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TEMA:

DESIGN AND CONSTRUCTION OF A BANANA SLICER MACHINE VERDE TO CRAFT PRODUCERS OF CHIPS.

SCIENTIFIC REPORT

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Design And Construction Of A Banana Slicer Machine Verde To Craft Producers Of Chips.

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Abstract. - The preparation of this paper is the design and construction of a green banana slicing machine for Fry artisan producers. The Company "CONFRYVAL" situated in the Parish of Juan Montalvo Canton Cayambe is funding the construction of green banana slicer.

The machine consists of four main parts which are: sliced system, transmission system, reducing system speed and system development. The purpose of the design and construction of this machine is to optimize the time, food safety and production chifles green bananas for the aforementioned company.

For parts of this machine was designed in the first instance using the Inventor 3D CAD Professional to have a geometric approach of the parts to use and endorse a proper use of the elements used. Following this mechanical design was performed, the results were compared with data from the simulations were performed in the virtual program verifying the accuracy of design for subsequent construction of the pieces , followed proceeded to assemble and join parts with the slicing machine consisting of green bananas.

Comparing a sliced between using the slicing machine and a hand; with the use of the slicing machine faster , cleaner products , sliced insurance process because it avoids having cut fingers or hands of those engaged in this work is obtained.

The machine performs slices with a thickness of 1 to about 2.7 mm, increasing the quantity and quality without leaving aside the safety of the final product, meeting the needs for which it was designed.

1. Introducción

Ecuador has great richness and variety of agricultural products, particularly fruit, thanks to having climatic and geographical privileges, is why it is one of the leading exporters of bananas in the world with a number of companies dedicated to this purpose.

In the process of sliced banana chips today have problems such as excessive time slicing, a poor cut slices, cutting risks due to direct exposure count rows of instruments dedicated to this end, all this is added to the direct handling.

The project presented then optimizes the process of sliced green banana establishing a secure mechanism to provide increased production in less time, with a slice thickness uniform, better hygiene and improving economic returns to the company.

2. Overview

2.1 Background Of Green Sliced Bananas

At present the process of sliced green banana is done mostly manually with disadvantages such as loss of time in the process, a poor cut, both physical discomfort and ergonomic that doing frequently reflected with discomfort health hazards due to cutting direct exposure to parts rows of instruments dedicated to slicing, all this is added the constant handling.

That's why we have seen the need for the implementation of a prototype machine green banana slicer which will benefit the implementation of slicing.

The following figure shows the sliced green bananas today.

Figure. 1. Sliced of chifles manually

2.2 Design Parameters

The main functions of the machine will be directed to perform work under the requirements required by the company are:

- Get as many slices of banana chips in less time.
- Get a sliced easily and quickly avoiding having physical discomfort that usually had to do this activity manually.
- Achieve excellent sliced minimizing the risks of cuts to make slicing.
- Have a system that enables autonomous product advancement toward the blades for slicing later.

2.3 criterio de diseño

The criteria to be considered for the design of the machine are as follows:

- Components that meet the standards of Hygiene and Public Health.
- High resistance to use of mechanical elements.
- Easy to use elements and replacement parts.
- lower construction costs.
- Ease of operation.
- Ease of maintenance and cleaning.
- control system engine friendly.
- thin slices of banana and uniforms.
- Design reliable product feed.
- Good ergonomics for operator handling.
- Protections for the engine in case of high voltages.

2.4 Materials Selection

Material selection of a machine or structural element is one of the most important decisions to be taken by the designer. For the present project will be built with materials AISI 304 standards for performance as this material offers are:

Hygienic properties: Ensures quality material allowing full aseptic hygiene prerequisite in certain applications such as hospitals, kitchens, and food and pharmaceutical facilities.

Corrosion Resistance: Low alloy steels, corrosion resistant in atmospheric conditions; the high-alloy steels may resist corrosion in most acidic media, even higher temperatures.

Mechanical strength: Feature by cold work hardening of some stainless steels used in the design to reduce thickness and therefore cost. Others may be heat treated to high strength components.

Facility for manufacture: Most can be cut, welded, forged and machined with satisfactory results.

Aesthetics: Available in many surface finishes. Easily maintained resulting in a high quality.

2.5 Types Slicers

2.5.1 Slicer vertical axis.

This sort of banana slicer has an engine that is subject to the structure vertically; It is this feature called slicer vertical axis.

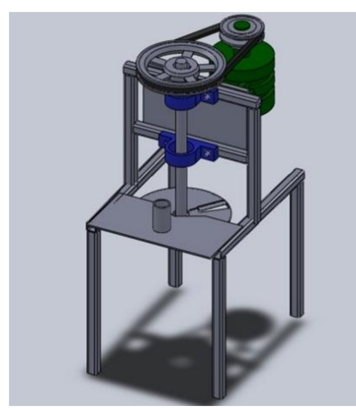

Figure. 2. Slicer vertical axis.

Advantage

- Ease of design.
- Low cost of construction.
- Does not require speed reducer.

- Simple structure to make
- Materials used readily available in the market.
- Easy machine operation.

Disadvantages

- Machine highest
- Difficult to assemble and disassemble the motor.
- not suitable design.
- Difficulty performing machine maintenance
- Does not meet safety standards in maintenance cases.
- Requires a minimum of two people to assemble or disassemble the engine.

2.5.2 Horizontal Axis slicer

Such banana slicer comprises a motor that is subject to the horizontal structure, the means by which transmits power by means of pulleys which consist of a belt or band which exerts an axis movement is held by bearings which provide stability and support of the shaft, consists of a rotating disc which has a blade at this allowing banana slices.

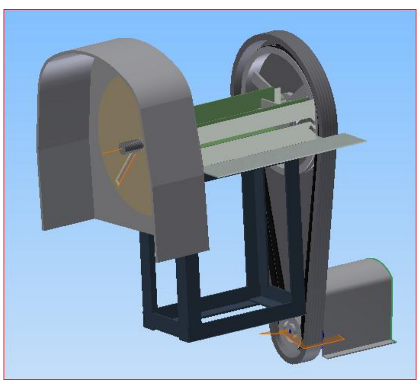

Figure. 3. Slicer horizontal axis

Advantage

- Ease of design, construction and assembly.
- High reliability.
- Low cost of development.
- No need for speed reducer.
- Greater stability.
- Easy maintenance of the machine.
- Blades are not directly exposed to the operator.

Disadvantages

- Ranked more physical space.
- Have greater weight.

To establish the best decision the advantages and disadvantages of the types of choosing the slicer slicers with major advantages is the horizontal axis and slicer that best design parameters and design criteria was assessed couples.

3. Design and Estimating Systems

3.1 Cutting System

To design the cutting system must determine the force needed to be exerted to overcome resistance to the court that has the product to be sliced.

For this force trials with different thicknesses of green bananas exposed to different forces was made; for obtaining the necessary cutting force, the force needed to slice the banana thicker for the calculations was taken.

Below you can see from Figure 4 that was obtained from tests performed at different thicknesses with their respective force necessary for perfect slicing.

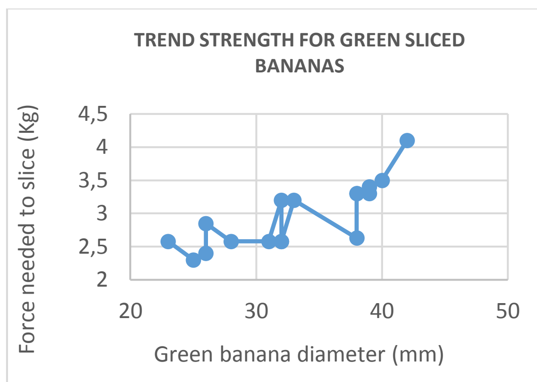

Figure.4. Diameters of green bananas and necessary force for cutting

As can be seen in Figure 4 is part of a green banana diameter of 23 mm with a necessary cutting force of 2.3 kgf (22.54 N) and a maximum diameter of 42 mm with a necessary cutting force 4 1 kgf (40.18 N); for purposes of calculation the strongest slicing will be taken.

So once known cutting force (Fc) and the cutting area (Ac) is derived to calculate the shear green banana (σ_c), taking the following:

$$\sigma_c = \frac{F_c}{A_C} \tag{1}$$

The cutting area is banana:

$$A_c = \frac{\pi\,(D)^2}{4} \tag{2}$$

Where:

D= Diameter with thicker green bananas

Replacing the data obtained from Figure 4 in Equation 2 is as follows:

$$A_c = \frac{\pi\,(0{,}042)^2}{4} = 0{,}00138\ m^2$$

Substituting the values in equation 1 we have the following:

$$\sigma_c = \frac{F_c}{A_C} = \frac{40{,}18[N]}{0{,}00138\ m^2}$$

$$\sigma_c = 29115{,}94\ [P_a]$$

The above data correspond to shear the green bananas.

3.5.1 Calculation of the disc blade holder

Figure 5 shows a diagram of the disc blade holder made in Inventor Professional CAD proposed to be used in the design of the machine.

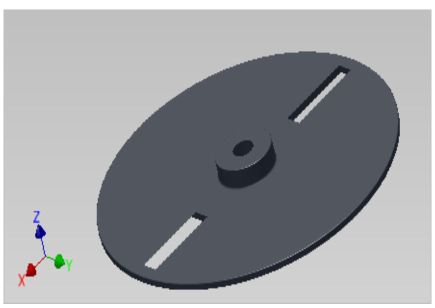

Figure. 5. Disco knife holder Inventor Professional.

We consider the cutting force is 40.18 N, the cut area is $0{,}00138\ m^2$ and the shear stress (σ_c) is $29115{,}94\ Pa$ proceeds to size the disk blade holder.

To obtain the total shear force (F_{TC}) multiply the cutting force (Fc) by the number of bananas is to slice at a time; in our case we have an average of 5-6 bananas to be sliced at a time, based on calculations use a 6 bananas to slice having the following:

$$F_{TC} = 40{,}18\ N * 6$$

$$F_{TC} = 241{,}08\ N$$

To determine the bending moment generated at the ends of the blade holder disc where equation 6 is used is as follows:

$$M_f = (F_e)\left({}^{D}/_{2}\right) \tag{3}$$

Where:

Fe= Thrust [Kgf]
d/2= Distance from the center of the disc to the edge of the blade [m]

$$M_f = 980N(0{,}17/2)$$

$$M_f = 83{,}3\ N_m$$

The bending moment generated in the disc blade holder for calculating the thickness that you need the disk.

$$\frac{M_f}{w} = \frac{S_y}{F.S} \tag{4}$$

Where:

M_f = Flector moment

$$w = \frac{D * e^3}{12}$$

Replacing in equation 4 we have the following:

$$e = 0{,}00813\ m \approx 8mm$$

Once the calculations performed disc blade holder 8mm thick that it will engage the blades with the dimensions shown below was obtained.

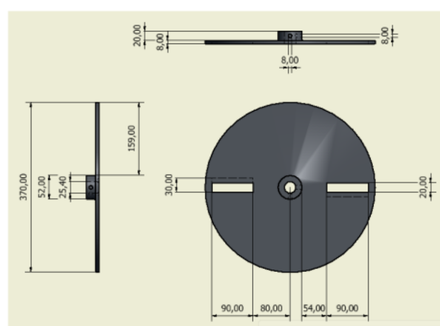

Figure. 6. Dimensions of the blade.

3.1.2 Dimensions considered in the blades

The dimensions have the blades are selected according to the requirements in the cutting process, it is for this reason that it has selected the dimensions shown below in Figure 7.

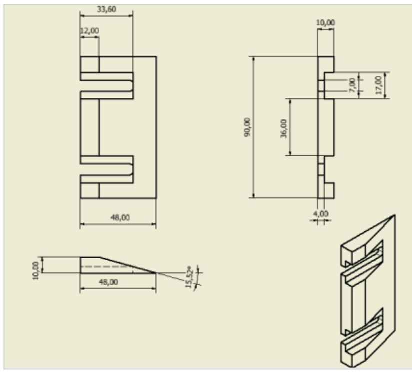

Figure. 7. Dimensions of the blades

3.1.3 Analysis of the knives using CAD Inventor Professional

A tool that facilitates predicting possible failures, parts, components or systems Inventor Professional CAD is the same we use to predict blade failure possible virtual program.

In Figure 8, the safety factor of the blade where it has a safety factor of 15 and a maximum minimum safety factor of 0 is displayed; this means that the blades will have no fails when performing work activities which was designed and built.

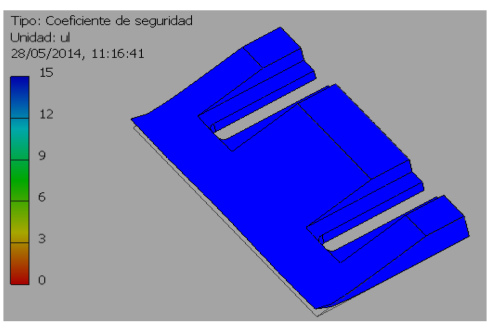

Figure. 81. Sharpe Security Blade

3.2 Axis Design

To design the shaft must take into account the loads that result from the various elements which interact in the design of the slicer; the shaft is coupled to the machine by means of bearings that provide stability and attachment as shown in the figure corresponding to the free body diagram.

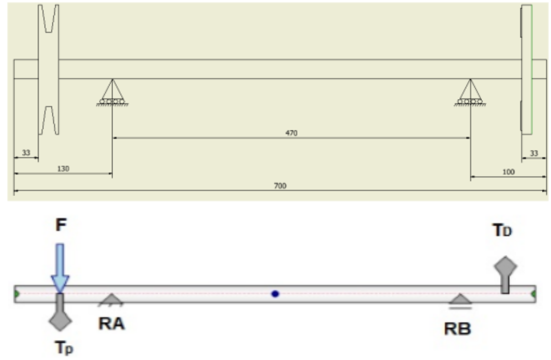

Figure. 9. Free body diagram of the shaft.

In Figure 10, the diagram of the shear force in the y-z plane indicated; Here it can be seen that the maximum time is 30.21 N which calculates the torsional force and z being applied to the shaft.

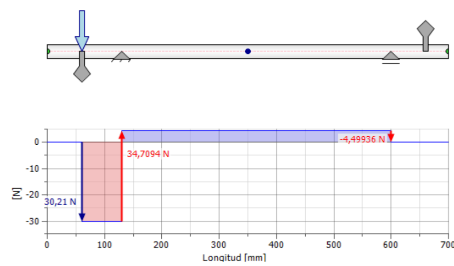

Figure. 102. Diagram of the cutting force in the Y-Z

In Figure 11 the maximum value of the bending moment on the shaft that is 3,021 Nm is determined; exerted on axis to the plane y-z.

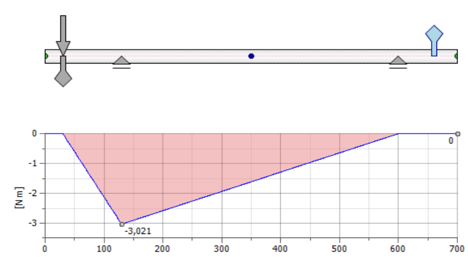

Figure. 113. Flector Moment diagram in the plane Y-Z

Performing the Mohr circle has the main efforts:

$\sigma_z = 13{,}13$ MPa
$\sigma_y = 0$
$\tau_{yz} = 9{,}38$ MPa

Figure 12 below where you can see the components Mohr circle as well as the safety factor for different thicknesses of axles of a stainless steel AISI 304 applied loads you have in this system by a static analysis is presented.

d		σ_z	τ_{yz}	σ_y	C	R	τ_{max}	σ_1	σ_2	Sy	n
in	m	MPa	MPa	MPa	MPa	MPa	MPa	MPa	MPa	MPa	.....
1/4 "	0,0064	821	586,3	0	410,5	715,2	715,2	1126,2	-305,2	310	0,22
1/2 "	0,013	97,9	69,9	0	48,95	85,33	85,33	134,28	-36,39	310	1,82
3/4 "	0,019	31,3	22,4	0	15,65	27,32	27,32	42,97	-11,65	310	5,67
1 "	0,025	13,13	9,38	0	6,56	11,45	11,45	18,01	-4,88	310	13,54
2 "	0,051	1,6	1,1	0	0,8	1,36	1,36	2,16	-0,56	310	113,9

Figura. 12. Safety factor for different shaft diameters

A dynamic analysis for calculating the safety factor based on the Goodman equation whereby a value of 8.43 is obtained is also performed. Which is acceptable with respect to the results obtained with the ECM distortion theory. Whereas in this case is lower because it is considered to fatigue loads.

$$\frac{1}{n} = \frac{\sigma'_a}{Se} + \frac{\sigma'_m}{Sut} \tag{5}$$

$$n = 8{,}43$$

3.3 Calculating Engine Power

To select the power output is determined by the power required by the disc blade holder and overcome this element generates torque; besides considering the safety factor that will protect you from failure due to shock, vibration or pulses.

The disc blade holder generates a torque of 45 Nm, each blade takes a time of 0.1 seconds to travel the 180º disc.

$$Pot = \frac{T}{t} \tag{6}$$

Where:

T= Torque
t= Time it takes to rotate the blade and then perform the second slice.

Replacing the values of Equation 6 has the following output:

$$Pot = \frac{44{,}59\ N.m}{0{,}1\ seg}$$

$$Pot = 445{,}9\ W = 0{,}59\ HP$$

Having calculated the power output power was obtained 0.59 Hp; considering friction losses due to unforeseen side supports the bearings, shaft, weight disk, and unforeseen loads such as blade binding by accident.
Then we have the following:

$$Pot = 0{,}59\ HP * 1{,}7 \tag{7}$$
$$Pot = 1\ HP$$

The engine used has the following characteristics.

Tabla 1. Features engine to use

BRAND:	WEG
TYPE:	DM
MODEL:	D56109
HZ:	60
POWER:	1 HP
RPM	1750
VOLTAGE:	110/220 V
AMPERAGE:	12/6.0 A
SF:	1,25

3.4 Choosing The Band

The transmission system is determined to obtain speed of 250-280 revolutions per minute (RPM), which is the range in which a very good quality is obtained as output.

To determine the diameter of the drive pulley is used the following equation

$$Dpm = \frac{RPM\ eje\ cond * D_{pc}}{RPM\ drive\ shaft} \tag{8}$$

$$= \frac{273{,}44\ RPM * (406.4)mm}{1750\ RPM} = 63.5\ mm \pm 20$$

Then the diameter of the driven pulley is determined by Equation 9.

$$Dpc\ eje\ cond = \frac{RPM\ eje\ motriz * D_{pm}}{RPM\ eje\ cond} \tag{9}$$

$$= \frac{1750\ RPM * (63.5\ mm)}{273{,}44\ RPM} = 406.4mm\ \pm 20$$

From the above equations it can be concluded that to obtain 273 RPM which is within the appropriate range for a good quality production and slicing you should use a pulley 16 and 2 ½ inches.

For design purposes is determined that F1/F2 = 3 with an angle of 180º, we have:

Fb= force generated by the band

$$Pd = (F1 - F2)Vb\ (Carlosama, 2013)$$

Where:

Pd= Design Potential = 3/4HP = 559,27 W

$$(\mathrm{F1} - \mathrm{F2}) = \frac{\mathrm{Pd}}{\mathrm{Vb}} \quad (10)$$

$$= \frac{559{,}27}{37{,}24} = 15{,}02\ \mathrm{N}$$

$$3\mathrm{F2} = \mathrm{F2} + 15{,}02$$
$$3\mathrm{F2} - \mathrm{F2} = 15{,}02$$

$$\mathrm{F2} = \frac{15{,}02}{2}$$

$$\mathrm{F2} = 7{,}51\ \mathrm{N}$$
$$\mathrm{F1} = 15{,}19\ \mathrm{N} + 7{,}51\ \mathrm{N}$$
$$\mathrm{F1} = 22{,}7\ \mathrm{N}$$

Thus the force exerted by the band on the shaft are:

$$\mathrm{Fb} = (\mathrm{F1} + \mathrm{F2}) = 22{,}7\ \mathrm{N} + 7{,}51\ \ \mathrm{N}$$

$$\mathrm{Fb} = 30{,}21\ \mathrm{N}$$

From the above calculations a value of 30.21 N was obtained, this is the force exerted on the shaft band, this value is important as it is to be taken for calculating the diameter of the shaft.

3.5 Selection Of Bearings

As stated previously used ball bearings have the same inner diameter which fits the diameter of the shaft to be used, which is why we need a ball 1 inch in diameter and 25.4 mm so it selects a UC bearing with nomenclature 205-16, which means it is a bearing with ball bearings for shaft shaft diameter of 25.4 mm along with this radial loads to be taken into the system.

3.6 Steel Structure

Next, the design might have the structure which should be capable of withstanding the components containing the green banana slicer is shown the structure dimensions were set according to factors such as ergonomics, design, lower cost, adaptation to the components that are included and stability.

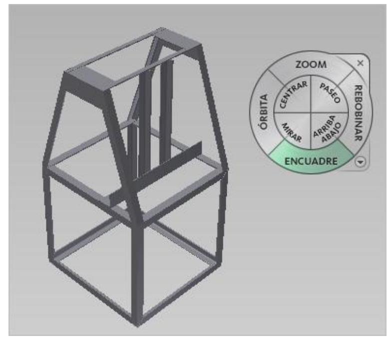

Figure 13: Machine frame designed in CAD Inventor Professional

Then you can plot the values of the maximum shear stress and the shear for different calculations, it is considered a beam of 500 mm and a force of 490 N as seen in the following figure:

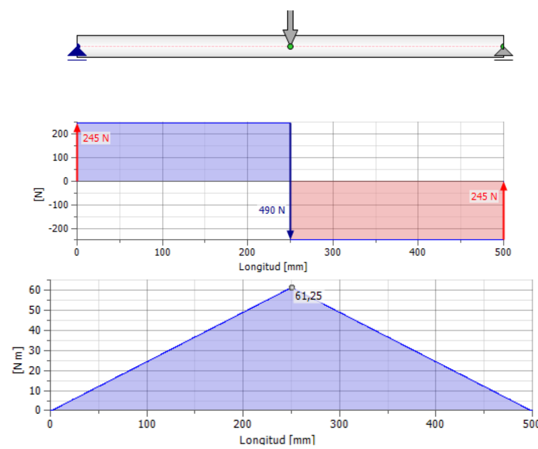

Figure14: Diagram Cortes and moments of the beam

To determine the L profile with equal sides of the safety factor of 3 was taken.

$$\sigma_{max} = \frac{S_y}{n} \quad (11)$$

$$\sigma_{max} = \frac{250\ \mathrm{MPa}}{3}$$
$$\sigma_{max} = 83{,}33\ \mathrm{MPa}$$

To calculate the characteristics of the profile using the following equation applies:

$$\sigma_{max} = \frac{M_{max}}{w} \quad (12)$$
$$w = \frac{M_{max}}{\sigma_{max}}$$

Where:
w = Module profile selection

$$w = \frac{61250}{83,33}$$
$$w = 735\ mm^3$$

Once we know the profile section module proceed to see on tables formed a value that matches or is very close to that obtained, according to calculations can be used in L shaped profile states that you can use profiles profiles L of 30 mm X 30 mm at the base and which will support the entire weight of the machine and of 20 mm X 20 mm at the top.

For the calculation of the safety factor Goodman failure criterion is used to be easy to use and what is very important is conservative; applying the formula we have the following:

$$\frac{1}{n} = \frac{\sigma'_a}{Se} + \frac{\sigma'_m}{Sut} \qquad (13)$$

$$n = 8,1$$

Once applied the criterion of Goodman concluded that use of the L profile with the above specifications will have a safety factor of 8.1 which is a very good value for the use of this element of the structure is performed the green banana slicer.

In Figure 15 is shown as are the restrictions and the forces applied to the structure to be used for the green banana slicer.

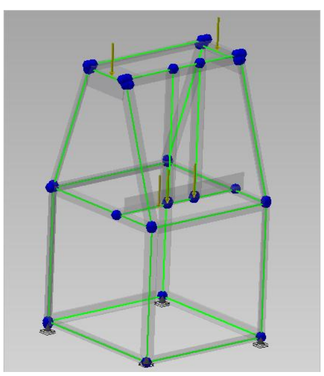

Figure. 15. Forces acting on the structure

In Figure 15 the displacement is taken into the structure of the machine having a maximum displacement of 0.02043 mm and a minimum of 0 mm is shown; taking into account the maximum displacement is negligible concluding that the structure has high reliability.

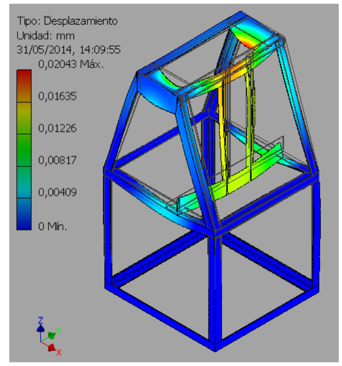

Figure. 16. Displacement of the structure

Having performed the simulation with the respective loads on the structure can be concluded that the structure is capable of withstanding the loads involved in the machine this can be confirmed by the simulation on the effort of Von Misses in CAD Professional Inventor to determine creep of the structure to obtain a maximum of 10.03 MPa corresponding to the part where he is resting the cutting system is the system most weight.

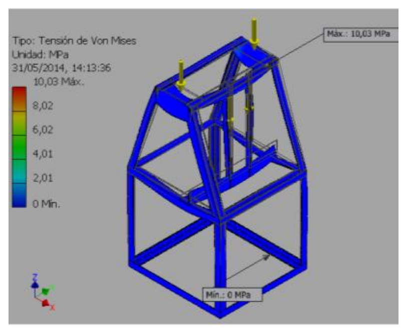

Figure. 17. Von Mises stress of the structure

The above data obtained from the simulation using the Von Mises stress shown that the design of the structure meeting the parameters set forth above to ensure stability of the same.

3.7 Advance System Contract

Green bananas before being sliced will be placed neatly to be pushed by the blade springs as shown in the following figure.

Figure. 18. Camera for feeding green bananas

For the construction of this camera AISI 304 stainless steel is used with a thickness of 3 mm ensuring food safety and long life of the machine; thickness aforementioned established to avoid distortions caused by strokes or other impacts as it will have a semiautomatic work pushing bananas inside are toward the blades, this would be through the implementation of springs which are subsequently detailed and for this it is essential that the camera has no subsidence or deformation that hinder or prevent normal development.

The torque in the spring of 2879.51 MPa is that value is used to determine the safety factor of the spring to be used.

Then the shear spring (τ_m) under service load using equation 14 is determined.

$$\tau_m = \frac{8*P*D}{\pi*d^3} * K_b \text{ (Budinas R., 2008)} \quad (14)$$

$$\tau_m = \frac{8(49N)(0{,}0098)}{\pi(0{,}001)^3} * (1{,}1)$$

$$\tau_m = 1345{,}1 \text{ MPa}$$

The shear stress is MPa 1345.1 will serve for the calculation of the safety factor as shown in Equation 15.

$$n = \frac{S_{sy}}{\tau_{max}} \quad (15)$$

$$n = \frac{2879{,}51}{1345{,}10}$$

$$n = 2{,}14$$

From equation 15 it is concluded that there is a safety factor of 2.14 is acceptable for use with spring characteristics and specifications above factor.

4. Results

4.1 Required Strength Results Returned To The Court

Figure 17 shows the force required cut green bananas depending on the diameter of bananas; low cutting force is 2,58 kgf (25 N) with a diameter of 23 mm and maximum force is 4,1 kgf (40,18 N) in a diameter of 42 mm banana.

For purposes of calculation to use the necessary force of magnitude greater than for the different calculations 40,18 N. force was used

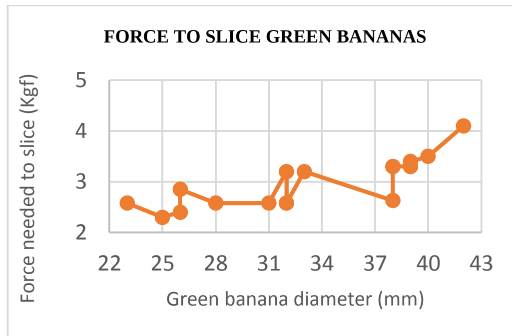

Figure. 17. Force required to sliced green bananas

As seen in Figure 18, the quality in the range of 50 to 200 RPM has an acceptance of 60% belonging to the good, for speeds ranging from 205 to 280 rpm 100% acceptance belonging to very good was obtained, a higher speeds from 285 RPM to have a downward trend in acceptance due to the quality of the slices begin to emerge with particular defects break the slices.

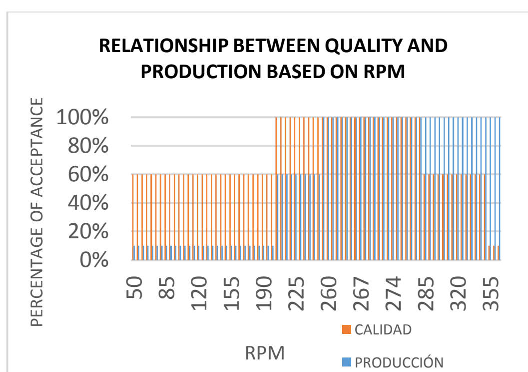

Figure. 18. Relationship between quality and production based on RPM

4.2 Comparison of Time By A Sliced And Manual Using Machine

In order to determine if it has met one of the objectives is necessary to make a comparison of time and production between a traditional or sliced manually using the banana slicer green; to set the time starts from the moment that bananas are peeled and ready for slicing.

In Figure 19 you can see the time spent in minutes for slicing and slicing amount of product having the data can be seen in the figure below.

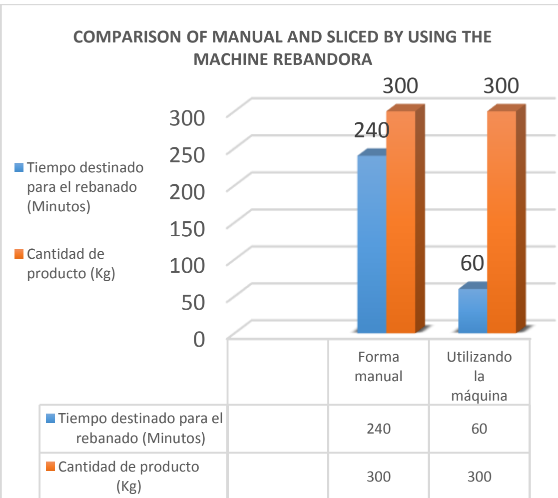

Figura. 19. Manual comparison slicer and using the slicing machine

From Figure 19 it can be seen that for slicing 300 Kg Product of green bananas manually 240 minutes or 4 hours delay while slicing the same amount of bananas using the slicing machine green banana takes time 60 minutes or about 1 hour; time optimization is great because if done manually slicing is performed of a banana on a banana while the machine utilization is done on each charge an average of 5 to 6 bananas while minimizing time considerably.

5. Conclusions and Recommendations

5.1 Conclusions

- By the completion of the slicing machine green bananas for making handmade chifles, an increase in the production of 11130 cases per month to 19500 cases per month thanks to the implementation of it was obtained, in addition he provides, safer slicing, uniform slices is also achieved success transverse and longitudinal cutting on the same machine without leaving aside the health and safety of the product.

- By building the green banana slicing machine is considerably reduced the time between a manual and sliced through the implementation of green banana slicer machine, currently an average of 300 kg of green bananas in slices within 1 time whereas previously the same amount of product slicing in a time of 4 hours, so meeting the design parameters established in the construction of the machine.

- For the construction of the machine was under ISO 22000 standards which manifest on the materials used for the construction of different types of machinery, which is why the machine is carried out in most stainless steel AISI 304, same as provides security and food safety that are developed.

- a minimum force of 22.54 N was required to slice bananas with a thickness of 23 mm in diameter and a maximum force of 40.18 N to slice green bananas with a diameter of 42 mm, for calculations is considered using the ensuring more effective force for cutting bananas with diameters smaller than 42 mm.

- For perfect slices the blade must be running at speeds between 260 and 280 RPM; these revolutions a very good production and excellent quality of the slices are obtained.

- Most elements of the slicing machine green bananas were selected according to the needs that were taken for construction as operation, maintenance, cleaning ergonomics considering that are readily available in the local market, a lower cost and that have good quality.

- The machine is designed and built to have a friendly maneuverability and easy operation allowing any person can operate it without any difficulty or jeopardize their safety or that of others.

- To predict failures in the design and construction of the machine computer programs with CAD applications; in this case the same as Inventor Professional provided valuable information for the respective calculations used software systems.

5.2 Recommendations

- When placing sliced transversely to produce round or banana chips placed in the feeding chamber bananas cut in half to enter easily into the feed chamber and is pushed into the blades.

- It is recommended to clean the machine after each day of sliced using different methods mentioned in Table 4 and 5 corresponding to maintenance and cleaning of stainless steel.

- The use of the maintenance manual that is in the part of the annexes to prolong the life of machine elements and have a proper use of it is recommended.

- You should always use the drive that has the machine this will prevent pushing green bananas into the blades with your hands as it may cause damage and / or cuts in them.

- It is recommended to follow the manual operation of green banana slicing machine before starting or performing any activity.

- To adjust the blades and the desired thickness is recommended with off-axis drive and go confirming the desired thickness and in this way will be much easier and faster to get the same calibration.

- It is recommended to calibrate correctly the blades preventing friction between the blades have the blade against because you can lose edge blades getting a poor cut and in the worst cases can reach the engine burn.

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