Automation of a seed on tray seeder machine

Oscar Arteaga, Katherine Amores, Héctor Terán, Richard Cangui, André Ramírez, Samanta Hurtado C, Dayana Inlago and Bryan R Chuquimarca

Universidad de las Fuerzas Armadas ESPE, Sangolquí, Ecuador.

E-mail: obarteaga@espe.edu.ec

Abstract: The machine aims to fully automate the process to sow seeds. Generally, these types of activities are semi-automatic, however, the proposed solution aims to improve the efficiency of the process and the reduction of human intervention. It mainly has a mechanical part whose technique is based on a four-bar system, as for the electronic and control part it is commanded by an Arduino card. The mechanical design was carried out using CAD software, and based on the results obtained by various flexural and deformation analysis software, it was possible to select the materials and the motor to be used. The process works from operational requirements such as: transmitting the linear movement of the components, placing and aligning the transport mechanism, transmitting enough power to drill and place the seeds and finally controlling the air flow. As a result, this automated method represents 25% more efficiency and a 50% reduction in personnel compared to the manual method. In the same way, a filling of 87% of cavities for seeds was obtained, this being its highest efficiency with a pressure in the range of 0.2 to 0.3 MPa in the pressure ejector

1. INTRODUCTION

The cultivation of certain seeds, from sowing until packing, requires a lot of handwork, it increase the cost of production [1][2]. Manual sowing requires experienced manual labour, to place the seed at a depth and in a suitable position, as the quality of the sowing and of the seed depends on a correct germination and developing of the plant. [1] [3] The high cost of process and the lack of availability of experienced handworkers in advanced countries has driven the creation of automatic and semi-automatic machines for this hard work. However, its performance is under the quality levels that are get by manual sowing. [4]

There are more complex seeds sowing by focusing on the mechanization of sowing, due to its size, shape and consistency. By On the other hand, tolerance for the uniform separation of seed, which directly affects the yield and quality of the harvest. [5]

The stage of punching, filling and sowing, in a process Technological cultivation in trays for a nursery dedicated to the production of seedlings, is the most important. [6] Nata mentions that a study has been possible about the general process used in the production of vegetable seedlings which consists of disinfection of trays, filling,

sowing, seed capping, transfer of tray, and extraction. For which they propose a semi-automatic sowing, that is, part of the process is done manually and the rest in a way automatic, reaching a high increase in production. [7] [8]
However, this study seeks complete automation in sowing process looking for better results in production.

Sani et al. [9] proposed an automatic seeder based android in laboratory scale aims to helping the farmers in the seeding process before planting in field.

In this article, the topic will be introduced and then the structure of the mechatronic design will be announced, which includes both the mechanical and electronic design, and will also cover the control system and the engine selection criteria. Therefore, there is the phase of tests and results represented in statistical graphs to obtain a better vision of what you want to obtain and finally we have the conclusions of the work done

2. MECHATRONIC DESIGN

From data collected is determined that the area of greatest interest is the punching and placement of seeds, these operations comprise the 65%, while the 35% comprise to the area of loading substrate, coating placement and removed tray. [10]

The operating requirements for the equipment are:
- Transmit lineal movement.
- Place and align the transport mechanism.
- Transmit power for the punching and placement of seeds.
- Control of air flow.

From interviews with experts and related investigation is determined that the most feasible alternatives are:
- a) Figure 1 shows sowing system through nozzles and guided by a 4-rod mechanism.
- b) Figure 1 shows chain-guided power transmission.
- c) Transmission of movement by pinion-rack
- d) Mechanism guided through axes
- e) Vacuum generator by ejector.
- f) Placement through engine by steps.

2.1. Mechanical design

In figure 1 is showed the mechanical design of sowing machine, it presents all the features presented above.

![Figure 1. Mechanic structure of automatic sowing machine.](image1)

![Figure 2. Detailed view of the planting set.](image2)

In Table 1 the components of section A are shown in detail with their respective material and mechanic features. Also, in figure 2 is shown the place of each component in the mechanical structure.
Table 1. Mechanical Components

| No. | Element            | Material          | Resistance to creep (MPa) |
|-----|--------------------|-------------------|--------------------------|
| 1   | Structure          | ASTM A36          | 250                      |
| 2   | Fixed link         | AISI 1018         | 370                      |
| 3   | Entry link         | AISI 1018         | 370                      |
| 4   | Cylindrical axe    | AISI 1018         | 370                      |
| 5   | Follower link      | Aluminum 6061-T4  | 145                      |
| 6   | Coupler link       | Aluminum 6061-T4  | 145                      |
| 7   | Dosing tub         | Aluminum 6063-T4  | 90                       |
| 8   | Punching rod       | Aluminum 6061-T4  | 145                      |

2.1.1 Planting set. It is composed by a dosing tub, dosing nozzles and a punching rod.

The dosing tub connected to the vacuum pump exerts a pressure of 600KPa over the walls, they support a compression force by the vacuum generator, the cross-sectional area is 676mm$^2$ due each side of dosing tub is 26mm, we have that the compression force over the wall is 405.6N. To determine the theoretical limit value, the effort is calculated taking into consideration the material of dosing tub, the calculated design effort is 24MPa when is taken into consideration a security factor of 2. Then is calculated the theoretical effort for the element, it results 30.42KN, that compared to the calculated force is 75 times larger, so the design is safe.

The punching rod exerts a normal effort of 50KPa, it is the value of effort exerted by each wall and multiplied by 11 which is the total number of projections the bar has, each one has a cross-sectional area of 445.56 mm$^2$, the needed force for each punching is 22.28 N, it will be called the $P$ force.

The rod has 11 sections due to the distribution of the tray. Therefore, as shown in Figure 3, the system is analyzed as a rod with simple supports at the ends.

The total length of the bar is 274 mm, and 11 punctual forces $P_1$ are applied over it symmetrically. From diagram of bending moment is determined the critical moment which is 8540.76 N.mm.

With the data in table 1 the resulting design effort is determined as 48.33 MPa, using a security factor of 3.

Then applying the equation of the maximum bending moment and each one of the derived equations, taking into consideration that the punching bar has a square section are obtained the following results:

- Maximum bending moment of 8540.76 N.mm
- Height of 8 mm and base of 20 mm
- Section module of 213.33mm$^3$
- Effort of 40.04MPa
- Security factor of 3.62
The sowing mechanism is composed by 4 elements, where the entry and follower links have a length of 140 mm, the fixed link has a length of 107 mm and the coupler link a length of 100 mm, they all comply with Grashoft law.

Entry links are placed over a rigid axis, its function is to transmit the power from electric actuator, this axis is subject to combined efforts, for that reason the analysis is done according to the theory of energy distortion.

The strength to which each entry link is subjected is 7.5 N, this force is determined from the weight is supported by each element. Also, there is a third force which is the balance counterweight of the shaft. For static design the axis is considered as a rod with simple supports at the ends. See figure 4.

The shaft has three punctual charges, the first and second belong to links at 30 mm and 330 mm from reference point and the third charge is the one of the counterweights at 184 mm from reference point.

With the bending moment diagram determined from figure 4, is established the critical bending moment as 2617 N.mm.

To determine the diameter of the shaft is used equation (1):

\[
\left( \frac{S}{S_y} \right)^2 + \left( \frac{S_s}{S_{ys}} \right)^2 = \left( \frac{1}{N} \right)^2
\]

Where:
Transmit lineal movement.
- \( S \): Sum of axial effort and flexion effort
- \( S_y \): Resistance to creep of material
- \( S_s \): Shear stress per torsion
- \( S_{ys} \): According to Von Mises-Henck theory it is equal to 0.577 \( S_y \).

It is determined that the diameter will be 8 mm, using this data is established that the effort over the shaft due to flexion and torsion effort is 52.06 MPa and 39.78 MPa respectively, using a security factor of 4.28.

With respect to entry link, it is subjected to a charge of 140 N, the free body diagram of this link is shown in figure 5.

The free body diagram shown a bar with a punctual charge and establishes a critical moment of 1050 N.mm. So that the design meets the standards is needed to use a security factor of 3.

With data of table 1 the following results are determined:
- Design effort 123.363 MPa
- Height of the link 1.5 m
- Resulting section module 9.38 \( mm^3 \)
- Effort to which the link is subjected 111.94 MPa
- Security factor 3.30
The design of follower, coupler, auxiliary and fixed links are similar to entry link.

The results for each one of the links are detailed in table 2.

| Link     | F [N] | M\text{max} (N-mm) | \sigma_D (MPa) | h (mm) | \sigma (MPa) | N (security factor) |
|----------|-------|---------------------|----------------|--------|--------------|---------------------|
| Follower | 7,5   | 1050                | 46,67          | 2.5    | 33.6         | 4.17                |
| Coupler  | 14,5  | 551                 | 46,67          | 2      | 29,51        | 4,74                |
| Fixed    | 89,9  | 28350               | 123,33         | 4,15   | 85,05        | 4,35                |

In the figure 6 is shown the analysis of the planting set, actual torque supplied by the motor over the axis and the pressure exerted by the substratum generate a minimum deformation over the fixed link, while its generated a maximum deformation over the coupler link, the follower link and in the planting set, this deformation is 0.1mm and it is negligible. In this way, it is verified that the design is secure and comply with all the requirements. The loads applied to the sowing set are shown in table 2 in row F (Force (N))

**Engine selection criteria.** The torque required for the movement of an engine is given by the sum of the torque of acceleration and working torque, being the torque of acceleration directly proportional to the total inertia of the system to be moved, multiplied by the speed angular, and inversely proportional to time required to accelerate the system. [11]. On the other hand, Load torque is directly related to the external forces and bearing radii. The inertia of the motor and reducer is 120e-7 kg.m² and the inertia of the sowing mechanism added to the load is of 48,1e3 kg.m². The angle of displacement is 170°, due to the sowing mechanism and the type of movement that should perform, each phase takes 3 seconds and the acceleration is given in 500ms, with these data it is established that the angular velocity of the load is 11.33 RPM. The friction force exerted is 22.75N, taking account that the coefficient of friction of the bearing is of 0.35 and the load exerted on the bearing It is 65N. With the data detailed above it is determined that the load torque is 2.312N.m and the torque of acceleration is 0.114Nm, therefore, torque the required motor is 2.43 Nm, for which select a motor with 20 watts of power and a couple of retention of 4 Nm.

**2.2. Electronic and control design**

**Electronic design.** Electric and electronic elements that compose the design of sowing machine are:

a) Actuators electrical: For the activation of the mechanisms of sowing and transport of trays DC motors is used with step control (SM). The stepper motors have additionally reducing boxes to raise their torque performance and soften starting loads, so they also have drivers own
designed to ensure optimal performance of the actuators.

b) Indicators: such as lights and buzzer, which emit visible and audible signals when the machine operates.

c) Drivers: The controller selected for the planter was an Arduino MEGA as shown in figure 7, because its characteristics were sufficient for the application.

**Control system.** Constitutes the intangible essence of the machine, allows operate in a coordinated way the systems (mechanism and equipment)[12] that make up the planter, all this managed through the control unit with Arduino Mega in which a sequence of algorithms is loaded programmed in "C" language, which allow the functions required by the user are carried out in the process of machine operation [13]. With the algorithm activated on the control card the operator must just press the buttons with the legends of: "On" and "start" to start the process of sowing, the sequence of activation of the commands shows on the LCD screen. Once the sowing process has started, the control unit activates the stepper motor that drives the pinion-rack mechanism in order to place the tray in the punching position, the signal is then sent to the stepper motor of the sowing mechanism and to the solenoid valve for suction of seeds and subsequent placement within the substrate holes of the tray; this process is repeated for 22 times until the matrix of 242 cavities in the tray is completed.

### 3. TEST AND RESULTS

Whit the first test it is intended to determine the efficiency of the sowing process under certain vacuum pressures, thus find the best system configuration for planted and seed absorption.

In the figure 8 is shown the efficiency of the sowing process under a pressure of 0.1MPa, where there is 41% of cavities without sowing, 59% cavities sowed and 0% of cavities on excess.

In the figure 9 is shown the efficiency of the sowing process under a pressure of 0.2 MPa, where there is 7% of cavities without sowing, 87% cavities sowed and 7% of cavities on excess.
Figure 8. Vacuum test at 0.1 MPa.

Figure 9. Vacuum tests at 0.2 MPa.

In the figure 10 is shown the efficiency of the sowing process under a pressure of 0.3 MPa, where there is 4% of cavities without sowing, 86% cavities sowed and 10% of cavities on excess.

In the figure 11 is shown the efficiency of the sowing process under a pressure of 0.4 MPa, where there is 8% of cavities without sowing, 82% cavities sowed and 10% of cavities on excess.

Figure 10. Vacuum test at 0.3 MPa.

Figure 11. Vacuum tests at 0.4 MPa.

According to the figure 8, it can be affirmed that the ideal pressure for better process efficiency is a pressure of 0.2 MPa that results in 87% of seeds sown.

For the second test it is taken as configuration by defect the results of test 1, being the Default parameters the following:

- Suction height 2mm.
- Vacuum pressure 0.2 MPa.
- Broccoli Seed.

Figure 12 shows the number of seedlings planted in different periods of time with a jump of 15 minutes, by a manual method with 4 operators and by the automated method that requires only two operators.
According to the results shown in figure 12, the number of seedlings planted with the automated method on average is 25% higher than the manual method in the same period and using 50% of the workers.

4 CONCLUSIONS

The design of the sowing mechanism through a 4-bar linkage presents an innovation in its operation that allows the punching of the substrate and the placement of the seed in a single operation; The benefits of this design are reflected in the construction of a more compact machine and lower cost. The pressure ejector must be in a range of 0.3MPa to 0.2MPa to achieve the maximum efficiency of the module of sowing that is 87% of cavities sown. Considering this configuration, the sowing module for real tests, evaluating the Efficiency of planting in an automated module vs a manual method, you get that the method automated is 25% more efficient and with the 50% reduction of personnel with respect to the manual method.

REFERENCES

[1]. E. Calderón Reyes, R. Serwatowski, J. M. Cabrera Sixto, C. Gracia Lopez 2003 Agrociencia vol 37, pp 483-493.
[2]. J. Bejarano 1998 Economicsofagriculture, (Venezuela: II CA Biblioteca Venezuela) pp 47-51
[3]. A. Mujica, A. Canahua, S. Raul 2010 Quinua Ancestral Cultivo de Los Andes vol24.
[4]. B. Niebel and F. Andris 2009 Industrial Engineering of Methods standards and design of work pp 311-314
[5]. A. F. Godoy 2015 Improvement of the design of the traditional grain planter.
[6]. J. Gaytán Ruelas, R. Serwatowski and C. Gracia López 2006 Agricultural Technical Sciences vol 15, p 28-33.
[7]. M. J. Nata 2016 Semiautomatic seed seeder of cruciferous vegetable seeds and their influence on the production of the “agrofuturo company”.
[8]. E. C. Clavijo Cornejo 2002 Design of the planting device in germination trays.
[9]. A A Sani et al 2019 J. Phys.: Conf. Ser. 1167 012059
[10]. A.P. Shevchenko, A.V. Bankrutenko, V.S. Koval, M.A. Begunov, E.V. Demchuk 2018 J. Phys.: Conf. Ser. 1059, p1.
[11]. H. Shen, Q. Lei, W. Chen 2017 IOP Conf. Ser.: Mater. Sci. Eng. 242, p2-3.
[12]. K. Nemtinov, A. Eruslanov, Y. Nemtinaov 2018 J. Phys.: Conf. Ser. 1084, p1.
[13]. Dr. K A SUNITHA GSGS Suraj, CH P N Sowraya, G Atchuyt Siram, D Shreyas and T Srinivas 2017 IOP Conf. Ser.: Mater. Sci. Eng. 197.