Journal of Physics: Conference Series

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Journal of Physics: Conference Series **1388** (2019) 012004 doi:10.1088/1742-6596/1388/1/012004

Design of a mechanical seeder

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Abstract. In the agricultural production processes that are carried out in most of the Colombian regions, some deficiencies can be observed in the way in which the seeds are sown. This is a task that is carried out manually, generating physical problems in the workers due to the enormous effort that they must make, in addition to the precariousness in how these works are carried out. The long periods that are involved in sowing greatly hinder its efficiency, something that directly affects the economy of the farmers. The purpose of this work is to design a mechanical seeder that facilitates the work of the operators by eliminating the manual operation of it and equipping them with equipment that performs the furrows in the ground and at the same time sows the seed. The results obtained corroborate that there is an adequate structural design, which will support the forces to which the machine will be subjected. In this way, it will be possible to contribute to the improvement of the sowing conditions of the farmers of the region. This design takes into account the number of seeds sown per hectare, which is about 20 kg. These data were obtained from farmers belonging to the Universidad Francisco de Paula Santander seccional Ocaña. Additionally, maximum deformation analysis was performed on the chassis, obtaining values of 1.791×10^{-4} m, as well as structural analysis using the Solidworks drawing tool.

1. Introduction

At present, conventional agricultural practice has a series of problems since the processes of sowing seeds are carried out in an artisanal manner, thus making the work of the farmers difficult. In addition, the conditions of the land make sowing difficult, increasing the time used to carry out this work, resulting in a negative impact on the health of the workers [1].

As a result, there is a need to implement a mechanical seeder, which seeks to reduce costs associated with agricultural production and improve working conditions for workers. Also, with the implementation of the seed drill, a reduction in the tools needed to carry out this task is expected, as well as improve the efficiency of the process, thus allowing greater profitability that contributes to improving competitiveness in the market, since, in countries such as Colombia, agriculture is one of the main economic sectors [2].

The selection of this design was made because, in a large part of the Colombian territory, small farmers are in charge of growing food in areas that, due to the irregularity in the land and low economic investment, do not allow the use of tractors [3].

This work can help to improve planting processes, reducing time and associated costs, allowing farmers to have higher profitability. On the other hand, this work allows different people of the country interested in researching in the region in this field to have a description of the conditions of the sowing, as well as those of the land. Therefore, the objective of this research is to design a mechanical seeder that can be manually operated by the workers, making easier the sowing work.

2. Methodology

The design of the mechanical seeder was carried out using the Solidworks tool, taking into account an extensive literature review, which was considered at the time of carrying out the design stages. The variables inferred in the process were previously selected, based on the characteristics of the soil of the region, which has clay loam properties [4]. Subsequently, calculations of the mechanical elements that make up the machine were performed. In addition, a study of finite elements was carried out in order to corroborate the data obtained during the design.

2.1. General considerations

In order to identify the variables involved in sowing, it is necessary to know the characteristics of the soil to be used, as well as the size and distribution of the particles of the specific area since this factor directly intervenes in the cutting tool design. In this case, the analyzed soil has clay loam characteristics with friction intervals between 0.35 and 0.63 [4].

The sowing speed is another important factor that influences the design, because the proper selection of it intervenes in the process of selecting the seeds and distributing them. According to [5] the recommended speed for seed drills with pneumatic dosing systems ranges between 4 and 8 Km/h, which are transported by tractors, but for manual mechanical seeders, this speed can be reduced to make the process more efficient.

Another aspect to take into account in sowing is the depth at which the seed will go, since, as mentioned above, the soil is a fundamental part of this process because certain specific depths obtain the greatest nutrients from the soil. In the case of sowing corn and bean seeds, a depth that varies between 2 and 4 cm is established [6].

In order to have the highest possible yield from the ground, seeds should be at a proper distance from each other and the rows. For maize grains, the distance between rows is less than one meter and between seeds less than 30 cm. The bean is kept in similar parameters but with a distance between rows less than 80 cm [7]. Table 1 shows the elements that make up the machine, as well as their definition.

Table 1. Definition of components [8].

Element	Definition
Doser	System that regulates the number of seeds to sow.
Furrow opener	Tool that makes ditches in the soil.
Furrow filler	Element that covers the furrow after the seed has been deposited.
Row marker	Tool that makes marks in the soil with the necessary spaces between furrows.
Hopper	A container with an opening in its lower part, which serves to make its contents pass little by little to another place with a narrower opening.
Frame	Structure on which the other parts of the machine are fixed.

The machine will have a hopper which is in charge of keeping the seed doser supplied. In the same way, the following requirements must be met [8]:

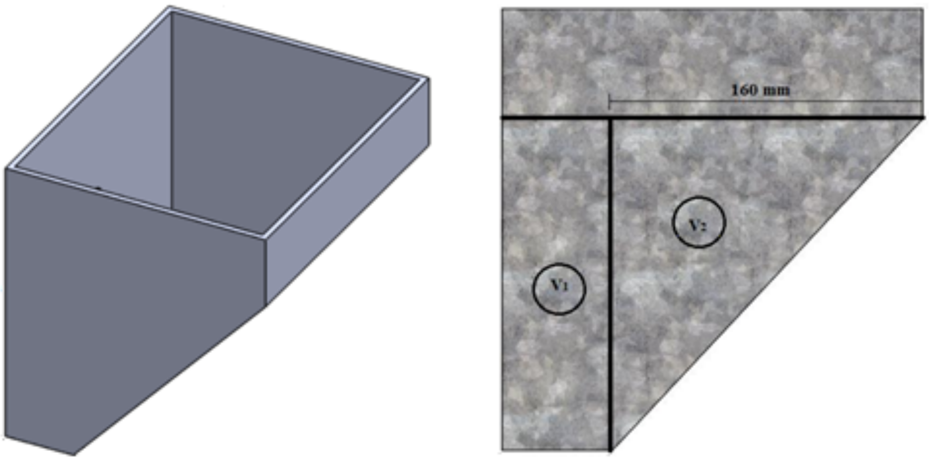
- The hopper material must not react chemically with the seed.
- Hopper material must prevent proliferation of biological contaminants.
- The material in the hopper must not react chemically with the cleaning and disinfectant products.
- The hopper material must be resistant to friction with the food.
- The hopper must be able to store a maximum mass of 4 kg.
- The hopper must support the stipulated weight without deforming.
- The exit angles of the hopper must be sufficiently inclined so that the seed flow is constant towards the doser.

- It can be detached for cleaning and maintenance.
- It can be properly fixed to the dosing machine to ensure constant feeding to it.
- The product must have a constant flow inside the hopper to facilitate its evacuation.

2.2. Design and calculation of the mechanical elements

The design of the machine was carried out using the CAD Solidworks tool, according to the pre-established parameters to satisfy the needs and its correct operation. It should be noted that the final design of the prototype cannot be exhibited because it is subject to a patent process.

2.2.1. Hopper design. The design of the hopper took into account the average number of seeds and the extent of land in which they are sown. The reference data were obtained from farmers of the experimental farm of the Universidad Francisco de Paula Santander seccional Ocaña, where it was determined that per hectare an average of 20 Kg of seeds are sown, which means that per hectare approximately 8900 seeds are sown. To satisfy the required volume, the following dimensions were established for the hopper [8]. Figure 1 shows the Hopper design according number of seeds sown.



(a) (b)

Figure 1. CAD hopper design (Solidworks) (a) general view and (b) slide view

Figure 1 shows the hopper to be used in the sowing of corn and beans seeds with their respective dimensions, for which the volume of seeds that this would contain was calculated according to Equation (1), Equation (2), and Equation (3):

$$V_T = V_1 + V_2 \quad (1)$$

$$V_1 = b * h * L \quad (2)$$

$$V_1 = 212{,}5000\ mm^3$$

$$V_2 = \left(\frac{b*h}{2}\right) * L \quad (3)$$

$$V_2 = 340{,}0000\ mm^3$$

$$V_T = 552{,}5000\ mm^3$$

According to [9], the average size of a seed is about 342 mm^3, having approximately 16,200 seeds, which translates into 3,634.8 g in total, taking into account that a seed weighs 0.225 g [8], which indicates that to sow a hectare is required to supply the hopper about 6 times.

2.2.2. Selection of the cutting tool. To make this selection, the variations in existing types of cutting tools were taken into account, and it was decided to choose the one that best suited the design and met the characteristics of the soil [10]. For this case, and analysing the different types of cutting tools for ploughing, and taking into account the ease of construction and implementation, in addition to the fact that the cost of power applied for its use is low, a straight cutting tool design was selected, starting from the analysis of finite elements carried out by [9]. Figure 2 shows the cutting tool selected, as well as the finite element analysis performed on the tool in order to know its strength.

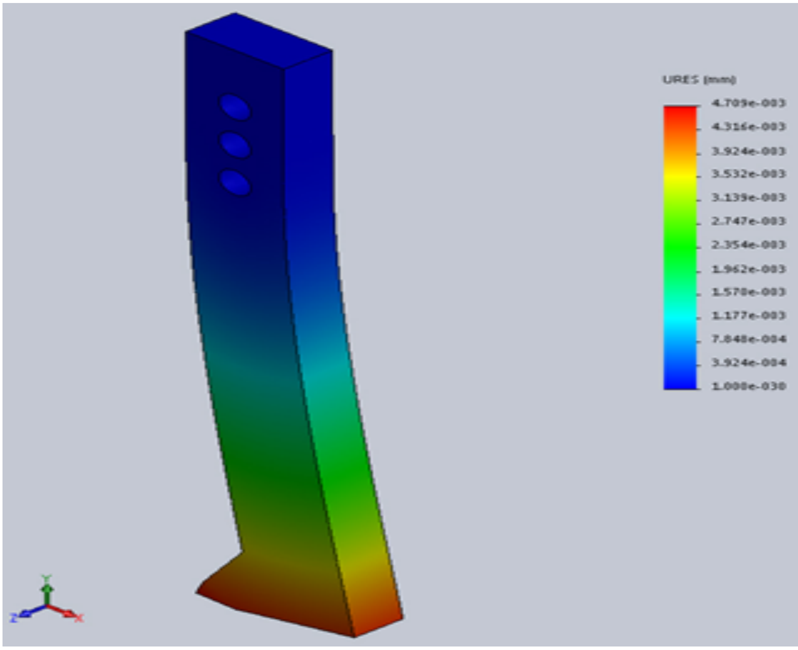


Figure 2. Finite element analysis for the cutting tools in Solidwoks.

The respective calculations were carried out in order to determine the resistance that the soil opposes to the blade, taking as important considerations the average speed of the machine, dimensions of the blade and the coefficient of friction between the soil and the metal that was obtained according to the type of soil. Table 2 shows the types of soil, as well as the coefficient of friction and specific energy of each type of soil [4].

Table 2. Friction of the soil with the material with respect to the type of soil [4].

Soil type	Specific Energy [N/mm^2]	Coefficient of friction
Sandy soils	0.0205947 – 0.0411894	0.21 – 0.42
Loam soil	0.0343245 – 0.0617841	0.35 – 0.63
Clay soils	0.0549192 – 0.0987	0.56 – 1.00

Obtaining from this a soil resistance of 42.14 N, with which the cutting element was designed.

2.2.3. Geometric design of the chassis. To carry out the design of the structure that forms the chassis, several profiles were selected to allow a better fastening of the elements, in addition to representing a lower weight and being conventional in the market, so the appropriate for this design was the plate profile [11].

For this case, the plate will be made of steel, and the shape and dimensions thereof are performed according to the needs, prioritizing an ergonomic design and a size that allows greater maneuverability and efficiency in seeding [12]. Apart from this, the mechanical seeder will have a series of accessories that will ensure its proper functioning, among these we find the guide wheel, located in the front part of the machine and is responsible for guiding the mechanical seeder through the furrow [13]. The covering chain is the element in charge of covering the furrow with soil after the seed has been deposited in order to guarantee its germination. The compacting wheel is pressed against the seed to prevent it from being exposed to the elements. The handlebars are the elements with which the direction of sowing is controlled by the worker. Finally, the system of dosing and distribution of the seed, which is formed by the hopper and the seed duct, works through a system of gears that distributes the seed at an appropriate distance between them to improve the use of land. Figure 3 shows the mechanical seeder with the elements described above.

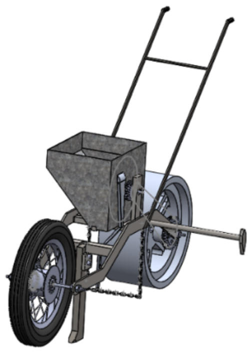


Figure 3. Final design of the mechanical seeder.

3. Analysis and results

By means of Solidworks design, a simulation of finite element analysis was performed on the mechanical elements that make up the mechanical seeder, thus validating the results of the calculations carried out in its design.

Figure 4 shows the displacement analysis performed in the case of the chassis, in which it is observed that the maximum displacement resulting from the forces applied in the prototype is 0.53 mm, a minimum displacement that does not affect the functionality of the process to a great extent.

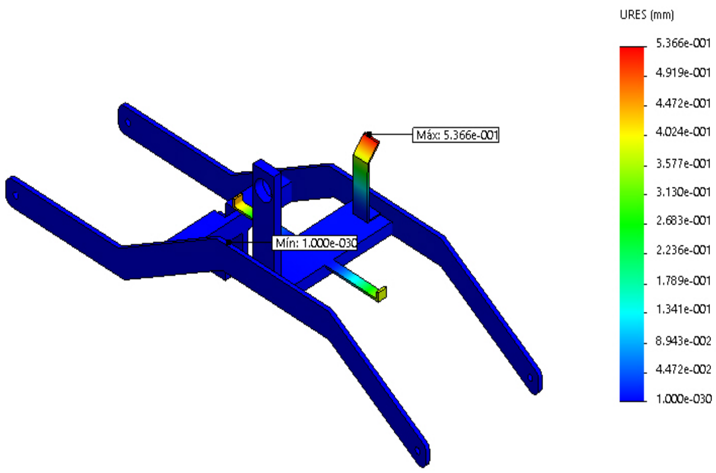
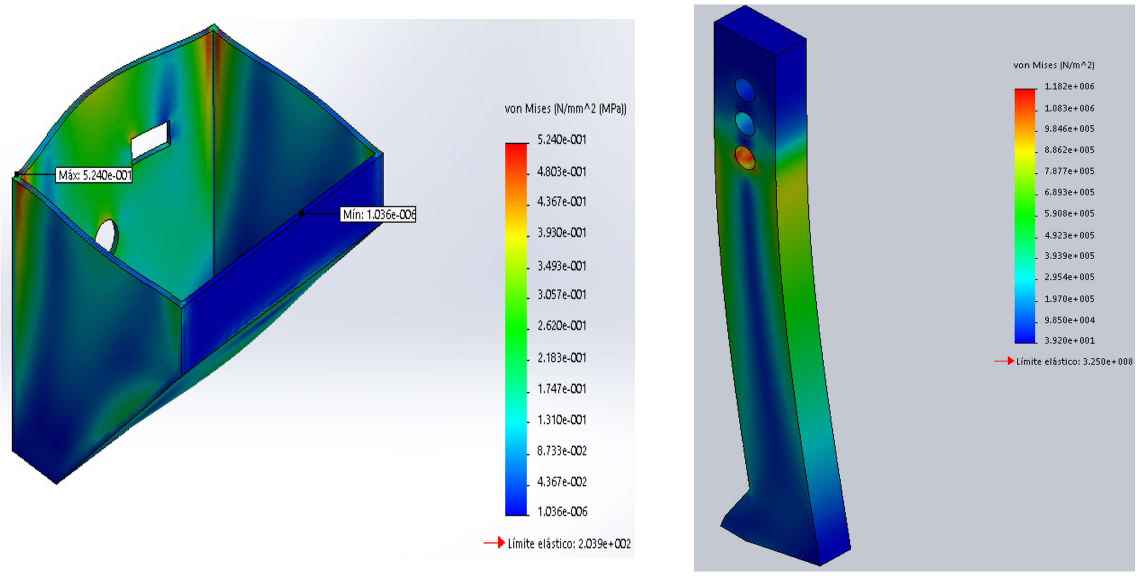


Figure 4. Resulting displacement analysis in Solidworks.

This displacement is due to the deformation, which is the change in size or shape of a body due to internal stresses. As a result, this analysis shows the chassis efficiency to withstand these deformations. For the design of the chassis, an AISI 1010 HR steel material was selected, resisting the 30 Kg, obtaining that the maximum tension does not exceed the elastic limit. Figure 5 shows the Von Mises stress analysis performed both to the cutting tool and to the hopper, obtaining favorable results in both, thus corroborating that the design carried out is optimal and complies with the design characteristics to which it will be subjected.



(a) (b)

Figura 5. Von Mises stress tests (a) Hopper and (b) Cutting tool.

Von Mises stress is a physical magnitude which is proportional to the distortion energy, also known as maximum shear strain energy, which is used in structural engineering in the context of failure as an indicator of good design for the materials, which is reflected in the strength of the materials and their useful life.

4. Conclusions

The machine is designed to meet the characteristics of sowing, working at speeds and distances between seed and furrow that allow greater use of the land, and with the elements that best suit the conditions thereof.

The materials of the designed elements are easily found in the market and are affordable, which represents a greater facility for its construction, prioritizing the cost-benefit relationship.

The cutting tool was designed according to the characteristics of the soils of the region, which facilitates the work of ploughing the land. The cutting tool carries out this work without suffering significant deformations, ensuring a long useful life.

The dosing system designed together with the hopper that contains the seeds to sow, facilitates the distribution of seeds in the soil, avoiding obstruction and breakage of seeds, exploiting the highest number of seeds and avoiding waste of raw material.

The machine has a system to cover the furrows where the seed has been placed, thus preventing external agents from interfering with the sowing process and maximizing the number of plants germinated.

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