MÁQUINA DESVAINADORA DE FRÉJOL SECO

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Resume— *This Project presents the design and construction of a husking machine for dry beans, its objective is to increase the shelling speed of the beans, reducing the labor cost and improving the living conditions of farmers.*
To achieve the stated goal, it was started with the mechanical system design and control of the husking machine for dry beans; it was proceed with its construction by optimizing the machine manufacturing costs focusing on farmers and small traders who wish to purchase it at an affordable price. Once the machine was constructed we proceeded to test the functioning and management of it allowing correcting errors and performing necessary adjustments to achieve the optimal operation of the machine. Finally, a user manual and machine maintenance for people who have acquired the machine have the necessary support when the use it without any problem was developed.

The husking machine of dry beans will occupy approximately a physical area of $2m^2$*; the shucked process will start with the entry of the dry beans to a feeding hopper supporting a capacity of 25 pounds of dry beans including its sheath. Subsequently it enters into a chamber where it will be shelled by a system of vanes that rotate at high speeds and generates impacts causing the separation of the beans from the sheath; the sheath will be expelled from the machine through the ventilated area by centrifugation while the beans will fall by gravity towards a mesh located at the exit of the machine.*

This machine will be operated by an AC motor at 110/220 V to provide motion to an axle via a transmission system by bands to the husking beans system. It will have an on, off and an emergency stop table of the machine with their respective securities; additional, the machine will be controlled through a sensor that checks whether the machine is being used by the user or on the contrary it will automatically turn off benefiting the energy save.

I. NOMENCLATURE

Speed, cost, dry Fréjol, Desvainadora, Hopper, Spin, Motor, Panel, Sensor, Automatic, Paddle, Shaft, Bands.

II. INTRODUCTION

The beans or Phaseolus vulgaris is a food that has been cultivated since about 8000 years ago, as part of the diet of people for their rich nutritional properties of protein and fiber.

In our country, it is known as beans or beans and is very common to serve it with rice and meat, poultry, pork or fish.

In the North of Ecuador a high percentage of farmers engaged in the cultivation of this plant for its good marketing and profitability. It can be planted in cold and warm climates for its adaptability feature of the different varieties, which are 150 worldwide and 50 in Ecuador.

The crop of this legume is performed 4 months after planting, when the pods open easily when pressed by hand.

Once extracted from the pod of the plant is necessary to select the tender beans and dry; tender beans encostala it for marketing to wholesale and dry beans enters a process shucked, which is hard, takes time, money and is labor intensive. Traditionally farmers tending is done dry beans in a large area on the floor and leave it in the sun for several hours the shell overlying dehydrated and then shucked it done by beating with wooden pieces for hours depending on the shuck amount.

This method used by farmers is not ergonomic, since when doing the shots beans have to stoop or kneel, affecting your posture, causing severe back pain, fatigue and discomfort in this agricultural work.

This whole process affects the daily output of beans available to the trader so they can make the sale; another drawback is that depending on its moisture content dry beans risks causing damage economic losses.

III. THEORICAL FOUNDATION

Between best varieties of beans grown in Ecuador have the bush beans and climbing beans or fickle.

A. Fréjol arbustivo

The scientific name of this variety of beans is Phaseolus vulgaris L., their center of origin in America (Mesoamerica, Andean Zone). In Ecuador it is grown in the valleys: The Chota, Salinas and Mira (Imbabura, Carchi) Guayllabamba and Tumbaco (Pichincha), Patate (Tungurahua) Gualaceo and Yunguilla (Azuay), Vilcabamba, Catamayo Malacatos (Loja) and in the foothills of mountains: Intag (Imbabura), Northwestern Pichincha, El Corazon (Cotopaxi) and Huigra

Chanchán (Chimborazo), Pallatanga (Chimborazo and Bolivar) and Chillanes (Bolívar), Javin and Chontamarca (Canar), with altitudes of 1200-2500 m. (Valley areas) and 1000-2200 m. (Foothills).

The climates of these sectors vary entity rainfall 300-700 mm of precipitation and temperatures in the cycle of 16 to 20 º C.
Franco Soils are sandy, with good drainage and pH: 5.5 to 7.5.
Cultivation cycles in soft bush beans is 80 to 90 days in valleys and foothills; dry and is 110 to 115 days in valleys and foothills and 150-165 days Guaranda (Bolívar).

The planting season is from February to April and September to November and April to July Valles in foothills (Peralta et al., 2010).

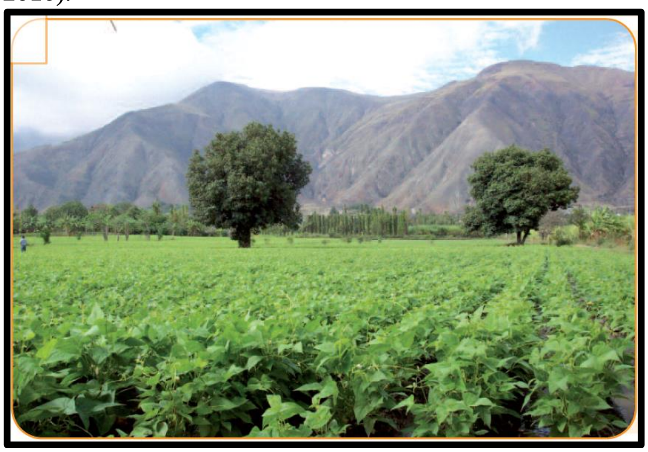

Figure 1 Fréjol arbustivo

Nota. Fuente: Peralta, E., Murillo, A., Mazón, N., Monar, C., Pinzón, J., & Rivera, M. (2010). *Manual agrícola del fréjol y otras leguminosas.* (p. 2). Recuperado de: http://www.iniap.gob.ec/nsit e/images/documentos/MANUAL%20FREJOL%20Y%20LEGUMI N%202010.pdf

*B. **Fréjol Voluble o Trepador***

The scientific name of this variety of beans is Phaseolus vulgaris L., their center of origin in America (Mesoamerica, Andean Zone). In Ecuador it is grown in the provinces of Carchi, Imbabura, Pichincha, Chimborazo and Bolivar, with altitudes between 2000-3000 meters above sea level.
The climates of these sectors vary entity rainfall 500-900 mm of rainfall in the cycle and temperatures from 12 to 18 º C.
The soils are clay loam Franco and with good drainage and a pH: 5.6 to 5.7.
Cultivation cycles fickle beans INIAP 412 Toa in tender is 160 days and dry is 180 days, from 421 Bolivar lNlAP assortment is 155 tender and dry is 185 days and 426 INIAP Canario seven Hills in tender is 100 days and dry is 160 days.
Planting time in the Sierra, is from September to January, depending on the area and foothills of mountains is from April to May (Peralta et al., 2010).

Figure 2. Formas de desarrollo del fréjol voluble o trepador

Nota. Fuente: Peralta, E., Murillo, A., Mazón, N., Monar, C., Pinzón, J., & Rivera, M. (2010). *Manual agrícola del fréjol y otras leguminosas.* (p. 15). Recuperado de: ttp://www.iniap.go b.ec/nsite/images/documentos/MANUAL%20FREJOL%20Y %20LEGUMIN%202010.pdf

C. Process bean agroindustrial

The agroindustrial process from harvesting beans includes the following steps:

- Harvest: Harvest dry pod should be done when the plants have reached physiological maturity, ie when the plant leaves have fallen, the dried pods are yellow and containing approximately 18 to 20% seed moisture, this can be known by checking pressure with a fingernail.

To start the plants is necessary to verify that 90% of all plants have changed color.

Threshing, depending on the amount, can be done manually, by trampling or animal by-blow on the floor, using wooden sticks. For large crops, the use of mechanical threshers (Peralta et al., 2010) is recommended.

- Classification of the wet and dry pod pod to the classification of the pods is done through touch and observation, farmers usually do inserting the nail into the sheath and depending on the degree of pressure that had to be classified as an wet or dry pod.

Another way is through this sheath color, so that when viewed from green sheath is wet and when seen yellow, the pod is dry.

- Process of dry shelled beans: the dry process shucked beans begins tending the dried pods on a flat surface evenly and weather, so that the direct sunlight get into the sheath for it to dehydrate and thus remove grain by trampling or animal by-blow on the floor using wooden sticks, in the case of small amounts (1-2 ha). The use of mechanical threshers is recommended for large crops.

The traditional practice of trampling truck damaged by crushing the seed and grain quality is significantly reduced (Peralta et al., 2010).

- Lens selection: this step is to remove waste from the pods were shelled after the process, ie the remains of grain that were damaged in the process and environmental impurities. This is performed by natural ventilation or using a ventilator.

Natural ventilation is the traditional and involves lifting into the air systematically certain amounts of grain using a shovel, so that the wind carries impurities and drop the beans clean.

- Storage: after selecting the best quality beans, it proceeds to store in bags to carry out their marketing.

The grain for consumption and seed should be stored in cool places from 10 to 12 º C and dry, with 70% relative humidity (the more the value of the relative humidity at 100% wetter approaches is) free of weevil (pests on crops) and grain moisture at less than 13% (Peralta, et al. 2010).

- Marketing: is being tested for the canning industry with solid red varieties (ICA Quimbaya, lNlAP 402, BRB 194, BRB 195, DRK 105), Black (G21-212, L88-63, A-55, Condor, Black San Luis) and yellow lNlAP lNlAP 480 420 Chota and Rocha).

For the preparation of flour were evaluated six commercial varieties and performance stand out for their bread lNlAP Rocha 480 (74%), Red Valley lNlAP 481 (69%) of Chota lNlAP Canario (68%), 430 lNlAP Portilla (67%) lNlAP Afroandino 482 (66%), Concepción lNlAP 424 (65%).

Red beans and purple speckled, are used by the government feeding programs.

For beans mottled red and purple mottled (with cream), dry grain, the potential market is Colombia.

For beans yellow (canary) dry or sweet grain market is national.

For white beans-size market is national, with emphasis on Easter (April) where it is customary to eat Fanesca known. No consumption of white beans, dry grain-size.

The variety lNlAP 421 Bolivar, full red color, has presented good characteristics and is being adopted by agribusiness for canning (Peralta et al., 2010).

IV. MACHINE DESCRIPTION

A. Description Construction of Dry Bean Machine Desvainadora

The whole structure of the machine is armed with structural square tube ASTM A-500, GRADE A, due to its good mechanical properties.
The cover of the machine in the outer zone is by steel plates hot rolled ASTM A-588M STANDARD GRADE A, of different thicknesses depending on your application.

In areas where there is direct contact with the grain, health standards, stainless steel plates NORMA AISI 304 which has features like resistance to corrosion and chemical attack of the environment and is used in the food industry can use.
The system performs dry shelled beans uses a stainless steel shaft Standard AISI 304, resistant to corrosion and easy environment machining; coupled thereto pallets are AISI 304 stainless steel, which is going to hit the beans in pods so that the grain out of its shell.
As bearings to use two rolling bearings of a row of balls which serve to support the shaft in the husking system while the driven V-belt pulley which is coupled to it.
A sensor for automatic shutoff, which is strategically located on the inside of the outlet area of the shucked beans, so that when the machine is not being used by the operator to turn off automatically after 10 minutes will be used.
The control circuit consists of electrical and electronic components, as well as a relay, thermal relay, contactor, switches, microprocessor, transistors, resistors and capacitors, which control the correct operation of the sensor and gives the signal to turn off automatically engine.
Panel power on / off and emergency stop will be located under the cargo area of the product, for two main reasons, the first is because it is near the place where the operator will be most of the time if an emergency arises and you need to switch off and the second reason is because there will be no risk of that board to physical shocks and damage.
Engine capacity and optimum rpm the system will be selected carefully shucked with field tests and mathematical calculations, so that the grain out of the highest quality possible and with minimal losses.

V. CALCULATIONS AND DIMENSIONING

A. Calculating machine structure

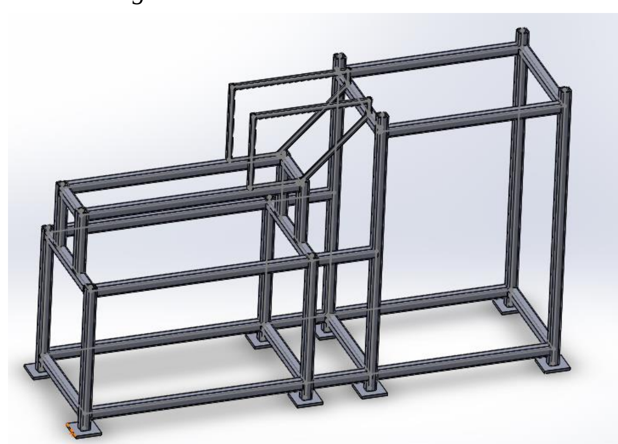

Figure 3. Machine Structure
Note. Source: Author (Luis Álvarez)

For the calculation of the structure of the whole machine was used slope-deflection method, which is so called because it relates the slopes and deflections unfamiliar with the load applied on the structure (Hibbeler, 2012).

Equation 1. Equation of time the fixed end

$$(\mathrm{FEM}) = \frac{P * L}{8}$$

source: Hibbeler (2012), cover.
FEM = fixed end time.
P = weight.
L = length of the beam.

We consider three distinct F'' F, FB and BB 'as clear are fixedly supported in F'' and B', the momentum equation for the fixed end FB applies:

$$(\mathrm{FEM})\mathrm{FB} = -\frac{140 * 71}{8} = -1242{,}5\ Kg.cm$$

$$(\mathrm{FEM})\mathrm{BF} = \frac{140 * 71}{8} = 1242{,}5\ Kg.cm$$

The angular displacements in F'' and B 'will be zero since a lateral displacement will occur:

$$\theta\mathrm{F}'' = \theta\mathrm{B}' = 0$$

where:
θ = angular displacement

The displacement angle rope course be zero since a lateral displacement will occur:

where:
$\Psi\mathrm{F}''\mathrm{F} = \Psi\mathrm{FB} = \Psi\mathrm{BB}' = 0$
Ψ = angle shift rope light

By the following equation calculate the internal moment at the near end of the course:

Equation 2. General equation slope deflection
$$MN = 2Ek(2\theta N + \theta F - 3\Psi) + (\mathrm{FEM})\mathrm{N}$$
Source: Hibbeler (2012)
Where:
MN = internal moment at the near end of the clearing.
E, k = modulus of elasticity and rigidity of the clearing.
$\theta N, \theta F$ = slopes of the near and far ends of the clearing or angular displacements at the supports; angles are measured in radians and are positive clockwise.
Ψ = rotation rope light due to a linear displacement; This angle is measured in radians and is positive in the clockwise direction.
$(\mathrm{FEM})\mathrm{N}$ = fixed end point in the holder near end.

Then we apply Equation 2 for light F'' F, FB and BB ':

Equation 3. Equation internal moment at the near end of the clearing F'' F
$$M\mathrm{F''F} = 2E\left(\frac{I}{105}\right)(2(0) + \theta F - 3(0)) + 0 = 0{,}019EI\theta F$$

Equation 4. Internal moment at the near end of the clearing FF''
$$MFF'' = 2E\left(\frac{I}{105}\right)(2(\theta B) + 0 - 3(0)) + 0 = 0{,}038EI\theta F$$

Equation 5. Internal moment at the near end of the clearing FB
$$MFB = 2E\left(\frac{I}{71}\right)(2(\theta F) + \theta B - 3(0)) - 1242{,}5 = 0{,}05EI\theta F + 0{,}027EI\theta B - 1242{,}5$$

Equation 6. Internal moment at the near end of the clearing BF
$$MBF = 2E\left(\frac{I}{71}\right)(2(\theta B) + \theta F - 3(0)) + 1242{,}5 = 0{,}05EI\theta B + 0{,}027EI\theta F + 1242{,}5$$

Equation 7. Internal moment at the near end of the clearing BB'
$$MBB' = 2E\left(\frac{I}{105}\right)(2(\theta B) + 0 - 3(0)) + 0 = 0{,}038EI\theta B$$

Equation 8. Internal moment at the near end of the clearing B'B
$$MB'B = 2E\left(\frac{I}{105}\right)(2(0) + \theta B - 3(0)) + 0 = 0{,}019EI\theta B$$

Six equations 3 to 8 contain eight unknowns. The two remaining quilibrio equations come from equilibrium of moments at joints F and B:

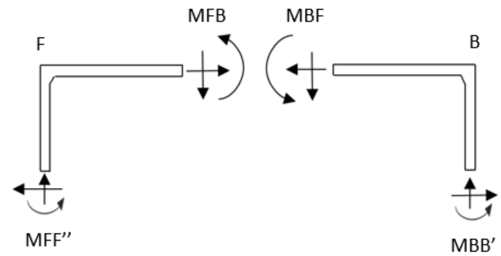

Figura 4. Balancing of moments in the gaskets I and K
Note. Source: Author (Luis Álvarez)

Equation 9. Equilibrium equation in its F
$$MFF'' + MFB = 0$$

Equation 10. Equilibrium equation in its B
$$MBF + MBB' = 0$$

To resolve these eight equations Equation 4 and Equation 5 are replaced in Equation 9 and we have:

Equation 11. Equation clear of the equilibrium equation in its F
$$0{,}088EI\theta F + 0{,}027EI\theta B = 1242{,}5$$

And Equation 6 and Equation 7 are replaced in Equation 10:

Ecuación 12. Equation clear of the equilibrium equation on the board B
$$0{,}088EI\theta B + 0{,}027EI\theta F = -1242{,}5$$

Substituting Equation 11 into Equation 12 and solving yields:

Equation 13. Equation clear of the equilibrium equations of the joints I and K
$$\theta F = -\theta B = \frac{21132{,}41}{EI}$$

Substituting Equation 13 in Equations 3 through 8 has:
$MF''F = 394{,}08\ Kg.cm$
$MFF'' = 788{,}16\ Kg.cm$
$MFB = -766{,}64\ Kg.cm$
$MBF = 766{,}64\ Kg.cm$
$MBB' = -788{,}16\ Kg.cm$
$MB'B = -394{,}08\ Kg.cm$

Based on these results and the diagram of moments is performed cuts.

Once obtained the results of maximum bending moment that will support the beam, we proceed to calculate H width and thickness of structural tube and square:

Material: Square Tube structural ASTM A-500 Grade A

$Sy = 2741{,}97\ Kg/cm^2$
Where:
Sy = fluence resistance

$\sigma d = 2109{,}21 \frac{Kg}{cm^2}$
Where:
σd = Recommended design stress for structural steel
Source: Mott, R.,L.,(2006).

Equation 14. Equation required section modulus 1
$S = \frac{M}{\sigma d}$
Source: Mott, R.,L.,(2006).
Where:
S = Section modulus required
M = Moment

Substituting the values, we have:

$$S = \frac{1718}{2109{,}21} = 0{,}81\ cm^3$$

Then we can use other equation required module section:

Equation 15. Equation required section modulus 2
$S = \frac{I}{c}$
Source: Mott, R.,L.,(2006).
Where:
I = Moment of inertia of the cross-sectional area.
c = distance from neutral axis to the farthest, in the cross section of the fiber beam.

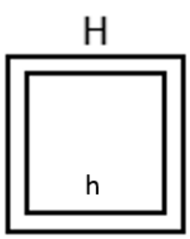

Figure 5. Perfil cuadrado hueco
Note. Source: Author (Luis Álvarez)

Equation 16. Equation of moment of inertia of a square hole

$$I = \frac{1}{12}(H^4 - h^4)$$
Where:
I = inertia moment.
H = external profile width.
h = internal width Profile

Equation 17. Equation of the distance from the neutral axis to the farthest fiber
$c = \frac{H}{2}$

Substituting Equation 16 and Equation 17 into Equation 15 we have:

Equation 18. Equation unobscured of the Equation required section modulus 2
$$S = \frac{\frac{1}{12}(H^4 - h^4)}{\frac{H}{2}}$$

Substituting the result of Equation 14 into Equation 18 and solving, we have:

Equation 19 Equation unobscured of the Equation required section modulus 1

$$h^4 = H^4 - 0{,}407H$$

We assume an H = 4.0 cm., And replacing in equation 19, we can calculate h = 3.99 cm and e = 0.01 cm.

A square structural tube width H = 4 cm and thickness e = 0.15 cm is selected in the catalog.

B. Static analysis of the structure using SolidWorks

Using this software we can perform an analysis of the structure of the machine, so that we can identify the behavior of the beams by placing the loads to which they will be subjected in real life.

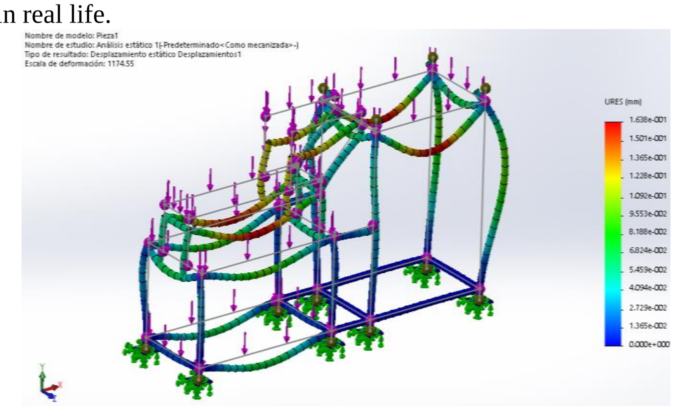
Figure 6. Desplazamiento estático de la estructura de la máquina
Note. Source: SolidWorks

Figure 6 shows that the maximum displacement that might occur in the structure of the machine is of 0.1638 mm, and the minimum offset is 0, and these values are close to zero, it is concluded that the design was done correctly is safe and supports loads without any problems.

C. Analysis of the safety factor for the criterion of Von Mises stresses

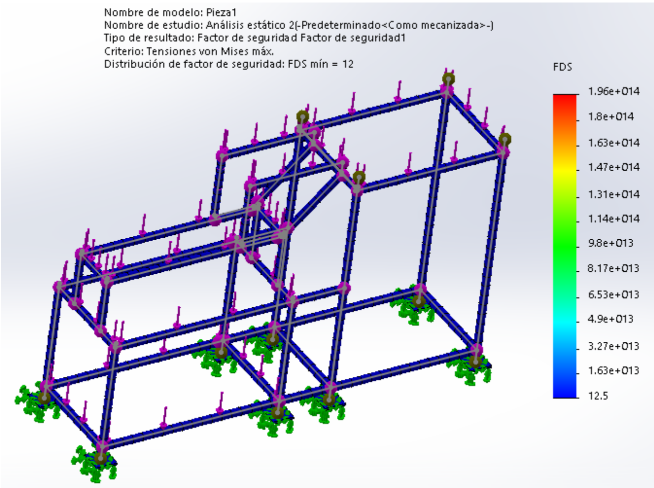

Figure 7. Tensiones de Von Mises

Note. Source: SolidWorks

D. Calculation of the optimal power and engine rpm

Through field testing optimal rpm and power output is selected:

Equation 20. Torque

$T = F * d$

Where:

T = maximum torque that the engine must overcome.

F = necessary force.

d = distance from the axis to which the force is applied F.

$$H = \frac{(103.94\ lb.in)(850\ rpm)}{63025}$$

$H = 1{,}4\ \text{hp}$

This result is multiplied by a correction factor of 1.6 for losses in the bands, support the shaft in the bearings, binding system shucked unforeseen weights and thus the final power output is as follows:

$H = 1{,}4\ \text{hp} * 1{,}6$

$H = 2{,}24\ \text{hp}$

2 hp motor with the following characteristics were selected:

Table 1. Features selected motor

Make	Weg
Model	LR 38324
HP(KW)	2(1,5)
V	110/220
A	27.60/13.80
HZ	60
RPM	1720
PH	1

Note. Source: Author (Luis Álvarez)

E. Calculation of the shaft and the transmission system

To begin the design, select the item:

Material: stainless steel shaft AISI 304

Mechanical properties:

Sy = 35 ksi

Source: Mott, R., L.,(2006). p. A-12.

Where:

Sy = fluency resistence.

Su = 85 ksi

Source: (Mott, R., L.,(2006). p. A-12.

Where:

Su = tensile strength.

Sn = 25 ksi

Where:

Sn = resistance fatigue.

To find the size factor, we assume a diameter D = 100 mm.

Equation 21. Factors size

$Cs = 0{,}859 - 0{,}000837D$

Donde:

Cs = factor size

Replacing the data we have:

$Cs = 0{,}859 - 0{,}000837 * (100)$

$Cs = 0{,}7753$

Reliability factor = 0,99

CR = 0,81

Where:

CR = desired reliability.

We then calculate the actual fatigue, superseding the values found above in the following equation:

Ecuación 22. Equation modified fatigue resistance

$S'n = Sn * Cs * CR$

Source. Mott,R.,L.,(2006)

Where:

S'n = actual fatigue resistance.

Cs = size factor.

CR = desired reliability.

Replacing the data we have:$S'n = (25\text{ksi})(0{,}770)(0{,}81)$

$S'n = 15{,}592\ \text{ksi} = 15\ 592\ \text{psi}$

Select a design factor:

$N = 2$

WhereDonde:

N = factor design.

It has selected a design factor N = 2, since the elements of the machine are under dynamic loads with an average confidence in all design data (Mott, R., L., 185).

Equation 23. Equation torsional couple on the driven pulley

$T = 63000(P)/n$
Source. Mott,R.,L.,2006
Where:
T = torsional par, [lb.pulg].
P = power, [hp].
n = speed, [rpm].
$T = 63000(2)/850$
$T = 148{,}24\ lb.pulg.$

Make the diagram of forces on the driven pulley for V band to calculate the bending force of the pulley on the shaft:

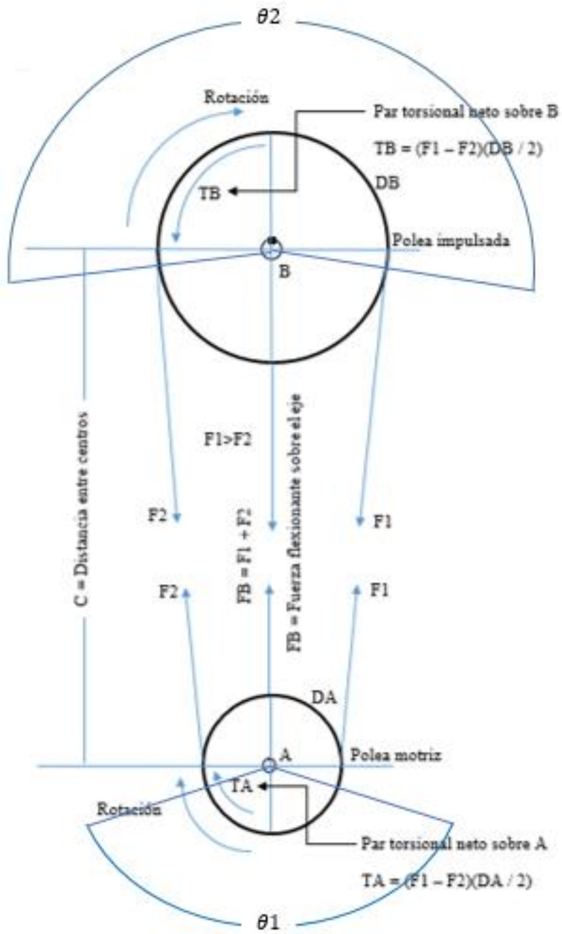

Figure 8. Diagram of forces in the drive and driven pulleys
Note. Source: Adapted of Mott, R., L. (2006). *Diseño de elementos de máquinas.* Cuarta Edición (p. 539). *México: Pearson Educación.*

Equation 24. Equation of the balance of forces
$$\frac{F1}{F2} = 5$$
Source: Mott,R.,L.,(2006)

Equation 25. Equation net torsional torque on B
$$TB = (F1 - F2)(\frac{DB}{2})$$
Source: Mott. p. 539

Equation 26. Equation unobscured net torsional torque on B
$$F2 = \frac{TB}{2 * DB}$$

Now we need to find the value of the diameter of the larger pulley DB:

Information:
Transmitted power = 2 hp.
Motor SPEED = W1 = 1720 rpm.
Out speed = W2 = 850 rpm.

We calculate the ratio of nominal speeds:
$$Relación = \frac{1720}{850} = 2{,}02$$

We assume a standard diameter of the drive pulley which satisfies the design guidelines of V-belt transmissions:

Standard size of the drive pulley, DA = 2.5 in. = 6.35 cm.

Equation 27. Nominal interval equation center distances
$$D2 < C < 3(D2 + D1)$$
Source: Mott,R.,L.,(2006)
Where:
C = distance between centers
D1 = DA = diameter of the drive pulley.
D2 = DB = diameter of the driven pulley.

The contact angle on the lower pulley should be larger than 120°:
$$\theta 1 > 120°$$

Equation 28. Equation contact angle of the band on the pulley of smaller diameter
$$\theta 1 = 180° - 2\sin^{-1}(\frac{D2 - D1}{2C})$$
Source: Mott,R.,L.,(2006)

To calculate the diameter of the driven pulley, DB use the following equation:

Equation 29. Equation relationship angular velocities
$$\frac{W1}{W2} = \frac{D2}{D1}$$
Where:
W1 = motor speed
W2 = out speed
Source: Equation 7-2, p. 270 Mott

Solve for D2 and replace the corresponding values:
$$D2 = \frac{D1 * W1}{W2}$$
$$D2 = \frac{2{,}5 * 1720}{850}$$
$$D2 = 5{,}058\ pulg = 12{,}85\ cm.$$
A standard 5in diameter = 12.7 cm is selected.
D2 = 5in

C (approximate distance between centers) = 53 cm.

Check if we meet the design guidelines for the bands in V:

$D2 < C < 3(D2 + D1)$
$15{,}05 < 39 < 3(15{,}05 + 7{,}87)$
$15{,}05 < 39 < 68{,}76$

$\theta 1 > 120°$

$$\theta 1 = 180° - 2\sin^{-1}\left(\frac{D2 - D1}{2C}\right)$$

$$\theta 1 = 180° - 2\sin^{-1}\left(\frac{12{,}7 - 6{,}35}{2 * 53}\right)$$

$\theta 1 = 173{,}13°$

The data we have found, meet the design guidelines and we can continue with the analysis of the bending force of the pulley on the shaft.

$$F2 = \frac{148{,}24\ lb.pulg}{2 * 5\ pulg}$$

$F2 = 14{,}824\ lb$

$F1 = 5F2$
F1= 74,12 lb

With the reactions obtained proceed to make the cuts and moments diagram.

We continue with the design by calculating the minimum acceptable diameter of the shaft at various points of the same. At each point we see the magnitude of the torsional torque and bending moment that there exist:

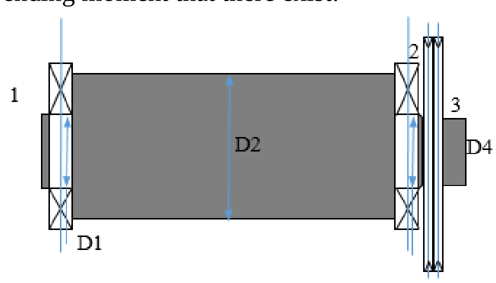

Figure 9. Diagram of the different diameters of the shaft
Note. Source: Author (Luis Álvarez)

Point 1: Point 1 is the seat of a bearing, there are no torsional or bending moments, but yes there is a vertical shear force equal to the reaction in the bearing.

We use the following equation to calculate the required diameter of the shaft at this point:

Equation 30. Equation of required shaft diameter

$$D = \sqrt{\frac{2{,}94Kt(V)N}{S'n}}$$

Source: Equation 12-16 Mott, p.545
Where:
D = required shaft diameter.
Kt = chamfer (bevel sharp = 2.5).
V = Vertical shear.
N = security factor. (N = 2)
S'n = actual fatigue resistance.

$$D1 = \sqrt{\frac{2{,}94 * 2{,}5(13{,}836\ lb\ )(2)}{15\ 592\ \text{psi}}}$$

$D1 = 0{,}01\ pulg$

This diameter is very small compared to other diameters are to be calculated, so we must select an appropriate diameter according to the size of a reasonable bearing.

2: Point 2 is the location of a bearing and has a sharp bevel on the left and right.

The diameter D2 to the left of 2 is specified after completing stress analysis and selecting the bearing at 2.

To calculate the diameter D3 in 2, we used the following equation:

Equation 31. Equation for shafts

$$D = \left[\frac{32N}{\pi}\sqrt{\left[\frac{KtM}{S'n}\right]^2 + \frac{3}{4}\left[\frac{T}{Sy}\right]^2}\right]^{1/3}$$

Source: Equation 12-24, Mott, p.548

Where:
D = sharp diameter.
N = security factor
Kt = chamfer (bevel sharp = 2.5).
M = bending moment
S'n = actual fatigue resistance.
T = torsional moment
Sy = fluency resistence.

$$D3 = \left[\frac{32(2)}{\pi}\sqrt{\left[\frac{(2{,}5)(489{,}17\ lb.pulg)}{15592\ psi}\right]^2 + \frac{3}{4}\left[\frac{148{,}24\ lb.pulg}{35\ 000\ psi}\right]^2}\right]^{1/3}$$

$D3 = 1{,}16\ pulg$

Point 3 is the location of the pulley where there is no time but if there is shear:

$$D4 = \sqrt{\frac{2{,}94Kt(V)N}{S'n}}$$

$$D4 = \sqrt{\frac{2{,}94(2{,}5)(102{,}78)(2)}{15592\ psi}}$$

$D4 = 0{,}3\ pulg$

We select the nominal diameters of the bearing standards:
D1 = 1 pulg
D2 = 1,25 pulg
D3 = 1 pulg
D4 = 0,9 pulg

F. Design of the drive pulley and driven pulley

We calculate the power of design to an electric motor par torsional normal working more than 15 hours per day, the service factor is 1.5; then:

$$Power\ design = 2\ hp * 1{,}5$$
$$Power\ design = 3\ hp$$

3VX a band for 3 hp at 1750 rpm at the input is recommended.

We calculate the length of the necessary band L by the following equation:

Ecuación 31. Equation stride length

$$L = 2C + 1{,}57(D2 + D1) + \frac{(D2 - D1)^2}{4C}$$

Source: Mott,R.,L.,(2006)
Where:
C = distance between centers
D1 = diameter of the drive pulley
D2 = diameter of the driven pulley

$$L = 2(53) + 1{,}57(12{,}7 + 6{,}35) + \frac{(12{,}7 - 6{,}35)^2}{4(53)}$$
$$L = 136{,}09\ cm = 53{,}58\ pulg.$$

Standard length is selected band 3V, L = 48 cm.

Compute the correct distance between centers, using the following equation:

Equation 32. Equation of the center distance

$$C = \frac{B + \sqrt{B^2 - 32(D2 - D1)^2}}{16}$$

Where:

$$B = 4L - 6{,}28(D2 + D1)$$

Source: Mott,R.,L.,(2006)

For this purpose we first calculate the value of B, replacing their corresponding values:

$$B = 4L - 6{,}28(D2 + D1)$$
$$B = 4136{,}09 - 6{,}28(12{,}7 + 6{,}35)$$
$$B = 424{,}726\ cm$$

With the value of B obtained, replace the data in the value equation and find the correct center distance C:

$$C = \frac{424{,}726 + \sqrt{424{,}726^2 - 32(12{,}7 - 6{,}35)^2}}{16}$$
$$C = 52{,}9\ cm = 20{,}86\ pulg$$

We calculate the correct value of the contact angle of the band in the smaller diameter pulley

$$\theta 1 = 180° - 2\sin^{-1}\left(\frac{D2 - D1}{2C}\right)$$
$$\theta 1 = 180° - 2\sin^{-1}\left(\frac{12{,}7 - 6{,}35}{2 * 52{,}9}\right)$$
$$\theta 1 = 173{,}12°$$

We calculate the nominal power

For a 2.5 inch pulley at 1720 rpm, the actual power rating is 1.75 hp.

We determine the correction factors
For $\theta 1 = 173{,}12°$
$Factor\ de\ corrección\ por\ ángulo\ de\ contacto, C\theta = 0{,}97.$

For L = 48 pulg:
$Correction\ factor\ for\ angle\ correction\ contacto, CL = 0{,}92.$

We calculate the corrected power rating band and the number of bands needed to handle the design power:

$$corrected\ power = C\theta * CL * P$$
$$corrected\ power = 0{,}98 * 0{,}92 * 1{,}75$$
$$corrected\ power = 1{,}5778\ hp.$$

$$Number\ of\ bands = \frac{design\ power}{corrected\ power}$$

$$Number\ of\ bands = \frac{3}{1{,}5778}$$
$$Number\ of\ bands = 1{,}90\ bandas$$

According to the data thrown select a number from 2 bands for our transmission system.

G. Control System

The control system comprises a microcontroller ATMEGA 8, objects SASSIN sensor, pushbuttons, pilot lights, contactor and overload relay.

Block diagram of the programmed instructions:

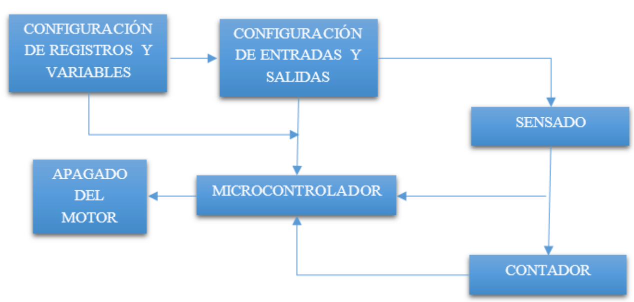

Figure 10. Diagrama de bloques

Note. Source: Author (Luis Álvarez)

Electrical wiring diagram:

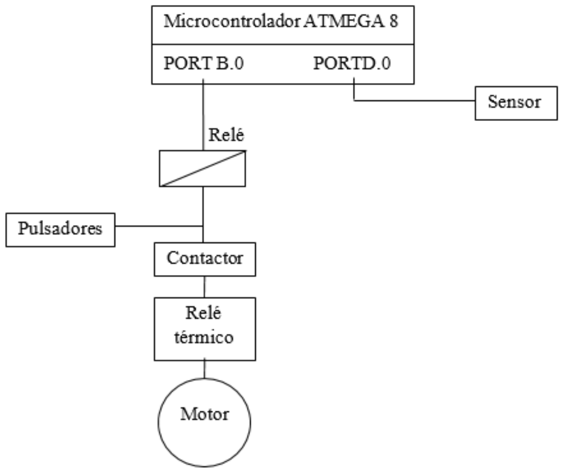

Figure 11 Diagrama eléctrico

Note. Source: Author (Luis Álvarez)

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VII. REFERENCES

Peralta, E., Barrera, V., Unda, J., Guala, M., Tacán M., & Batallas, M. A. (2001). *Estudio de la producción, poscosecha, mercadeo y consumo de fréjol arbustivo en el Valle del Chota, Ecuador.* Recuperado del sitio de internet de Instituto Nacional Autónomo de Investigaciones Agropecuarias: http://www.iniap.gob.ec/nsite/images/documentos/ESTUDIO_PRODUCCIoN_POSCOSECHA_MERCADEO_CONSUMO_FREJOL_ARBUSTIVO_VALLE_CHOTA_ECUADOR.pdf

Peralta, E., Murillo, A., Mazón, N., Monar, C., Pinzón, J., & Rivera, M. (2010). *Manual Agrícola de Fréjol y otras Leguminosas. Cultivos, variedades y costos de producción* (Publicación Miscelánea No. 135). Recuperado del sitio de internet de Instituto Nacional Autónomo de Investigaciones Agropecuarias: http://www.iniap.gob.ec/nsite/images/documentos/MANUAL%20FREJOL%20Y%20LEGUMIN%202010.pdf

Aguilar, D., & Haro, D. (2010). *Diseño y construcción de una máquina desvainadora de fréjol para los pequeños agricultores de la parroquia de Ambuquí en la provincia de Imbabura.* Escuela Politécnica Nacional, Quito, Ecuador.

Hibbeler, R. C. (2012). *Análisis Estructural.* México: Pearson Educación.

Mott, R. L. (2006). *Diseño de elementos de máquinas.* México: Pearson Educación.

Richard G. Budynas y J. Keith Nisbett. (2008). *Diseño en ingeniería mecánica de Shigley.* Octava edición. (p. iii).

VIII. BIOGRAPHY

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