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# STUDY, DESIGN AND PRODUCTION OF AN AUTOMATIC COTTONSEED WEIGHER IN A BAGGING STATION

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## ABSTRACT

This article talks about the design and construction of an automatic weighing system for cotton seeds in a bagging station. It is essentially focused on the weighing of seeds by an automatic weighing system, in order to avoid quantification errors linked to production and the uncertainties of readings linked to traditional weighing. To do this, a system was designed and built with two seed reception hoppers and a feed chute. The system also includes mass sensors, presence detectors and jacks. A PLC is provided and intended for the operation of the process control. It will send information to the pre-actuators from input data (sensors), instructions and a computer program.

**KEYWORDS**: Automatic Weighing System, Traditional Weighing, Mass Sensors, Presence Detector, Programmable Logic Controller.

## 1. INTRODUCTION

Currently the industrial world must offer quality products within short deadlines and at competitive cost [1]. With the continual advancement of technology, the criteria of demands do not stop only at the increase of productivity but also ensure a superior quality of these products, the improvement of working conditions and the increase of safety [1]. But these objectives can only be achieved if they respect the requirement of modern industry which can be described as an industry of quality and quantity which also continues to require more and more control equipment [1]. Even cotton seed plants are not an exception. Cotton is a vegetable textile fiber, resulting from the fluff composed of long, fine, silky filaments which enclose the seeds of the cotton plant [2]. Cotton fibers are used in textiles while the seeds are mainly used in oil mills [1], [3]. On the other hand, cockles and cakes are intended respectively for boiler feed and animal feed [1, 3]. However, it should be noted that these products (fiber and seed) find their best types of quality in the performance of the technical installations and means used in the ginning plant. To shell cotton is to separate the fiber from the seed. The seed cotton ginning process varies from mill to mill. After this separation step, each product derivative continues its process until packaging. Benin has about ten ginning factories scattered throughout the country. But unfortunately, none of them have a proper automatic weighing system at the station. Usually in these stations, workers take a significant amount of time to bag a bag (including moving the bag to weigh it, checking its weight and if necessary, manually adjusting its weight). All these operations lead to reading uncertainties, quantification errors, the accumulation of a large number of bags awaiting weighing and above all poor management of time and human resources. In cement factories, agro-food, medical or pharmaceutical industries, there are different kinds of weighing machines [4], [5]. But given the peculiarity of cottonseeds and the fact that they are always coiled with a little fiber, these weighing machines cannot be used in ginning plants. In addition, automatic cottonseed weighing machines manufactured in Europe are relatively expensive and prices range from $ 4,000 to $ 90,000 []6, [7].

Faced with this bitter observation and in the desire to increase yield, to minimize production errors and above all to optimize time, it was deemed useful in the context of this work to improve traditional weighing. We have therefore studied, designed and produced an automatic weighing machine. It is easily adaptable to the bagging system unlike the imported device which imposes a new architecture and exorbitant cost. The automatic weighing machine is made of sturdy materials and remains the ergonomic and economical solution for the company.

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## 2. MATERIALS AND METHODS

### 2.1 Description of the automatic weighing machine

FIG. 1 is a representation of the weighing machine to be produced. This figure was made with SolidWorks software. The weighing machine is essentially composed of two (02) hoppers, one (01) feed chute, six (06) bending mass sensors, three (03) jacks, two (02) presence sensors, one (01) frame, three (03) distributors, two pneumatic vibrators, two (02) junction boxes and one (01) electrical box.

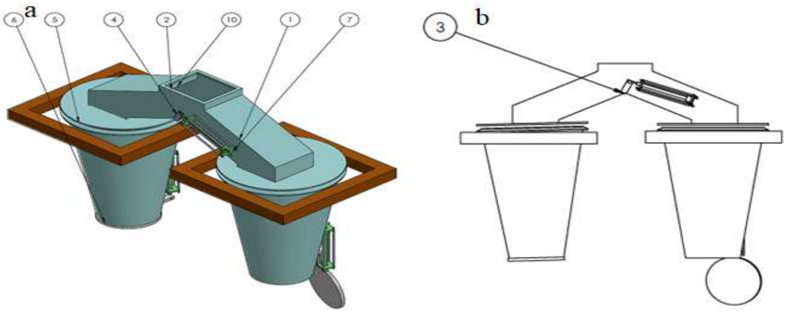


***Figure 1. Representation of the weighing machine: (a) Block diagram of the weighing machine in isometric view, (b) Plan drawing of the weighing machine***

Legend: 1-feed chute, 2-receiving hopper, 3-bypass, 4-bypass rod 5-cover, 6-hatch, 7-cylinder, 8-beam UPN

### 2.2 Function of each component

#### *2.2.1 Receiving hoppers*

The hoppers allow the seed to be received up to the desired maximum weight thanks to the load cells and the feed screw.

#### *2.2.2 Feeding chutes*

These are small channels connected to the feed screw that slope just enough to drop the seeds into the container.

#### *2.2.3 Chassis*

It serves as a support for each cyclone as well as a support for the weight sensors. It consists of U iron assembled by welding. It must guarantee the stability of the machine and ensure easy handling of the latter.

#### *2.2.4 Double-acting pneumatic cylinders*

There are a total of 03 cylinders A, B and C. The cylinders B and C are located on each hopper for opening and closing the hatches. Jack A is located at the level of the chute for bypassing.

#### *2.2.5 Electrically operated bi-stable 5/2-way valves*

These are pre-actuators which on the order of the control part ensure the distribution of power to the actuators (cylinders).

#### *2.2.6 Magnetic limit switch sensors*

These are sensors located on the cylinder and identify the retracted or extended position of the cylinder rod.

#### *2.2.7 Bending load cells*

These are sensors located on three sides of each weighing container. They convert a force into an electrical signal and are ideal for tank or hopper weighing applications.

#### *2.2.8 Junction boxes*

This is to link the mass sensors together with a good of 3. The output of this box will go to the display.

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### *2.2.9 Presence sensors*

These sensors make it possible to detect the presence of bags before the hatches are opened.

### *2.2.10 Pneumatic vibrators*

They are attached to each cyclone. Their main functions are to make each cyclone vibrate in order to facilitate the descent of the seed.

### *2.2.11 Electrical box*

It is essentially composed of a programmable controller, terminal blocks, relay trunking, connection wires, input and output modules, a two-pole circuit breaker

### 2.3 Principle of operation of the weighing machine

At rest, the rods of cylinders A, B and C are retracted (opening of the hatches) and the mass sensors indicate 0 kg on the display. Pressing the cycle start pushbutton causes the rod to exit from cylinders A and C. The output of the rod from cylinder A allows the seeds to fall into one of the hoppers. When the desired weight is reached (reading of 50 kg on the display), we will have the re-entry of the cylinder rod A, thus closing the access to the channel of this hopper and thus allowing the seeds to be poured into the second hopper. When the PS1 sensor (container bag presence detector) signals the presence of a bag, we will notice the retraction of the cylinder rod C causing the hatch to open, thus emptying the seeds into the bag. When the desired weight is reached in the second hopper (reading 50 kg on the display) and the PS2 sensor (container bag presence detector) will signal the presence of a bag under the hopper, the retraction of the rod of the hopper will be noticed at cylinder B at the same time, causing the opening of the trap door, thus emptying the seeds into the bag. After evacuation of the seeds from the hopper and reading of 0 kg, the trap door will be closed through the exit of the rod of cylinder B. Cylinder A changes position to fill the empty hopper.\

A pneumatic vibrator is installed on each hopper to facilitate the descent of the seed during the emptying. The latter starts up when the display shows 50 kg and stops when the display shows 0 kg on the screen in order to collect more seeds. An on-off switch allows switching to automatic mode to resume the cycle. An emergency stop button turns off the entire system. While one of the hoppers is emptying the other receives the seeds. In order to describe the different steps that we have developed for automatic weighing, we have used the language of Grafcet to detail the corresponding operation (see figure 2).

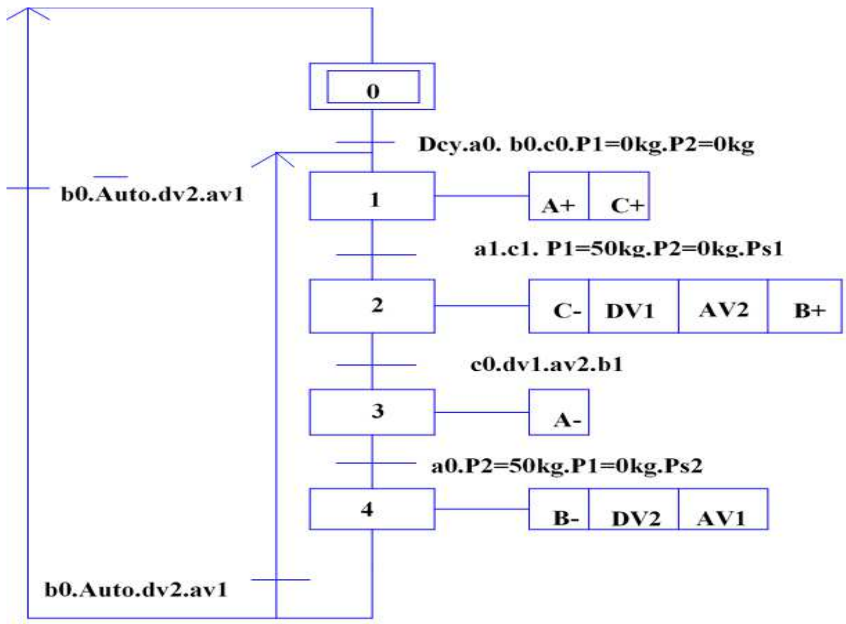


*Figure 2: Grafcet level II*

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Table 1 shows the nomenclature of the components of grafcet level II

***Table 1: Nomenclature of grafcet level II components***

| Function to be performed | Pre-actuators | Actuators | Associated sensors |
|---|---|---|---|
| Hopper | Bi-stable 4/2 way solenoid valve<br>A +: cylinder output<br>A-: cylinder retraction | Double acting cylinder A | A1<br>A0 |
| | Bi-stable 4/2 way solenoid valve<br>B +: cylinder output<br>B-: cylinder retraction | Double acting cylinder B | B1<br>B0 |
| | Bi-stable 4/2 way solenoid valve<br>C +: cylinder output<br>C-: cylinder retraction | Double acting cylinder C | C1<br>C0 |
| Bag presence detectors | | | Ps1 and Ps2 |
| Mass sensors | | | P1 and P2 |
| Pneumatic vibrator | AV 1 & AV2: stop vibrator 1 & 2<br>DV1 & DV2: start vibrator 1 & 2 | | |

Note: When pressing Dcy, the automation checks the initial position of the jacks, otherwise it returns to the initial position.

Figure 3 shows the pneumatic connection circuit of our system.

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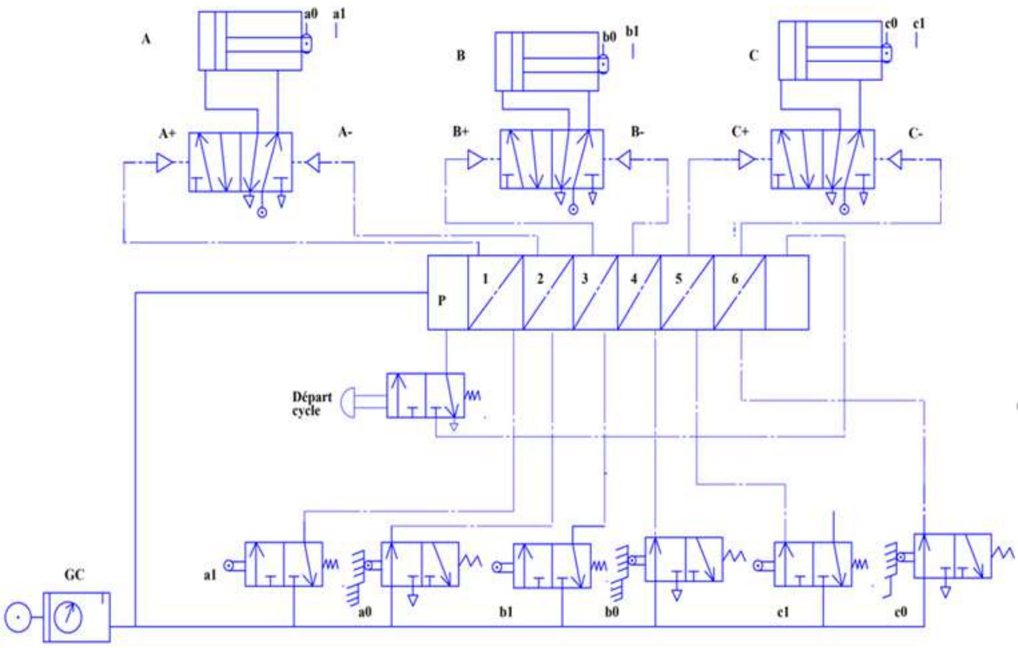


***Figure 3: Pneumatic connection circuit***

The pneumatic sequencer represents a means of carrying out sequential automation. The pneumatic sequencer is a linear association of modules. Each module is built from a bi-stable memory and logical scopes. Each step of the operating cycle of a sequence corresponds to a module of the sequencer. Table 2 shows the nomenclature of the Pneumatic Connection Circuit.

***Table 2: Pneumatic Connection Circuit Nomenclature***

| Benchmark | Designation | Fonction |
|---|---|---|
| GC | Compressor | Sucks in the air from the outside and delivers it to the conditioning circuit. . |
| a0, a1, b0, b1, c0, c1 | Limit switch | Detects retraction of the cylinder rod<br>Detects the output of the cylinder rod |
| A, B, C | Double acting pneumatic cylinders | Push the coin |
| A1, A0, B1, B0, C0, C1 | Electro-pneumatic bi-stable 5/2-way valve | Feeds the cylinder |
| P | Pneumatic sequencer | |

**2.4 Modeling**

This part is devoted to the inventory of the mathematical models relating to the various components of the weighing machine. These models reflect the physical phenomena that govern the operation of the main components.

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***2.4.1 Galvanized sheet (making the receiving hopper and the feed chute)***

The choice of materials is made taking into account the conditions of use, elements, stresses and products in contact with the parts. In our case, the purpose of the device is to collect the cotton seeds until the mass of 50 kg is obtained. Thus, for the preparation of the receiving hopper and the feed chute, general purpose non-alloy steel was chosen, more precisely the reference galvanized sheet S235 standard 10025, length 3000 mm, width 1500 mm, thickness 11.5 mm.

***2.4.2 Design of beams UPN S235***

Calculation of the deformation of the UPN 200 S235 beam of length L = 620 mm (= 317.8 cm4; E = 200,000 MPa.). Since we have 08 UPN beams all embedded and identical, we will model the case of a single beam.

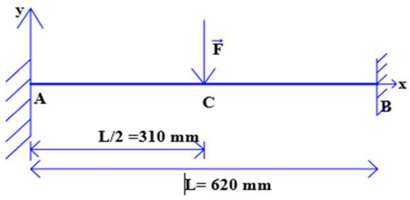


***Figure 4: Modeling of the embedded UPN beam***

Statistical equation [3]

$A_y = B_y = \frac{F}{2}$ (Symmetry) (1)

$\sum M_z/A = MA - \frac{FL}{2} + MB + BY * L = 0$ (2)

MA = MB = symmetry

The system is hyper static of order 1.

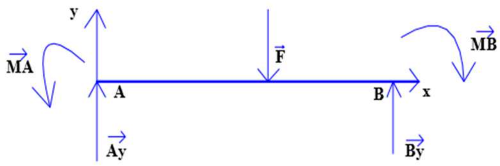


***Figure 5: Modeling of the forces applied to the embedded UPN beam***

Deformation equation [3]

Calculation of bending moment when $0 \leq x \leq \frac{L}{2}$

$M_{fz} = AY.x - MA$ (3)

We use the expression of deformation

$$E.I_{GZ}.y'' = AY.x - MA \quad (4)$$

$$E.I_{GZ}.y' = AY.\frac{x^2}{2} - MA.x + C1 \quad (5)$$

$E.I_{GZ}.y = AY.\frac{x^3}{6} - MA.\frac{x^2}{2} + C1.x + C2$ (6)

$y'(0) = 0 \implies C1 = 0(limits\ conditions)$ (7)

$y(0) = 0 \implies C2 = 0\ so\ E.I_{GZ}.y = Ay.\frac{x^3}{6} - MA.\frac{x^2}{2}$ (8)

Taking into account the symmetry of the deformation $y'\left(\frac{L}{2}\right) = 0$ therefore we have:

$0 = \frac{Ay}{2}\left[\frac{L}{2}\right]^2 - MA.\left[\frac{L}{2}\right] \Rightarrow MA = \frac{Ay.L}{4}$ and $A_y = \frac{F}{2}$ $so\ MA = \frac{FL}{8}$ (9)

We therefore have: $MA = -MB = \frac{FL}{8}$ (10)

Modeling of shear force and bending moment

For $0 \leq x \leq \frac{L}{2}$ (11)

$we\ have : V_y = -\frac{F}{2}$ (12)

$with\ F = m * g;$ (13)

for $\frac{L}{2} \le x \le L$ (14)

$we\ have: \boldsymbol{V_y} = \frac{\boldsymbol{F}}{\boldsymbol{2}}$ (15)

Bending moment $M_{fz}$ [5]

For x = 0; we have: $M_{fz} = -\frac{\boldsymbol{FL}}{\boldsymbol{8}}$ (16)

For x = $\frac{\boldsymbol{L}}{\boldsymbol{2}}$ ;we have: $M_{fz} = \frac{\boldsymbol{FL}}{\boldsymbol{8}}$ (17)

For x=L; we have: $M_{fz} = -\frac{\boldsymbol{FL}}{\boldsymbol{8}}$ (18)

Determining the maximum deflection at the point C

From (6) we have: $E.I_{GZ}.y = Ay.\frac{x^3}{6} - MA.\frac{x^2}{2}$ and $A_y = \frac{F}{2}$ (19)

So: $E.I_{GZ}.y = \frac{F}{12}x^3 - \frac{FL}{8}x^2$ (20)

Let x = $\frac{\boldsymbol{L}}{\boldsymbol{2}}$ (21)

we have;

$E.I_{GZ}.y = \frac{F}{12} * \left[\frac{L}{8}\right]^3 - \frac{FL}{16} * \left[\frac{L}{2}\right]^2$ (22)

$E.I_{GZ}.y = -\frac{FL^3}{192}$ (23)

$$we\ deduce\ that\ y\left(\frac{\boldsymbol{L}}{\boldsymbol{2}}\right) = fmax = -\frac{FL^3}{192.E.I_{GZ}} \quad (24)$$

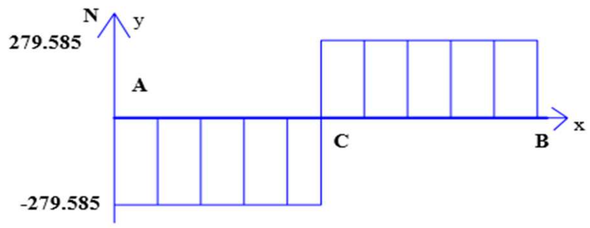

*Figure 6: Diagram of the shear forces diagrams.*

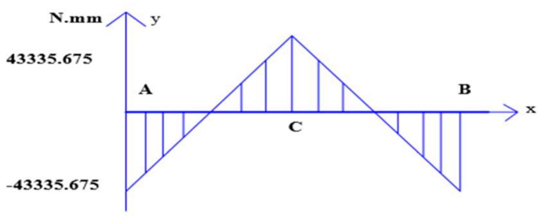

*Figure 7: Diagram of the diagrams of the bending moments.*

### *2.4.3 Sizing of the receiving hopper (truncated cone)*
The characteristics of the conical shaped hopper are: Large diameter = 600 mm; Small diameter = 320 mm; Height = 900 mm; Desired overall efficiency: 0.99

### *2.4.4 Sizing of double-acting cylinders*
Characteristics of a double-acting cylinder

A cylinder is determined by its stroke and its diameter:

- the length of the displacement to be used depends on its stroke,
- the force to be developed depends on its diameter and the air pressure.

Developed effort

The theoretical thrust of a jack is given by the relation:

$F = p.S$ (25)

with F in N, p the pressure in bar, S the piston surface in $cm^2$

In reality, the force developed by the jack must be greater than the theoretical thrust to take friction into account.

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A coefficient of increase called the load rate is adopted. Most often, a load rate Tc = 60% is adopted.
The force developed by the jack is given by:

$$F = \frac{M*g}{T_c} \quad (26)$$

A cylinder does not develop the same force at the exit or retraction of the rod. The thrust is greater at the rod exit than at the rod retraction.
At the end of the rod, the area of the piston on which the thrust is applied is equal to;

$$S1 = \frac{\pi D^2}{4} \quad (27)$$

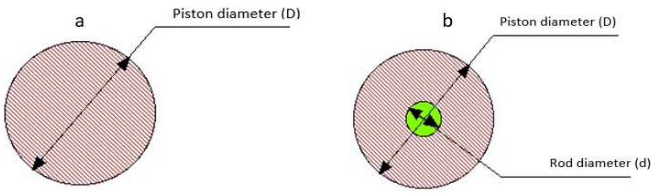


***Figure 8. (a) Piston surface at rod outlet (b) Piston surface at rod retraction.***

When the rod enters, the surface is only:

$$S2 = \frac{\pi(D^2-d^2)}{4} \quad (28)$$

Like S2 <S1, at constant pressure, the force developed is less important when entering the rod than when exiting the rod.
The surface of the piston exiting the rod is defined by:

$$S = \pi D^2/4 \quad (29)$$

The theoretical and actual thrusts in the forward stroke at the exit of the cylinder rod as well as the frictional resistance are determined respectively from relations (30), (31) and (32);

$$F_{th} = S.p \quad (30)$$

$$F_n = S.p - F_r \quad (31)$$

$$R = F_{th}/10 \quad (32)$$

The area of the piston at the entry of the rod is defined by:

$$S' = \pi/4\ (D^2-d^2) \quad (33)$$

The theoretical and actual thrusts in the rear stroke at the entry of the cylinder rod as well as the frictional resistance, are determined respectively from relations (34), (35) and (36);

$$F_{th} = S'.p \quad (34)$$

$$F_n = S'p - F_r \quad (35)$$

$$R = F_{th}/10 \quad (36)$$

**2.5 Estimation of the cost of the weighing machine**

The cost of the weighing machine was determined by taking into account the total price of items, labor and supplies. Table 3 shows the list of parts, their references and the quantity.

***Table 3: List of articles***

| N° | Article name | Reference | Amount |
|---|---|---|---|
| 1 | Programmable robot<br>And all these accessories | TWDLCDA40DRF<br>COMPACT<br>EXTENSIBLE BASE-<br>24Vdc-24 INPUTS<br>24Vdc-16 OUTPUTS | 01 |
| 2 | Programming software | TwidoSuite_v0220_11 | 01 |

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| | | | |
|---|---|---|---|
| 3 | Electrical box | 50X50X25 cm | 01 |
| 4 | Double acting pneumatic cylinder with magnetic sensor | CDA2L63-605Z | 03 |
| 5 | Bending load cell | RUBBERKIT-FX. 10 KG ……… 300KG | 06 |
| 6 | Pneumatic piston vibrator | FP-35-M | 02 |
| 7 | Photoelectric sensor (sensor value beam 10-30VDC | 26124 | 02 |
| 8 | UPN steel beams | UPN 200X75X8.5 STEEL S235 | 10 |
| 9 | Air dryer filter | 94169 | 01 |
| 10 | Cycle start push button | XB4ATEXD | 01 |
| 11 | LEGRAND on-off switch | 27543 | 01 |
| 12 | Galvanized sheet metal | 20/10 | 02 |
| 13 | Plain sheet metal | 20/10 | 02 |
| 14 | Red flexible wire 1.5mm² | H07V6K RED | 1 Roll |
| 15 | Black flexible wire 1.5mm² | H07V6K BLACK | 1 Roll |
| 16 | 2kg anti-rust paint | | 02 |
| 17 | 2kg paint container for finishing | LUMMUS COLOR | 02 |
| 18 | Basic electrode box | 6011 | 05 |
| 19 | M10 bolt | Ø 10/150 | 20 |
| 20 | LCD display | | 02 |

Let Pa be the total price of the items; Pbe the cost of the design office; Pf the cost of supplies and contingencies and Pt the total price;
This implies: $P_t = P_a + P_{be} + P_f$ (37)

## 3. RESULTS AND DISCUSSION

After making the equipment, we carried out tests. The test consisted of filling 50 kg bags of cotton seeds. When the plant is operating at 25% of its capacity, there is a filling time of around 20 to 25 seconds. At 50% of its capacity, the time to fill a bag varies between 15 to 20 seconds. At 75% (of its capacity), the bag filling time now varies in the order of 10 to 15 seconds. When the plant is operating at full capacity, that is at 100% of its capacity, the filling time is packets of 10 seconds. During our test, we placed particular emphasis on the case where the plant is operating at full speed because the system would have to be able to respond at full power. Our analyses are therefore based on the last case here presented i.e. when the plant is operating at full capacity.

The results from the application of the mathematical models of the various components of the weighing machine are grouped in tables 4, 5, 6 and the estimated cost of the weeder in table 7.

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*Table 4: Values of the characteristic parameters of the shear force (UPN beam)*

| x(m) | 0≤ x ≤310 | $310 \leq x \leq 620$ |
|---|---|---|
| $V_y$ (N) | -279.59N | 279.59N |

*Table 5: Values of the characteristic parameters of the bending moment (UPN beam)*

| X (m) | X=0 | X=310 | X= 620 |
|---|---|---|---|
| $M_{fz}(N.m)$ | -43335.675 | 43335.675 | -43335.675 |

By calculating the maximum deflection at point C, i.e. at the center of the beam we find
$fmax = -1{,}092\ mm$

*Table 6: Values of the characteristic parameters of the jacks*

| Developed effort (N) | Piston area exiting the rod ($cm^2$) | Theoretical thrust | Friction resistance (daN) | Actual thrust in forward stroke (daN) | Piston surface at rod retraction ($cm^2$) | Theoretic al trust (daN) | Friction resistance (daN) | Real thrust in reverse travel (daN) |
|---|---|---|---|---|---|---|---|---|
| 931.95 | 19.625 | 117.75 | 11.775 | 105.97 | 16.485 | 98.91 | 9.891 | 89.019 |

*Table 7: Estimate of the cost of the weighing machine*

| Total price of items or parts ($) | Design office Price ($) | Cost of supplies ($) | Total Cost ($) |
|---|---|---|---|
| 6350 | 2000 | 1630 | 9980 |

**3.2 Analysis of the results**

With the existing system, workers take an average of 20 seconds to finish with a bag including weighing, checking the weight and manually adjusting the weight if necessary. The working time on this equipment is reduced because they no longer need to weigh manually by placing the bag on a scale, worse still adjusting the weight.

This new equipment eliminates the labor of manual weighing and, above all, reading errors. The device is advantageous from a security point of view and the whole system is automated. From a performance point of view, weighing is more efficient. From an environmental point of view, the machine contributes to the reduction of dust. Several advantages are linked to this change. From an economic point of view, it contributes to the profitability of the plant.

After analysis of Tables 4 and 5, it was possible to obtain the maximum deflection at point C; that is to say in the center of the beam we find;

From the analysis of Table 6, it emerges that we use a double-acting cylinder whose rod length would be between 15 and 20 cm given the expected result.

Table 7 allowed us to estimate the cost of the weighing machine. The total cost of manufacturing this equipment is $ 9,980.

## 4. CONCLUSION

The study proposed a design and construction of an automatic weighing machine for seed bagging in a cotton ginning factory in Benin. This new equipment will eliminate the drudgery of manual weighing and above all

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reading errors, then allow more optimal management of time and human resources. The components of the machine were mostly ordered and the rest carried out on site. It will sustainably improve the production income of all ginning plants. The manufacture of the proposed equipment should have considerable socio-economic benefits for factories and automation engineers in particular and will open up many business opportunities in general.

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