

# **Design and Simulation of Maize Sheller for Small Scale Farmers**

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## **Abstract**

This study work seeks to develop a low cost design of a portable maize shelling machine for small scale farmers by reducing manufacturing cost and thereby making readily available on the market for the ever growing number of maize farmers in Zimbabwe. Three possible solutions were conceptualized, by comparing various parameters and use of a binary dominance matrix; a motor powered, combined de-husker and sheller was chosen for further development. Using locally available materials, explicit specifications of components were provided. SolidWorks 2015 was used to generate both 2D and 3D engineering drawings of the final developed solution. Also some design simulations and economic analysis were done. Estimated manufacturing costs of the product amounted to USD296.

**Keywords :** De-husking, sheller, maize, cost, design, farmer, sustainable.

## **1. Introduction**

Maize, also known as corn, is an important cereal grain widely consumed as food by man in almost all parts of the world. Nwakaire, et al.(2011), indicated that maize ranks third after rice and wheat in countries like India. In Zimbabwe, maize constitutes the staple food, with an average of 1.8 million metric tons required annually to feed both people and livestock. Darudkar and Handa (2015) consider maize to be also a vital raw material used in the production of various industrial products which include corn starch, corn oil, corn syrup and food sweeteners. In Zimbabwe, on average, one hectare produces about 0.8 metric tons of maize. Recent government programs such as the Targeted Command Agriculture have also brought about a sharp increase in the production of maize. The farming season of 2016/2017 had an average of 1.8 metric tons per hectare, recording a total of 2.2 million metric tons of maize throughout the country, Mutenga(2017).

Maize crop goes through various stages of processing depending on the end use. Nwakaire, et al.(2011) lists harvesting, drying, de-husking, shelling, storing and milling as some of the most common processes practiced. Shelling is defined as the process of separating the seed or kernels from the cobs. It is an indispensable process that is aimed at maximizing storage space and lessening difficulty in handling of the grains. Adeleye, et al.,(2015) mentions maize shelling to be probably the most necessary operation in relation to the utilization of the commodity as it affects the subsequent processes and storage.

Mogaji(2016) however reports shelling to be a very tedious task, especially when done manually. Though tedious sometimes, Nwakaire, et al.(2011) still considered shelling as a process that improves shelf life and increases the net profit obtained by the farmer. Darukda & Handa (2015), also reported the average kernel price to be approximately twice that of the cob. Hence, decorticating the kernels and selling them by themselves will generate more income for the farmer.

The difficult yet important process of shelling maize necessitates the design and production of maize shelling machine. Existing ones are mostly electric, hence sometimes not practically useful to the remote farmer who does not have access to electricity. Aremu, et al.(2015) argues that the few mechanical maize shellers are usually heavy and typically require more power input to operate yet they result in a low product quality considering the percentages of seed breakage and purity. Such arguments therefore clearly indicate that innovative designs of these shelling machines is still paramount.

## **1. Background**

Maize shelling is a post-harvest process. Abigissa and Befikadu(2015) define it as the process of detaching the maize kernels from the drycobs, best achievable at a moisture content of about 13%. Many farmers in the developing world still face a serious challenge with maize shelling. This is because the process is tedious when done manually, which is usually the case, and requires a considerable number of hours or even days of intensive labor. Some resort to manual means of shelling such as hand shelling, repeatedly beating cobs in sacks with sticks or spreading it over plastered ground floor in the house or outdoors. Low efficiency, high levels of wastage through breaking of kernels, dirt and excessive labor hours attend such methods.



Figure 1 Dry maize cob with some shelled kernels.

The most popular maize shelling techniques are manual, which is rubbing the maize cobs against one another by hand or by direct removal of kernels by pressing them between thumb and hand palm. This has a low capacity of about 8kg/hr. to 10kg/hr. The highly intensive labor involved and low working rates result in large amounts of time being employed. The study seeks to design a cost effective maize shelling machine for use by small to medium scale maize producers. As well as to design a portable and cost effective maize shelling machine, using locally accessible materials, skills, labor and technology.

## **2. Review of maize shellers**

Maize shelling is an indispensable post-harvest process defined by Nwakaire(2011) as a process of separating the seed or grain from the cobs. It is considered necessary if one is to bring out the quality of maize before converting it to any one of its various end products. This is usually done for purposes of lessening difficulty in handling, transportation and storage of grains. It is also conducted as a measure to minimize post-harvest losses, which, according to Dagninet, et al.(2017), span all the stages from harvesting to final consumption. It is evident therefore, as noted also by Karansinh, et al. (2017), that lack of maize shellers is a major problem to maize production.

### **2.1 Maize properties that affect shelling**

Oriaku, et al(2014) indicated that maize is easier to shell when dry than when it is wet. Yet still, Patil, et al(2013) mentions that even the dry and hardened maize is sometimes painful to shell and may often cause injuries when done manually. Too much dryness also renders the seed more susceptible to mechanical damage. Dagninet, et al.(2017) considers maize shelling to be difficult above a moisture content of 25%. The difficulty is accompanied by increased operational energy required and also poor grain stripping efficiency. Best shelling is achievable when the maize is suitably dry, with the moisture content of about 13 to 14 %. It is therefore apparent that the shelling of maize is a function of its moisture content.

In many rural areas, maize kernels are removed from the cob by hand, according to Patil, et al(2013).



Figure 2 Shelling by hand.

However, Patil, et al(2013)also noted that the alternatives to shelling maize by hand that existare often unaffordable and difficult to accessby subsistence farmers. This results in manual means of maize shelling being more popular. Traditional methods of shelling maize are still considerably common in Zimbabwe, especially to the remote farmer. Rubbing thecobs against one another, using one's fingers, beating the cobs with a wooden plank or treading with animals are some of the methods as reported by Dagninet, et a.(2017). The use of pestle and mortal likewise can be used to detach grain from the cobs. These methods however usually result in much damage being done to the grains, which further encourages the infestation of various pests during the storage.

## **2.2 Types of maize shellers**

Simple hand-held tools: Simple hand held tools are widely employed in the process of maize shelling. Pictured below is a metallic device that can be hand held and is used for shelling maize. It comprises of teeth that protrude perpendicularly from the inside of the cylindrical wall.



Figure 3 Tapered cylindrical metallic shelling device, (Gemplers, 2017)

The device is tapered so as to accommodate the similar shape of maize cob and also to accommodate the varying sizes. It works effectively, though it is very slow since it can only process one cob at a time, hence it is not suitable for large scale production. It can be largely employed at household level.

Small crank operated devices:Another innovative yet simple hand held shelling device comprises of a small rotating disc that is linked to a rotary arm. The disc is cylindrical and has teeth that are used to pluck out the kernels from the cob. Usually it is accompanied with a drop can or it can be a separate container where the kernels drop after being shelled. It is operated by one individual. It is really simple to operate, working at slightly greater speed than the conical sheller described above.

Mechanical manual shellers: Mechanical shellers are relatively applicable to both small and medium scale maize production. Adeleye, et al.,(2015) commented that mechanical threshers are mostly used by large scale cultivators of maize. The principle of operation used is friction, which is applied to the maize kernels through teeth from a large rotary discs. The cobs are fed in through the hopper and they go into the drum where the shelling disk is mounted. Shelling is accomplished as the disc is rotated, Anant and Arunkumar,(2014).



Figure 4 John Deere mechanical maize shelling machine

Average sized maize shellers have an output that ranges between 30 kg per hour to 120 kg per hour when manually operated. They are advantageous in that most of them separate the cob and the shelled kernels during the process. They are also reported to cause very minimal damage to the kernels, hence an increased shelf life of the resulting shelled maize. Large scale shelling for commercial purposes is not possible with them due to accumulated fatigue.

Electromechanical (motorized) shellers: The principle of operation is similar to that of mechanical shellers. The major difference is in the type of power employed to run the machine. Motorized shellers use electric motors to drive the shelling mechanism, which is usually either a bar or a disc. According to Oriaku, et al.(2014), motorized shellers usually have satisfactory shelling performances. Their major disadvantage lies in their inapplicability to the marginalized farmer who may lack access to electric power.



Figure 5 Red and Green motorized maize sheller. (Zhengzhou Aix Machinery Equipment Co., LTD, 2013)

Figure 5 above clearly shows the hopper. The hopper would generally vary in shape, its main use being to direct the maize cobs to be shelled into proper orientation as it enters the shelling section. After the hopper, the roller with the teeth arranged in a helical manner around the rotating drum are responsible for the shelling of the kernels. As the drum rotates, the maize cobs are beaten by the teeth and thus causing the kernels to fall off. The helical arrangement

of the teeth is responsible for propelling the cob to the end section where it is thrown off with all the kernels having been shelled. It can be seen also that below the rollers is a screen with small holes. These function as outlets of the individual shelled kernels into a collection section directly below the screen. Also, large industrial maize shellers are usually prohibitively expensive.

### **2.3 Challenges of maize shelling**

Adawole, et al.(2015)indicated some of the most common problems that are faced by operators who use maize shelling machinesare among others leakage of shelling drum, packing of kernels, disposal of maize cobs, manual feeding, high cost of purchase, corrosion of machine parts and high level of impurities.

## **3. Methodology and materials**

The researchers visited the local Mbarehome industrial site to appreciate available maize shelling mechanisms, and to appreciate presently employed methods and materials in manufacturing maize shellers. Three design concepts were generated as proposed possible solutions to some of the identified shortcomings from available literature. Careful consideration and analysis on various parameters led to the selection of the best suitable concept for detailed design formulation was done through the use of a binary dominance matrix. SolidWorks 2015, a computer aided software, was used to generate both 3D and 2D assembly drawings of the design. Specifications were also made as to the type of material for each component.

## **4. Detailed design development**

### **5.1 Design concept**

The detailed design process followed after a tri-knobbed cylinder was selected for further development using the binary dominance matrix. Some parameters were considered in meeting the design objective. The tri-knobbed cylinder is designed to be driven by an electric motor. It consists of a hopper, cover plate, pulleys, shelling cylinder and outlet channels as shown Figure 6.

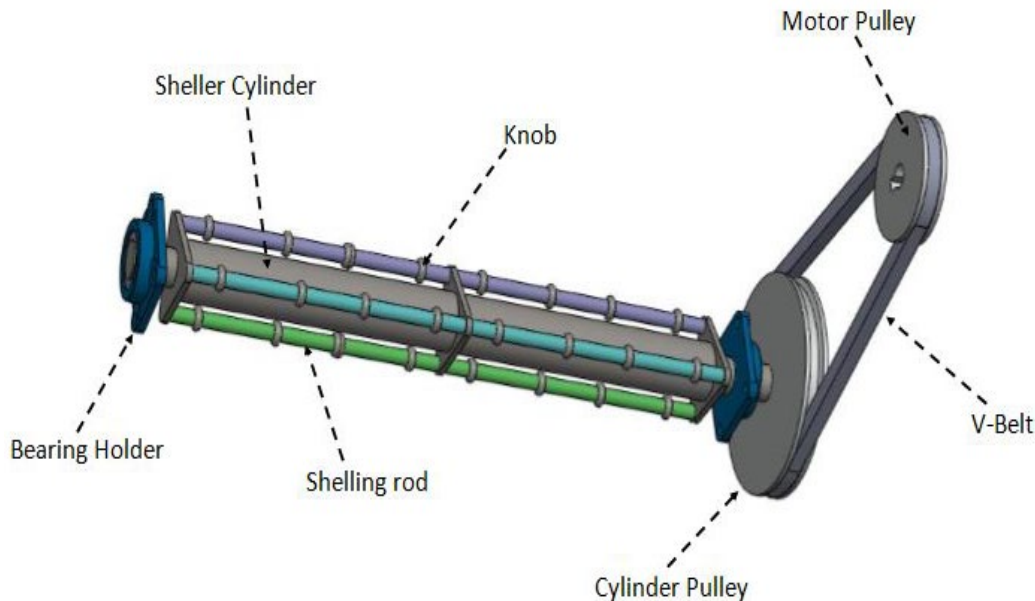


Figure 6 Tri-knobbed cylinder bar mechanism

Its operating principle is based on impact forces interaction. As the cylinder rotates, it interacts with the maize cobs and their contact result in the falling off of kernels, thus achieving the shelling desired. The mechanism is simple to operate, achieves increased working rate, and enables concurrent separation of husks, cobs and kernels.

### **5.2 Mechanism operation**

Shelling of maize is attained either by shear or impact forces. The developed concept utilises impact force exacted by a shelling cylinder to the maize cobs and achieves shelling at a faster rate. The dry maize cobs are fed into the top



section of the machine through a feed hopper which stands directly above the de-husking rollers. The cobs are de-husked as they slide along the spiral coiled shafts. The de-husking results as an effect of the high speed of rotation of the helical coiled rollers, driven by an electric motor, while they press the cobs towards the outer rubberized rollers. The spiral effect pushes the de-husked maize cobs towards the end of the machine, where they are then channeled to the shelling unit which lies directly below. The shelling roller or cylinder is driven by the same electric motor. Husks directly fall off and do not interrupt the shelling process. Beneath the shelling unit, a vibrating sieve serves to clean the kernels towards their outlet.

### 5.3 Design of components

The major components of the design are stand frame, feed hopper, drive mechanism, shelling cylinder, kernel sieve, de-husker shaft, gears, husk slide plate and cob re-channelling plate.

#### a. Stand frame

This is going to be made from angle iron. The frame and stand will be responsible for offering the skeletal support and rigidity to the entire unit.

The overall dimensions of the machine are:

Length  $l = 650\text{mm}$ , Breadth  $b = 386\text{mm}$ , and height  $h = 750\text{mm}$ . (Chosen)

Material: 40 x 40 x 3mm Angle iron. (Chosen)

The material was chosen on the basis of its ready availability locally and in that it is able to formulate a frame of sufficient strength yet maintaining minimal weight.

#### b. Feed hopper

The feedhopper is needful for ease of feeding in the maize cobs into the maize sheller. The design of the feed hopper should allow natural or gravitational flow of the maize cobs.

Material: 1 mm Iron sheet.

The feed hopper is designed based on a criterion called 'the angle of repose' or 'friction angle of rest'. This is defined as the maximum slope at which any heap of loose material will stand before it slides. For agricultural materials, at least  $8^\circ$  more than the angle of repose is recommended for inclination. The angle of repose for maize is  $28^\circ$ . The hopper is designed as a gravity discharge unit, meaning that only gravitational force is required to feed the maize cobs in to the machine. Proportionality and aesthetics were also considered in the design of the feed hopper.

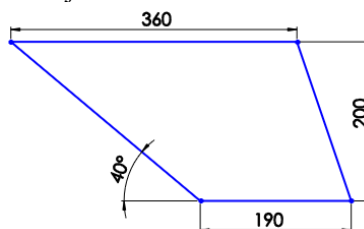
Dimensions (Chosen):

Top part 360mm x 280mm.

Bottom part 190mm x 280mm.

Height 200mm

The measured angle of repose or friction angle of maize  $\alpha$  is the angle of the base to the vertical and was calculated to be  $40^\circ$ . Hence, since this inclination of the hopper is greater than the angle of repose of maize plus  $8^\circ$ ; the hopper will necessarily do its expected job.



$$\begin{aligned} \text{Volume of hopper } v_h &= \text{Area } a_h \times \text{depth } d \\ \text{Trapezium Area } a_h &= \frac{h(a+b)}{2} = \frac{0.2(0.36+0.19)}{2} = 0.055 \text{ m}^2 \\ v_h &= 0.055 \times 0.28 = \mathbf{0.0154 \text{ m}^3} \end{aligned}$$

**c. Drive mechanism**

The drive mechanism of the maize sheller consists of an electric motor, pulleys and v-belts. The electric motor is the source of power. The pulleys, linked by the belt, are responsible for transmitting power to the various shafts in the machine. The pulley ratios will define the required speeds for the processes.

**d. Shelling cylinder**

The shelling cylinder is responsible for achieving the shelling process. It is to be driven by the motor through pulley and belt assembly.

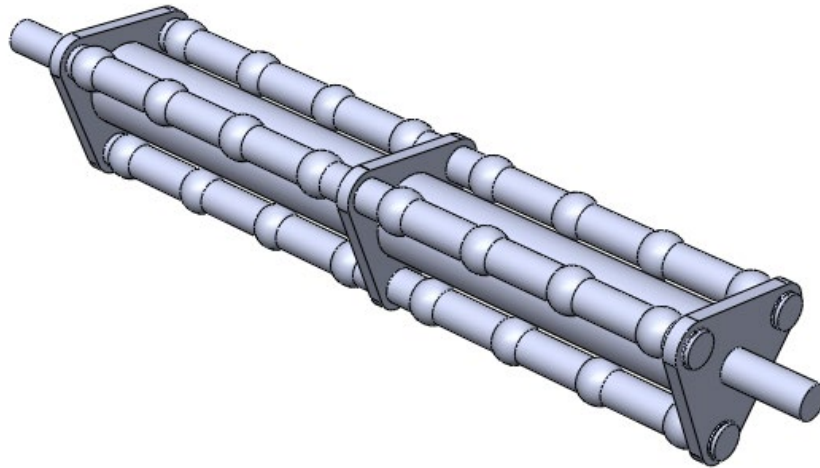


Figure 7 Shelling cylinder assembly

**e. Kernel sieve**

A sieve is required to separate between the shelled kernels and the cobs. The shelled kernels fall off directly onto a sieve and pass through while the cobs are retained. The sieve is to be a thin metallic sheet that has small holes in it.

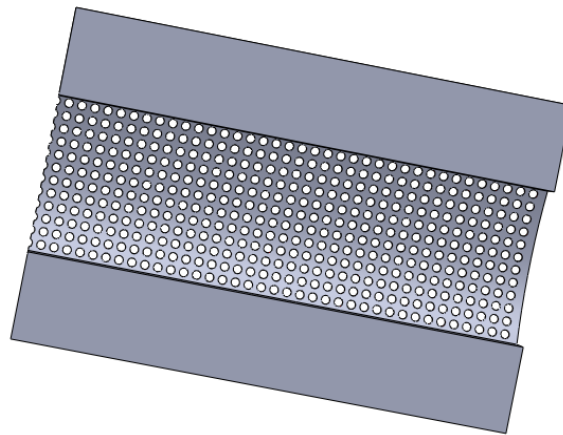


Figure 8 Metallic kernelsieve.

**f. Spiral rod-wound shafts**

Two central shafts will be coiled with a thin iron rod in a helical manner. A pair of gears will mate them to allow them to spin with the same speed. A pulley links one of these shafts to the drive motor for power. The spiral effect will be responsible for the propelling of the maize cobs as they undergo de-husking.

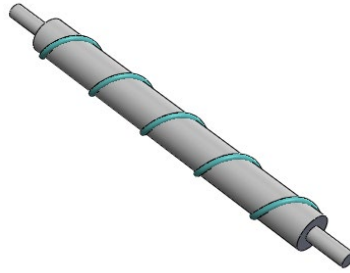


Figure 9 Spiral-wound de-husker shaft

From Tables the mechanical properties of the grades of carbon steel used for ordinary shafts. The material chosen for the shafts is mild steel 40C8 having the yield strength of 320 MPa.

**g. De-husking unit**

In accordance with the principles of the SCAMPER design technique, a de-husking apartment is combined with the shelling one into one machine unit. This serves to eliminate the need for a separate de-husking process, as is the case with most maize shellers. The de-husking unit of the machine will consist of four shafts.

**h. Rubberised shafts**

Two outer shafts have rubber protrusions which are responsible for the de-husking of maize due to high friction coefficient between the rubber and spiral iron rod mentioned above. The helical coiled rods serve to push the maize cobs outwards and the husks got trapped between the two rotating shafts and thus are plucked off.



Figure 10 Rubber covered de-husker roller

**i. Top cover**

This is made from a thin metallic sheet. It covers the maize cobs as they undergo de-husking. It is provided with openings that are used to access the top part of the machine in cases of jamming of a maize cob between the de-husking rollers.

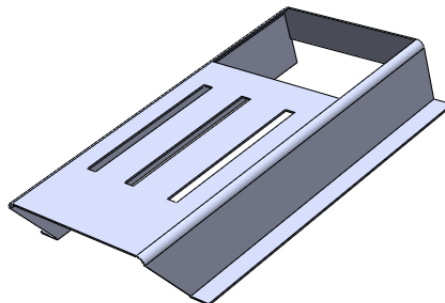


Figure 11 Top cover



The final solid works maize sheller is as given in Figure 15 below.

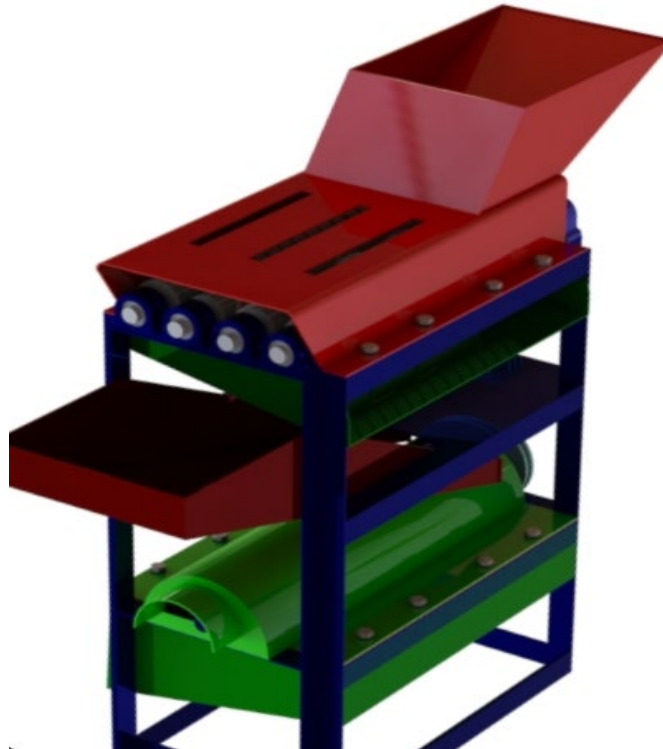


Figure 12 Assembled maize sheller machine

The economic advantages of an electro-mechanic maize sheller have well-nigh been over emphasized throughout the text. To the farmer, time and opportunity cannot be missed if one is to maximize in profits. On average, a farmer produces about 0.8 metric tonnes of maize per hectare in Zimbabwe.

## 5. Recommendations

The maize sheller design should also incorporate a blower or fan to enhance cleaning of shelled kernels. For improved safety, a guard bar or cage may be inserted over the belt and pulleys. For effective shelling, a maize moisture content of above 14% dry basis is recommended to improve the yield. Also addition of wheels is required for easy mobility within shelling area. For bigger operations an automatic packaging unit may be attached to the machine. The design has to be modified to incorporate other sources of power. If labor is included the cost of the machine (about US\$450.00) may still be relatively high for farmers of little means to invest.

## 6. Conclusion

The need of innovative maize shellers by Zimbabwean maize producers is well defined. It was found that the production of this design makes economic sense and is worth it. Its production cost of USD297 is reasonably good compared to its potential economic benefits to anyone who would use the machine. It poses no environmental threats and all the required materials and skills are locally available, therefore it can be concluded that the design project must be implemented to save time during maize shelling by the small scale holder farmers.

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