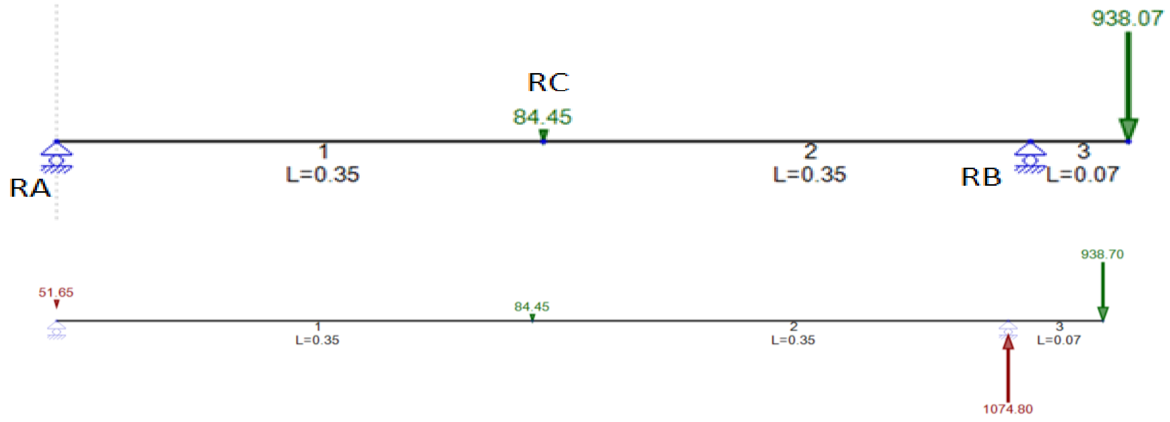


Figure 3.17. The force acting on drum shaft (dimensions are in mm).

Where: RA = Reactions at the support (N)

RB = Reactions at the support (N)

W_d = Weight at a drum pulley (N)

Representations of the vertical forces:

Taking moment about RA, the moment about counter clockwise is (+)

$\sum$MA=0 ……………………………………..……………………..………………..(3.73)

-0.35 X 84.45N + 0.7mX RB –0.77m X 938.07 = 0

-29.56 + 0.7RB – 722.31 = 0

0.7RB = 29.56+ 722.31= 751.87Nmm

RB = 1074.8N

$\sum$FY=0 ………………...……………….………………………………………(3.74)

RA + RB = 84.45 + 938.07

RA= 84.45 + 938.07- RB

RA = 1022.52– 1074N

RA = -51.65N

At A, MBV = 0

At C, the shaded area1

MBV = -51.65N x 0.35m = -18.08Nm

At B, the shaded area 2

MBV = -136.1N x 0.35m– 18.08Nm = -65.71Nm

At D, the shaded area 3

MBV = 938.70 x 0.07– 65.71N= 0

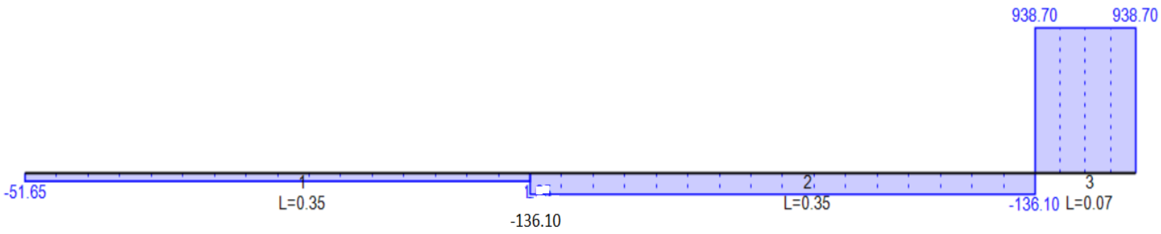


Figure 3. 18. Shear force diagram for cylinder shaft

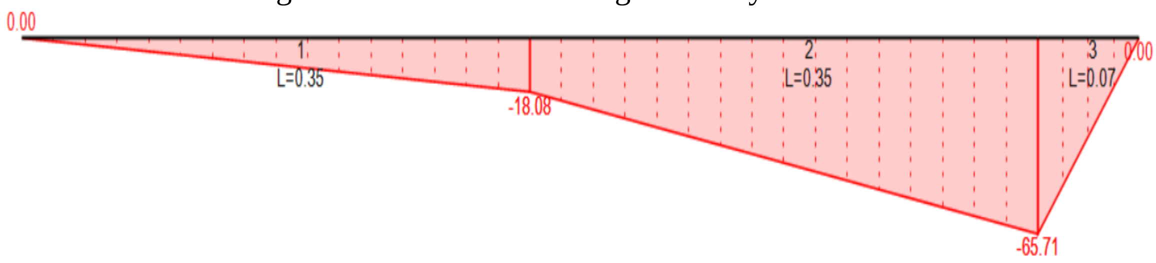


Figure 3. 19. Bending moment diagram for cylinder shaf

The applied maximum bending moment on the shaft is 65.71Nm. Assume there is no horizontal bending moment operating on the shelling shaft. The BM operating on the shelling shaft can be computed using the equation (3.75) (Khurmi and Gupta, 2005).

$$Mb=\left[(Mv)^2+(Mh)^2\right]^{1/2} \quad \text{...(3.75)}$$

$$Mb = \left[(-65.71)^2+(0)^2\right]^{1/2} = 65.71Nm$$

3.6.18. Determination of shaft diameter

The shaft was subjected to torsional, bending, or combined stresses, according to Mohammed & Hassan (2012), and the shaft diameter was determined using equation (3.76):

$$d^3=\frac{16}{\pi\tau_{max}}\sqrt{\left[(ktxMt)^2+(kbMb)^2\right]} \quad \text{..(3.76)}$$

Where: d = Diameter of the shaft, (mm),

τ_{max} = Maximum allowable stress of mild steel shaft with keyway (40Mpa)

kb = Combined shock and fatigue factor applied to bending moment 1.5

kt = Combined shock and fatigue factor applied to a torsional moment 1.0

Mb = Maximum bending moment 65.71Nm

Mt = Torsional moment (60.69Nm)

$$d^3=\frac{16}{\pi 40}\sqrt{\left[(1x60690)^2+(1.5x65710)^2\right]}$$

d = 24.52mm

3.6.19. Design of shaft when subjected to twisting moment

The diameter of the shelling drum shaft to attach the driven pulley was calculated only on the basis of the twisting moment (or torque). The diameter of the shaft was calculated using the equation (3.77) (Khurmi and Gupta, 2005).

$$\frac{T}{J} = \frac{\tau}{r} \quad \text{.......................................} (3.77)$$

Where: T = Twisting moment (or torque) acting upon the shaft (Nm)

J = Polar moment of inertia of the shaft about the axis of rotation (m^4)

τ = Torsional shear stress (42 MPa taken for mild steel,).

r = Distance from the neutral axis to the outer (d/2)

d = Diameter of the shaft (mm)

We know that the polar moment of inertia for a circular solid shaft is:

$$J = \frac{\pi x d^4}{32} \quad \text{.......................................} (3.78)$$

$$\frac{T}{\frac{\pi d^4}{32}} = \frac{\tau}{d/2} \quad \text{.......................................} (3.79)$$

$$d^3 = \frac{16T}{\pi\tau} \quad \text{.......................................} (3.80)$$

$$T = \frac{Px60x1000}{2\pi xN} \quad \text{.......................................} (3.81)$$

Where: T = Torque on driven pulley shaft (Nm)

N = Revolution of the cylinder shaft (rpm)

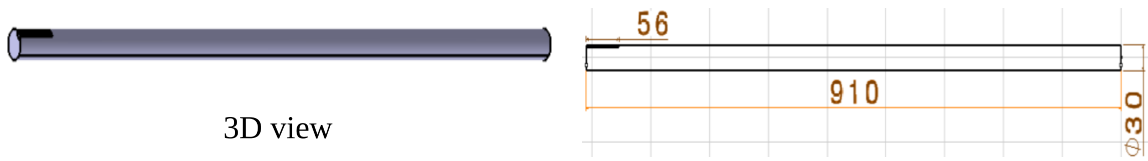
$$T = \frac{1.73x60x1000}{2x\pi x170} = 97.17Nm$$

Putting T value in equation (3.66) above

$$d^3 = \frac{16x97170}{\pi x42} = 23mm$$

d = 23mm

The designed shaft diameter when subjected to bending and twisting moments was found to be 29.24mm and 27.6mm, respectively, based on the preceding considerations. The proposed shaft diameter of 30mm diameter shaft was chosen for the shelling cylinder shaft based on the factors of safety (20%) and availability.



3D view

2D view

Figure 3.20. Shelling cylinder shaft

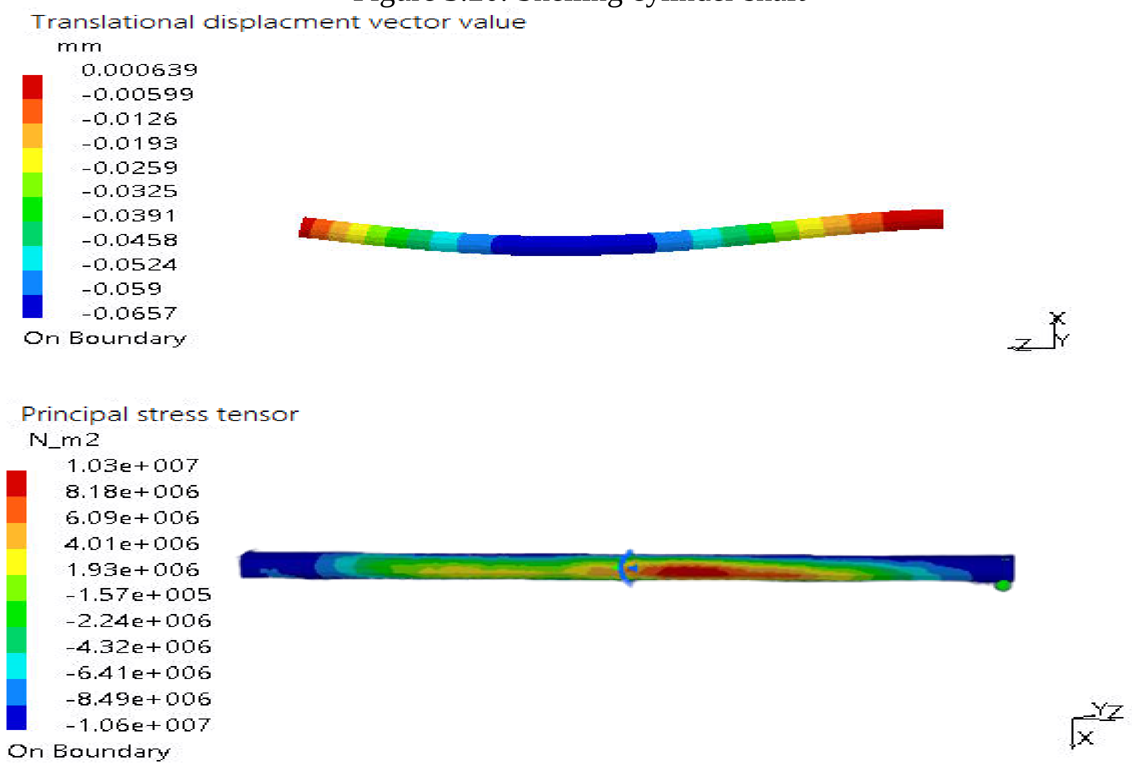


Figure 3.21. Stress analysis of shelling cylinder shaft

CATIA simulations were used to conduct the analysis, and actual geometry was inserted to the software. This simulation allows seeing how much the cylinder shafts are displaced and stressed. Load due to reactant force on the drum shaft derived from the above calculation, which are reactant forces on the cylinder shaft. And the load created by reactant force is 84.45 N and 938.07N. The output results in maximum translational displacement on the cylinder shaft is 0.000639 mm and the maximum stress distribution on the drum shaft 1.03 x 10^7 N/ m^2 which is below the allowable stress of mild steel indicates the shaft is safe.

3.6.20. Blower shaft

3.6.20.1. Determinations of bending moment

For estimating the size of the blower shaft, a similar approach was used with the cylinder shaft. The torsional tension was used to compute the tension on the belt. As a result, the following moment was calculated:

The angle of contact made by the belt on the blower pulley was estimated according to equation (3.30).

$$\alpha_1 = 180° - 1\sin^{-1}\left(\frac{80\text{-}420}{2x670}\right) = 3.38\text{rad}$$

$$\frac{T_1}{T_2} = e^{0.3x3.38} = 2.76$$

T1 = 2.76T2

Where V = Fan belt speed

Belt speed and belt tension was estimated using the equation 3.31, 3.32, 3.33, 3.34, and 3.35 simultaneously.

$$V = \frac{\pi\ 892x0.08}{60} = 3.73\text{m/s}$$

For 1.45 hp engine

$$T_{1\text{-}}T_2 = \frac{1.08\text{kw}}{3.7\text{m/s}} = 289.54\text{N}$$

2.76T2 – T2 = 289.54N

1.76T2 = 289.54N

T2 = 164.5N

T1 = 454.05N

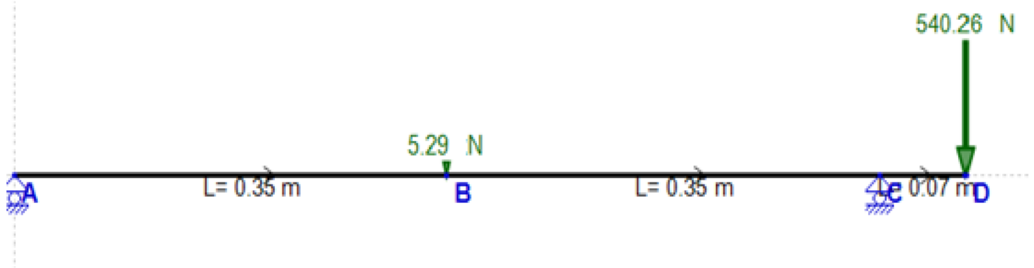
T_{load} = 454.05N + 164.5N + 5.29N = 623.84N

The vertical bending moment and summation of force was determined according to equation (3.83) and (3.84)

For vertical load

W_V =Wpxsin60 …………..……………..……..…...……………..……………….(3.82)

W_V = 623.84sin60 = 540.26N



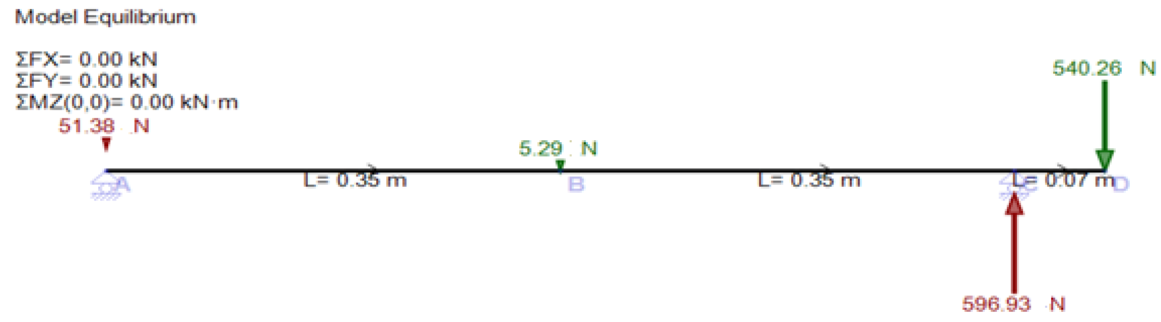


Figure 3. 22.The force acting on drum shaft

$\sum$MA=0 ……………………………..………..………..……………………………(3.83)

RC = 596.93N

$\sum$FY=0 ……………………..…………………………………………..……….(3.84)

RA =51.38N

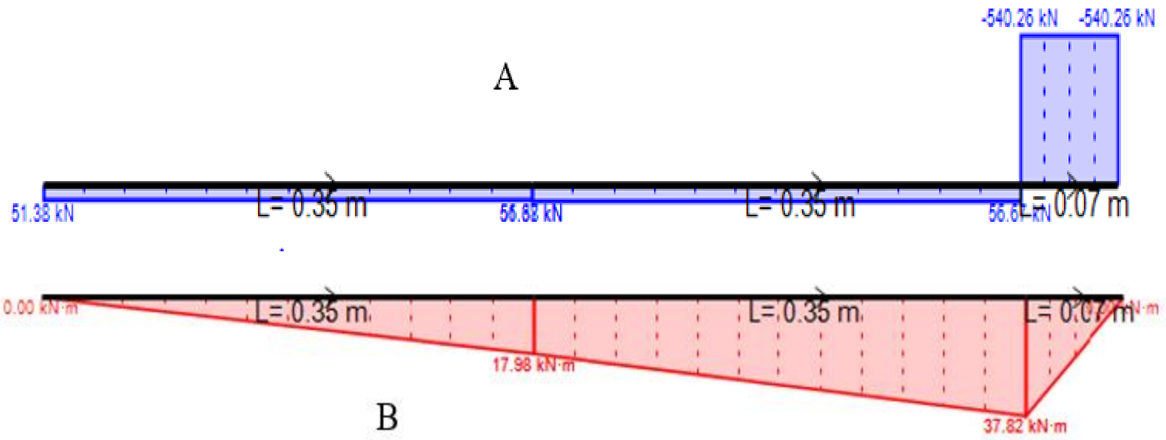


Figure 3. 23. Vertical shear force and bending moment diagram

Where: A- Shear force diagram and B- Bending moment diagram

For horizontal force

W_h =WPxcose60 ………………………………………………………………(3.85)

W_h = 623.84cos60 = 311.92N

Using equation (3.85) and (3.86) RA =31.19N and RC = 341.11N

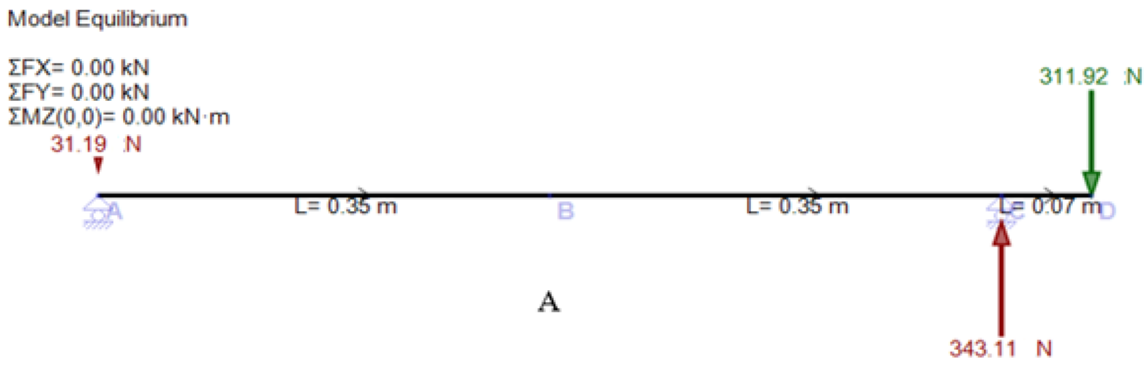


Figure 3. 24. Horizontal load applied of fan shaft

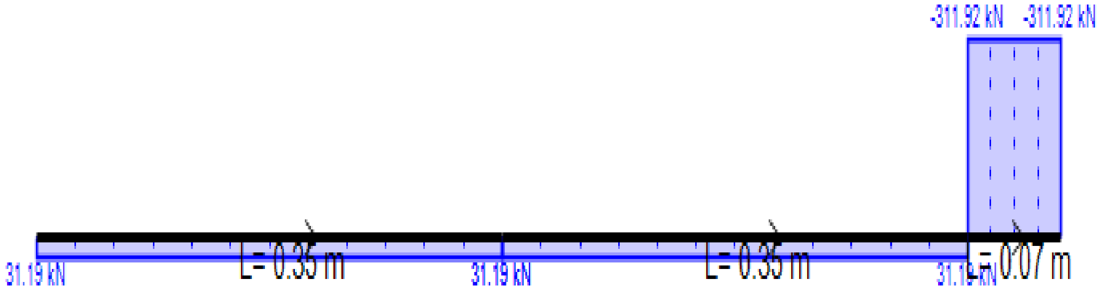


Figure 3. 25.Horizontal shear force diagram

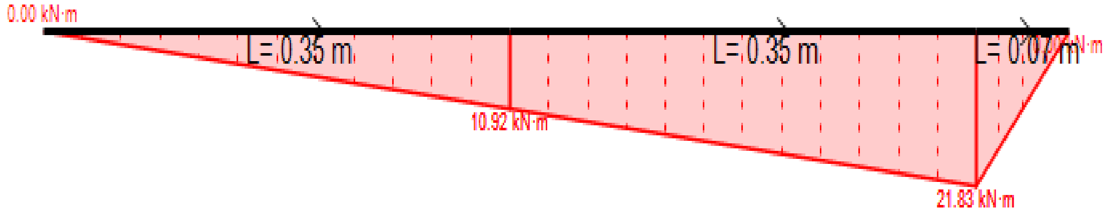


Figure 3. 26. Horizontal bending moment diagram on fan shaft.

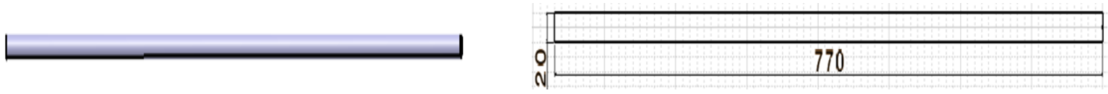
The applied maximum bending moment on the shaft was calculated as equation (3.77) revealed that 43.67Nm (Khurmi and Gupta, 2005).

3.6.20.2. Dominations of torsional moment for blower shaft

The twisting moment (T) for belt drives was calculated using equation (3.71) and found to be 6.33Nm for blower shaft.

$$T = (247.94\text{-}89.8)\frac{0.08}{2} = 6.33\text{Nm}$$

The designed shaft diameter when subjected to bending and twisting moments was found to be 19.89mm and 27.6m, based on the preceding considerations. The proposed shaft diameter of 20mm diameter shaft was chosen for the blower.



3D view 2D view

Figure 3.27. Blower shaft

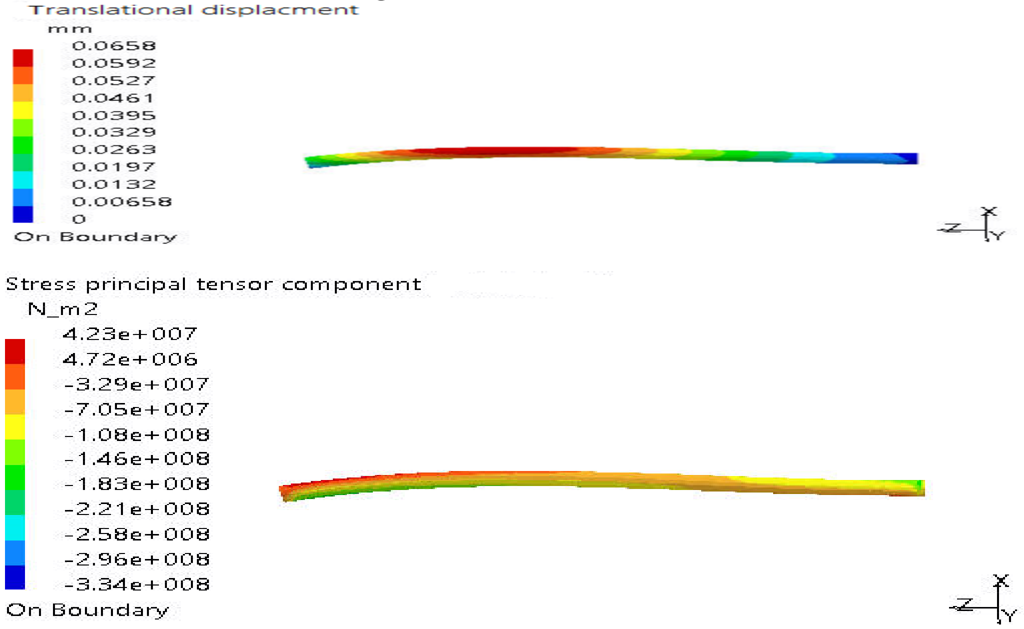


Figure 3.28. Stress analysis of fan shaft

CATIA simulations were used to conduct the analysis, and actual geometry was inserted into the software. This simulation allows seeing how much the fan shafts are displaced and stressed. Load due to reactant force on the fan shaft derived from the above calculation, which are reactant forces on the fan shaft. And the load created by reactant force is 5.29 N and 628.89N. The output results in maximum translational displacement on the fan shaft is 0.0658 mm and the maximum stress distribution on the fan shaft 4.23 x 10^7 N/ m^2 which is below the allowable stress of mild steel that indicates the shaft is safe.

3.7. Determination of the Weight of Component Parts of the Sheller

It was required to determine the weight of the shelling cylinder, shelling cylinder pulley, shelling cylinder shaft, body cover, concave, kernel outlet, pod outlet and frame in order to estimate the overall weight of the sheller and loads on the shelling shaft of the machine. As a result, all component part weights were calculated using appropriate equations (Bhandari, 2010)

3.7.1. Determination of the weight of shelling cylinder

The weight of the sheller was determined in order to know the amount of load being exerted on the shaft by the shelling cylinder. This weight is expressed as the equations (3.86) (Bhandari, 2010).

$$W_{sd} = \rho \text{ x } V_{sd} \text{ x g x n} \quad \ldots\ldots(3.86)$$

Where: W_{sd} = Weight of Shelling drum (N)

ρ = Density of shelling cylinder materials (kg/m^3)

W_{db} = Weight of cylinder bar (N)

W_{dp} = Weight of cylinder bar support plate (N)

V_{sd} = Volume of sheller cylinder material (m^3)

G = Gravitational acceleration due to gravity (m/s^2)

d = Diameter of sheller shelling materials (m)

L_d = Length of sheller drum material (m)

t = Thickness of the shelling material (m^3)

n = Number of materials

$$W_{sd} = 8\text{x}7850\text{kg/m}^3\text{x}\pi\left(\frac{0.012^2}{4}\right)\text{x}0.96\text{mx}9.81\text{kg/s}^2 = 45.02\text{N}(4.59\text{kg})$$

W_{sd} = 39.44N + 45.02N= 84.45N (8.6kg)

3.7.2. Determination of weight of shelling cylinder shaft

The weight of shelling cylinder shaft can be determined as follows

$$W_{sh} = \rho\frac{\pi d^2}{4}\text{xLsxg} \quad \ldots\ldots(3.87)$$

Where: W_{sh} = weight of drum shaft (N)

ρ = Density of shaft material (7850kgm^{-3})

d = Diameter of shaft (0.3m)

g = Gravitational acceleration due to gravity (9.81kgs^{-2})

L_{sh} = Length shaft (0.81m)

$$W_{sh} = 7850\text{kgm}^{-3}\text{x}\frac{\pi\text{x}0.03^2}{4}\text{x}0.81\text{x}9.81\text{m/s} = 44.09\text{N (kg)}$$

3.7.3. Determinations of weight of fan shaft

The weight of the fan was calculated as follows

$$W_{fs} = \rho\text{xvsxg} \quad \ldots\ldots(3.88)$$

$$V_{fs} = \pi\frac{d^2}{4}\text{xL} \quad \ldots\ldots(3.89)$$

Where: W_{fs} = weight of fan shaft (N)

ρ = Density of shaft material (7850kgm^{-3})

d = Diameter of shaft (0.02m)

g = Gravitational acceleration due to gravity ($9.81kgs^{-2}$)

L_{sh} = Length shaft (0.81m)

$$W_{fs} = 7850kg/m^3 x \pi x \frac{0.02^2}{4} x 0.81m x 9.81m/s^2 = 19.6N(2kg)$$

3.7.4. Determination of the weight of the shelling cylinder pulley

The weight of pulley on a shaft can be determined as follows

$$W_p = \rho \frac{\pi d^2}{4} x L_S x g \qquad \text{.....(3.90)}$$

Where: W_p = Weight of drum pulley (N)

ρ = Density of pulley material ($2710kgm^{-3}$)

d = Diameter of drum pulley (0.42)

g = Gravitational acceleration due to gravity ($9.81kgs^{-2}$)

L_{sh} = Length shelling cylinder pulley (.067m)

$$W_p = 2710kgm^{-3} x \frac{\pi 0.42^2}{4} 0.067m x 9.81kg/s$$

3.7.5. Determinations of weight of motor pulley

The weight of pulley on a shaft can be determined as follows

$$W_{fp} = \rho \frac{\pi d^2}{4} x L_{mpx} x g \qquad \text{.....(3.91)}$$

Where: W_{fp} = Weight of fan pulley

D_{mp} = Diameter of motor pully (0.08m)

ρ = Density of pulley material ($2710kg/m^3$)

L_{mp} = Length of pulley material (.04m)

g = Acceleration due to gravity ($9.81kg/m^3$)

$$W_{fp} = 2710x \frac{\pi 0.08^2}{4} x0.04x9.81 = 5.34N\ (0.54kg)$$

3.7.6. Determinations of weight of fan pulley

$$W_{mp} = \pi x \rho x \frac{d_{fp}^2}{4} x L_{mp} x g \qquad \text{.....(3.92)}$$

Where: W_{mp} = Weight of motor pulley

D_{fp} = Diameter of fan pulley (0.08m)

ρ = Density of pulley material ($2710kg/m^3$)

L_{mp} = Length of motor pulley material (0.04m)

g = Acceleration due to gravity (9.81m/s^2)

$$W_{mp} = \rho\frac{\pi 0.08^2}{4}x0.04x9.81 = 5.34\ (0.54kg)$$

3.7.7. Determination of the weight of the sheller body cover

The weight of the outer cover of the groundnut Sheller prototype was estimated as follows:

$$Woc = Voc \times \rho \times g \quad \text{……………………………………………………….(3.93)}$$

$$V_{oc} = LxWxT \quad \text{……………………………………………………..(3.94)}$$

Where: W_{oc} = Weight of side outer cover

W_{ofc} = Weight of front outer cover

W_{oc} = Total weight of outer cover

V_{oc} = Volume of outer cover

L = Length of material (m)

T = Thickness of material (m)

W = Width of material (m)

ρ = Density of outer cove

G = Gravitational acceleration due to gravity

$$W_{ofc} = 2x7850x0.575x0.78x0.0015x9.81 = 92.98N(9.48kg)$$

$$W_{osc} = 2x7850x0.63x0.575x0.0015x9.81 = 83.7(9.48kg)$$

$$W_{oc} = 92.98+83.7 = 176.68N(18.14kg)$$

3.7.8. Determinations of weight of kernel outlet

$$W_o = \rho xWxLxT \quad \text{……………………………………………………….(3.95)}$$

Where: W_o = Weight of outlet (N)

ρ = Density of kernel outlet material (7850kg/m^3)

W =Width of kernel outlet (0.28m)

L = Length of kernel outlet (0.72m)

T = Thickness of kernel outlet material (0.0015m)

$$W_o = 7850x0.285x0.72x0.0015x9.81 = 23.29N(2.37kg)$$

3.7.9. Determination of the weight of the concave of the sheller

$$W_{RM} = V_{RM}x\rho xg \quad \text{……………………………………………………….(3.96)}$$

$$W_{RM} = V_{RM}x\rho xg \quad \text{……………………………………………………..(3.97)}$$

$$W_{SM} = VW_{RM} = V_{RM} x\rho x g_{SM} x\rho x g \ldots\ldots\ldots\ldots(3.98)$$

$$V_{SM} = WxLxT \ldots\ldots\ldots\ldots(3.99)$$

$$V_{RM} = L_{RM} x \frac{\pi D^2}{4} xNr \ldots\ldots\ldots\ldots(3.100)$$

Where: W_{RM} = Weight of round mild steel material (N)

W_{SM} = Weight of sheet metal

W_{TC} = Total weight of concave

V_{RM} = Volume of round mild steel material (m^3)

ρ = Density of mild steel material (7850kg/m^3)

G = Gravitational acceleration (9.81m/s^2)

L_{SM} = Length of sheet metal mild steel (0.05m)

W_{SM} = Width of sheet mild steel material (0.03)

T = Thickness of mild steel material (0.0015m)

D = Diameter of round mild steel (0.008m)

L_{RM} = Length of round mild steel material (0.07m)

Nr = Number of round mild steel material = 47

$$W_{RM} = 7850kg/m^3 x0.7mx\pi x \frac{0.008m^2}{4} x47x9.81m/s^2 = 127.4N\ (12.98kg)$$

$$W_{SM} = 7850Kkg/m^3 x0.05mx0.03mx0.0015mx9.81m/s^2 x2 = 34.65N\left(3.53kg\right)$$

$$W_{TC} = 127.4N + 34.65N = 162.05N(16.5kg)$$

3.7.10. Determination of weight of the frame

The weight of the frame was calculated as follows.

$$W_{fm} = V_{fm}\ x\ \rho_{fm}\ x\ g \ldots\ldots\ldots\ldots(3.101)$$

$$V_{fm} = R_{fm}\ x\ L_{fm}\ x\ W_{fm} \ldots\ldots\ldots\ldots(3.102)$$

Where: W_{fm} = Weight of frame material (kg)

V_{cfm} = Volume of frame material column (m^3)

V_{flm} = Volume of frame length material (m^3)

V_{fwm} = Volume of frame width material (m^3)

W_d = Width of frame material (kg)

L_{fm} = Length of frame material (m)

T_{fm} = Thickness of frame material (m)

V_t = Total volume of frame material (m^3)

ρ = Density of frame material (kg /m^3)

ns = Number of parts

g = Acceleration due to gravity (m/s^2)

$V_{cfm} = 0.002x1.3x4x0.04x4 = 0.0016m^3$

$V_{flm} = 0.002x0.7x4x0.04x4 = 0.00022m^3$

$V_{fwm} = 0.002x0.5x4x0.04x4 = 0.00016m^3$

$V_t = 0.0016m^3 + 0.00022m^3 + 0.00016m^3 = 0.00198m^3$

$W_{fm} = 7850kg/m^3 x0.00198m^3 x9.81m/s^2 = 152.47N(15.54kg)$

3.7.11. Determinations of weight of hopper

The weight of the hopper was calculated as follows

$$W_{hm} = V_{hm} \text{ x } \rho \text{ x } g \quad \text{...(3.103)}$$

$$V_{hm} = LxWxT \quad \text{...(3.104)}$$

Where: W_{hm} = Weight of hopper material (N)

V_{hm} = Volume of hopper material (m^3)

L = Length of the hopper (0.4m)

W = Width of hopper (0.2m)

T = Thickness of the material (0.0015m)

$V_h = [0.415x0.485x0.0015x2] + [0.4x0.415x0.0015] + [0.415x0.485x0.0015] = 0.0011m^3$

$W_{hm} = 0.001m^3 7850kg/m^3 x9.81m/s^2 = 84.7N(8.6kg)$

3.7.12. Determinations of the weight of fan

The weight of the fan blades was determined using the relation (Mohammed, 2009);

$$W_f = \rho xVxg \quad \text{...(3.105)}$$

Where: W_f = Weight of the fun blade (N)

ρ = Density of the fan galvanized steel blade = 7850kg/m^3

g = Acceleration due to gravity = 9.81m/s^2

V = Volume of the fan blades = 8.452x10^{-5}m^3

$Wf = 7850x8.452x4x9.81 = 26.5N(2.65kg)$

3.7.13. Weight of top cover

The weight of top cover was determined as follows

$$W_{tc} = \rho \text{ x } V_{tc} \text{ x } g \quad \text{...(3.106)}$$

$$V_{tc} = WxWxT \quad (3.107)$$

Where: W_{tc} = Weight of top cover

ρ = Density of material = 7860kg/m^3

V = Volume of top cover (m^3)

W = Width of top cover (0.865m)

L = Length of top cover (.7m)

T = Thickness of top cover (0.02)

$$Wtc = 7850kg/m^3 x0.865mx0.7m0.002mx9.81m/s^2 = 9.26N(0.944kg)$$

3.7.14. Weight of pod outlet

The weight the pod outlet was determined as equations

$$W_{pout} = \rho x V_{pout} xg \quad (3.108)$$

$$V_{pout} = WxLxT \quad (3.109)$$

Where: W_{pout} = Weight of pod outlet

ρ = Density of material

V_{pout} = Volume of material

g = Acceleration due to gravity

T = Thickness of material

W = Width of material

L = Length of material

$$V_{pout} = 0.47mx0.7mx0.0015m = 4.9m^3$$

$$W_{pout} = 7850kg/m^3 x0.00049m^3 x9.81m/s^3 = 38N\ (3.8kg)$$

Table 3. 4. Total mass of all component's parts of the groundnut sheller

S/N	Component	Materials	Quantity	The total weight (kg)
1	Frame	Square tubing mild steel	1	30.6
2	Shelling drum	Mild steel rod	1	5.39
3	hopper	Mild steel sheet	1	8.6
4	Drum shaft	Mild steel	1	3.37
5	Fan shaft	Mild steel	1	1.996
6	Drum pulley	Aluminum	1	14.25
7	Motor pulley	Aluminum	1	0.54

8	Fan pulley	Aluminum	1	0.132
9	Outer cover	Mild steel sheet	1	18.14
10	Kernel outlet	Mild steel sheet	1	0.83
11	Concave	Mild steel rod	1	14.2
12	Fan	Mild steel sheet	1	0.66
13	Pod outlet	Mild steel sheet	1	3.8
Total				133.568

3.8. Construction and operation principles of groundnut sheller

The groundnut sheller parts were built using software to acquire dimensions from the design (CATIAV5). The machine was consisting of a frame, a drum with a helically welded reinforcement steel bar, a shaft, a concave, an exterior cover, a hopper, a pod outlet, a kernel outlet, a belt, and an engine.

3.8.1. Construction of the groundnut sheller

The detailed parts and materials for construction of the groundnut sheller is shown in table 3.1. The main components of the sheller were constructed and assembled.

Frame: it was designed with square tubular bar mild steel of 40mm by 40 and 3mm thickness were cut to the length of 700 x 550mm to form the top resting platform for shelling cylinder and bearings. The same square tubular bar mild steel was cut to a length of 1000mm to form standing legs for the frame. The operations are cutting, welding and drilling.

Shelling cylinder: The drum was made from three flat plates of mild steel of 464mm diameter. The 12mm diameter reinforcement steel bar was rolled with the rolling machine and stretched to form a helical shape. Eight helically rolled reinforcement bar was welded on flat plates on a circular pattern with 45° from one bar to the next. The center of the plate was drilled with 30mm diameter to accommodate the shaft. The four flat belts were bolted on the helically welded bar which acts as a beater to release kernels from pods. The process of constructing a drum is cutting, bending, and welding.

Concave: It was constructed using four round bars with 10mm diameter on which reinforcement mild steel bar were bent to form a half-circle and welded at 233mm spacing. The concave was designed to allow kernels to pass through and to prevent unshelled groundnut pods during shelling. The 4mm diameter round bar was helically welded with

1200mm pitch length and 664mm height. The operations carried out were cutting and welding.

Hopper: The hopper was made up of a mild steel sheet of 1.25mm thickness; it serves as an inlet for the groundnut pods. The mild steel sheet was cut to dimensions 400mm×400mm with a height, 200 mm. The operations carried out were cute and welded.

Top cover: The top cover was made of a 1.5mm thick mild steel sheet of 700mm by 864mm. It was rolled to form a half-cylinder of 630mm diameter, and angle iron with 700mmx30mm and 2mm thick was welded at both sides to strengthen. A flat plate with 630mm diameter and 3mm thickness was welded at both ends to prevent the splash out of the groundnut pod during shelling. The center of the flat plate was marked and cut out by 40mm diameter to allow the cylinder shaft to pass through. The operations carried out were cutting and welding.

Kernel outlet: The outlet was made of a mild steel sheet of 1.25mm thickness cut and rolled to give a half-circle of 200mm by 720mm in length. The outlet was bolted on the frame beam at both ends by an inclination of 18°. The outlet is designed to collect all the kernels from the concave and deliver them to a receiver.

Pulley: The pulley for this groundnut sheller machine, the motor drives pulley of 80cm diameter, fan pulley of 80mm diameter, and the diameter of cylinder shaft pulley of 420mm was selected based on velocity relationship and horsepower rating of the engine.

Selection of belt: The procedure for selecting a V-belt drive is dependent on the engine horsepower and the speed (rpm) rating. V-belt of a cross-section, density, cross-sectional area, and allowable tensile stress (σ) were taken as $1000kg/m^3$, $104mm^2$, and 2.5MPa was chosen.

Selection of engine: For this groundnut sheller machine, a 5hp diesel engine was chosen for the performance evaluations based on availability of the motor and the specifications were mention in appendix F. The engine was mounted on the motor set by using two pairs of 260mm x 30mm x 3mm dimensions and provision was made to slide in x-y direction, the engine to get desired tension on the belt.

3.8.2. Operation principles of groundnut sheller

The machine was designed and constructed to release the groundnut kernel from its pods; this is achieved by the rotary motion of the shelling cylinder. A 3.73kw (5hp) diesel engine provides drive-through belt connections to drive the pulley on the shelling drum. The groundnut pods were introduced to the machine through the hopper and passed through the restricted concave clearance between the shelling units.

The flat belt bolted on a helically welded reinforcement bar beats the groundnut pods through the shelling unit and at the same time shells the groundnut by rolling, shearing, impact, and crushing action against the helically welded round bar on concave and each other. Because the beaters are arranged in a helical pattern, the whole pods move along the length of the sheller in the forward direction until they release kernels from the pods. The helically welded round bar welded on the concave can increase the retention time for unshelled groundnut. Under the shelling cylinder, there is the perforated concave which allows the kernels to drop easily out of the shelling unit. The outlet is designed to collect grains from all sides of the concave into a receiver.

3.9. Machine performance evaluation

Performance evaluation of the constructed engine-driven groundnut sheller was carried out at Melkassa agricultural research center with commonly grown Babile and Burree groundnut variety in accordance with procedures prescribed below.

3.9.1. Preliminary test

The moisture content and kernel to pod ratio were determined in the laboratory prior to the performance evaluation of the groundnut sheller. The constructed sheller was evaluated for the combination of various treatments. Before starting the actual testing, belt tension, and direction of rotation of pulleys were checked. The clearance between the shelling cylinder drum and the concave was determined using a digital Vernier caliper. The shelling cylinder drum speed was also recorded using a tachometer. After preliminary setup, the machine was placed on a level surface to ensure the machine's stability. Then the engine was started and the speed was adjusted at a particular rpm using a speed regulator as per the treatment combination planned.

Before commencing the test, the machine was running for 10 minutes at different speeds and feed rates. This test was conducted to know the soundness and quality of construction of different components of the machine. During at no-load test, the observations were made with respect to slippage of belts, the presence of knocking or rattling sounds, slackness of any components, and the presence of an oscillation in the machine during the operation.

3.9.2. Actual test

The commonly grown Babile groundnut varieties used in the test was obtained from East Arsi Zone Golcha district and Burree varieties from East Wollega Sasiga district at the field and the moisture content was tested and sun-dried to 7.2% (d.b). The testing of the machine was done at this moisture content and three different shelling cylinder peripheral speeds and three concaves to cylinder drum clearance in three replications as shown in appendix tables B. Known weight of groundnut pods was manually loaded in the hopper and the sheller was set to run at clearance settings of 14mm, 16 mm, and 18mm and sieve sizes of 10mm. Before the groundnut pods were released into the shelling chamber, the sheller was run empty to stabilize the rotation.

The weight of the pods that were completely shelled and unbroken kernels, completely shelled but broken, partially shelled and unbroken, partially shelled and broken and the weight of unshelled pods was determined at the end of each run. The number of shells winnowed out and those collected with the seeds were recorded.

The performance evaluation of the groundnut sheller has carried out 8-hour duration at specified moisture content, shelling drum speeds, and feed rates. During the evaluation, a sample was collected from the main grain outlet for further analysis. The various performance evaluation parameters were calculated from the measured values made on each treatment and dependent parameters on each treatment combination.

The performance of the developed groundnut sheller was evaluated based on the following indices; shelling efficiency, cleaning efficiency, damaged kernels, scattered loss, and throughput capacity. These were achieved using the procedure outlined by (Mohammed & Hassan, 2012).

3.9.2.1. Shelling efficiency

Shelling efficiency is the ratio of the mass of the shelled groundnut to the total mass of the groundnut expressed in percentage as following equation (3.110 and 3.111 (Alonge *et al.*, 2016).

$$\text{Shelling efficiency} = \left(100 \text{ - Percent of un-shelled groundnut}\right) \qquad (3.110)$$

$$\text{Se} = 1\text{-}\frac{\text{Qu}}{\text{Qt}}\text{x}100 \qquad (3.111)$$

Where: Se = Shelling Efficiency (%)

Qt = Total weight of groundnut sample (Kg),

Qu = Weight of unshelled groundnut (Kg)

3.9.2.2. Cleaning efficiency

Cleaning efficiency is the ratio of the total quantity of grains collected per unit time per weight of whole materials collected at the outlet is expressed in percentage as equation (3.112).

$$Ce = \frac{Wg}{Wc} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.112)$$

Where: Ce = Cleaning efficiency (100%)

Wg = Total weight of sound and broken groundnut kernel collected per unit time (Kg)

Wc = Weight of whole materials collected at the outlet (Kg)

3.9.2.3. Percent of kernel mechanical damage

Percent of kernel mechanical damage was estimated as the ratio of the weight of broken kernel to the weight of kernels shelled including the broken kernels and it was determined according to the equation (3.113) (Kulbhushan *et al.*, 2017).

$$Kd = \frac{Wd}{Wg+Wd} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.113)$$

Where: Kd = Kernel damage in percent (%)

Wd = Weight of damaged kernels (Kg)

Wg = Weight of good kernels shelled (Kg)

3.9.2.4. Scattered loss

The scattered loss was estimated by equation (3.114) (Alonge *et al.*, 2016).

$$SL = \frac{Ws}{Wt} x100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.114)$$

Where: Sl = Scattered loss (%)

Ws = Weight of losted groundnut (kg) (Kg)

Wt = Total weight of groundnut (Kg)

3.9.2.5. Output capacity

Machine Output Capacity is the quantity of groundnut shelled in a given time by the machine and it was determined by the equation (3.115) (Alonge *et al.*, 2016).

$$Cp = \frac{Wk}{T} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.115)$$

Where: Cp = Output capacity (Kg/hr)

Wk = Total weight of kernel collected per unit time (kg)

T = Total time of shelling (hr)

For each run of shelling, the variety, drum peripheral speeds, clearance, shelling efficiency, cleaning efficiency, and percent kernel damage were recorded. Moisture content was measured by using oven-dry methods.

3.10. Experimental Design

The experiment was designed as 3x3 factorial in a randomized complete block design (RCBD). Three different levels of cylinder peripheral speeds; 130, 170, and 210 rpm and concave to cylinder drum clearances 14, 16, and 18 mm with three replications at each treatment were considered for the evaluation of the developed machine using 4 kg of groundnuts at 7.2% (d.b). After each test was finished, the groundnuts were randomly sampled, and separated by hand to identify good, broken and unshelled kernels.

3.11. Statistical Analysis of Data

The results of the performance test for various groundnut sheller treatments were examined with the use of an analysis tool included in the SPSS software program. Analysis of Variance (ANOVA) and Least Significant Difference (LSD) methods was used to assess the effect of the variables, their interactions, their significant differences, and to determine the most appropriate concave clearance and cylinder peripheral speed among the selected clearances and speeds. For the statistical conclusion, F-test levels of significance were employed at ($P<0.05$).

3.12. Economics of the Engine-driven Groundnut Sheller

The estimated cost of a product refers to the total cost of manufacturing a product. The entire cost includes material costs, labor charges, and additional expenses. The material cost refers to the purchasing price of the materials utilized in the product. Labor cost refers to the cost of labor involved in the production of a product, including the cost of the machine. Other expenses, according to Bouaziz *et al.* (2006), are all costs other than material and labor costs. The machine's operational cost components were estimated in Birr (ETB). Its operational cost is calculated and established in the appendices table E.

3.12.1. Fixed cost

The following steps were used to compute the fixed cost.

3.12.1.1. Depreciation

Depreciation is the loss of an asset value owing to use, time, wear and tear, technology outdating or obsolescence, and other factors. The annual depreciation was determined by equation (3.116) (Kepner *et al*., 2005).

$$D = \frac{C\text{-}S}{LxH} \qquad (3.116)$$

Where: D = Depreciation per hour (ETB/hrs.)

C = Capital investment cost (ETB)

S = Salvage value, 10% of the capital investment ETB,

L = Life of the machine in hours or years

H = Duration in hour

3.12.1.2. Interest

The interest cost is determined based on the machine's average investment, considering the machine's worth in the first and last years. Equation (3.117) was used to compute annual interest on the investment (Kepner *et al.,* 2005).

$$I = \frac{CxS}{2} x \frac{i}{H} \qquad (3.117)$$

Where: I = Interest per hour ETB/hr.

i = Interest per year (10 % per year

C = Capital investment cost (ETB)

S = Salvage value, 10%of the capital investment, ETB

3.12.1.3. Housing, taxes, interest and insurance

Each of the titles above was computed as 1% of the machine's initial cost.

$$\text{Housing cost per hour } (\text{ETB/hr.}) = 1\% \text{ of the initial cost of the machine} \qquad (3.118)$$

$$\text{Taxes cost } (\text{ETB/hr.}) = 1\% \text{ of the initial cost of the machine} \qquad (3.119)$$

$$\text{Insurance cost } (\text{ETB/hr.}) = 1\% \text{ of the initial cost of the machines} \qquad (3.120)$$

$$\text{Total fixed cost } (\text{ETB/hr.}) = \text{Depreciation} + \text{Interest} + \text{Insurance} + \text{Taxes} + \text{House cost}$$

3.12.2. Operating cost

The following parameters were used to compute the machine's variable cost.

3.12.2.1. Maintenance and repair cost

When only total lives of repair and maintenance costs are used it is assumed that they accumulate linearly with accumulated life. The variable repair and maintenance costs per hour are following this approach depends on the intensity of machines use (Kepner *et al.*, 2005)

$$RCH = PPx\left(\frac{1}{100}\right)x\left(\frac{TR}{TH}\right) \qquad (3.121)$$

Where: RCH = Repair and maintenance cost

PP = Purchase price

TR = Total repair cost as a percentage of PP (total accumulated repair cost)

TH = Total technical life (total accumulated hours).

3.12.2.2. Fuel cost

Fuel cost was determined by direct measuring the amount of fuel consumed per kg of groundnut in the field test.

Fuel cost = Fuel consumption x Fuel price (birr / L) (appendix E3)

3.12.2.3. Lubricant cost

It can be calculated based on maintenance costs, oil prices, or oil use. The average lubrication cost in ETB/hr is 1.5 percent of the diesel cost (Kamboj *et al.,* 2012) (appendix E3).

3.12.2.4. Operators cost

Earnings are determined based on the hourly wages of workers. It varies depending on the country.

3.12.2.5. The total cost of the machine cost per hour

The total cost per hour of the developed machine can be calculated by the summation of the fixed and variable costs per hour and calculated as equation (3.122).

$$\text{Total operating cost per hour} = \text{fixed cost }(\text{ETB/hr.}) + \text{Variable cost }(\text{ETB/hr.}) \qquad (3.122)$$

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

The groundnut shelling machine was designed, developed, and constructed. During the field test, the operating principles of the intended and developed machines were discussed, contrasted, and presented. Many parameters were measured and recorded in the workshop during manufacturing and performance evaluation operations, as shown in the figure in appendix D. The results of the field tests were analyzed using SPSS software, depending on the measurement types and needs.

4.1.Physical and Mechanical Properties of Groundnut

Groundnut physical parameters play a significant role in determining sheller features and performance attributes. The clearance between the shelling cylinder drum and the concave results in an effective shelling operation determined by the pod size. The maximum, minimum, and average values, as well as their standard deviations, are provided in table 4.1.

The major diameter is the part of the pod which houses the kernel and is the one used in grading the pods. The mean width was 13.73mm for Burree varieties and 12.46mm for Babile varieties.

Table 4.1. Physical and mechanical properties of groundnut pods

Physical properties	No	Varieties	Minimum	Maximum	Mean	Std. Deviation
Length pods	100	Burree	24.83	42.46	34.3978	4.94213
		Babile	28.90	44.28	38.16	5.15
Width pods	100	Burree	10.63	19.22	13.72	1.32
		Babile	9.14	16.95	12.46	12.19
Thickness pods	100	Burree	7.16	15.77	12.14	1.37
		Babile	6.91	13.97	10.94	1.82
Length of kernel	100	Burree	8.76	21.92	15.66	2.97
		Babile	7.24	16.63	13.29	1.97
Width of kernel	100	Burree	5.26	11.14	8.64	1.14
		Babile	4.29	12.18	7.54	1.49
Thickness of kernel	100	Burree	5.06	10.91	7.72	1.00
		Babile	4.18	11.34	6.27	1.23
Arithmetic mean diameter (mm)	100	Burree	14.65	19.43	15.87	2.11
		Babile	16.18	20.92	18.36	2.38

Geometric mean diameter (mm)	100	Burree	13.54	18.02	14.85	3.57
		Babile	12.64	21.83	17.89	3.98
Sphericity (decimal)	100	Burree	0.47	0.54	0.52	0.95
		Babile	0.45	0.53	0.50	0.76
Surface area (mm2)	100	Burree	9938.23	1091.12	1005.47	89.53
		Babile	892.29	1029.63	994.42	76.29
Aspect ratio (%)	100	Burree	32.12	45.43	39.92	6.94
		Babile	27.26	37.84	32.65	5.34
Groundnut pod shapes	100	Burree	1.96	2.97	2.50	0.93
		Babile	2.48	3.36	3.04	1.08
Crops shapes for kernels	100	Burree	1.66	1.98	1.81	0.96
		Babile	1.69	1.36	1.76	1.08
Porosity (%)		Burree	43.19	51.63	48.81	5.97
		Babile	40.09	47.68	45.12	3.72
1000 weight of pod (g)		Burree	560.90	572.10	569.70	1.22
		Babile	560.70	582.5	570.40	2.35
Angle of repose (degree)		Burree	29.20	37.50	30.8	1.80
		Babile	31.60	37.60	34.6	1.52
Friction angle (degree)		Burree	33	38	35.3	2.5
		Babile	36	38	37	1.2

Where: N = Number of samples

As illustrated in Tables (4.1), the basic geometric parameters of the groundnuts were determined. Burree groundnut pods measured 34.39 mm, 13.72 mm, and 12.14 mm in length, width and thickness respectively and Babile groundnut pods measured 38.16 mm, 12.46 mm, and 10.94mm in Length, width and thickness respectively. For the Burree and Babile varieties, the shelled geometric parameters were determined to be 10.14 mm and 7.45 mm, respectively. Babile verities has the smallest mean diameter than Burree variety and it has a larger size in length than Burree variety.

From the ratio of length to width of groundnut kernels were found 1.81 and 1.76 for Burree and Babile Varieties respectively. The results were failed in the range 1.75 to 2.31; therefore, the shapes of groundnut kernels were classified under Oblongus which is long cylindroids in shape. These results were similar with (Kara *et al.*, 2013).

4.2. Performance Evaluation of Diesel Engine-driven Groundnut Sheller

The performance of the engine-powered groundnut shelling machine was clearly demonstrated through evaluations of its shelling efficiency, mechanical damage, unshelled groundnut, scatter loss, and cleaning efficiency, which were carried with a known weight of two groundnut varieties, which are, Burree and Babile. The influence of a single factor on a performance parameter was determined by computing the average output values at each factor level and the results obtained were analyzed graphically. In the tests conducted under this section, shelling speeds ranging from 130 to 210 rpm and concave to cylinder drum clearance 14 to 18mm were used, and the findings are displayed in the following.

4.2.1.Shelling efficiency

Maximum shelling efficiency of 98.72% and 97.25% were observed for Burree and Babile varieties, respectively, at maximum cylinder speed of 210 rpm and minimum concave clearance 14 mm. These results were better than (Gelgelo, 2016). The minimum shelling efficiency 81.00% and 79.25% were observed for Burree and Babile Varieties, respectively, at a minimum cylinder speed 130 rpm and maximum concave clearance 18 mm.

Figures (4.1) and (4.2) show the machine's shelling efficiency increased as the cylinder speed increased from 130rpm to 210 rpm for both varieties. This result has the same trend as that of (Nyaanga *et al.,* 2007; Rostami *et al.,* 2009). The increase in the shelling efficiency was more as the cylinder peripheral speeds increased from 130 rpm to 170 rpm, thereafter the shelling efficiency slightly after 170 rpm. This could be due to the energy imparted to the pods being higher at higher cylinder speeds, resulting in higher shelling. As a result, at high cylinder speeds, shelling efficiency was increased.

The result shows as concave clearance increased from 14 to 18 mm at a moisture content of 7.2% (d.b) the shelling efficiency decreased for both groundnut varieties. These trends were agreed with the results reported by (Isaac *et al.,* 2015). This is because increasing the concave clearance decreased the material's contact with the concave and cylinder, which decrease the pod's crackability.

Appendix table C2 shows, that the clearances and cylinder speed were found to have a substantial impact on shelling efficiency. When the cylinder speed and concave clearance were changed, the shelling efficiency changed drastically. According to the results of the correlation analysis, R^2 = 0.985 indicates that changes in concave clearances and cylinder speed have a strong positive relationship, and R^2 sum = 0.979 indicates that changes in cylinder speed and concave clearance have a positive impact on groundnut shelling efficiency at (p<0.01). The impact of cylinder speed, as well as the interactions of cylinder speed and concave clearance, was highly significant at (p<0.01) for both varieties.

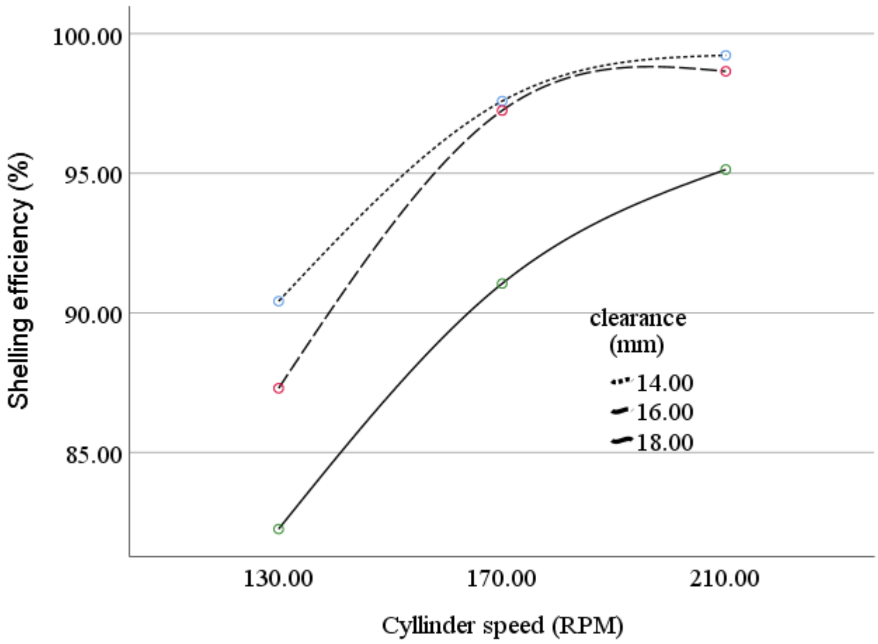


Figure 4.1. Effect of cylinder speed and concave clearance on shelling efficiency for Burree varieties

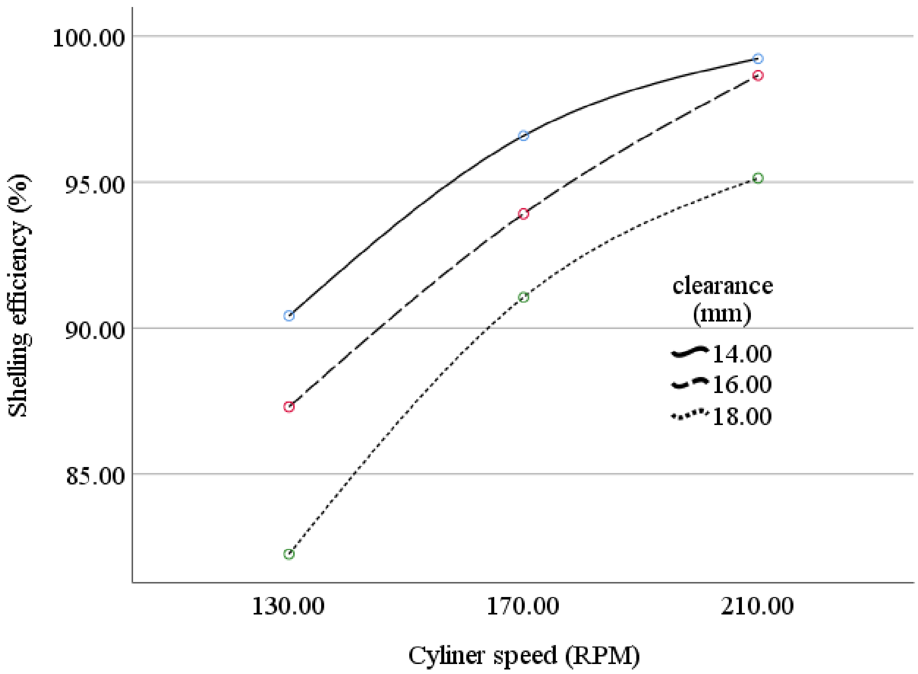


Figure 4.2. Effect of cylinder speed and concave clearance on shelling efficiency for Babile variety

4.2.2.Cleaning efficiency

Figures (4.3) and (4.4) show that maximum cleaning efficiency (98.92%) for Burree and (97.25%) for Babile Varieties were obtained at 210 rpm cylinder speed and 14 mm concave clearance, whereas minimum cleaning efficiency of 82.32% and 83.78% were recorded at 130 rpm cylinder speed and 18mm concave clearance for Burree and Babile varieties, respectively.

Cleaning efficiency increased significantly when cylinder speed increased from 130 rpm to 170rpm, then increased slightly from 170 rpm to 210 rpm for both varieties. When the cylinder speed was increased from 130 rpm to 210 rpm cleaning efficiency increased from 79.35% to 98.72% for Burree varieties and from 89.28% to 98.91% for Babile varieties, at 14mm concave to cylinder clearance. This shows cleaning efficiency was directly related to cylinder speed, which indicates that cleaning efficiency increased as cylinder speed increased. Because the blower speed was increased, as cylinder speed increased, the fan speed was increased by 5 time than cylinder speed, the beater rotated at a high speed, causing the pods to accumulate less weight, causing certain pods to get to a finer state, and the air pressure line followed the pods through the pod's collection chute. The maximum cleaning efficiency (98. 92%) and (97.25%) were observed at higher cylinder speed and minimum concave clearance for Burree and Babile varieties respectively. This was higher than finding Alonge *et al.,* (2016), Gelgelo (2016); Muhammad & Isiaka, (2019) but inlined with reported by (Hoque *et al.,* 2018).

Cleaning efficiency improved as the cylinder speed increased, but decreased as the concave clearance increased. This result has the same trend as (Afify *et al.,* 2007). Increased concave clearance also increased the unshelled number of pods and increase the weight of the material handled by the air stream, resulting in a decrease in cleaning effectiveness due to insufficient air pressure to transport the items away.

The R^2 value for two varieties of was greater than 0.99 for change in cylinder speed and less than 0.95 for clearance change. According to the correlation analysis results, changes in concave clearances had no positive relationship but the change in cylinder speed had a highly positive relationship with cleaning efficiency. According to ANOVA, cylinder speed had a highly significant impact on cleaning efficiency ($p<0.01$) (Appendix table C3).

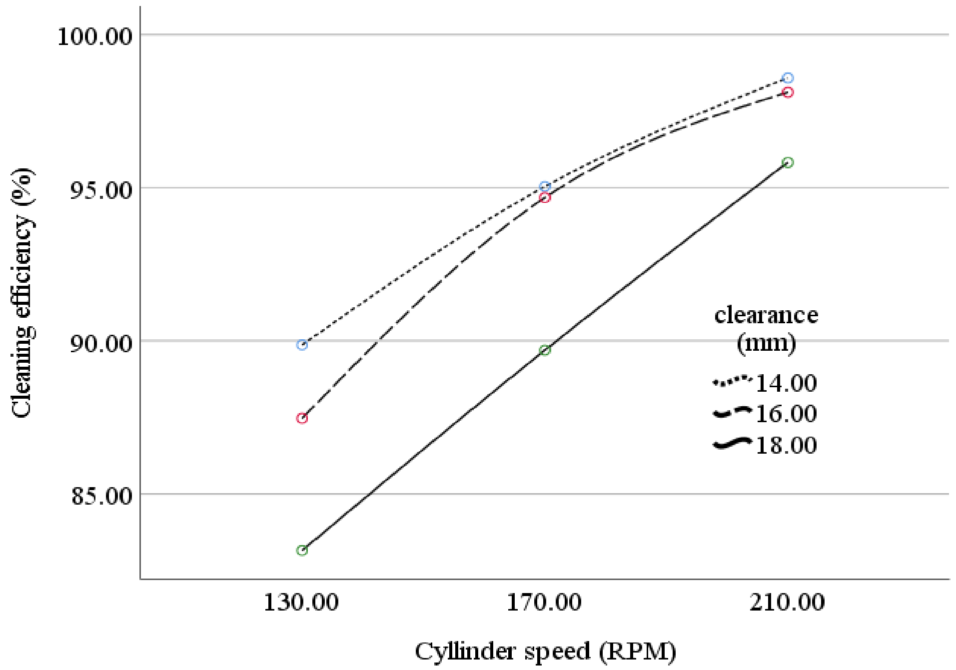


Figure 4.3. Effect of cylinder speed and concave clearance on cleaning efficiency for Burree variety

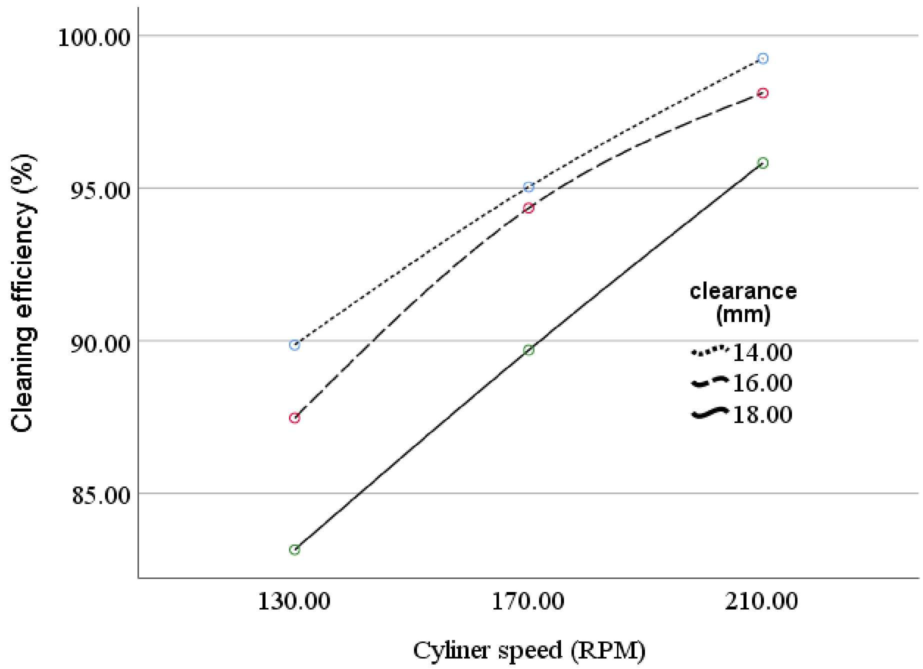


Figure 4.4. Effect of cylinder speed and concave clearance on cleaning efficiency for Babile variety

4.2.3.Percentage of kernel mechanical damage

For both the Burree and the Babile varieties, the lowest percentage (5.05%) and (8.47%) of groundnut kernel mechanical damage was observed at a maximum concave clearance of 18 mm and a minimum cylinder speed of 130 rpm for Burree and Babile varieties respectively.

This result revealed that the developed machine has less mechanical damage than reported by Alonge *et al.*, (2016), but higher than Hoque *et al.*, (2018). The maximum breakage (29.43) and (32.78) was observed at a minimum concave clearance of 14 mm and at a maximum cylinder speed of 210 rpm for Burree and Babile varieties, respectively. For all three clearances, the groundnut kernel breakage increases slightly from 130 rpm to 170 rpm and significantly thereafter 170 rpm, as shown in figures (4.5) and (4.6).

The percentage of kernel mechanical damage decreases as concave clearance increases. It was directly related to cylinder speed and had an indirect effect on concave clearance. It may be due to the free flow of groundnut at higher concave clearance, which resulted in reduced effect of impact, rubbing, and frictional forces. This has the same trend with Rostami *et al.*, (2009); Shukla *et al.*, (2019).

The result of the ANOVA of shelled pods with broken kernels presented in Appendix table C4 the value of (R = .991 and R^2 = .987) shows the change in concave clearance and cylinder speed has a strongly positive relationship with groundnut kernel damage and strong positive effect on kernel breakage. The change in cylinder speed and concave clearance and their interaction had highly significant at (P< 0.05). This result is agreed with (Tertsegha *et al.*, (2021).

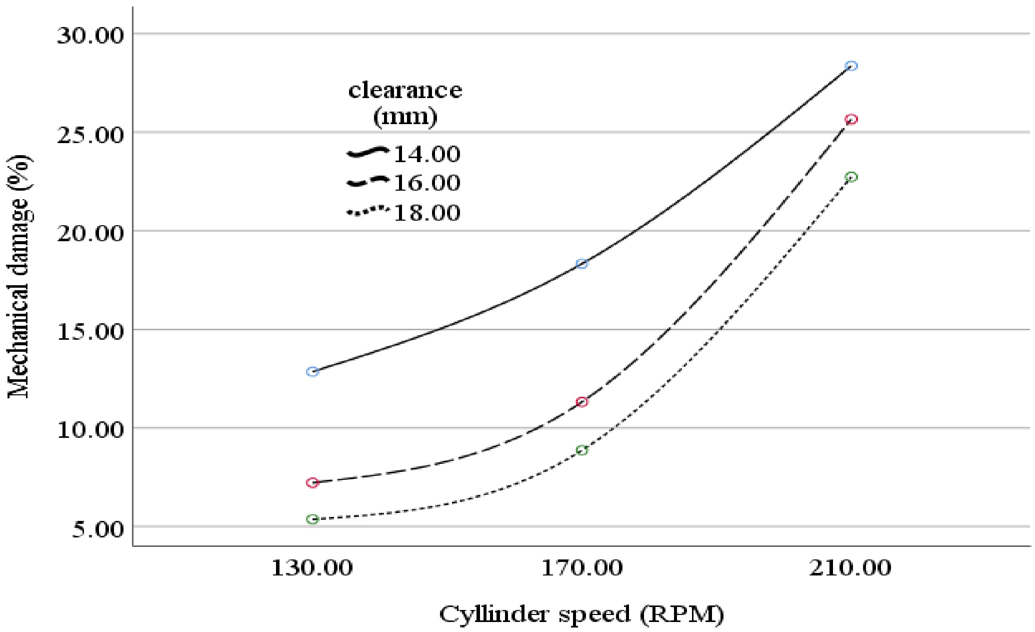


Figure 4.5. Effect of cylinder speed and concave clearance on kernel mechanical damage for Burree variety

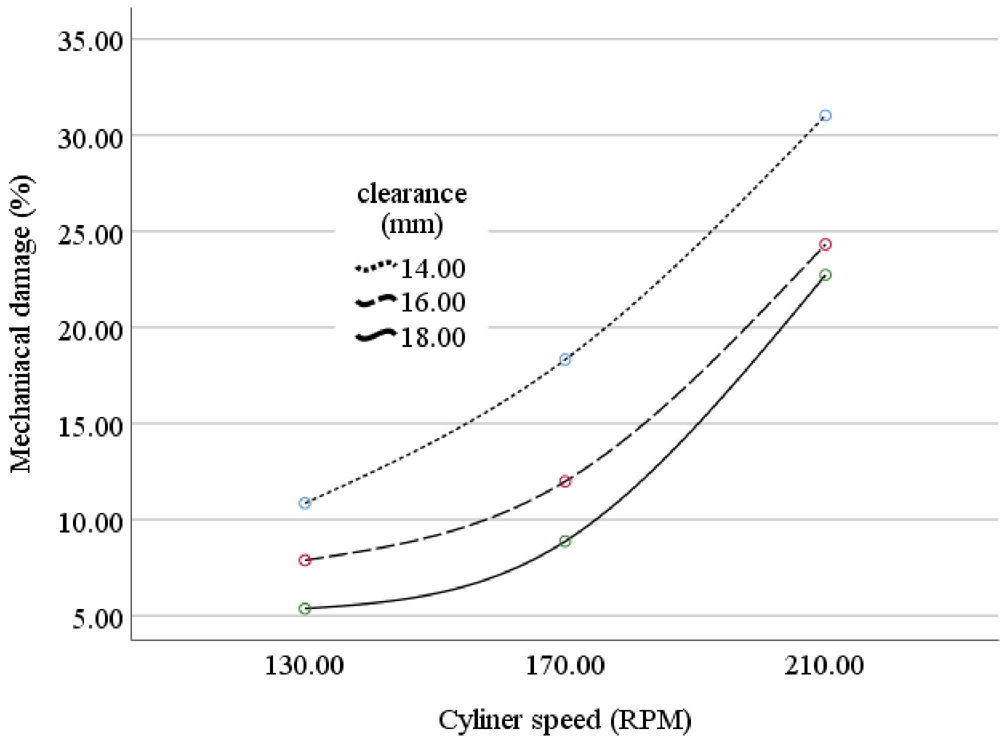


Figure 4.6.Effect of cylinder speed and concave clearance on kernel mechanical damage for Babile variety

4.2.4.Percentage of scattered loss

The lowest proportion of kernel losses (0.0%) and (0.09%) was recorded at 130 rpm shelling cylinder peripheral speed and 18 mm concave clearance, whereas the highest percentage (0.32%) and (0.35%) of kernel losses were seen at 210 rpm shelling drum peripheral speed and 14mm concave clearance (Appendix B1 and B2). This is better than reported by Muhammad & Isiaka, (2019). Figures (4.9) and (4.10) shows the gradual rise in the percentage of scattering loss from 130 rpm to 170 rpm and a quick increase from 170 rpm to 210 rpm.

The effects of variables such as cylinder speed and concave clearance on the percentage of kernel losses of the groundnut sheller machine were statistically analyzed and shown in the (Appendix Table C6). The effects of cylinder speeds on the scattered losses were highly significant (P <0.01), while their interactions and change in concave clearance were not significant (P< 0.05).

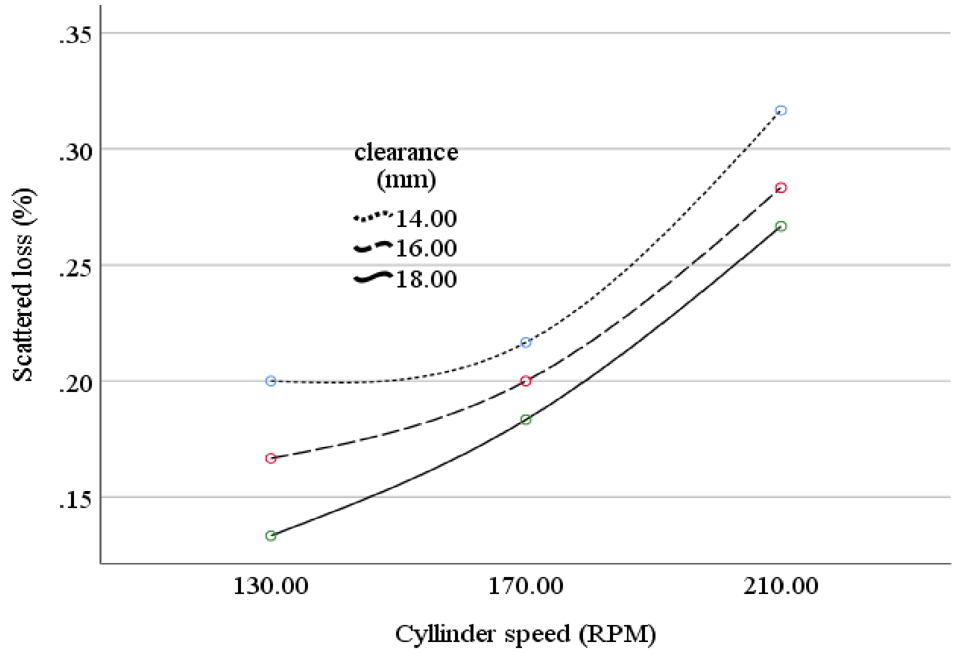


Figure 4. 7.Effect of cylinder speed and concave clearance on scatter loss for Burree variety

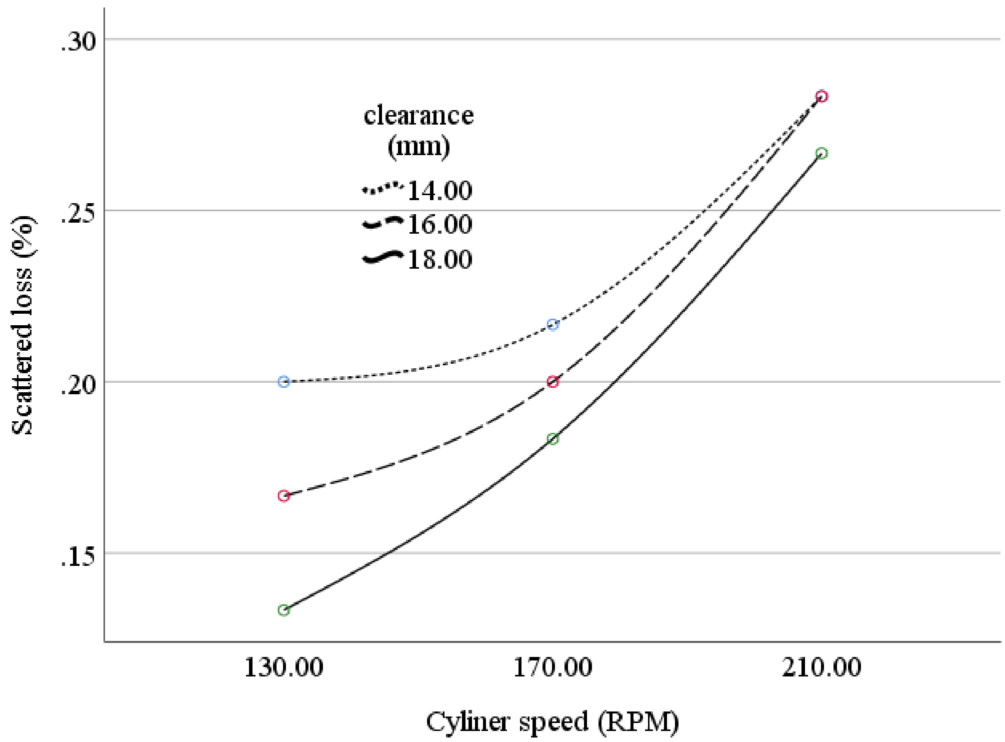


Figure 4. 8 Effect of cylinder speed and concave clearance on scatter for Babile variety

4.2.5.Throughput capacity

From the figures (4.11) and (4.12), the machine's throughput capacity increased significantly as the cylinder speed increased. However, when the concave to cylinder clearance increases, the machine throughout put capacity of the machine decreases. For Burree and Babile varieties Appendix B1 and B2, the maximum machine throughput capacity (477.85kg/hr) and (448.7kg/hr) were recorded at 14 mm concave clearance and 210 rpm drum speed, while the minimum throughput capacity (76.33kg/hr) and (88.14kg/hr) were recorded at 18 mm concave clearance and 130 rpm cylinder speed for Burree and Babile varieties respectively. At 170 rpm and 16 mm concave clearance the throughput capacity was recorded 308 kg/h and 282.61kg/h for Burree and Babile varieties respectively. These results were better than those reported by (Tertsegha *et al.*, 2021; Hoque *et al.*, 2018).

According to the ANOVA table, changing the concave clearance and cylinder speed had a strongly positive relationship, and had a highly positive impact on the machine's throughput capacity. At P <0.01 Appendix (table C1) the impacts of cylinder speeds on the machine's overall throughput capacity were highly significant.

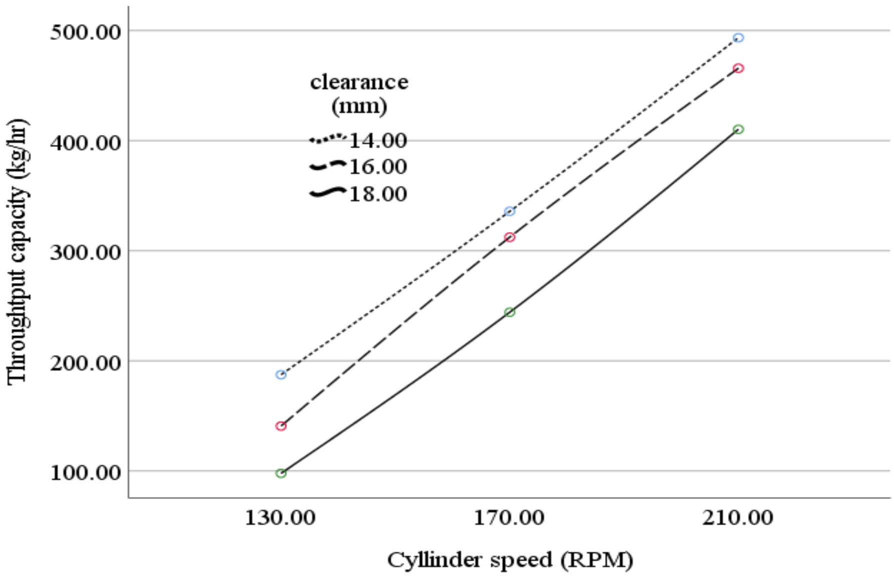


Figure 4.9. Effect of cylinder speed and concave clearance on throughput capacity for Burree variety

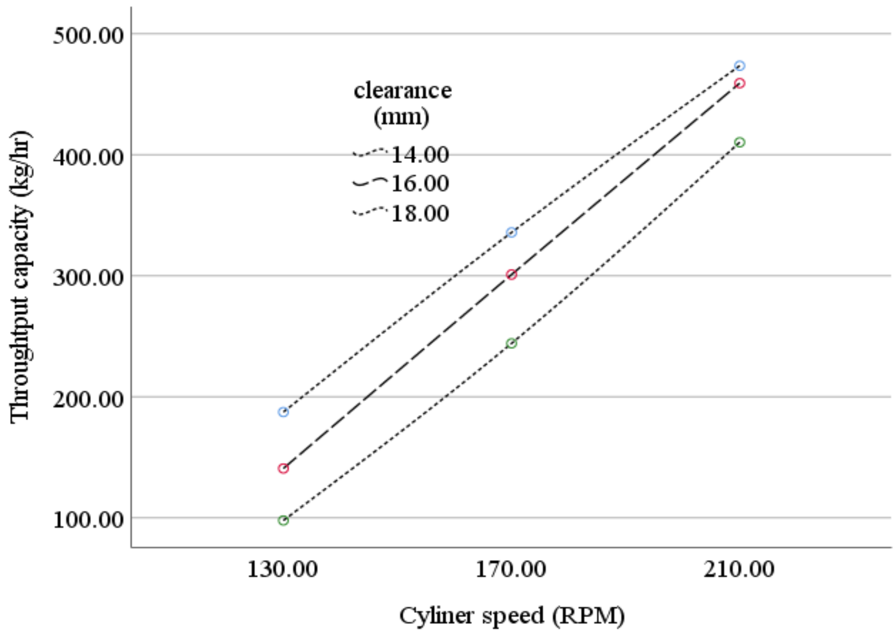


Figure 4.10. Effect of cylinder speed and clearance on throughput capacity for Babile variety

Table 4. 2. Summary of the performances of the existing groundnut sheller machine and the new developed machine.

Authors		Shelling efficiency (%)	Cleaning efficiency (%)	Mechanical damage (%)	Unshelled (%)	Scatter loss (%)	Output capacity (Kg/h)
The new developed machine performance at optimum conditions							
The new developed machine at (170 rpm & 16 mm)	Burree	96.25	94.80	11.65	3.75	0.15	308
	Babile	94.44	93.01	13.74	5.56	0.20	282.61
The existing machine performance							
(Gelgelo, 2016).		92.07	95.13	6.34			210.11
(Muhammad & Isiaka, 2019)		98.32	50.63	4.33		3.24	239.81
(Hoque, 2018)		88.82	99	2	9.18		115
(Mohammed & Hassan, 2012)		78	85	1.1			345.4
(Alonge *et al.*, 2016)		83.2	86.7	17.4	9		
(Tertsegha *et al.*, 2021)		92.41	84.46	6.93			211.65
(Adenigba and Sedara, 2021).		95.80	81.40	11.01			97.98
(Kittichai,1984)		98		45			

CHAPTER FIVE

5. SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1. Summary

This study was carried out at Melkassa Agricultural Research Center, department of agricultural engineering, on significant aspects of shelling pods, with the particular goal of developing, constructing, and assessing the performance of an engine-driven groundnut sheller.

Two commonly grown groundnut varieties, Burree and Babile, were used for this investigation. Standard methodologies were used to determine the engineering parameters of the selected groundnut varieties (shape, sphericity, true density, bulk density, surface area, angle of repose, and coefficient of friction). In the Melkassa Agricultural Engineering Workshop, different components of the sheller machine were designed and machine components were constructed. The machine was powered by a 3.75 kw diesel engine during performance evaluations (Appendix F). The engine speeds were adjusted by engine throttle and its operated at three throttle levels, 2/5, 3/5 and 3/4.

The performance of the sheller was evaluated with major influencing factors, such as concave clearance (14 mm, 16 mm, and 18 mm) and cylinder peripheral speeds (130 rpm, 170 rpm, and 210 rpm) at 7.2% (d.b) moisture content of groundnut pods, in order to optimize the operational parameters of the machine for efficient performance.

The sheller's performance was evaluated using 108kg for each locally produced Burree variety and Babile variety. Different characteristics were determined and studied, including throughput capacity (kgh^{-1}), shelling efficiency (%), cleaning efficiency (%), unshelled pods percentage (%), kernel mechanical damage (%), and scatter loss (%).

5.2. Conclusions

Groundnut is produced in large quantities in Ethiopia. However, shelling and cleaning procedures remain one of the most difficult tasks for farmers. Ethiopian farmers do not have access to efficient groundnut shellers. An engine operated groundnut sheller machine was developed to overcome these issues.

A shelling cylinder with a diameter of 448 mm and a length of 664 mm is used in the sheller. It is made up of three metal sheet plates with a diameter of 448mm and eight helically welded reinforcing steel on sheet metal plates. Four flat belts were helically tightened on a reinforcing steel bar, impacting and squeezing the crop to separate pods from kernels. The semicircular perforated lower concaves are constructed of 8mm diameter reinforcing steel bar with an 8 mm aperture size. The minimum power requirement of the machine is 2HP.

The sheller is simple, lightweight, and requires less power to shell groundnuts, and it has a lower initial investment compared to existing power-operated groundnut shelling systems. The sheller can assist to significantly reducing the cost of labour needed in shelling as well as the amount of time spent shelling on small farms, due to the low energy needs. It will also enhance groundnut production and processing in Ethiopia since the sheller is inexpensive, simple to maintain, and operate; also, it was constructed with locally accessible materials, making spare parts readily available for repair and replacement of broken components. The sheller will definitely help to solve the long-term problem of groundnut shelling, particularly for small-scale farmers.

The performance of the machine was then evaluated for its shelling efficiency, cleaning efficiency, scatter losses, unshelled, machine throughput capacity and kernel mechanical damage. As the cylinder speed increases, the shelling efficiency increased, the shelling capacity, kernel mechanical damage increased while the percentage of unshelled reduced. Increase in blower speed increased the cleaning efficiency and the blower loss. The sheller's optimum operating conditions are 170 rpm cylinder speed and 892 rpm blower speed with total shelling efficiency of (96.25% and 94.44%), cleaning efficiency of (94.80% and 93.01%), scatter loss of (0.15% and 0.20 %), unshelled (3.75% and 5.56%) throughput capacity of (308kg/hr and 282.61kg/hr) for Burree and Babile varieties respectively, at concave clearance of 16mm. According to the results of the performance test, the developed machine was peripheral for both Burree and Babile varieties but Burree variety is more appropriate for this machine than Babile variety.

5.3. Recommendations

The groundnut sheller machine developed for use with local cultivator Burree and Babile varies groundnut appear to be most efficient at cylinder speed of 170 rpm and 16mm concave clearance, when the pods moisture content is 7.2% (d.b) and the feed rate is 5.13 kg/min. Nonetheless, it is recommended that:

- The machine will be re-evaluated at the machine minimum power requirement (2HP) and at different feed rates using different varieties of groundnuts.

- The groundnut kernels were broken by colliding with cylinder plate sheet metals and top cover after being shelled. The internal part of the top cover and drum plate should be covered with rubber to minimize the percentage of breakage.
- The sieve should be designed and installed blow the shelling concave with oscillation mechanisms during shelling and cleaning, to separate the kernels from unshelled and pods for further shelling.
- The unshelled groundnut should be refilled into the hopper and re-shelled. The amount of groundnut braked during shelling operation should be used for peanut butter and oil extraction.
- Sieve should be installed under shelling concave with oscillations mechanism to separate the broken, good kernel and shelled pods.
- Systematic, coordinated and relentless efforts are made to make the machine affordable or jointly owned, adopted efficiently used to produce quality groundnut that will fetch a premium price.

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APPENDIX A

Appendix A: Physical properties of cassava sample calculation.

1) Moisture content

$$Mc = \frac{Ww\text{-}Wd}{Ww} x100$$

$$Mc = \frac{68.7\text{-}63.72}{68.7} x100=7.2\%$$

2) Geometric mean diameter

$$Dg = (LXWXT)^{1/3}$$

For Burree Varieties

$$Dg = 34.39x13.73x12.14^{1/3} =17.89$$

For Babile Varieties

$$Dg = 38.16x12.46x10.94 = 17.32$$

3) Sphericity $(\phi = \frac{(LxWxT)^{1/3}}{L} = \frac{Dg}{L})$

For Burree Varieties

$$\phi = \frac{17.89}{34.39} =0.52$$

For Babile varieties

$$\phi= \frac{17.32}{34.39} =0.50$$

4) Surface area (Sa)

$$Sa=\pi Dg^{2}$$

For Burree varieties

$$Sa = \pi 17.89^{2} = 1,005.47mm^2$$

For Babile varieties

$$Sa = \pi 17.32^{2} = 942.42mm^2$$

5) Aspect ratio (R)

$$R = \frac{W}{L} x100$$

For Burree varieties

$$R=\frac{13.73}{34.39}x100=39.92$$

For Babile varieties

$$R=\frac{12.46}{38.16}x100=32.65$$

6) Groundnut kernel shapes

$$Shape=\frac{L}{W}$$

For Burree varieties

$$Shape=\frac{15.66}{8.64}=1.81$$

For Babile varieties

$$Shape=\frac{13.29}{7.54}=1.76$$

APPENDIX B

Appendix table B.1: Average experimental data for the evaluation of groundnut shelling machine for Burree varieties

S.N.	Clearance (mm)	Cylinder speed (rpm)	Total weight of groundnut(kg)	Weight of good kernel (kg)	Unshelled groundnut (kg)	Kernel damage (kg)	Pods collected from kernel outlet (kg)	Operation time (min)	Percent of kernel damage (%)	Cleaning efficiency (%)	Shelling efficiency (%)	Percentage of unshelled (%)	Output capacity (kg/h	Percent of scatter loss (%)
1	14	130	4	2.31	0.38	0.38	0.32	1.23	10.46	90.16	89.25	10.75	194.42	0.20
2	14	130	4	2.16	0.42	0.34	0.28	1.32	9.98	90.16	90.25	9.75	182.62	0.25
3	14	130	4	2.16	0.39	0.42	0.31	1.29	12.11	89.28	91.75	8.25	185.10	0.15
4	14	170	4	2.09	0.17	0.56	0.38	0.71	17.60	95.46	96.20	3.80	338.26	0.25
5	14	170	4	1.96	0.28	0.57	0.42	0.72	19.03	94.46	97.95	2.05	333.88	0.15
6	14	170	4	2.09	0.22	0.53	0.39	0.70	18.36	95.19	95.60	4.40	335.20	0.25
7	14	210	4	2.26	0.07	0.96	0.04	0.50	28.36	99.91	98.72	1.09	477.85	0.28
8	14	210	4	2.31	0.11	0.96	0.03	0.51	29.43	98.92	98.20	1.20	468.75	0.30
9	14	210	4	2.01	0.08	0.98	0.05	0.05	27.30	98.92	98.15	1.28	473.91	0.27
10	16	130	4	2.43	0.43	0.35	0.17	1.70	7.47	87.77	88.15	11.85	141.05	0.15
11	16	130	4	2.33	0.5	0.33	0.14	1.72	8.30	86.47	86.25	13.75	139.41	0.20
12	16	130	4	2.38	0.49	0.27	0.11	1.69	7.88	88.16	87.50	12.50	141.87	0.15

13	16	170	4	2.28	0.16	0.39	0.06	0.78	11.31	94.15	94.10	5.90	304.55	0.25
14	16	170	4	2.24	0.15	0.42	0.05	0.82	12.39	94.80	93.20	6.80	289.76	0.15
15	16	170	4	2.31	0.29	0.34	0.07	0.78	11.26	94.08	94.44	5.56	308.61	0.20
16	16	210	4	2.14	0.08	0.78	0.06	0.51	24.02	97.67	98.45	1.55	468.00	0.30
17	16	210	4	2.06	0.15	0.83	0.02	0.53	25.32	98.94	98.75	1.25	456.06	0.25
18	16	210	4	2.17	0.16	0.96	0.05	0.52	23.64	97.74	98.75	1.25	453.30	0.30
19	18	130	4	2.74	0.74	0.31	0.242	2.57	5.36	83.78	82.25	17.75	96.33	0.25
20	18	130	4	2.65	0.71	0.34	0.31	2.44	5.05	82.32	83.53	16.47	98.14	0.15
21	18	130	4	2.82	0.83	0.27	0.18	2.43	5.70	83.35	81.00	19.00	98.93	0.00
22	18	170	4	2.58	0.54	0.38	0.151	0.97	9.00	89.34	92.05	7.95	246.21	0.25
23	18	170	4	2.57	0.58	0.34	0.24	0.96	9.46	89.62	90.10	9.90	248.55	0.15
24	18	170	4	2.49	0.62	0.42	0.09	1.01	8.15	90.11	91.00	9.00	237.62	0.15
25	18	210	4	2.23	0.38	0.4	0.098	0.58	24.40	95.79	95.25	4.75	408.02	0.30
26	18	210	4	2.35	0.32	0.39	0.06	0.58	20.75	96.19	94.95	5.05	414.24	0.25
27	18	210	4	2.532	0.53	0.26	0.16	0.58	23.05	95.50	95.20	4.80	408.63	0.25

Appendix table B. 2: Average experimental data for the evaluation of groundnut shelling machine for Babile Varieties.

S.N.	Clearance (mm)	Cylinder speed (rpm)	Total weight of groundnut(kg)	Weight of good kernel (kg)	Unshelled groundnut (kg)	Kernel damage (kg)	Pods collected from kernel outlet (kg)	Operation time (min)	Percent of kernel damage (%) ()	Cleaning efficiency (%)	Shelling efficiency (%)	Percentage of unshelled (%)	Output capacity (kg/h	Percent of scatter loss (%)
1	14	130	4	2.31	0.38	0.38	0.32	1.22	14.13	79.35	88.50	9.50	196.19	.20
2	14	130	4	2.16	0.42	0.34	0.28	1.57	13.60	78.13	89.50	10.50	152.62	.25
3	14	130	4	2.16	0.39	0.42	0.31	1.55	16.28	78.66	89.25	9.75	155.10	.15
4	14	170	4	2.09	0.17	0.56	0.38	0.79	21.13	82.81	95.75	4.25	301.26	.25
5	14	170	4	1.96	0.28	0.57	0.42	0.80	22.53	78.33	96.00	7.00	299.88	.15
6	14	170	4	2.09	0.22	0.53	0.39	0.81	20.23	81.11	94.50	5.50	295.20	.25
7	14	210	4	2.26	0.07	0.96	0.04	0.53	29.81	96.70	96.15	3.85	447.85	.32
8	14	210	4	2.31	0.11	0.96	0.03	0.53	29.36	95.89	97.25	2.75	448.75	.30
9	14	210	4	2.01	0.08	0.98	0.05	0.55	32.78	95.83	97.00	.00	433.91	.30
10	16	130	4	2.43	0.43	0.35	0.17	1.83	12.59	82.25	89.25	10.75	131.05	.15
11	16	130	4	2.33	0.5	0.33	0.14	1.85	12.41	80.61	87.50	12.50	129.41	.20
12	16	130	4	2.38	0.49	0.27	0.11	1.81	10.19	81.54	87.75	12.25	131.87	.15

13	16	170	4	2.28	0.16	0.39	0.06	0.86	14.61	92.39	96.00	4.00	278.55	.25
14	16	170	4	2.24	0.15	0.42	0.05	0.89	12.79	93.01	96.25	3.75	269.76	.15
15	16	170	4	2.31	0.29	0.34	0.07	0.78	13.83	88.04	95.75	4.25	282.61	.20
16	16	210	4	2.14	0.08	0.78	0.06	0.54	26.71	95.42	98.00	2.00	438.00	.30
17	16	210	4	2.06	0.15	0.83	0.02	0.55	28.72	94.44	96.25	3.75	436.06	.25
18	16	210	4	2.17	0.16	0.96	0.05	0.54	30.67	93.71	96.00	4.00	443.30	.30
19	18	130	4	2.74	0.74	0.31	0.242	3.14	10.16	83.78	81.50	18.50	76.33	0.01
20	18	130	4	2.65	0.71	0.34	0.31	2.72	11.37	74.56	82.25	17.75	88.14	0.09
21	18	130	4	2.82	0.83	0.27	0.18	2.43	8.74	75.37	79.25	20.75	88.93	0.11
22	18	170	4	2.58	0.54	0.38	0.151	0.97	12.84	81.07	86.50	13.50	246.21	.25
23	18	170	4	2.57	0.58	0.34	0.24	0.96	11.68	78.02	85.50	14.50	248.55	.15
24	18	170	4	2.49	0.62	0.42	0.09	1.01	14.43	80.39	84.50	15.50	237.62	.15
25	18	210	4	2.23	0.38	0.4	0.098	0.59	15.21	84.62	90.50	9.50	408.02	.30
26	18	210	4	2.35	0.32	0.39	0.06	0.58	14.23	87.82	92.00	8.00	414.24	.25
27	18	210	4	2.532	0.53	0.26	0.16	0.59	10.61	78.03	86.75	13.25	408.63	.25

APPENDIX C

Appendix table C1. Analysis of variance and descriptive statistics for machine throughput capacity.

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	481657.246a	8	60207.156	4068.281	.000
Intercept	2408011.941	1	2408011.941	162712.690	.000
Clearance	35753.879	2	17876.940	1207.969	.00
RPM	445243.573	2	222621.787	15042.861	.000
Clearance * RPM	659.793	4	164.948	11.146	.001
Total	2889935.572	27			
Corrected Total	481923.631	26			

a. R Squared = .999 (Adjusted R Squared = .999)

Appendix table C2. Analysis of variance and descriptive statistics for machine shelling efficiency.

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	816.627a	8	102.078	150.481	.000
Intercept	234562.965	1	234562.965	345785.989	.000
Clearance	195.558	2	97.779	144.143	.000
RPM	604.316	2	302.158	445.433	.000
Clearance * RPM	16.752	4	4.188	6.174	.003
Error	12.210	18	.678		

Total	235391.803	27			
Corrected Total	828.837	26			

a. R Squared = .985 (Adjusted R Squared = .979)

Appendix table C3. Analysis of variance and descriptive statistics for machine cleaning efficiency.

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1582.528a	8	197.816	242.181	.000
Intercept	6599.763	1	6599.763	8079.909	.000
Clearance	265.746	2	132.873	162.673	.000
RPM	1305.577	2	652.788	799.191	.000
Clearance * RPM	11.205	4	2.801	3.430	.002
Error	14.703	18	.817		
Total	8196.994	27			
Corrected Total	1597.231	26			

Appendix table C4. Analysis of variance and descriptive statistics for machine kernel damaged.

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1582.528a	8	197.816	242.181	.000
Intercept	6599.763	1	6599.763	8079.909	.000
Clearance	265.746	2	132.873	162.673	.000
RPM	1305.577	2	652.788	799.191	.012

Clearance * RPM	11.205	4	2.801	3.430	.0
Error	14.703	18	.817		
Total	8196.994	27			
Corrected Total	1597.231	26			

a. R Squared = .991 (Adjusted R Squared = .987)

Appendix table C5. Analysis of variance and descriptive statistics for machine percentage of unshelled.

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	816.518a	8	102.065	150.305	.000
Intercept	1245.897	1	1245.897	1834.760	.000
Clearance	195.521	2	97.761	143.966	.000
RPM	604.251	2	302.125	444.923	.000
Clearance * RPM	16.746	4	4.186	6.165	.002
Error	12.223	18	.679		
Total	2074.638	27			
Corrected Total	828.741	26			

a. R Squared = .985 (Adjusted R Squared = .978)

Appendix table C6.Analysis of variance and descriptive statistics for machine percentage of scatter loss.

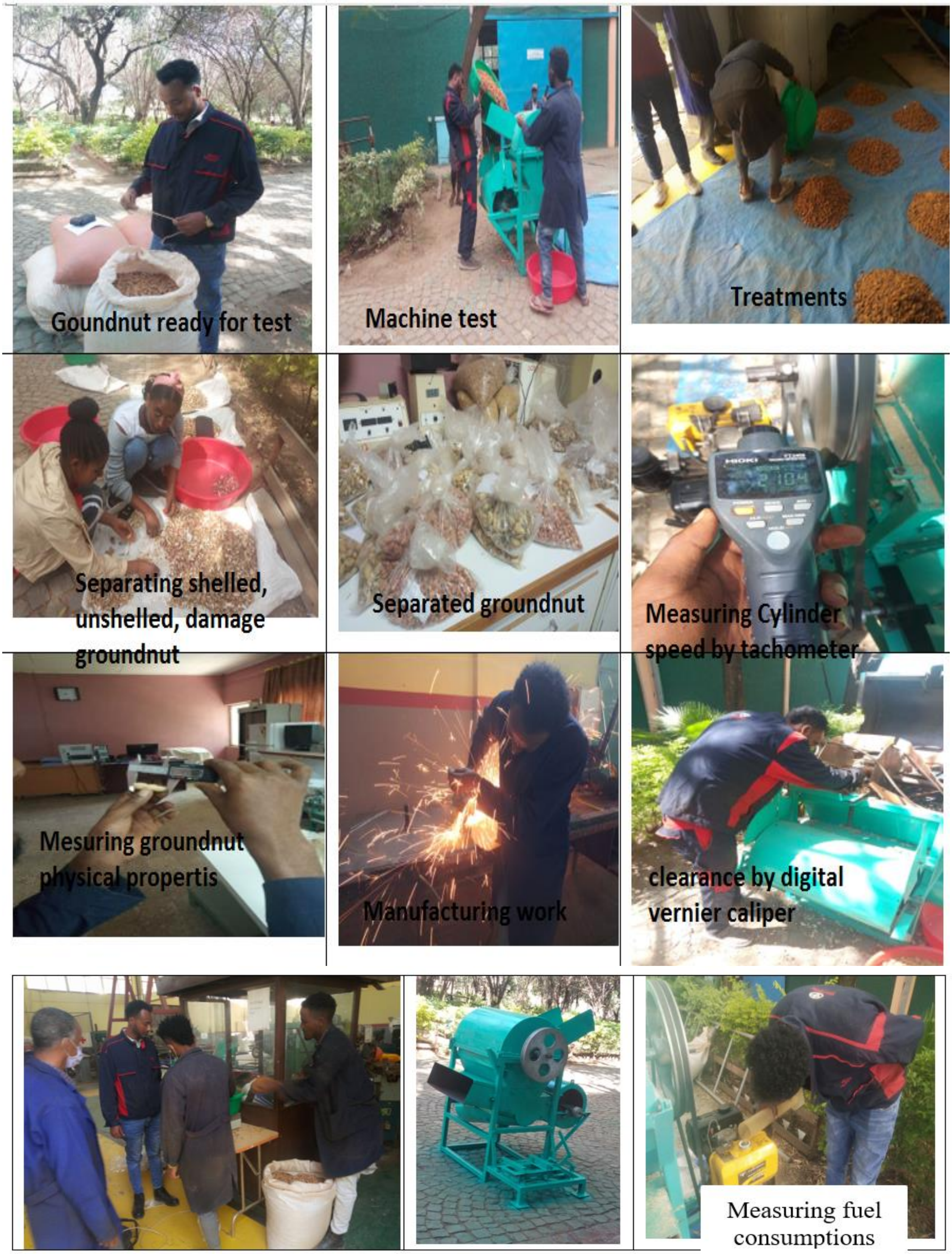
Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.067[a]	8	.008	2.508	.050
Intercept	1.246	1	1.246	370.893	.000
Clearance	.007	2	.003	1.020	.220

RPM	.059	2	.029	444.923	.000
Clearance * RPM	.002	4	.001	.152	.960
Error	.060	18	.003		
Total	1.374	27			
Corrected Total	.128	26			

a. R Squared = .527 (Adjusted R Squared = .317)

APPENDIX D

Appendix D: Experimental work, machine adjustment and field test.



Under manufacturing

Babile variety

Burree variety

APPENDIX E

Appendix E: Materials, specification and costing for the groundnut sheller

Appendix table E.1. Materials for construction of shelling machine and cost

	Component	Types Material	Specifications	Quantity	Unit price (ETB)	Total price
1	Frame	Square tubular bar iron	40×40×1200mm	2	170.00	340
2	Shelling drum	-Metal sheet -round bar -Flat belt	Ø446mm×4mm Ø12mm×640mm 4 x 40mm x 600mm	1 8 4	75.00 15.60 25.00	75.00 124.80 100.00
3	Drum shaft	Mild steel rod	Ø30mm×770mm	1	76.00	46.00
4	Blower shaft	Mild steel rod	Ø20mm×770mm	1	55.00	35.00
5	Concave	Reinforcement steel Round bar	Ø8mm×660mm Ø4mm×45mm	27 6	4.80 2.00	130.00 12.00
6	Top cover	Metal sheet	5400mmx700mm	1	180.00	180.00
7	Hopper	Metal sheet	200mmx400mm	3	80.00	135.00
8	Bolt and nut	Mild steel	M12	12	2.00	26.00
9	Rolling bearing	Mild steel	P206	2	60.00	120.00
10	Ball bearing	Mild steel	P204	2	40.00	80.00
11	Motor pulley	Cast aluminum	Ø80mm×40mm	2	200.00	800.00
12	Drum pulley	Cast aluminum	Ø420mm×56mm	1	450.00	450.00
13	Electrode		Gauge 12 Ø2.5	1	100.00	100.00
14	Paint		Liter	1	150.00	150.00
15	Belt	Black rubber	B83	2	50.00	100.00

16	Diesel engine motor		1 Cylinder	1	7500.00	7,500.00
	Sub-total					10,503.80
17	Labor cost	13% of material cost (assumed)				1,178.19
18		Material wastage 2.5% of material cost				262.595
19	Machine cost	15% of material cost (assumed)				1,365.49
	Grand total					15,097.87

Appendix table E.2 Production cost

No	Type of machine	Machine cost/hr	Working hour	Cost (ETB)	Labor cost/hr	Working hour	Cost (ETB)
1.	Universal metal cutting	20	10	200	8	10	80
2.	Welding machine	15	20	300	8	20	160
3.	Power hack saw	10	6	60	8	6	48
4.	Lath machine	30	12	360	8	12	96
5.	Rolling machine manual	12	10	120	8	10	80
6.	Radial drill machine	12	10	120	8	10	80
7.	Grinding machine	15	15	225	8	15	120
8.	Bending machine	12	8	96	8	8	64
	Sub total			1481			720

Appendix E1: Fixed cost

Cost of materials + construction cost, 10,503.80ETB

Salvage value = 10% total cost of machine, 1,050.3ETB

Production cost =720ETB

Number of labour used for construction work = Two @75.00ETB per day

Working hours per day = 8 h

Number of working days = 10 days

Cost of labour for construction work: 2 × 10 × 75 = 1,500ETB

Assume cost of machines as 15 % of material cost =1,575.57ETB

Total Construction cost of the groundnut sheller machine

= Cost of raw material + Cost of labour for construction + Cost of machines + production cost.

= 10,503.80ETB +1,500ETB + 1,575.57ETB + 720ETB= 14,299.37ETB

The construction cost of the groundnut sheller machine was, 14,299.37ETB

The following assumptions were considered for determining the cost of the groundnut sheller machine.

Useful working hours =8000

Useful life years =10

No. of labours per day =2

No. of working hours per year = 8000hr

Salvage value @ 10% total cost of sheller

Rate of interest on fixed capital = 12 % of total cost of sheller

Taxes per annum = 2 % of total cost of machine

Housing =1 % of total cost of machine

Repair and maintenance = 4% per annum of total cost of sheller

Production cost of the groundnut sheller machine = 14,299.37ETB

Appendix E2: Fuel and Oil Cost

Fuel cost for shelling groundnut can be calculated as.

Fuel cost = Fuel consumption X Fuel price (birr / L)

From filed test, 3.9ml of fuel was consumed to shell 1kg of groundnut at ¾ of throttle speed which = 0.0039liter/kg

For two varieties of groundnut 0.84liter of fuel was used to shell 216kg of groundnut.

Therefore: fuel cost = 0.84liter x 28.94birr/liter = 24.3ETB

Oil cost = 1.5% of diesel cost = 0.015 x 24ETB = 0.36ETB

APPENDIX F

Appendix table F. 1.Engine specifications

S.NO.	Parts	Specifications
1	Brand name	CHANGFA
2	Model number	CF170F(E)
3	Made	china
4	Fuel	Diesel
5	Ignition mode	Compression ignition
6	Power	5hp
7	Rotational speed	1800rpm
8	Number of cylinders	single
9	Cylinder arrangement	vertical
10	Number of strokes	four