University of Puerto Rico
Mayagüez Campus
Mechanical Engineering Department

Project Advance: Fertilizer Machine

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Introduction/ Problem statement

The main goal of this course is to utilize the engineering methodology to create possible solutions to a known and specified problem. This term was dedicated to a plantain farm which had very clear concerns and needed an engineering approach to resolve their needs. In our case we would be working with the fertilizer irrigation system. The main concern of the client is the need of multiple workers to complete a single task. The current process suffers from high set up time and workforce dependency. The main idea is to reduce the quantity of workers needed to spread the fertilizer, creating a device that satisfies the specifications. The device must comply with ease of use and maintenance although the client is open to replace worn out parts after each use if cost is low. Waste reduction and budget must be kept in mind to increase profit to our client without sacrificing the safety. It is very important to understand that safety is one of the main points in design to reduce possible damage to operator, plant and staff on the work area.

Objectives

The current task is prepared to evaluate the actual capacity of fertilizer irrigation system on the plantain farm in Añasco P.R. Throughout the semester, undergrad students from the department of Mechanical engineering will be gathering data and important information about specific problems. Using the engineering method students must propose possible solutions, this ideas must converge to one final model that would accomplish the desired task. To reduce subjective decisions some tools must be used to take optimal direction. The students must eliminate secondary options using decisions matrix and classification matrix. After the final decision is made an engineering analysis must be made to evaluate the viability of the device. Finally students must provide a Bill of Materials(BOM) and detail explanation of what would be do for the manufacturing process.

Current Situation

In Puerto Rico, the availability of the workforce for agriculture has been a problem in recent years. Currently the process of fertilizer irrigation takes a long time (one day), labor and is done completely manually. To fertilize a certain amount of plants, is necessary to distribute the fertilizer bags along the land and then a group of people goes plant by plant, fertilizing each one of them. This process requires a lot of effort by the workers and there is no control over the quantity of material (4 ounces to half a pound) that is added to each plant.To resolve this situation from the engineering point of view, a series of investigations and experimental processes will be carried out to acquire data and thus be able to provide solutions. Some steps of this process are:

Recollect information from the farmer

The plantain farm in Anasco have approximately 1000 plants sown per acres. Every plant has a distance of four feet between each other, and their height varies from six inches to fifteen feet. The first time that the plant is fertilized is about a month and a half after is planted. The quantity of fertilizer will depend of the time planted and the height of the plant. For a little plant the quantity is about four ounces and for a bigger plant is about half of a pound.

Analyze the resources of the farm: Tractor

Since in the market nothing meets the specifications and the budget, a new product was design. The motivation for the design of the fertilizer machine, was to design a product that can be attached to the tractor and in the same time meet the specifications mentioned before. The purpose of integrate the tractor is to do more in a less time. Since the farming industry have a deficit in workforce, the use a tractor allows to use only one employee to do the job. Also, the tractor can load a major quantity of fertilizer, accelerating the process.

Watch videos on Youtube to generate ideas

These two videos help in the process of generate ideas given that are products that are already in the market and in current use.

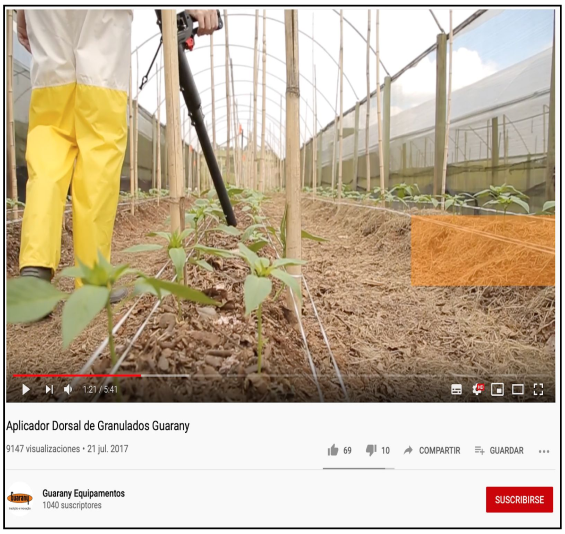


Figure 1: "Aplicador Dorsal de Granulador Guarany"

Figure 2:"Aplicador de Fertilizante Manual"

Both products of the videos have some advantages that served as inspiration for the design of the fertilizer machine. One of the advantages is the method to storage the fertilizer, given that is like a backpack and easy to carriage. To the fertilizer machine, a backpack is not considerable but bring the idea to use something that is compact and easy to implement to the tractor. The other advantage is the guide tubes because the precision to drop the fertilizer is greater and prevent the reduce the waste of fertilizer. This is important in the design of the fertilizer machine given than if the waste of fertilizer are reduce, less sacks of fertilizer has to be bought and will bean economic impact to the farmer.

Visit stores and see fertilizer machines

The fertilizer machine analyzed and used in the store was the "Turf Builder EdgeGuard Mini Broadcast Spreader". The advantage of this machine that have a mechanism that allow to drop different quantities of fertilizer. This specification is important to the design of the fertilizer machine given that the plantains planted need different quantities of fertilizer like mentioned before**.**

Figure 3: Turf Builder EdgeGuard Mini Broadcast Spreader

Methodology

Functional Decomposition for Complex Systems: Classification Matrix

The functional decomposition for complex systems is a tool that helps to analyze a series of functions or concepts individually. The Classification Matrix for the Fertilizer Machine is given below, where 4 functions like Intermittent flow, Volume, Final Material Deposit and Storage tank was presented with some concepts.

	CONCEPT 1	**CONCEPT 2**	**CONCEPT 3**	**CONCEPT 4**
FUNCTION A Intermittent flow	Microcontrolador	Sliding gate	Rotating plate	Plant as Actuator
FUNCTION B Volume Control	eTimer O/C	Fixed qty cup	Mechanical Timing	
FUNCTION C Final Material Deposit	Ramp	Nozzle	PVC tube	Free Fall
FUNCTION D Storage tank (Hopper)	Re use Condorito	Cone Hopper	Rectangular Hopper	

Table 1: Functional Decomposition for Complex Systems: Classification Matrix

Concepts

To the research to selected the best idea, three concepts with alternatives design was create:

Concept A: Chain Mechanism

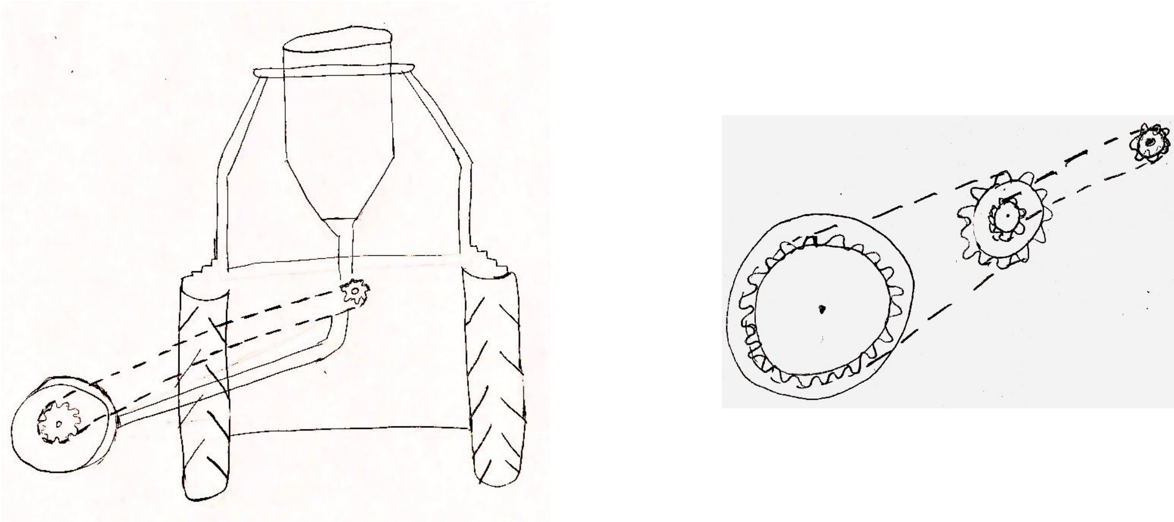


Figure 4: Sketches of the Chain Mechanism

Figure 5: Condorito Hooper

In this concept, the Condorito Hooper will be connected to the rotating wheel. Also, will have a chain from PTO with proper sprocket velocity reduction to spin the wheel to the desire material output rate. The fertilizer will be distributed using PVC Tubes.

Concept B: Sliding Gate

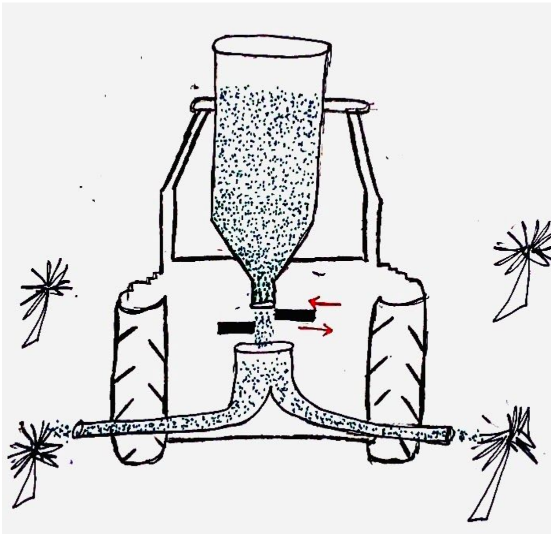
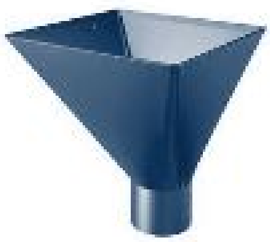


Figure 6: Sketch of the Sliding Gate Concept



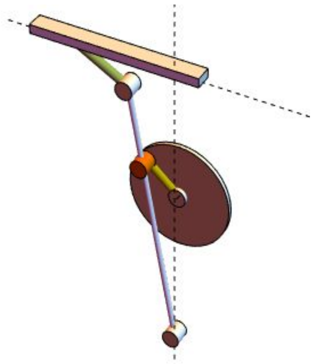
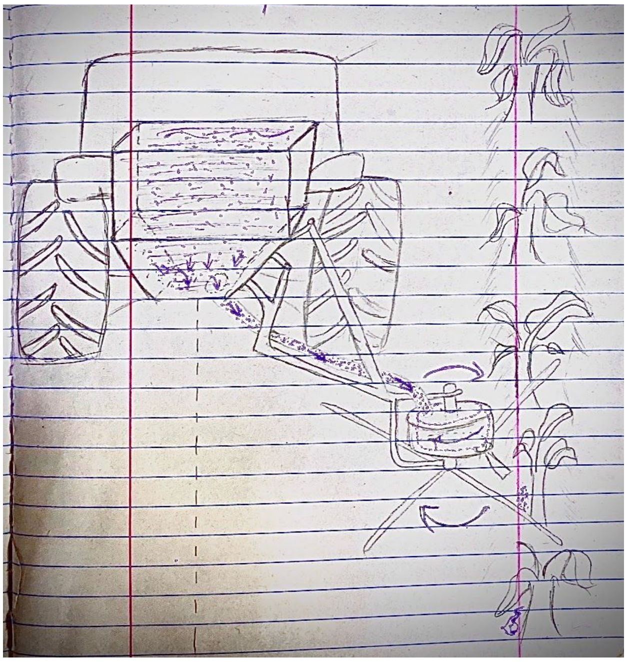


Figure 7: Hopper use in this concept **Figure 8:** Mechanism of the sliding gate

In this concept, a rotation to linear motion mechanism will be attached to PTO with proper gear velocity reduction to control the gate. The ideal hooper to the concept is a aftermarket steel hopper shown in Figure[7]. A inverted “Y” shape guides made from PVC pipes at a desired inclination will be attached to the gate.

Concept C: Plant Actuator



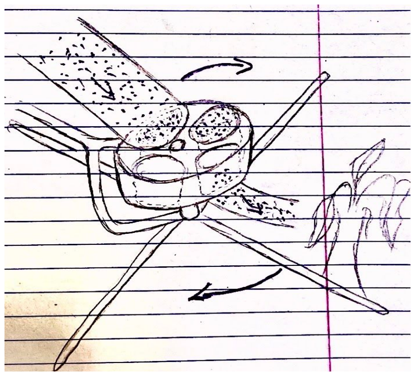


Figure 9: Sketches of the Plant Actuator

In this concept, a aftermarket hooper will be attached to a Y shaped guides tubes made from PVC leading to the horizontal rotating wheel. The wheels will be controlled by a rotational force created by contact from guidelines and plants as the tractor moves forward. The final material will be position by a small minimal ramp. The PTO will be neglected in this operation.

Decision Matrix

The decision matrix was used to choose the best concept to the fertilizer machine. The three concepts previously mentioned were analyzed with some evaluation criteria. The evaluation criteria were cost, automated, safety, reliability and simple design. Giving points to the concepts where 0 is the lowest score and 10 the highest, the best concept was selected. In this case, the concept with a higher punctuation was the Plant Actuator with a total of 6.2.

		Concept A Chain mechanism		**Concept B Sliding gate**		**Concept C Plant actuator**	
Evaluation Criteria	**Wt**	**Val_1**	**Wt x Val_1**	**Val_2**	**Wt x Val_2**	**Val_3**	**Wt x Val_3**
Cost	.15	5	0.75	3	0.45	6	0.9

Automated	.25	5	1.25	5	1.25	4	1.00
Safety	.20	2	0.4	6	1.2	7	1.4
Reliability	.25	4	1	5.5	1.375	8	2
Simple Design	.15	5	0.75	4	0.6	6	0.90
Totals	1.0		**4.14**		**4.875**		**6.2**

Table 2: Decision Matrix for the Fertilizer Machine

Detailed Analysis

The design process was divided in a series of steps to ensure organization and coherence. In this part of the document students will be presenting the entire engineering method used to create the solution for the client. The division of the steps will start with the calculations and diagram necessary to explain the critical thinking, following with the Computer Aided Design of the model with dimensions to show what would be the final product of the mechanism and finally the Bill of Material and fabrication estimation. The calculation steps are:

Arm Maximum Angular Position

In order to find the maximum and minimum angles that the mechanism arm can reach a iterative program was made using Microsoft Excel.The main basis of this program is the Pythagorean Theorem. Basically two(2) impact points were established, the first at 10 inches from the pivot point and the second at 15 inches. Each impact point combined with the arm length(18 inches) and a distance traveled by the plant form a triangle (see Figure 10). Using the Pythagorean Theorem the program calculate the hypotenuse length. One side of the triangle in a fixed length(impact distance) and the other side(variable side) is changing its length 0.5 inches each iteration (blue dots in figure 4). Once that calculation of the hypotenuse exceeds the arm length, in this case 18 inches, means that at that distance the arm has its maximum angle and occurs at that distance of the variable side.The angle is also given by the program and is calculated using the inverse tangent formula. This procedure is done for both impact distances(10 and 15 inches). The maximum angle obtained for the impact distance mentioned above are 56° for the impact at 10 inches and 33.69° for the 15 inches impact.

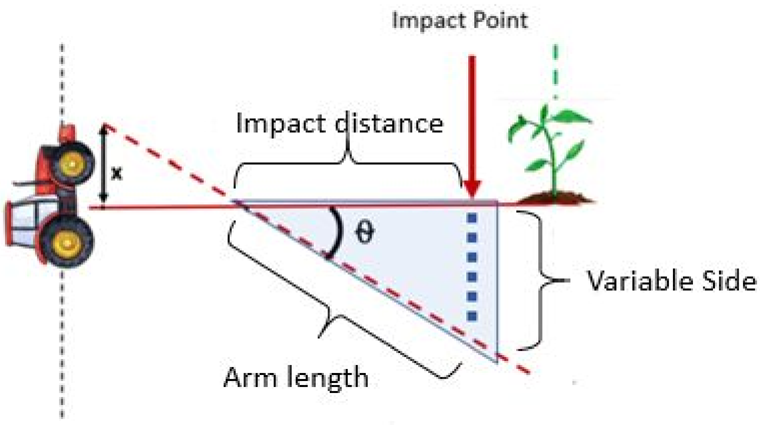


Figure 10: Angular Position Method Diagram

Impact Force

To calculate the impact force at the plant it is important to understand conservation, for that reason work is equal to the change in in momentum or kinetic energy. Since the movement is horizontal potential energy is not considered and friction force is neglected when compared to spring and impact force. The initial velocity of the arm is assumed equal to the tractor velocity and terminal velocity is considered zero after impact an just before returning. Figure 5 shows the movement of the tractor where the red line is the initial position before impact of the arm and the intermittent line is the second position after impact.

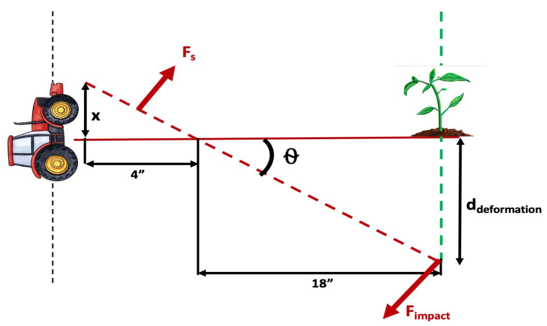


Figure 11: Movement of tractor and arm before and after impact

The materials selected for the build are chosen to be of easy access maintaining the lowest weight possible to reduce impact force suffered by the plant. From NX siemens the weight of each part of the mechanism contributing to impact was analyzed, resulting in a mass of .30 lb for the PVC arm .50 lb for the housing and spindel and .03 lb of solder. Mcmaster supplier offered the necessary information to understand that these material will surpass the test of cycles and time.

From the calculations made in Excel for operational impact area at 10 in and 15 in, it was observed that for impact at 10 in resulted in a deformation of 1.25 ft and angle of 56 degrees inversely for impact at 15 in resulted in a deformation of .83 ft and a angle of 36.6 degrees. It is safe to say assume that the impact force at 15 in will be greater since it would have less deformation to absorb force. The equation used to calculate impact force was [4], this equation was a result of the combination of equation [1] and [2] satisfying conservation.

$$Work = F \times d$$ **Equation [1]:** For work

$$Kinetic\ Energy\ (KE) = \frac{1}{2}mv^2$$ **Equation [2]:** For Kinetic energy

$$W = \Delta KE$$ **Equation [3]:** For Conservation

$$F_{impact} = \frac{1}{2}\frac{mv^2}{d_{deformation}}$$ **Equation [4]:** For impact Calculation

$$F_{impact\ @10"} = \frac{1}{2} \times \frac{0.83lb \times (2.93\frac{ft}{s})^2}{1.25\,ft} = 2.85\ \ lb \times \frac{ft}{s^2} = 2.85\ lbf$$

$$F_{impact\ @15"} = \frac{1}{2} \times \frac{0.83lb \times (2.93\frac{ft}{s})^2}{0.83\,ft} = 4.29\ \ lb \times \frac{ft}{s^2} = 4.29\ lbf$$

For both cases the force is under the 7 lbf that would be the maximum force the plant would resist, this means that the mechanism satisfy specifications. Also being under on all the operational area will ensure safety of the plant if the tractor operator slightly increases velocity by error.

Spring Force

To find the force exerted on the spring a moment sumatory was done on the arm since the impact force would be absorbed by the spring. It is assumed that the force at 15 in will create a larger force on the spring because it has a larger distance to create moment. The force on the spring will be transmitted with a ratio hence pivot provides a shorter length to the spring mount.

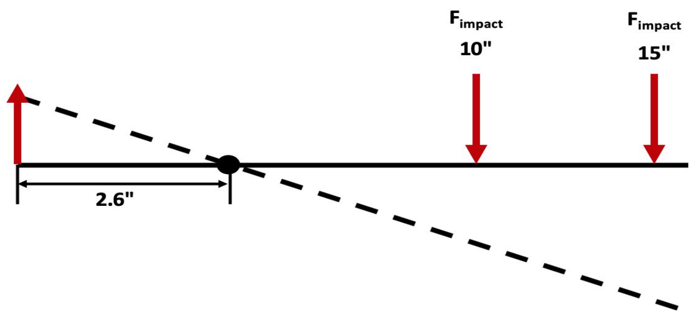


Figure 12: Diagram of forces for the arm

$$\Sigma M = 0$$
$$F_{s\,@15"} \times 2.6" = F_{imp@15"} \times 15"$$
$$F_{s\,@15"} = 4.29lbf \times \frac{15"}{2.6"}$$
$$F_{s\,@15"} = 24.75\ lbf$$

$$\Sigma M = 0$$
$$F_{s\,@10"} \times 2.6" = F_{imp@10"} \times 10"$$
$$F_{s\,@10"} = 2.85lbf \times \frac{10"}{2.6"}$$
$$F_{s\,@10"} = 10.96\ lbf$$

Spring Deformation

To choose the correct spring one must know the amount of deformation of the spring, the method use for this was rectangle triangles with the angles at impact for 10 in and 15 in and with a hypotenuse of 2.6 in that is the distance from the pivot to the spring location. It was observed that the closer a impact is to the pivot the greater would be the deformation.

Hypotenuse= 2.6”	ϑ=56° when the impact is at 10”	ϑ=33.69° when the impact is at 15”

Table 3: Data to calculate the spring deformation

$x @ 10 = (sen(56)) \times (2.6in)$ $\quad$ $x @ 15 = (sen(33.69)) \times (2.6in)$

$x @ 10 = 2.16\ in$ $\quad$ $x @ 15 = 1.44\ in$

Spring Constant

To calculate spring constant the equation [5] was used for both operational impact area, using the spring force and deformation previously calculated.

$$F = kx$$ **Equation [5] :** Hooke's Law

$$k_{@\ 10"} = \frac{10.96\ lbf}{2.16\ in} = 5.07 \frac{lbf}{in} \qquad k_{@\ 15"} = \frac{24.75\ lbf}{1.44\ in} = 17.18 \frac{lbf}{in}$$

Spring Selection

To make a selection of a spring it is important to mention some of the requirements that must be taken in consideration. the before stated refers to:

- It must support max force of 24.75 lbf without plastic deformation.
- Also it must be able to deforme 2.16 inch for many cycles.
- Finally the constant of the Spring must be under the value of 5.07 lbf/in.
- After research was done it was found on Mcmaster a spring that would best satisfy our requirements. Spring part number: 94135K38.

Force on the sliding door

The density of the fertilizer is not specific in any specifications of the product (K-fol). Since the components of the fertilizer are phosphorus, potassium, magnesium, sulfur and boron, the density of the fertilizer is approximated 110.704 lb/ft^3. The process to calculate the density is shown in Table 4. The percent of each component in the fertilizer was multiplied by the density of the component, the density of the fertilizer is the sum of this multiplications.

Component	% of Component in the fertilizer	Density of the component	$\rho \times \%$
K_2O	55%	$2.35\ \frac{g}{cm^3} = 146.71\ \frac{lb}{ft^3}$	$80.69\frac{lb}{ft^3}$
P_2O_5	20%	$2.39\ \frac{g}{cm^3} =\ 149.20\ \frac{lb}{ft^3}$	$29.84\frac{lb}{ft^3}$
Mg	0.0660%	$1.74\ \frac{g}{cm^3} = 108.64\frac{lb}{ft^3}$	$0.07\ \frac{lb}{ft^3}$
S	0.0800%	$2.067\ \frac{g}{cm^3} = 129.04\ \frac{lb}{ft^3}$	$0.10\frac{lb}{ft^3}$
		Total of $(\rho \times \%)$	$110.70\frac{lb}{ft^3}$

Table 4: Calculations for the gravity of the fertilizer

The force applied on the sliding door is caused for the pressure of the fertilizer across the components of hopper, elbow and PVC Tube. In this case, every component was analyzed separately. The first component to be analyze was the hopper [Figure 13].

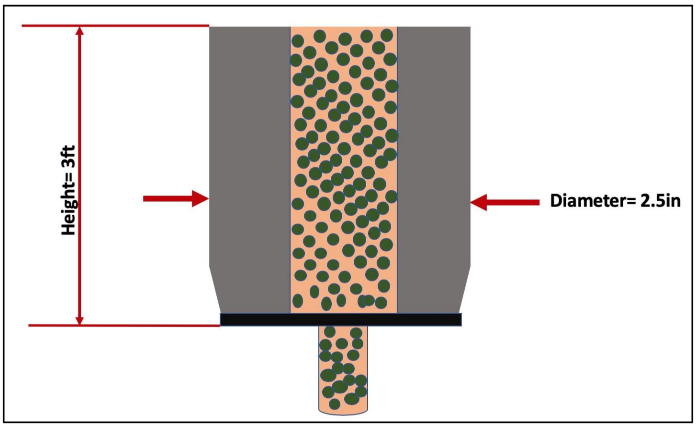


Figure 13: Diagram of the hopper in the analysis of force of pressure

The hopper is connected to a PVC tube of a diameter of 1.5in. For this reason, the force in the sliding door will be caused for the pressure of fertilizer located above the exit of the hopper. To better analysis and for the worst scenario, the force was analyzed in a diameter of 2.5in. The formula used to calculate the pressure was Equation 6 , where force is equal to the weight of the fertilizer.

$$Pressure = \frac{Force}{Area} \qquad \textbf{Equation [6]}$$

Given the Second Law of Newton, weight is equal to mass per gravity Equation [7]. Since the mass of the fertilizer is unknown, mass was substitute for density applied in terms of mass Equation [8]. Then, applying the equation of volume of cylinder Equation [9] was applied in the formula of density. Finally the pressure was calculated using Equation [10], where density is equal to 110.70, height of the cylinder 3 ft and gravity $32.2\frac{ft}{s^2}$.

$$F_{weight} = mass_{fertilizer} \times gravity$$ **Equation [7]**

$$mass_{cylinder} = \rho \times Volume_{cylinder}$$ **Equation [8]**

$$Volume_{cylinder} = Area \times height_{cylinder}$$ **Equation [9]**

$$P = \frac{(\rho V) \times (Area \times height)}{Area}$$

$$Pressure_{hopper} = \rho \times height_{cylinder} \times gravity$$ **Equation [10]**

$$Pressure_{hopper} = 110.70\frac{lb}{ft^3} \times 3ft \times 32.2\frac{ft}{s^2}$$

$$Pressure_{hopper} = 10,693.62\frac{lb}{ft-sec^2}$$

To calculate the force Equation [11] was used, but in this case analyzing the perpendicular area of the tube. The calculation of the area is given by equation [12], where diameter is equal to 2.5 in(0.2083ft). Finally the force in the sliding door caused by the hopper is equal to 11.29 lbf.

$$F_{hopper} = Pressure \times Area$$ **Equation [11]**

$$Area = \frac{\pi \times d^2}{4} = \frac{\pi}{4} \times (0.2083ft)^2 = 0.034ft^2$$ **Equation [12]**

$$F_{hopper} = 10,693.62 \times 0.034ft^2 = 11.29\ lbf$$

The second component analyzed was the 45° elbow above the tube of the hopper. A diagram of the analysis is given by Figure 14. Since the elbow have an angle of 45°, the resultant of force was calculated using the value of F_{hopper} at the specific angle. Using Equation [13], Equation [14] and Equation [15], the force of hopper-elbow is 8.64lbf.

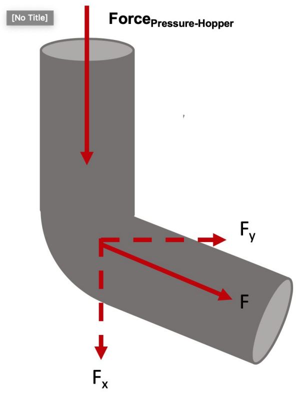


Figure 14: Diagram of the analysis of 45deg elbow

$$R_x = F_{hopper} \times (1 - cos(45 \circ))$$ **Equation[13]**

$$R_x = 11.29lbf \times (1 - cos(45 \circ)) = 3.31lbf$$

$$R_y = F_{hopper} \times (sen(45 \circ))$$ **Equation[14]**

$$R_y = 11.29lbf \times sen(45 \circ) = 7.98lbf$$

$$F_{hopper-elbow} = \sqrt{(R_x)^2 + (R_y)^2}$$ **Equation[15]**

$$F_{hopper-elbow} = \sqrt{(3.31)^2 + (7.98)^2} = 8.64lbf$$

The third and last component analyzed was the PVC tube with the sliding door in the end. It is important to mention that the quantity of fertilizer that the plants need will influence in the selection of the diameter. Since the small plants need 4 ounces of fertilizer, a small diameter will be helpful. In the other hand, the bigger plants need approximately more fertilizer and a large diameter to drop the fertilizer. Since the the sliding door will be variable and adjusted to an specific diameter, the force was calculated in Excel varying the diameter. The equation used for calculated the pressure is Equation[16], where in this case height is equal to 3sen(45) because the tube is in an angle of 45 degrees. Solving the equation, the pressure is equal to $7561.53\frac{lb}{ft-sec^2}$. This equation can be calculated without varying the diameter because the pressure does not depend of the diameter. Then, using Excel the force in the PVC Tube was calculated using Equation[17] and varying the diameter. Finally, the total force in the sliding door is calculated using equation[18] A diagram of this analysis is given by Figure[15] and the Table[5] with the values of Total Force.

$$Pressure_{PVC\ Tube} = \rho \times gravity \times height_{PVC\ Tube}$$ **Equation[16]**

$$Pressure_{PVC\ Tube} = 110.70\frac{lb}{ft^3} \times 32.2\frac{ft}{s^2} \times 3\ sen(45) = 7561.53\frac{lb}{ft-sec^2}$$

$$Force_{\ PVC\ Tube} = Pressure_{PVC\ Tube} \times Area$$

$$Force_{\ PVC\ Tube} = Pressure_{PVC\ Tube} \times \frac{\pi}{4} \times d^2$$ **Equation[17]**

$$Force_{sliding\ door} = F_{\ hopper-elbow} + Force_{PVC\ Tube}$$ **Equation[18]**

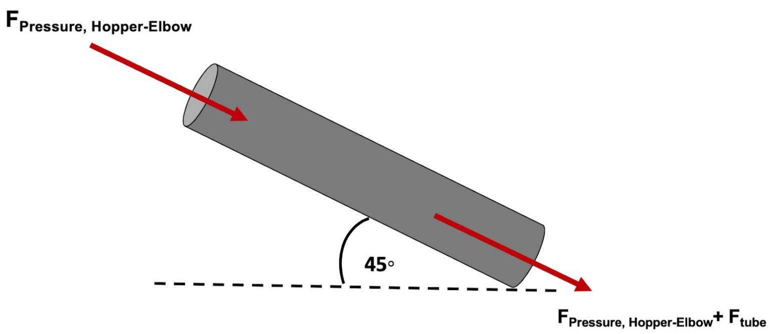


Figure 15: Diagram of the analysis of the PVC Tube and Sliding Door

d [in]	d [ft]	Area [ft^2]	$Force_{Total}$ [lbf]
0.05	0.0042	1.36E-05	8.65
0.1	0.0083	5.45E-05	8.65
0.15	0.0125	0.000123	8.67
0.2	0.0167	0.000218	8.69
0.25	0.0208	0.000341	8.72

0.3	0.025	0.000491	8.76
0.35	0.0292	0.000668	8.80
0.4	0.0333	0.000873	8.85
0.45	0.0375	0.001104	8.90
0.5	0.0417	0.001364	8.96
0.55	0.0458	0.00165	9.03
0.6	0.05	0.001963	9.10
0.65	0.0542	0.002304	9.18
0.7	0.0583	0.002673	9.27
0.75	0.0625	0.003068	9.36
0.8	0.0667	0.003491	9.46
0.85	0.0708	0.003941	9.57
0.9	0.075	0.004418	9.68
0.95	0.0792	0.004922	9.80
1	0.0833	0.005454	9.92

Table 5: Excel sheet with the calculations of the total force in the sliding door varying the diameter

Fertilizing Process Optimization

Based on the data acquired from the client about the actual fertilization process the implementation of this mechanism can quantified to have an overview of how the labor time will be impacted. In order to do these calculations the following assumption were made:

- For the actual process, 5,500 plant were fertilized in 8 hours shift.
- Tractor speed of 2 MPH
- No Fertilizer refilling time
- Tractor U Turn needed to start the next line of plant was neglected
- Each plantation Line have 132 plants every four(4) feets
- All plants impact the arm at the 10” inches mark (0.43 second opened)

Actual process:

5,500 plants $\frac{5{,}500\ plants}{8\ hours\ \frac{60\ min}{1\ hours}} = 11.45\ plants/min$

Actual process requires more than one(1) person.

Process With implement mechanism:

Total distance traveled by the tractor:132 plant at 4 feet each one =528 feets long

Using tractor speed: 2MPH=2.93 ft/s

Total Time for one line of plant= $\frac{528\,ft}{2.93\,ft/s} = 180\ seconds$, the tractor need to go for each side o f the plant , then the time is doubled, Total Time=360 seconds(6 minutes)

$\frac{132\ plants}{6\ min} = 22\ plants/min$

The fertilization Process with the mechanism implemented have a reduction of 48% in the labor time. The process that currently takes 8 hours to do with more than one person, can now be done with only one person in 4 hours and 10 minutes.

Prototype Build Plan

In order to have a better perspective of the mechanisms operation, the team decided to make the first version of a prototype. In this version, most of the components have real dimensions but are made of alternative materials according to the availability at the time of manufacturing. In the case of spring, it does not have the specifications required by the design because it was purchased from a local general hardware store. However, a soft spring with enough deformation was chosen, which is what is needed for the mechanism.

List of material used for the prototype version 1.0:

- ⅛ PVC panel(1)
- 3 ft long PVC Pipe of 1.25" diameter(1)
- 45 degrees PVC elbow(1)
- Recycled plastic bottle(hopper)
- Hot Glue
- Spring

Figure 16: Prototype side view

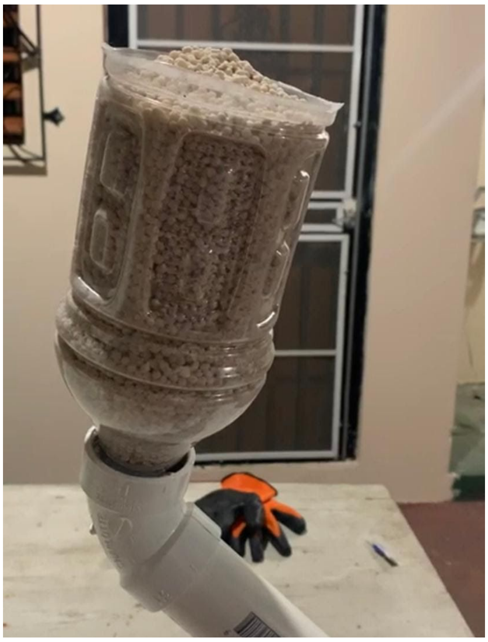


Figure 17: Plastic bottle used as Hopper

Figure 18: Prototype mechanism Top View

Calibration

Why calibration is necessary?

The Fertilizer machine consist on several moving parts being gate, arm, sliding door and ramp which operates at different parameters. The before mentioned is necessary to place the necessary amount of fertilizer in a desired area. A system composed of several parts can suffer and be affected by error occurring from fabrication tolerances and external influences including:

- Incorrect angle of ramp
- Distance for the ramp deposit
- Errors on the opening of the sliding door

These possible errors can be eliminated or reduce with relative ease by creating a calibration process and corrections. The calibration can be done to a prototype to ensure that all the data gathered is optimal, after the final built is done one must calibrate such mechanism and must verify parameters prior to use.

Requirements

- Deposit two (2) ounces of fertilizer for small plants.
- Deposit four (4) ounces of fertilizer for adult plants.

Process

To calibrate the mechanism the next steps must be taken in consideration:

1. The gate was estimated to be open 0.43 seconds(s) when the input or arm was impacted at 10 in and 0.28 seconds when impacted at 15 in this must be experimentally check with a prototype since this will be the base for all other calibrations.

2. The opening of the sliding door must be determine to ensure the fertilizer release is sufficient to satisfy requirements limiting the opening of the 2 inch tube. This is done by opening the sliding door starting from a closed position and taking samples of the quantity released by operating the mechanism. The process must be repeated incrementing the opening into required amount of fertilizer is deposit.

3. Currently the ramp is 6 inch long, that length must be tested observing that the deposit falls under the plant leaves area. The accepted distance is the circumference of the plants leaves, in the case of the small plants is around 18 in. This step is most important for small plants, considering to maintain the ramp as short as possible to prevent material or parts from poking or hurting the plants.

4. The ramp is design to be at a 45 degree angle, this angle seems to be appropriate and can be modified by loosening the bolt 14 and rotating to desired angle. This angle can determine the final position were the fertilizer is deposit.

5. All other components of the mechanism are design to be fixed or anchor at a specific location for that reason it would not require calibration only occasional inspection.

Calibration measurements

It is recommended to take around 30 to 40 measurements to be able to provide a complete analysis. Each measurements should be taken under different conditions simulating operational parameters to obtain a large distribution of data covering all possibilities. The before stated will offer the data necessary to create the optimum final calibration.

Fabrication

Base

A top view of the base is shown in the figure [19]. The numbers represent the principal components and are explained with more detail below.

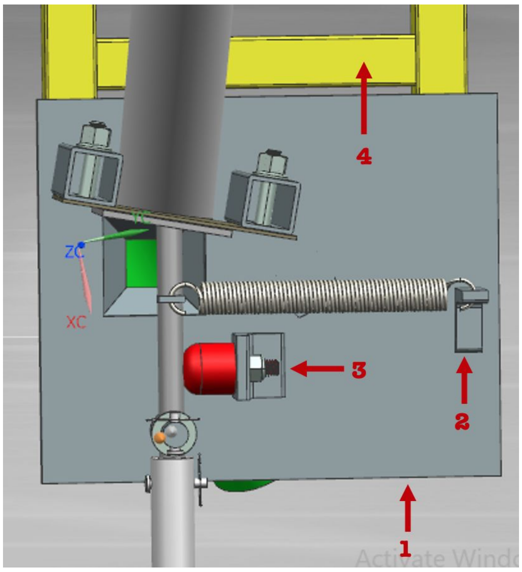


Figure 19a: Top view of the base of the mechanism

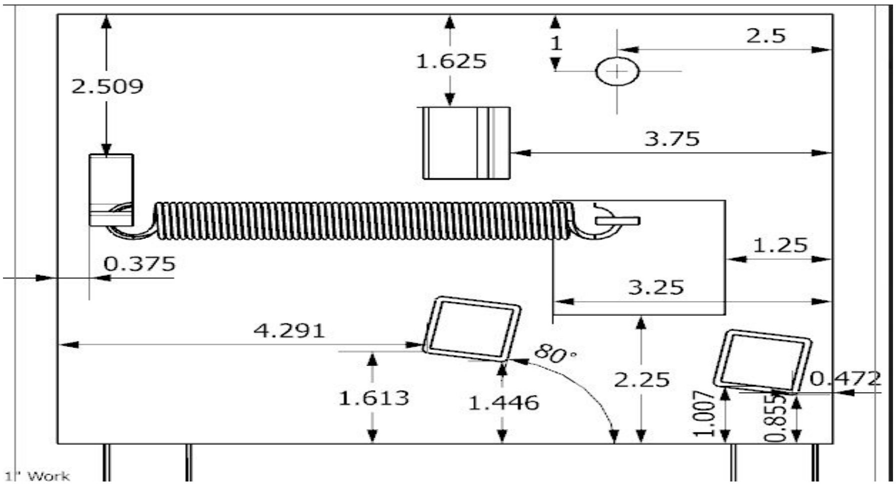


Figure 19b: Top view of the base sketch

- The plate of the base [1] is a sheet of a thickness of ¼”. The dimensions of the plate are 9” long and 7.5” width.
- Two steel angles must be weld to the plate. One of the angles is for the support of the spring and the other is for the bumper to resist impact. The angle of the spring [2] have a length of ½” and the angle of the bumper [3] 1.25”.
- The supports [4] of the base are 3 tubes of dimensions of 1”x1”. This dimensions of this tubes will depend of the mounts of the tractor. This supports will be welded to the base.

Activation Arm

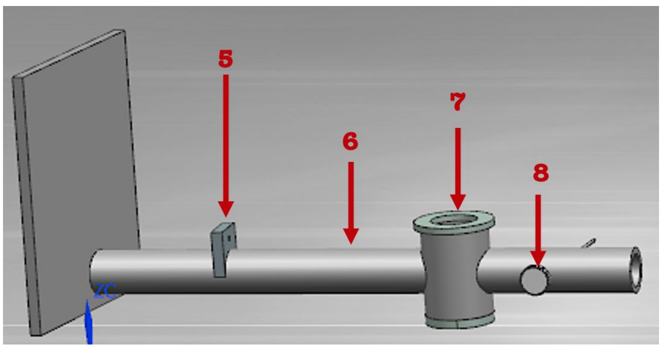


Figure 20: Isometric view of the activation arm from the gate to the pivot

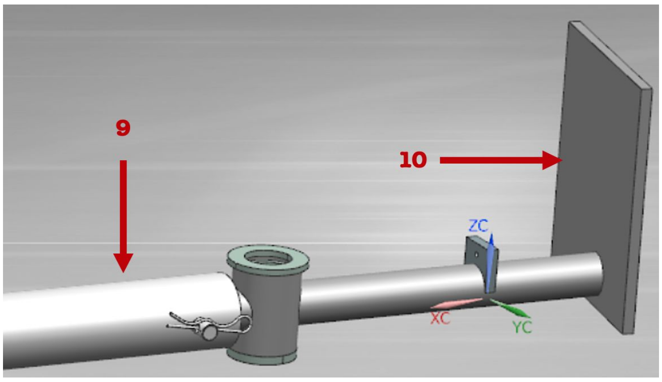


Figure 21: Isometric view of the activation arm from the pivot to the arm

- For the fabrication of the impact arm, an Alloy tube [6] of a diameter of ½" have to be cut to a length of 4" and 2". The tube with the length of 4" will be welded to the gate and the one of 2" will be welded to the tube of the pivot.
- A spring mount [5] must be welded to the tube of ½" . This mount have a diameter of ¼".
- The components of the pivot [7] are a bearing, a washer, the tube and a pin to hold everything in place.
- For the fabrication of the impact tube, a PVC Tube [9] of an inner diameter of ½" and outer diameter o ¾" must be used. The tube have to be cut to a length of 18 inches. This tube will be inserted in the Alloy tube that is welded to a side of the pivot and have a length of 2". A pin [8] have to be used in this arm to secured the components.

Ramp

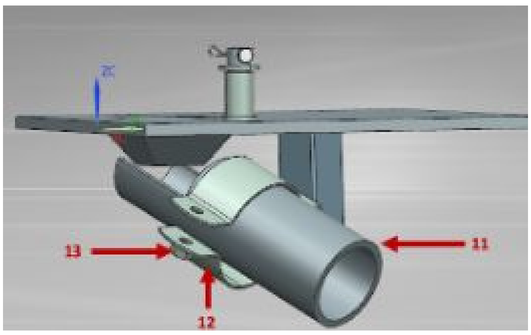


Figure 22: View of the ramp from a lower front perspective

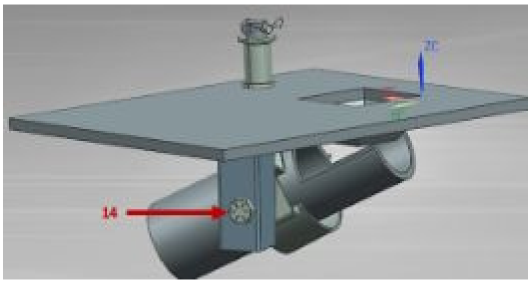


Figure 23: View of the ramp from a lower back perspective

- The fabrication for the ramp a 2 " PVC pipe is used and cut to a length of 6 ".
- A notch must be made at 2 " from one end of the pipe cutting the pipe at a 90 degree angle until 1" of depth is reached. After this is done a perpendicular cut is done finalizing the ramp called 11 in figure [22].
- To secure the ramp a clamp must be attached to the base using [Grade 8 Steel, 5/16"-18 Thread, 1.5" Long called 14 in figure[23], bolt and nut [5/16"-18 Grade 8]
- After the clamp is secured at the desired angle using bolt 14 the ramp is placed in clamp and tighten in place with [¼”-20x1.5”] bolt. [bolt and nut is provided with clamp]

Sliding Gate

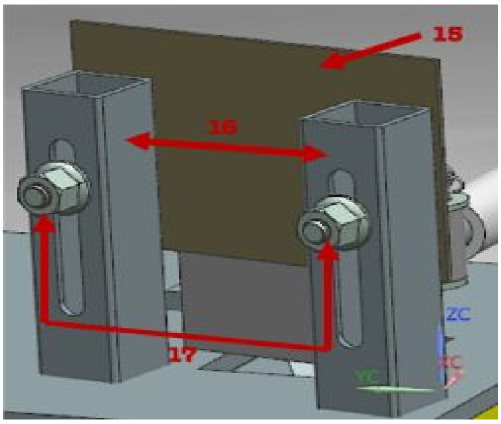


Figure 24: View of the sliding gate assembly from a back perspective

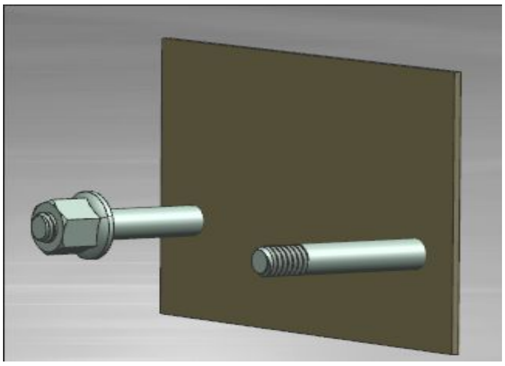


Figure 25: View of the sliding door with welded studs from a back perspective

- To secure the sliding gate, a mount must be done using slotted 1" x 1" tubes welded to the main base in the specified location at figure[24] and [25].
- Such pipes require a notch to provide movement for the plate observed on figure [24] with number 16.
- The sliding gate is made from $\frac{1}{16}$ " steel with dimensions of 2.5" x 2.875" plate, two [M8x1.25mm-40mm] long steel stud must be welded to plate shown in figure[25].
- Once the before mention is fabricated the plate must intersect the 1 in base and secured with anti vibrations nuts at desired opening.

Final Assembly

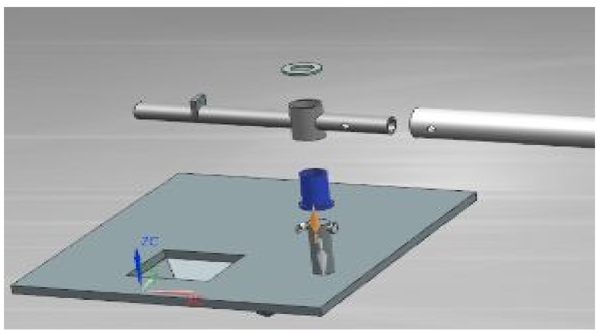


Figure 26: View of the activation arm assembly

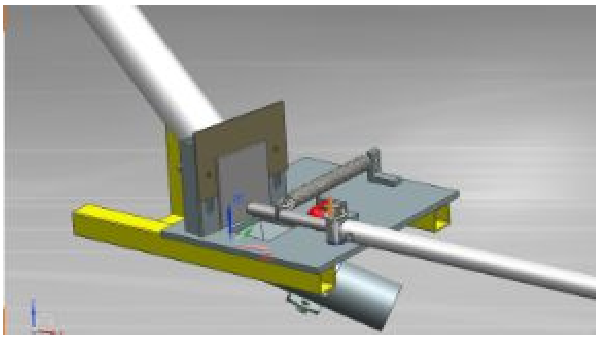


Figure 27: View of the final assembly

- The assembly is divided into a set components for ease of manufacture, after the explanations of the before mention a complete assembly must be done including minor and fixed components.
- The base plate is where all other components will be place in there final state.
- First set of components that need to be attached is the sliding gate components including securing plate as mention in that section.
- It would be convenient to install the activation arm as this time to ensure a adequate fit with the sliding gate, it is important to attach the anti friction sleeve on the shaft before arm. After the arm is placed a washer is position and pin to hold everything in place. To complete the arm the PVC part is press fitted and secured with a pin.(everything mention can be observed in figure[26]).
- To finish all top placed parts the minor components must be placed including bump stop and spring. The bump stop is placed in L bracket secured with a nut shown in figure [27]. In regards of the spring is slided into the anchor points shown in figure [27], such spring is hold in place by tension.
- Once the top side is finish the lower components can be added as explained in the ramp section.

Bill of Materials

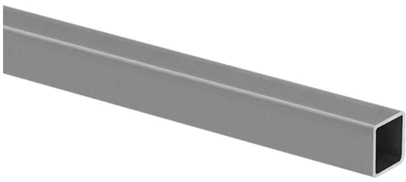
Base

Low-Carbon Steel Sheet
https://www.mcmaster.com/6544k24

• Material: Low Carbon Steel • Thickness: ¼” • Width: 10” • Length: 10”
Price: $49.93 each

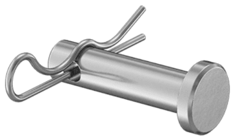
Low-Carbon Steel 90 Degree Angle
https://www.mcmaster.com/9017k76-9017K761/

• Material: Low-Carbon Steel • Shape Type: 90 degrees • Wall Thickness: ¼” • Outside: Height & Weight: 1 ¼”
Price: $5.81 each

Low-Carbon Steel Rectangular Tube
https://www.mcmaster.com/6527k264

• Wall Thickness: 0.083" • Outside Size: 1" x 1"
Price: $21.99 Each

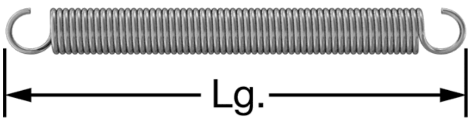
Activation Arm

Easy-to-Weld 4130 Alloy Steel Round Tube	**Easy-to-Weld 4130 Alloy Steel Round Tube**
https://www.mcmaster.com/89955k269-89955K261	*https://www.mcmaster.com/89955k158-89955K154*
	
• Material: 4130 Alloy Steel • OD: ½” • Thickness: 0.049” • Length: 1ft	• Material: 4130 Alloy Steel • OD: ¾ ” • Thickness: 0.058” • Length: 1ft
Price: $7.59 Each	**Price: $10.56 each**

Thick-Wall Dark Gray PVC Pipe for Water	**Zinc-Plated 1004-1045 Carbon Steel Clevis Pin**
https://www1.mcmaster.com/48855k21	*https://www.mcmaster.com/97245a604*
	
• Material: PVC Plastic • OD: 27/32” • ID: 0.546” • Length: 5 ft	• Material:1004-1045 Carbon Steel • Diameter: 3/16” • Length: ¾”
Price: $4.36 Each	**Price: $3.93 pack of 10**

302 Stainless Steel Corrosion-Resistant Extension Spring

https://www.mcmaster.com/94135k38



- Material: 302 Stainless Steel
- Length: 6”
- OD: 0.641”
- Loads
    - Min: 4.77lbs
    - Max: 26.38lbs

Price: $7.14 Each

Threaded-Stud Bumper

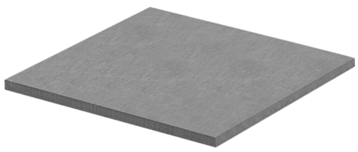
https://www.mcmaster.com/9541k11

- Material: Polyurethane Rubber
- Thread Size: 5/16"-18
- Thread Length: 7/8"
- OD: 1"

Price: $10.16 Each

Ground Low-Carbon Steel Sheet

https://www1.mcmaster.com/1388k382

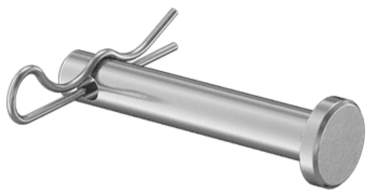


- Material: Low-Carbon Steel
- Width: 3”
- Length: 3”
- Thickness: ⅛”

Price: $10.36 each

Zinc-Plated 1004-1045 Carbon Steel Clevis Pin

https://www.mcmaster.com/97245a609



- Material: 1004-1045 Carbon Steel
- Diameter: 3/16"
- Usable Length:15/16"

Price: 2 x $4.16= $8.32

Aluminum Washer

https://www.mcmaster.com/93286a049

- Screw Size: 1/2"
- ID: 0.515"
- OD: 0.875"

Price: $5.83 per pack

1-1/2 in. x 2 ft. PVC Sch. 40 Pipe

https://www.homedepot.com/p/Charlotte-Pipe-1-1-2-in-x-2-ft-PVC-Sch-40-Pipe-PVC-07112-0200/100581718

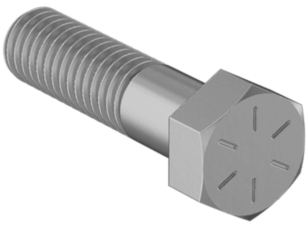
- Length: 2ft
- Inside Diameter: 1.21”
- Outside Diameter: 1.90”

Price: $3.56

Ramp & Sliding Gate

Zinc Yellow-Chromate Plated Hex Head Screw

https://www.mcmaster.com/91257a587



- Grade: 8 Steel,
- Thread: 5/16"-18
- Long: 1.5"
- Partially Threaded

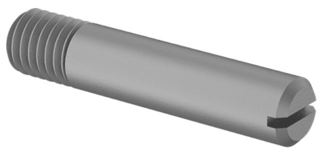
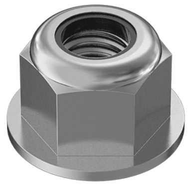
Price: $11.89 per pack

Threaded-Rod-Mount Clamping Hanger

https://www.mcmaster.com/3006t94

- Grade 8
- Material:
- Zinc Yellow-Chromate Plated
- Thread Size: 5/16"-18

Price: 3.84 per pack

Partially Threaded Steel Stud	Medium-Strength Steel Nylon-Insert Flange Locknut
https://www.mcmaster.com/97493a132	*https://www.mcmaster.com/92461a400*
	
• Thread Size: M8 x 1.25 mm • Long: 40 mm	• Class 8 • Material: Zinc-Plated, • Thread: M8 x 1.25 mm
Price: $6.86 per pack	**Price:$9.70 per pack**

TOTAL	**$181.83**

Recommendations

- The principal recommendation for the continuation of this project is to work with the analysis and simulations of the principal components of the fertilizer machine. The recommended software to work with the analysis is Ansys. The analysis and simulations have to be done to the ramp, the sliding door and the activation arm. The results of this analysis will determine if some changes in the design, dimensions and materials have to be done.
- The other recommendation is to accomplish the correct calibration with the prototype of the fertilizer machine. A calibration process is recommended previously in this report in the section of "Process of Calibration". For the calibration is recommended to build a prototype using the specified spring. The results of this process also will determine the finals materials and dimensions of the fertilizer machine. When the calibration is done, the manufacturing process of the product can start.

- Decrease the estimated total cost looking for better options of materials because the majority of the suggested materials to buy came in packages and only one or two are necessary. Visit local hardware stores could be useful for this task.

Assessments

Critical thinking along with engineering design is used to solve problems that affect society in a cost effective way. In the case of our design, reducing the workforce and the heavier work benefits the health of the workers and extends their performance when working. In the same way we impact social welfare since we help to better use the available time of all the people who in one way or another are part of the process that a plantation requires.

The economic factor is directly impacted with the reduction in time and the number of people it takes to do a specific task. In our case, the mechanism that is presented for the fertilization process does the same job with only one person and in half the time, while in the current process without the mechanism, all the personnel that the farm has available to work. In addition, each worker requires more physical effort and exposes him to an injury, limiting the available manpower, which with the presented design is potentially reduced.

Modern society is greatly impacted by the technology advances, creating consequences that are not anticipated by the designer. Problems start to occur when such complications outweigh the positive benefits of the design. For this and many more reasons ethical considerations must be included in the engineering process no matter where the practice is being held. Understanding the previous mentioned we can assure that the ASME Canons were considered in our design process. Safety and welfare was our primal requirement for the project development, guiding the design to avoid injuries and negative impact to plant, field, operator and society in general as inputted by Canon [1]. The group proposed the simplest design possible reducing variables and created a predictable mechanism for the positive use of all type of clients. It is believed that our design is a solution that was carefully developed only using our area of competence and skills as express by ASME Canon [2]. A Professional conduct was established between the client, team members and leader professor to provide a positive work environment and avoid conflicts as required by Canon [4]. When considering our professional responsibilities one can mention the detail incorporated in the evolution of the project, making sure all the data needed is projected on presentations and informs. Experiments and prototypes were done throughout the progress demonstrating our responsibility and commitment to test and hand in a functioning mechanism. Social and environmental considerations was also accounted by creating this design or tool to help the agriculture society expand. Finally it is understood that all the data and necessary guidelines are provide in this inform to proceed with this project and inject engineering in the agriculture area.

Conclusions

After completing all the process that was possible it is understood that the objectives to this point have been satisfied. The before stated it is said since the engineering process has been used in every part of the design leading to this final report. Upon a fine analysis and calculation it is believed that the chosen mechanism will complete the desire task with the needed specifications. It is understood that the model presented would be the final design with the latest modifications. After the modification detailed in the inform, such design would only need experimental testing. For the nexts steps students will be calibrating and gathering experimental data from a complete prototype, this is recommended before building a final product. Although it was not possible to fully calibrate our final prototype a general calibration process was created to detail the pending calibration for the spring. It is recommended to take the prototype to the plantain farm to expose the mechanism to the operating field and examine its potential. After the last mention is done the final mechanism can be build using the fabrication process included. It is concluded that the project gave our team much needed exposure in the engineering area with unexpected challenges, despite the before stated the team developed the project as far as possible.