Volumetric dosing system of dyes and support for the preparation of color in a textile laboratory

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Abstract. *Every day laboratory processes in the textile field are more complicated and tedious and as technology advances industries have been forced to include automation as an essential part of their processes. This project is developed on a specific need in the textile laboratory Indutexma plant, which is the dosage of dyes, this task is done manually by the laboratory workers and requires time, concentration and skill to ensure the accuracy of dosing. The proposed system contributes to the automation of the development process color, the system can locate each of the dyes and dispense the desired amount using electromechanical actuators controlled by a digital controller developed in Labview software which has also helped develop an easily operable interface user. In order to optimize costs, a computer was used as a controller thanks to the advantages of programming and control offered by the Labview program and how machine interface was selected an Arduino as card data acquisition since it has a large number of analog and digital outputs and inputs.*

Keywords

Dosage, pipette, system, volumetric, controller.

1. Introduction

Textile companies dedicated to the cleaners are currently undergoing expansion because Ecuadorian society demands greater national textile production. For this reason the industries are forced to continuously improve each of their production processes because only in this way the quality and competitiveness of the product is guaranteed. Among the many production processes that are one of the initial processes in the development of textile is the development of color, this process is vital because of the precision with which this stage run depends the quality of the other processes and therefore the final product. The process of color development consists of several tasks made manually, one of the most essential is the dosage of liquid dyes, this project focused precisely on automating this task because it is where errors and delays are committed, that affect the quality of the final product.

Indutexma textile factory located in the area of Punyaro in the city of Otavalo has the necessary equipment and textile machinery to perform various processes such as: weaving, dyeing and finishing textiles. Specifically, the laboratory Indutexma factory is engaged in a large percentage of their time to the development of dyes for textiles, here the initial samples that will start the entire process tinturaci of a fiber once the hue of the sample has been approved, here is where the volumetric dosing system was implemented to automate the task of dosage for color preparation sample.

Figure. 1. Dosage of dyes performed manually. (Indutexma, 2016)

The task dosage is an iterative process and requires a lot of concentration to do it manually, also because the lab workers work under pressure and must run an extensive workload per day, flaws in the color tones in the samples were presented, this is a direct consequence of precision errors that are committed in the dosage of liquid dyes. Currently with the implemented system it could reduce significantly errors that occur in dosing, preventing failures in samples shades. Use of the system has also reduced the workload on laboratory workers moving to some extent repetitive manual labor dosing, the system implemented has also allowed to have a larger organization regarding the distribution of dyes since all dyes used in the process now distributed within the system.

Figure. 2. Volumetric system implemented

2. Materials and Methods

Automation of the dosing process for preparing dyes to color development is not a new issue since at the time there are several commercial companies that design and sell textile machinery including several types of dosing systems. In order to establish the most appropriate system to the needs of the textile factory laboratory Indutexma a detailed study of all tasks, methods and instruments involved in the metering process in that laboratory was performed. The following task are some of the most important.

2.1 Process color development in the textile laboratories

A textile laboratory meets multiple roles in the development of textile fabric, one of which is the initial stage of dry cleaning; in the color development process for the dry cleaner meets basically three functions:

Creating a color: is to formulate a new color which has no prior prescription preparation.

Sample preparation: involves following a previous prescription for a color sample proposed, samples are generally subjected to quality controls for approval.

A color reproduction: is the investigation of the materials that make an existing color for later playback.

In all three processes should prepare materials and dispense dyes and auxiliaries to form the desired final color. This project focused specifically on the stage dosing.

2.2 Dosage of auxiliaries and dyes in color preparation

A color recipe contains three essential elements, those are water, dyes and auxiliaries. This is centered in the dosing of dyes and auxiliaries.

A color recipe generally has the structure illustrated in the following figure:

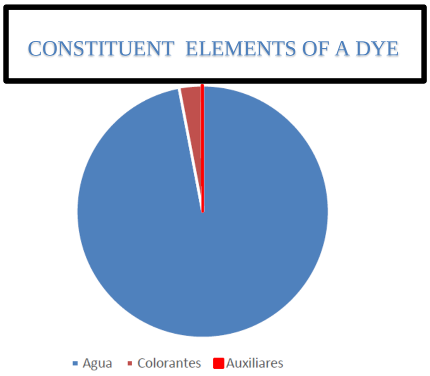


Figura. 3. Constituent elements of a dye (Lockuán Lavado, 2012)

Most recipes have a total volume of 60 [ml] as prepared in containers mixing and dyeing support a maximum of 60 [ml] Of this total volume about 2 [ml] are dyes and auxiliaries, and volume remaining is water. Each recipe color is composed of a mixture of the three primary colors: yellow, blue and red, each have a dosage range that can range from 0.01 [ml] to 10 [ml], similarly auxiliary can range from 0.01 [ml] to 5 [ml].

2.3 Instruments used for dosing in a textile laboratory

It is known as an instrument to any artifact or utensil designed to perform a specific technical task. The tools help in some way to facilitate manual labor, also allow channel a physical or mechanical effort made by a human being, so that all that energy take advantage and work is done more efficiently and accurately.

There are instruments specifically designed to facilitate the various tasks required to do in a textile laboratory, usually they are almost the same instruments used in any chemical laboratory, which are presented below in detail because it is necessary to know the use and functions that allow each of them. The main instruments used in the textile laboratory Indutexma are divided into two groups:

Material container: is every element that provides the ability to store a material either in solid or liquid state within these will have jars of all kinds of material, flasks, containers sample preparation etc.

Volumetric Material: *Anyone instrument permitting a measurement of volume of a material or particular compound is known as volumetric laboratory, there is bulk material of various types, designed for each function and need laboratorist. Most standard volume material is available in glass built within these are the pipettes, burettes, and pipettors.* (Integra, 2014)

2.4 Dosing Process Automation

The need to automate the process of dosing born long ago. As already noted in previous sections, already exist systems in the market developed for this purpose, however despite the versatility of these devices does not exist yet on the market a system that meets the needs of the national textile industry and whose purchase value production volume justifies it. This project has proposed the design and construction of a metering system that fits both the technical requirements of production and the economy of national textile enterprises.

Indutexma textile factory works mostly with cotton fibers and polyester, for which the proposed system was designed exclusively to work with these two types of fibers. It should also be noted that the restrictions and limits are applied in the same given by the production system and the required needs exclusively here

System requirements:

The system proposed in this project aims to streamline the process of reproduction of samples of dyes in the textile factory laboratory Indutexma. Once observed carefully the needs and complications that arise in the development of this process, the parameters that the proposed system must meet established. Listed below are each must have characteristics that present the proposed system:

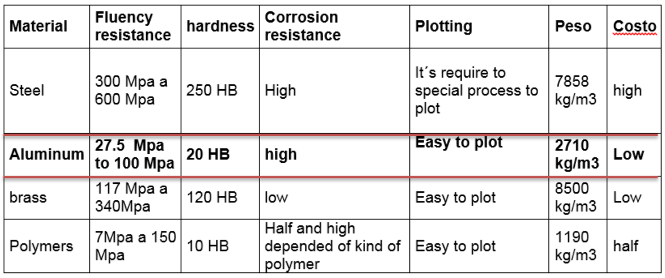
Dosing accuracy of 90%, automatic dispensing, have the number of bottles equal to the minimum required for dye recipes for the preparation of samples of cotton and polyester (15 minimum and 20 minimum polyester cotton).

2.5 Mechanical design of the dosage system

To ensure agility dosing process was due to make a design that allows the location of all the necessary materials for the process (in this case are auxiliary and dyes) within a small physical space and also the design of a movement system coordinate for the location of the dyes and dosage thereof below axles entire design process described:

Selection of construction material

To select the construction material of the support structure was necessary to consider all the factors that influence the process as corrosion of some products and the system requirements and evaluate all the advantages and disadvantages of each material themselves to consider; between the major system requirements should be considered stiffness, weight, corrosion resistance and material cost.



Material	Fluency resistance	hardness	Corrosion resistance	Plotting	Peso	Costo
Steel	300 Mpa a 600 Mpa	250 HB	High	It´s require to special process to plot	7858 kg/m3	high
Aluminum	**27.5 Mpa to 100 Mpa**	**20 HB**	**high**	**Easy to plot**	**2710 kg/m3**	**Low**
brass	117 Mpa a 340Mpa	120 HB	low	Easy to plot	8500 kg/m3	Low
Polymers	7Mpa a 150 Mpa	10 HB	Half and high depended of kind of polymer	Easy to plot	1190 kg/m3	half

Table 1. Comparative table of materials (Mott, 2000)

Mechanical design of support structure and motion system axes

This design concentrates all mobility in the dispenser providing three degrees of freedom. Bottle has a base static dyes that allows the dispenser placed in vials for each dye.

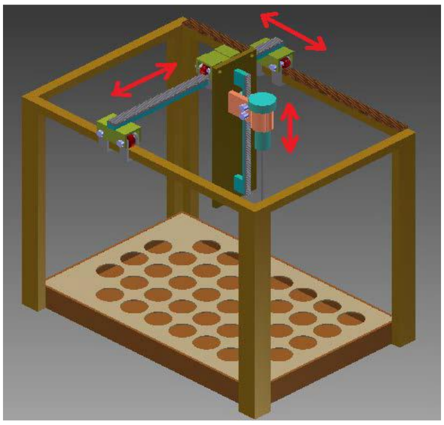


Figure. 4. Design of structures of support and axis movement

Analysis and simulation of the critical elements of mechanical design proposed

Are considered critical design elements to sections that are bearing a load within the system in this case the only load-bearing elements are the axes of movement then the analysis is as follows:

Load analysis:

For the analysis of the load was taken into account the weight of the dispenser and support structure for the dispenser, resulting in a load of 2.5 [Kgf] equivalent to 24.5 [N], this load is distributed along the two axes of movement being the longest axis which more load stand for this reason analysis on the transverse support beam (which is the axis of movement), where the load is applied it is made as shown in the following figure:

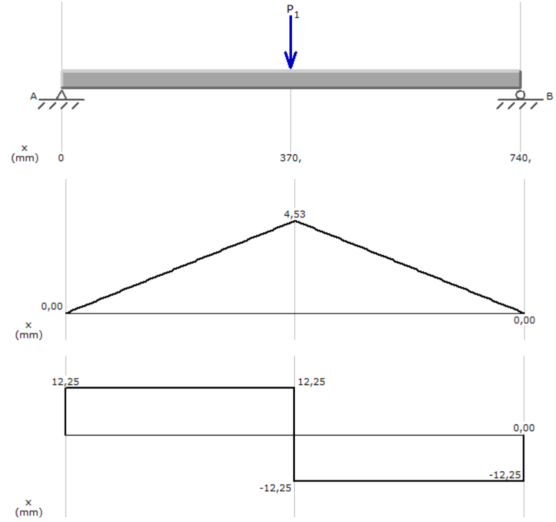


Figure. 5. (Moment diagram and cuts) Analysis of charge in the transverse support bar

Can be seen in the figure the maximum moment that occurs in the bar is 4.53 [N.m]Análisis de esfuerzos

05.24 load [N] only produces a bending moment in the bar so that only a bending stress in the same occurs.

Calculation of bending stresses

$$T_x = \frac{M_A}{s} \qquad (1)$$

Where: MA = bending moment about the fulcrum A in [Nm], s = section modulus in cubic meters [m3]. Tx = normal bending stress in Pascals [Pa].

Calculation module section of the bar

$$s = \frac{b \times h^2}{6} \qquad (2)$$

Where: b = length of the base of the rectangular section of the bar in meters [m], h = height of the length of the bar rectangular in meters [m].

Given the following data proceeds to the calculation to determine the bending stresses to which the bar is subjected.

M= 4.53 [Nm], b= 0.02[m], h= 0.02[m].

s=0.02×0.022/6
s= 1.3×10-6 [m3]

Now it proceeds to calculate the normal bending stress applying equation (1)

Tx=4.53/0.00000133
Tx=3.397×106[Pa]

Security factor

By not produced any other effort proceed to calculate the safety factor applying the theorem of Von Misses

$$T' = (T_x^2 - T_x * T_y + 3 \times Z_{xy})^{\frac{1}{2}} \qquad (3)$$

Where: T'= Effort Von Mises in Pascals [Pa], Tx = normal bending stress in the x axis in Pascals [Pa], Ty = normal bending stress on the shaft and in Pascals [Pa], Zxy = torsional shear in the xy plane in pascals [Pa].

As the only effort is Tx occurs calculating the Von Mises stress it takes the same value of Tx. Then you have to:

T’=3.397×106[Pa].

Then the safety factor is calculated for bar analyzed taking into account the creep resistance of aluminum, Sy = 34 [MPa.]

T’=3.398×106[Pa].
Sy=34000000[Pa].
n=34000000/3.398×106
n=10.007

Simulation Von Mises stress analysis

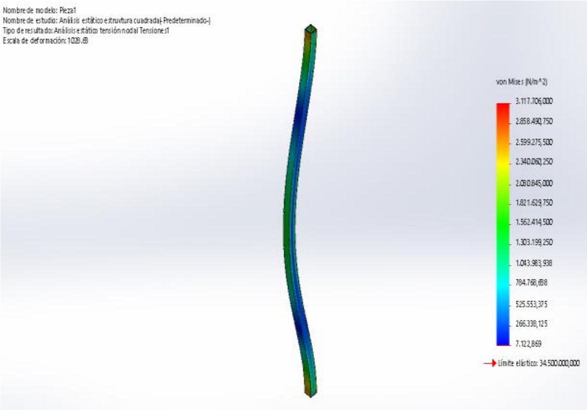


Figure. 6. Simulation Von Mises stress analysis

the results with those obtained theoretically simulation validated.

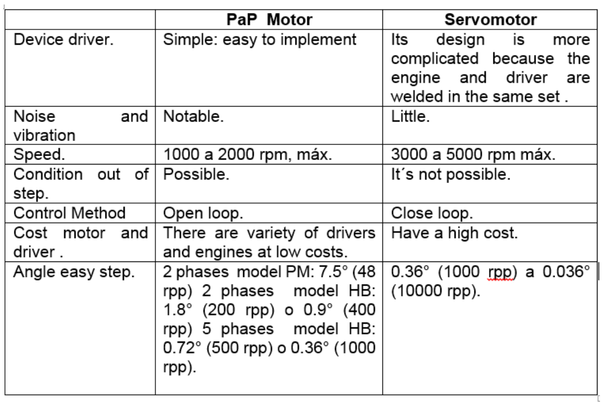
2.6 Electronic design volumetric dosing system

To make the design of the proposed electronic control system and to have a clearer idea of the control circuit, it was an analysis and selection of each of the elements forming part of the system. The following describes generally each:

Actuators: Indispensable requires an actuator for moving the dosing pipette and taking into account the different types of moves that need to be made, analyzed between using stepper motors or servomotors.

Device driver: in any of the two options will require a controller that allows the user to control system actuators according to the need of the system.

Control Interface: This system requires an interface that allows data to enter the dyes and dye amounts required dose that would be translated to the electrical system are desired positions of the actuators.



	PaP Motor	Servomotor
Device driver.	Simple: easy to implement	Its design is more complicated because the engine and driver are welded in the same set .
Noise and vibration	Notable.	Little.
Speed.	1000 a 2000 rpm, máx.	3000 a 5000 rpm máx.
Condition out of step.	Possible.	It´s not possible.
Control Method	Open loop.	Close loop.
Cost motor and driver .	There are variety of drivers and engines at low costs.	Have a high cost.
Angle easy step.	2 phases model PM: 7.5° (48 rpp) 2 phases model HB: 1.8° (200 rpp) o 0.9° (400 rpp) 5 phases model HB: 0.72° (500 rpp) o 0.36° (1000 rpp).	0.36° (1000 rpp) a 0.036° (10000 rpp).

Table 2. Comparative motors table (Pachón, 2009)

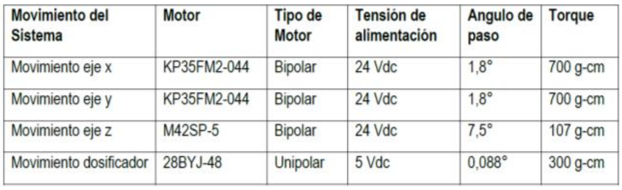
After reviewing the characteristics of each of these types of actuators engines they were selected by step for the movement of the axes in the system for its advantages of precision and low cost.

Actuators: Motor steps (PaP)

The stepper motors are electromechanical devices that are mainly characterized by their ability to rotate it into precise increments or steps are shaped like any engine with a rotor and a stator unlike these have several coils. Only in the stator, each coil receives a pulse which induces a magnetic field in the rotor and forces it to rotate a precise angle, so that these motors are controlled by devices that generate a train of synchronized pulses to each coil stator.

Because of its ability to rotate into segments, these engines offer a great advantage in positioning systems also can be easily controlled by an open loop control, which also means lower costs of implementing the control.

The characteristics of each of the motors selected for both axes movement to the movement of the dosing described



Movimiento del Sistema	Motor	Tipo de Motor	Tensión de alimentación	Angulo de paso	Torque
Movimiento eje x	KP35FM2-044	Bipolar	24 Vdc	1,8°	700 g-cm
Movimiento eje y	KP35FM2-044	Bipolar	24 Vdc	1,8°	700 g-cm
Movimiento eje z	M42SP-5	Bipolar	24 Vdc	7,5°	107 g-cm
Movimiento dosificador	28BYJ-48	Unipolar	5 Vdc	0,088°	300 g-cm

Table 3. Table of motors characteristics

To design the controller for each engine in order the following steps were performed: 1. Data acquisition: No. of pulses / angular position to obtain the transfer function of each motor, 2. analysis of the temporal response of each function transfer obtained 3. - Stability analysis using Routh, 4. Calculation of steady-state error, 3. Analysis of system response impulse and unit step input, tuning method 4. Cohen- Coon to determine the type of controller.

Once these steps for each of the engines was determined to implement a PD controller for positioning each motor so that the overall control scheme is established as follows for engines used in the positioning of the axes.

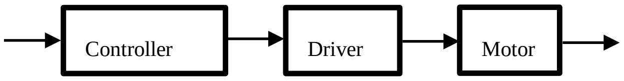


Figure 7. Control diagram of positioning motors

As an example we have the control diagram for the motor x-axis:

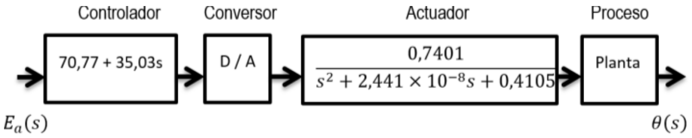


Figure 8. Block diagram of the control system for the engine of x axis

In case of the metering motor, an encoder is added to determine the position of the shaft, so that it has the following control scheme:

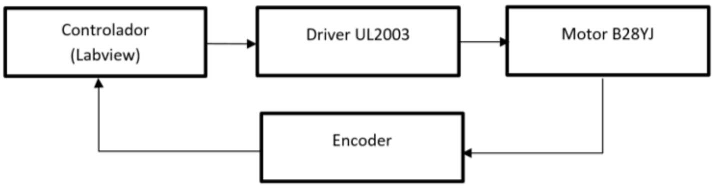


Figure 9. Control diagram for the motor dispenser

It should be noted that although a PD feedback control from the encoder only is controlling the position of the rod of the dispenser and thus the volume of liquid is controlled dosing so that even if a control loop has closed with used regarding the position of the dosing this becomes an open-loop control over dosing.

Control Interface

The control interface is the tool that allows the user to enter the corresponding dosage values recipe data. It has chosen the Labview environment to develop user interface, as it provides a graphical programming environment, easy to use and understand.

Communication between Labview and drivers for the motors is done through the interface: Labview Interface For Arduino (LIFA), which allows linking all functions Labview with the ports of inputs and outputs offered by the Arduino board, ie it is used the arduino card as a data acquisition (DAQ). (National Instruments, 2014)

To get a clearer idea of electronic control for each of the actuators is necessary to understand the process of overall system which is described in the following flow chart:

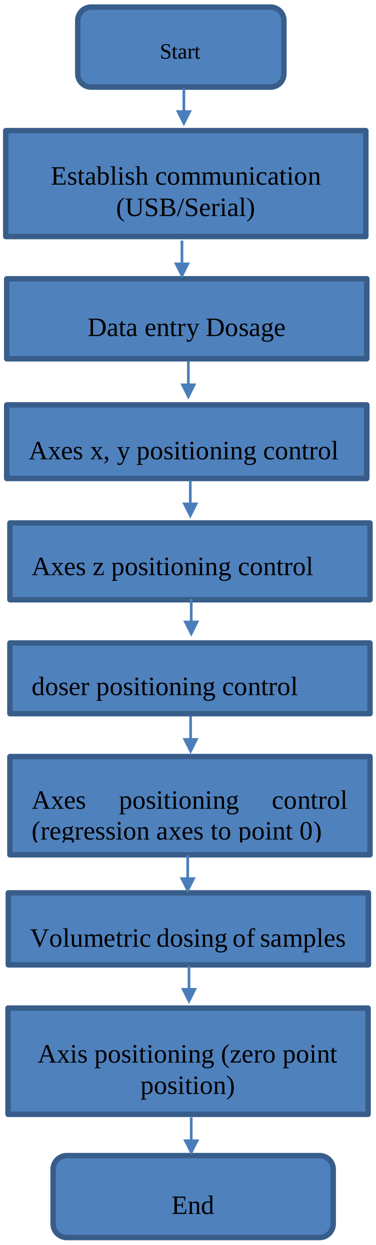


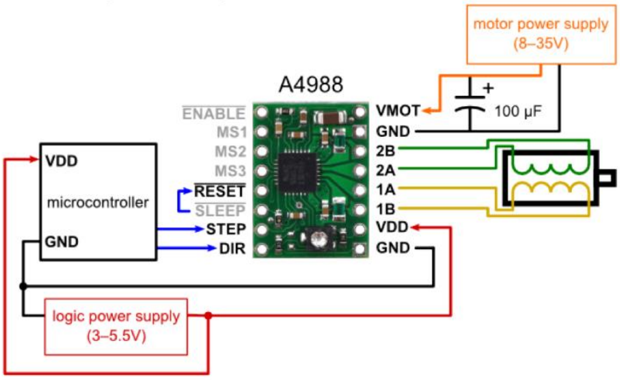
Figure 10. Flowchart of operation of electronic control

Driver's device

Drivers are electronic devices that enable the reception of control parameters and transform the control signal for operating voltage motors described below drivers generally used in the motor control system.

The A4988 driver is an integrated circuit manufactured based on the Chip A4988, which generates based on two input parameters: pulse and direction, a PWM signal controlled and synchronized for each coil stepper motor, can only be used with engines bipolar steps and offers a current gain up to 2 [a] and also supports a supply voltage motor 8-35 [V] ideal for controlling stepper motors low voltage.

Figure 11. Electrical connection diagram A4988 driver (Pololu, 2015)



The ULN2003 driver built on the integrated circuit the same name allows motor control to low voltage unipolar steps, was used for the engine case to the dispenser as this is a bipolar motor of 5 [V]. This driver allows the synchronized control of stepper motor coils with four input variables which correspond to the PWM signal generated by the controller for each of the motor windings.

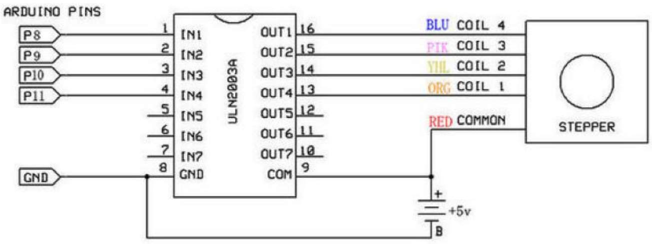


Figure 12. Electrical connection diagram driver ULN2003 (42Bots, 2013)

3. Results

After making several test runs it is determined improvement in the proposed evaluation parameters such as dosing accuracy and time then tests to determine each of these parameters and their respective results are shown.

3.1 Dosing accuracy

The metering accuracy is a measurable parameter can therefore be assessed more easily, to quantify this parameter two methods of evaluation are applied in textile laboratories to measure performance and precision with laboratory workers in dosage were made, the evaluation methods to be applied are: comparison of patterns with the gravimetric method and evaluation of repeatability of measurements.

Pattern matching with the gravimetric method

The procedure is detailed evaluation by this method: 1. Define-dosing patterns in units of volume, 2. Establish appropriate relationships to each pattern in units of weight, 3. Perform the appropriate dosages to employers established using the system to evaluate, 4. Perform the measurements corresponding to the weight of the dosages performed by the system, 5. Compare the values obtained in weight units.

In the table below you can see the metered values obtained in the tests and the respective calculation error in measurement:

No	pattern value (g)	Measured value (g)	error (g)	Percent of error	Percent of precision
1	0,1	0.1092	0.0092	9.20%	90.80%
		0.0907	0.0093	9.30%	90.70%
		0.1084	0.0084	8.40%	91.60%
		0.0901	0.0099	9.90%	90.10%
		0.1095	0.0095	9.50%	90.50%
2	0,5	0.5372	0.0372	7.44%	92.56%
		0.5384	0.0384	7.68%	92.32%
		0.5309	0.0309	6.18%	93.82%
		0.4882	0.0118	2.36%	97.64%
		0.4782	0.0218	4.36%	95.64%
3	1	1.0205	0.0205	2.05%	97.95%
		1.0325	0.0325	3.25%	96.75%
		0.9405	0.0595	5.95%	94.05%
		1.0325	0.0325	3.25%	96.75%
		0.9524	0.0476	4.76%	95.24%
4	2,5	2.4181	0.0819	3.28%	96.72%
		2.5913	0.0913	3.65%	96.35%
		2.4138	0.0862	3.45%	96.55%
		2.542	0.042	1.68%	98.32%
		2.4232	0.0768	3.07%	96.93%
5	5	4.8887	0.1113	2.23%	97.77%
		4.8859	0.1141	2.28%	97.72%
		5.0451	0.0451	0.90%	99.10%
		5.0451	0.0451	0.90%	99.10%
		4.9725	0.0275	0.55%	99.45%
6	8	7.8311	0.1689	2.11%	97.89%
		7.898	0.102	1.28%	98.73%
		7.9511	0.0489	0.61%	99.39%
		7.9481	0.0519	0.65%	99.35%
		8.0245	0.0245	0.31%	99.69%
		Total:		**4.02%**	**95.98%**

Table 4. Table sample measurement and precision error rates

Given these values the average percentage of machine accuracy was calculated:

Average percentage of system accuracy = 95.98%

Average percentage of system error = 4.02%

Evaluation of repeatability of measurements

Repeatability is the ability you have to make several measurements with equal precision, ie if several measures with the same volume are performed at different times, the measurement must be exactly the same for any volume of the same value. The procedure for an evaluation by this method is as follows: 1. Establish a single value-a pattern, 2. Preparation of samples: Perform various numbers of dosages value set as unique pattern, 3. Perform measuring mass of each sample obtained by the system, 4. Compare that all the samples obtained with the system have the same value of mass.

To perform this test a set of 42 measurements of patterns 2.5 took measurements of 5 and 42 after which the following results were obtained [ml.] [Ml.]:

Average	2,4851
Variance	0,0003
Standard deviation	0,01647606
Max.	2,5364
Min.	2,4489
Maximum error	0,0875

Table 5. Table Average, variance and standard deviation calculated for set of patterns 2.5 [ml]

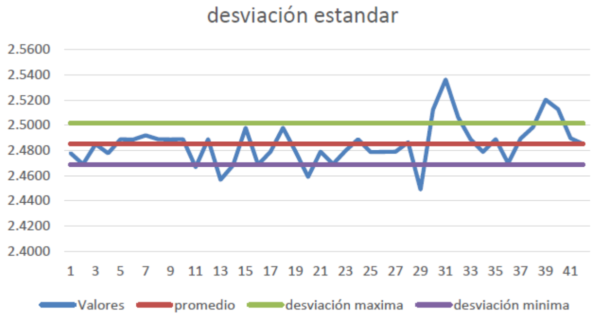


Figure 12. Graphic standard deviation for set of measurements of 2.5 [ml.]

The parameters calculated for the pattern of 5 ml and analysis of these data is shown:

Average	4.9393
Variance	0,0021
Standard deviation	0,04572023
Max.	4,9978
Min.	4,7985
Maximum error	0,1993

Table 6. Table Average, variance and standard deviation calculated for set of patterns 5 [ml]]

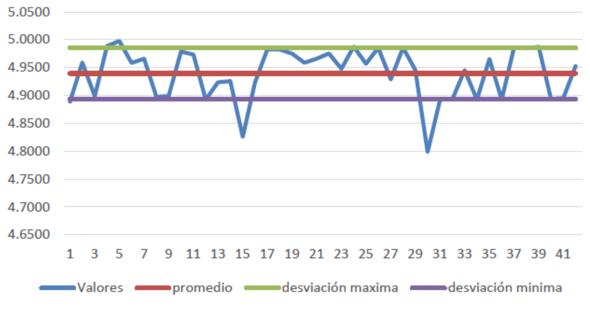


Figure 13. Graphic standard deviation for set of measurements of 5 [ml.]

Once these data calculated proceeds to calculate the percentage of repeatability of each of the sets of parameters using the formula

$$Porcentaje\ de\ repetitividad = \frac{Promedio\ datos - Desviación\ estandar}{Promedio\ datos}\% \qquad (4)$$

In both sets of values a percentage of 99% repetitiveness is obtained.

3.2 Time of dosage

The speed with which the recipes are prepared is also one of the most critical parameters to be assessed as the dosing accuracy is also a measurable and quantifiable parameter,

The dosing time is the time from which has been sent to run the program and this has begun to run until it finished making all dosages to evaluate this parameter have made several recipes of colors in the system and has obtained the average preparation time color: 17 colors dosed in the system took 16:45 minutes so the average color preparation is: 0:50 seconds.

4. Conclusions

The system developed in this project allowed to increase the quality of the process, several trials with different patterns in which the metering accuracy error ranged between 0.01 and 0.05 [ml] were performed. After examining these results the differences between the proposed system and the traditional manual method is observed. Could be obtained as a result in the testing phase speed preparation color up to 50 seconds maximum and accuracy percentage 95.98% while the manual method the minimum preparation time per color is 1 minute 30 seconds and the accuracy percentage is up 89% in addition it varies from person to person, the proposed system increased metering accuracy 6.98% compared to the manual process and speed of the process was increased 34.44%.

We accomplished a functional and practical design for the proposed with the help of two CAD software system: which allowed virtually simulate the performance of the machine and the resistance that offer the same good results that led to the construction of it.

The design of the proposed system which responded satisfactorily and helped to optimize the distribution of space for products and likewise takes full advantage of the resources proposed for the implementation of automatic dosing system was built.

A digital controller was implemented on a CPU with the help of Labview software which also allowed to build an easy HMI interface to understand and operate for the user. To make the system more strength and stability we recommend using an industrial controller such as a PLC to control the machine independently, for future improvement is advisable to use a CPU only as an interface and thus wean the control stage.

Performance tests of the system were conducted in both the mechanical and the electrical part and control to verify proper operation of the system after which it was found that the system meets the proposed system construction such parameters as stability mechanical and electrical to an approximate proposed in the preliminary cost and quality parameters mentioned in the main objective of the project. One of the key issues still open to improvement is the optimization of actuators and motion system axes, if required expand system capacity however is vital calculate the current supply for all engines They are dealing in the system, since according to this criterion must perform the step of adequate power to allow correct transmission of data between the arduino interface and drivers of each engine.

If required increase the accuracy of dosing it is recommended for each individual dosing bottle instead of a single changeable pipette, for this is required to replace the dispenser with a robotic arm to manipulate individual dispensers.

This project was designed for the specific needs of a textile laboratories if you want to develop the project so that it is applicable to various sectors it is necessary to increase the number of bottles of products containing a greater range of products available for preparation dye

Most systems designed for the purpose of dosing using CNC controllers type, so it is also recommended to implement in the future a CNC control for this system, which will also allow you to gain greater accuracy and speed to the system.

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