Design of an Automated Powered Peanut Shelling Machine.

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Abstract. Groundnut is predominantly grown by communal farmers in Zimbabwe. The price of shelled kernel is approximately double that of pod. Hand shelling of peanuts is a time consuming and laborious process which is mostly used in the remote areas in Zimbabwe. Manual shelling of peanuts using "Manual Sheller's" has been adopted to reduce the time invested in hand shelling. These machines have high defective rates of almost 50% which reduce the overall gain achieved by the farmer after harvesting. As a result, the need has risen to design an automated powered peanut Sheller machine automated using a Program Logic Controller and having a servomotor as its actuator to solve the high labour, huge amounts of time lost through shelling and the low efficiency of previous Sheller designs. First hand results were obtained in this project by determining the crushing force required to shell peanuts at approximately 10% moisture content. Regression models were then used to standardise these results to enhance accuracy. Shelling throughput, automatic gap adjustment, shelling efficiency, mechanical damage are some of the parameters used to determine the overall performance of the peanut Sheller. However exhaustive research on peanut engineering properties has to be done in future to lay out a foundation for improved future designs. On an overall note, this project includes the design and assembling of different components to come up with an environmentally friendly machine that meets the set objectives.

Keywords: Design, automated, peanut, Sheller.

1 Introduction

Groundnut production in Zimbabwe has registered a steady increase since the start of the 21st century and has received a lot of support from the Government, Private Sector and Non-Governmental Organizations. This is largely due to the contribution of largely smallholder farmers in communal and resettlement areas. Contract farming between small-holder farmers and processing companies like the Grain Marketing Board (GMB), AGRISEEDS, REAPERS, Willard Foods (SNV Zimbabwe, 2012) among others has helped create a sustainable market in the country which has helped increase production. In addition groundnuts, are also a good source of proteins, energy, edible oils, minerals and peanut butter thus being widely grown in Zimbabwe.

1.1 Background to the Study

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In Zimbabwe, groundnuts are mostly grown by resettlement and communal farmers in Farming Regions 2 to 3 under dry land conditions (SNV Zimbabwe, 2012). Small-holder groundnut growers are assumed to be above 1.5 million, while the number of commercial farmers is estimated to be below ten thousand (SNV Zimbabwe, 2012). National commercial demand for groundnuts is estimated at between 120 000t and 130 000t per year (USAID, 2010). Basically there are four types of peanuts which are Runner, Virginia, Spanish and Valencia. These are shown in Figure 1 below:

Figure 1. Types of peanuts / groundnuts

The Runner type has medium uniform sized kernels. As a result they are good for roasting since the kernels are roasted evenly. The Virginia type is the largest of them all characterised by their large kernel size. The Spanish type has the smallest kernel size. This type has a very high oil content. Last but not the least, there is the Valencia type. This is a sweet tasting peanut which when opened up about three or more kernels can be found. Shelling of groundnuts occurs at factory or household level. Hand shelling is predominantly common at the household level. Manual shelling machines locally produced are also commonly used. At factory level, shelling is done at large scale using electrically powered shelling machines. Hand shelling is time consuming and laborious (Kinyanjui, et al., 2011) Manual operated shelling machines have high defective rates and is a tedious process (FAO, 2010). A company X in Zimbabwe manufactures combined manually and electrically powered machines but they are not automated resulting in low efficiency (50%), (high kernel breakage rate) and also tedious manual iterations in finding the optimum shelling gap. The research is basically to design an automated powered peanut shelling machine for
Company X Engineering. The objectives for the design project are:

- To develop an automated system that has control over all shelling processes which significantly reduces human effort required.
- To improve input capacity from 50kg/hr to 100kg/hr.
- To come up with a design that does cost more than US $1000.00.
- To design a self-adjusting thresher system that efficiently shells different nut types and sizes and reduces groundnut defection to below 2%.

1.2 Justification of this research.

The justification for this research is increased quality of kernel produced, reduced time and cost. This is illustrated in the figure 2 below;

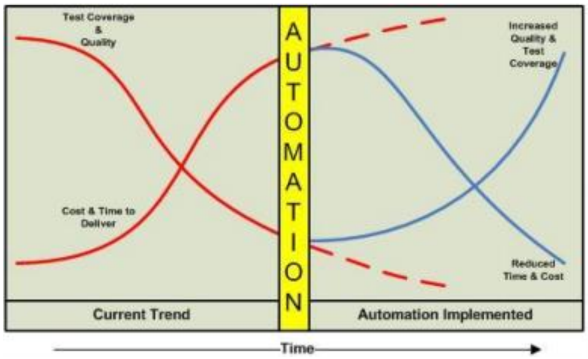

Figure 1. Cost Automation Graph

Figure 2 explains that the quality of shelled kernel low (most of the kernel is damaged) before automation is implemented. The cost and time invested in manual shelling is also high before automation is implemented. This is shown in the 'current trend' side of figure 2. The of implementing automation of the peanut Sheller is high, but however as time goes the advantages of automation are evident as shown by the reduced time and cost required. Also the quality of shelled kernels increases together with the output and throughput. However automation together with optimising the overall peanut sheller improves the overall shelling performance.

2. Materials and methods

2.1 System sizing

An experiment to reduce a sample of 50 peanuts to approximately 10% moisture content was done by the researcher at the University of Zimbabwe, Faculty of Agriculture at the department of Crop Science. A heat oven at a constant temperature of 75̊C and an electronic balance were the instruments used by the researcher to determine the moisture content. After determination of the moisture content, another experiment to determine the average force required to crush the peanuts at a moisture content (approximately equal 10%) was done at the University of Zimbabwe, Mechanical Engineering Laboratory using a Monsanto Tensometer and crushing jaws. Direct measurements for the length, width and thickness of a sample of ten peanuts were made by the researchers. A Vernier Callipers was used for measurements. These measurements were then optimized for the design calculations by employing the normal distribution technique. Drawings software's like AutoCAD and SolidWorks were used by the researcher to come up with assembly drawings and the Von Mises stress analysis in components such as shafts. Dimensioning was carried out using

AutoCAD. The SMT Client IMO software, a Programmable Logic Controller was used by the researchers to come up with an automation program. Moisture content of approximately 10% was obtained by the researcher. Thus, the crushing force required to shell peanuts is to be found at this moisture content.

2.2 Determination of crushing force for the shells.

The researchers used the following determine the force required to shell peanuts

- Monsanto Tensometer, Grippers and Vernier Callipers.

1. A sample of ten peanuts with a moisture content of 9.8% was taken and had its length, width and thickness measured with a Vernier Callipers.
2. The sample was then placed between the jaw Grippers of the Monsanto Tensometer and subjected to a crushing force in which suitable increments where used to adjust the Tensometer. This is shown in the figure 3 below.
3. Effort is slowly applied causing the gripper jaws to move slowly and consequently crushing the peanuts in the process. The Tensometer has readings in Newtons.
4. As the force is applied, a quick rise in the mercury level is observed. Mercury rise is proportional to the force crushing the peanuts.
5. The level to which the mercury rises shows the force required to crush the peanuts.
6. Force is slowly continuously applied crushing the peanuts until the kernels are separated from the pod.
7. Results were recorded and tabulated.

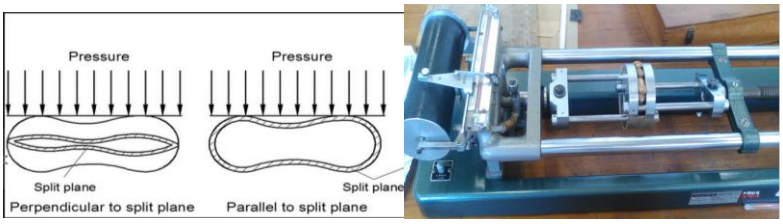

Figure 3. Determination of the crushing (shelling force) for a sample of ten peanuts

The length, width and thickness of the ten peanuts were tabulated as shown below;

Table 1. Readings of width, length and thickness of the peanut Sheller

Length (mm)	Width (mm)	Thickness (mm)
26.10	7.55	4.80
26.35	7.90	4.85
26.30	7.85	4.80
25.80	6.80	4.25
28.55	9.35	5.60
27.70	8.25	5.35
29.30	9.65	5.85
26.40	7.95	4.90
28.05	9.10	5.70
30.70	10.75	6.20

The standard deviation of the above readings was subsequently calculated using the formula; [**Standard Deviation**] = **s** = $\sqrt{\frac{\sum_{i=1}^{10} x^2{}_i - \left(\frac{\sum_{i=1}^{10} x_i}{n}\right)^2}{n-1}}$

Thus for length, s = $\sqrt{\mathbf{2.6379}}$**, = ± 1.63 mm**

Hence for width, s = $\sqrt{\mathbf{1.378}}$**; = ± 1.17 mm**

And for Thickness, s = $\sqrt{0.3556}$; = ± 0.60 mm

Thus calculating the means; Mean of length = $\frac{275.25}{10}$ = **27.525± 1.63 mm;** Mean of Width = $\frac{85.15}{10}$ = **8.515± 1.17 mm;** Mean of thickness = $\frac{52.3}{10}$ = **5.23± 0.60 mm.** Note: Since this is a random sample of peanuts with different sizes it is necessary to optimize the averages of the length, width and thickness.

Percentage Accuracy of length = $\frac{27.525-1.63}{27.525}$ = **94%; Thus taking standard accuracy as 95%; X – Z.** $\frac{\alpha}{2}.\frac{S}{\sqrt{N}}$ **<** μ **< X + Z.** $\frac{\alpha}{2}.\frac{S}{\sqrt{N}}$**; W**here, X = Mean length = 27.525mm

S = Standard Deviation = 1.63. From Statistical Tables; Z = 1.96 and $\frac{\alpha}{2}$ = 0.025. Substituting into the formula, = 27.525 – 1.96. 0.025.$\frac{1.63}{\sqrt{10}}$ < μ < 27.525 + 1.96. 0.025.$\frac{1.63}{\sqrt{10}}$ = 27.4997 < μ < 27.55. Thus the optimum length of the peanut is **27.55mm.**

Percentage Accuracy of Width = $\frac{8.515-1.17}{8.515}$ = 86%; **Thus taking standard accuracy as 90%; X – Z.** $\frac{\alpha}{2}.\frac{S}{\sqrt{N}}$ **<** μ **< X + Z.** $\frac{\alpha}{2}.\frac{S}{\sqrt{N}}$ Where, X = Mean Width = 8.515mm

s =standard deviation = 1.17mm; From Statistical Tables; Z = 1.6449 and $\frac{\alpha}{2}$ = 0.05

Therefore optimum width = 8.515 – 1.6449. 0.05. $\frac{1.17}{\sqrt{10}}$ < μ < 8.515 + 1.6449. 0.05. $\frac{1.17}{\sqrt{10}}$ = 8.485 < μ < 8.5454 = **8.5454mm.**

Percentage Accuracy of Thickness = $\frac{5.23-0.6}{5.23}$ = 88.5%; **Thus taking standard accuracy as 90%; X – Z.** $\frac{\alpha}{2}.\frac{S}{\sqrt{N}}$ **<** μ **< X + Z.** $\frac{\alpha}{2}.\frac{S}{\sqrt{N}}$**;** Where X = Mean Thickness = 5.23mm; S = standard deviation = 0.6mm. From the Statistical Tables; Z= 1.6449 and $\frac{\alpha}{2}$ = 0.05. Therefore optimum thickness = 5.23 - 1.6449.0.05. $\frac{0.6}{\sqrt{10}}$ < μ < 5.23 + 1.6449.0.05. $\frac{0.6}{\sqrt{10}}$ = 5.214 < μ < 5.2456 = **5.2456mm**

Thus by taking three samples of 10 peanuts and crushing them on the Tensometer the results of each test was, 34N, 35N and 38N. The average force was found to be 35.667N which approximately 36N. Hence on average, the force acting on each peanut is **3.6N.**

Power Required = Energy x Capacity of Shelling Machine. **Sheller Machine to be designed for a capacity of 150 kg/hr.** Thus, Power Required = **7 005.979887 J/kg x 150 kg/hr = 1 050 896.936 J/hr; = 291.9158 J/s; = 292 W**

Converting into Horsepower = $\frac{292}{746}$; **= 0.3914 HP**

Thus taking into account a **FACTOR OF SAFETY OF 2,** the power required becomes; **Power = 0.3914 x 2 = 0.7828 HP.** For Design, take the **POWER REQUIRED** as **0.8 HP;** Selecting motor from the standard horse power ratings shown below;

Standard Horsepower Ratings: Standard horsepower ratings of electrical motors - 1 to 4000 hp are indicated below:

- 1, 1 1/2, 2, 3, 5, 7 1/2, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100, 125, 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 3000, 3500, 4000

Thus a standard motor of **1Hp having it's speed specification as 1400 rpm** (**Motor 1 HP Single-Phase 1400 RPM Open 110V/220V)** is chosen to power the inner drum, shaft and shell the groundnuts.

2.3 Automation of the peanut sheller

The rotating disk mechanism consisted of mild steel bars mounted on a rotating drum. Shelling is achieved using this concept when the rotating bars beat the peanuts thus generating an impact force sufficient to break the pods thus shelling the peanuts. Gap management is critical in as far as shelling of peanuts is concerned, hence automatic gap adjustment is going to be achieved by making use of a Programmable Logic Controller (PLC) and a servomotor. A servo-motor is a special type of motor which can be operated automatically up to a certain extent (limit) for a given command (signal) with the help of an error-sensing feedback mechanism to correct the performance. The control system of the servo motor is further enhanced by combining it with a PLC. A PLC is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon an existing program to monitor and control the condition of the output variables and devices. Inside the PLC is a Central Processing Unit (CPU) containing an executable program that tells the PLC how to perform the following instructions:

- Executing the monitoring and control instructions contained in the Control Program
- Communicating with other devices such the servomotor among others
- Performing internal regulatory housekeeping actions like internal diagnostics, communication among others.

For this research, the researcher programmed the PLC using Ladder Logic. The Ladder Diagram (LD) is a graphical programming language. Thus let;

I01 = Initial switch (First signal)

M01 = Initial speed corresponding to the first signal, G01 = Initial Gap setting corresponding to the initial speed, I02 = Second switch (Second signal Input), T01 = Timer, T02 = Timer, G02 = Second gap setting, I03 = Third switch (Third input signal), G03 = Third gap setting. Program from the PLC is as follows:

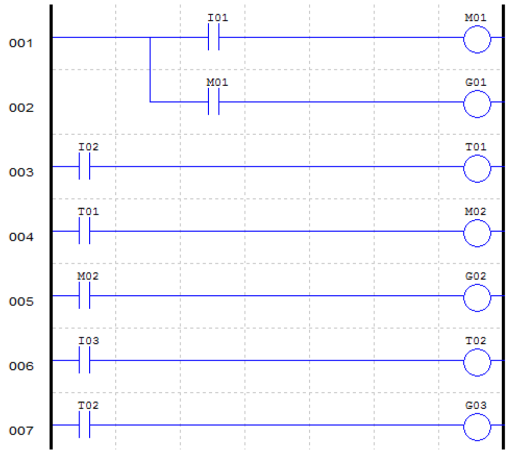

Figure 4. PLC (SMT Client IMO Software Version 3.3.100200) Automation Program

Now, when switch I01 is activated, it sends a signal to the DC servo motor which makes it run at a speed (M01) proportional to the signal sent. When the speed is reached, it in turn acts as a contact on which the initial gap setting relies on. Thus when the speed contact is activated that's when the initial gap setting is obtained. Now a mechanism converts this limited rotary motion of the servo motor into vertical motion thus enabling the sieve screen to move towards the flat bars mounted onto the rotating drum hence automatically adjusting the shelling gap. Thus when the servo motor's output shaft rotates clockwise, conversion of this rotary motion makes the sieve screen move vertically upwards and anticlockwise rotation makes the sieve screen move vertically downwards. The shaft of the DC motor is coupled with another shaft called the output shaft through the aid of a gear assembly. The gear assembly is used to step down the high speed of the motor's shaft to low speed at output shaft of the servo system to enable it to lift loads. The gear reduction assembly is shown in the diagram below:

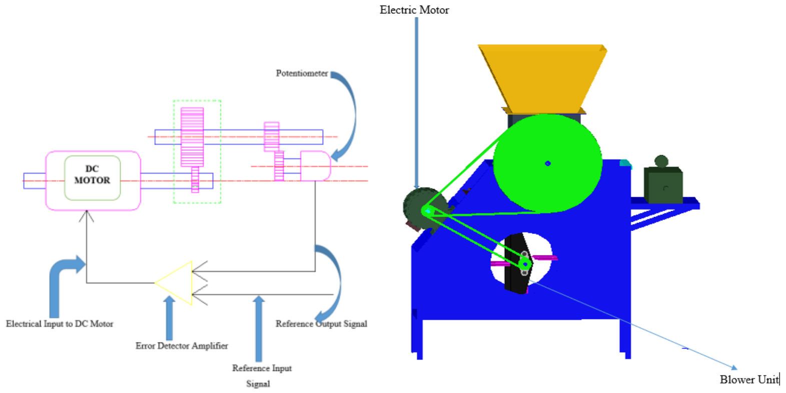

Figure 4. a.) Reduction gear assembly of the servomotor, Automation using servomotor b.) Assembled peanut sheller

The voltage adjusting control switch (knob) of the potentiometer is connected with the output shaft by means of another gear assembly such that during rotation of the shaft, the knob also rotates thus creating a varying potential in accordance with the principle of the potentiometer. Now when the signal is received from the PLC, the electrical potential is increased due to the angular movement of the knob together with the system shaft to the required angular displacement which is proportional to the required vertical distance. This electrical potential is taken to the error detector feedback amplifier together with the input reference commands (input signal).

3 Discussion

For example, if the initial gap setting between the sieve screen and the flat bars mounted on the rotating drum is 10mm which corresponds to the optimum gap for shelling the smallest peanut type the Spanish variety. If instead, the largest Virginia type is to be shelled, then a signal is sent from the PLC to the servomotor. This signal will be delayed being implemented by an On-Delay timer (T1), programmed to delay opening its contacts by 3 seconds to avoid damage to vital components of the system. Once the 3seconds have elapsed, the timer turns on its contacts allowing the signal to reach its intended component. The signal then communicates to the servomotor to rotate up to a certain angle say, 45° which would correspond to a new vertical gap setting of approximately 25mm ideal for shelling the Virginia Peanut.

The signal from the PLC also tells the servomotor that once the angular displacement has been reached it should stop there and then wait for further instruction. Hence as the angle increases from 0° - 45°, then the resulting voltage from the potentiometer subsequently increases. Thus at 45° the voltage reaches a value that is equal to the required input command voltage to the automation system. Thus when the angular displacement of 45° is reached then the difference between the reference output signal (from the potentiometer) and the reference input signal (from the command) is zero. As a result, the output voltage from the amplifier is zero.

Hence the motor becomes stationery at the required position. The servomotor will remain at this stationery position until another command signal is sent from the PLC to move the shaft to a new position corresponding to another new vertical gap setting. The potentiometer in this case acts as the sensor, feeding the reference output voltage into the amplifier which then compares it with the command signal. A digital or analogue position sensor encoder can be used instead of a potentiometer. The summary of the whole automation process is shown below:

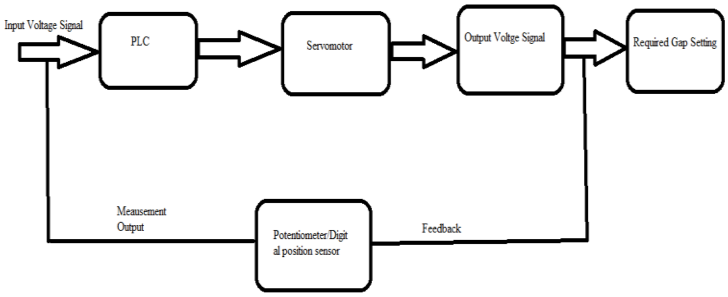

Figure 5. Summary of Automation process

For transmission of torque, a servomotor with the following specifications:

- 11.5Nm real continuous heavy duty torque
- 12VDC Power, and 3A at full load
- 90° travel in 1.5s
- Double roller bearing output shaft

4 Conclusions and Recommendations

4.1 Conclusions

The aim and objectives of this project which are mainly automatic gap adjustment and increasing shelling efficiency were met in this project. The concave sieve considerations for the three types of peanuts (Virginia, Runner and Spanish) were also met since shelling efficiency is dependent on the sieve performance in relation to the pod size being fed into the hopper. This made the Sheller machine versatile as a wide range of peanuts can be shelled using the automatic gap adjustment.

4.2 Recommendations

- Before feeding the groundnuts into the machine, care must be taken to make sure that the groundnuts are free from stones, soil among others which would damage the shelling bars.
- Groundnuts should be graded before shelling so that gap adjustment is put into effect with relative ease. Grading can be achieved by passing the groundnuts through a vibrating screen with perforations underneath. Groundnut with the same average size are then collected underneath the vibrating screen.
- The concave sieve screen must be regularly checked for blockages as some peanuts can block the perforations underneath the sieve screen.
- Bearings should be greased after approximately every 5000hours of service
- More work has to be done in finding the appropriate mechanism to convert the rotary motion of the servomotor into vertical motion
- Extensive study of peanut physical and engineering properties must be done to establish a good floor for design

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