v. 4, n. 28, 2024

Journal of
Engineering
Research

Acceptance date: 27/12/2024

SCREEN PRINTING MACHINE AUTOMATION, CALCULATIONS AND DEVICE SELECTION

Navarro Soto Ricardo
Instituto Politécnico Nacional, ESIMEZ UPALM ESIME Zacatenco, Ciudad de México

Velázquez Vázquez María de Jesús
Instituto Politécnico Nacional, ESIMEZ UPALM ESIME Zacatenco, Ciudad de México

Castillo Sánchez Martín
Instituto Politécnico Nacional, ESIMEZ UPALM ESIME Zacatenco, Ciudad de México

Abstract: The objective of this work is to automate a manual screen printing machine, with the consequent increase in productivity, mathematical equations developed from the analysis of empirical processes with which the screen printing process was originally developed were applied, based on these calculations it was determined to integrate detection sensors, PLC's, primary and final control elements, valves and other automation elements, machine diagrams were also developed such as: control loop, electrical, pneumatic, phase space and PLC programming lines. A reduction in production times from 4 days to only one day was achieved, which has an impact on the increase of profits.
Keywords: Automation, screen printing, screen printing, printing, frame, mesh.

INTRODUCTION

Engineering as such in its beginnings was generated from experimentation, trial and error, over time it was refining its processes, but it is finally with the help of mathematics when it is formalized, making mathematics a very powerful tool that allows you to develop analytical processes for problem solving, creating models of real systems that allow us to predict behaviors and solve problems through mathematical language. The word serigraphy has its origin in the Latin word "sericum" (=silk) and in the Greek "graphé" (=action of writing, describing or drawing). Serigraphy is a printing process that consists of the passage of ink through a stencil that serves as masking, attached to a stretched screen on a frame. The oldest antecedents of this system have been found in China, Japan and the Fiji Islands, where the inhabitants printed their fabrics using banana leaves, previously cut out with drawings and which, placed on the fabrics, used vegetable paints that colored those areas that had been cut out. During World War II, the United States discovered the appropriateness of this system for marking war material both in factories and on the war fronts themselves, and remains of portable workshops were found after the war ended. The development of advertising and industrial mass production from the 1950s onwards made screen printing the indispensable printing system for all those supports which, due to the composition of their material, shape, size or special characteristics, are not suitable for typography, offset, rotogravure, flexography, etc. printing machines. Screen printing is the system that offers the greatest possibilities, since it has practically no limitations whatsoever.

The screen printing machine to be automated is used to print cylindrical and conical plastic containers, with a capacity from half a liter to one liter. In an 8-hour shift, approximately 5,000 prints are made, as shown in Figure 1. The vertical movement is located in the head where the screen is placed and which is raised to place the object to be printed and once the object is placed, it lowers to start printing the object. This is done by means of a pedal which, when depressed, activates a mechanical spring system that lifts the screen head and when released allows the head to descend. The horizontal movement is also located in the head for the screen and when moving from left to right is how the print is made on the object placed. This is done by means of bearings placed at the rear of the head connected to a slide located at the base of the machine, this movement is performed by the operator by moving the head with his hands in the direction required, either from right to left or vice versa [1, 2].

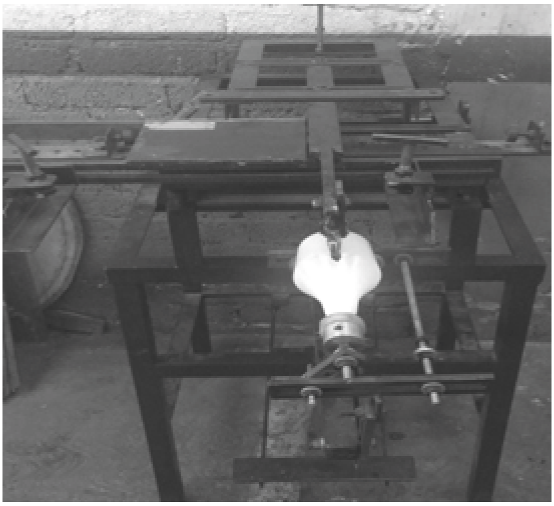

Figure 1. Cylindrical printing machine

METHODOLOGY

CALCULATION OF PNEUMATIC CYLINDERS

In order to perform the calculation of pneumatic cylinders, the following must be considered:

1. The weight to be displaced by the cylinder.
2. The length the stem will travel.
3. Gravity, as this affects the work performed by the actuator.

Taking these variables into account, it should be calculated [3]:

Strength:

Equation 1. $F = m * G$

Where: m = mass to be displaced [Kg] and G = gravity [$^{m}/_{s^2}$].

Forward section (previous): Equation 2 is used to calculate the forward section.

Equation 2. $S_{avance} = \frac{\pi \cdot \emptyset_e^2}{4}$

Back (rear) section: for the back section we use Equation 3.

Equation 3. $S_{retroceso} = \frac{\pi \cdot \emptyset_e^2}{4} - \frac{\pi \cdot \emptyset_v^2}{4} = \frac{\pi \cdot (\emptyset_e^2 - \emptyset_v^2)}{4}$

Where: for both formulas

$\emptyset_e$ = Piston Diameter

$\emptyset_v$ = Piston rod diameter

Volume: once the results of Equations 2 and 3 are obtained, the forward volume (Equation 4) and the backward volume (Equation 5) are calculated.

Equation 4. $V_{av} = S_{avance} * C$

Equation 5. $V_{ret} = S_{retroceso} * C$

Where C= Career

With the results of Equations 4 and 5, the Total Volume can be calculated with Equation 6.

Equation 6. $V_T = V_{av} + V_{ret}$

Flow rate: once the total volume has been calculated, the flow rate is calculated using Equation 7.

Equation 7. $Q = \frac{V_T}{T}$

Where T= total time the cylinder will cycle.

Cylinder for Horizontal Screen Shift

The horizontal displacement system where the screen is placed has an approximate weight of 5 kg and the screen frame has a weight of 500 g, considering that this is made of wood as it is the most common, giving a total weight of approximately 5.5 kg, the cylinder should have a stroke of 260 mm.

Substituting values in equation 1, equation 8 is obtained.

Equation 8. $F = (5.5kg) * (9.81m/s^2) = 53.955\ N$

According to the values of equation 8, the values of equation 9 are obtained.

Equation 9. $\emptyset_v = 4\ mm \qquad \emptyset_e = 12\ mm$

Substituting the values of equation 9 in equation 2 gives equations 10 and 11.

Equation 10. $S_{av} = \frac{\pi \cdot \emptyset_e^2}{4} = \frac{\pi \cdot (12)^2}{4} = 113.097\ mm^2$

Equation 11. $S_{ret} = \frac{\pi \cdot (\emptyset_e^2 - \emptyset_v^2)}{4} = \frac{\pi \cdot ((12)^2 - (4)^2)}{4} = 100.530\ mm^2$

Journal of Engineering Research ISSN 2764-1317 DOI https://doi.org/10.22533/at.ed.3174282419118

Substituting the values of equations 10, 11 and the piston stroke in equations 4 and 5, equations 12 and 13 are obtained.

Equation 12. $V_{av} = S_{av} * C = (113.097) * (260) = 29\,405.22\ mm^3 \rightarrow 0.0294\ L$

Equation 13. $V_{ret} = S_{ret} * C = (100.530) * (260) = 26\,137.8\ mm^3 \rightarrow 0.0261\ L$

Substituting the values of equations 12 and 13 in equation 6, we obtain eq.14

Equation 14. $V_T = V_{av} + V_{ret} = (29\,405.22) + (26\,137.8) = 55\,543.02\ mm^3 \rightarrow 0.0555\ L$

Substituting the value of equation 14 and the operating time of the cylinder in eq.7, we obtain eq.15.

Equation 15. $Q = \frac{V_T}{T} = \frac{(0.0555\ L)}{(0.0666\ min)} = 0.8333\ {}^{L}/_{min} \rightarrow 0.2201\ gpm$

Cylinder for Vertical Displacement of the Screen

It is estimated that the entire head of the machine where the screen is placed, which is lifted by a pedal located at the bottom of the machine, weighs approximately 20 kg and that the cylinder should have a stroke of 85 mm.

Substituting values in equation 1, equation 16 is obtained.

Equation 16. $F = (25kg) * (9.81m/s^2) = 245.25\ N$

According to the values of eq.16, we have the values of eq.17

Equation 17. $\emptyset_v = 10\ mm \qquad \emptyset_e = 25\ mm$

Substituting the values of eq. 17 in eq. 2, equations 18 and 19 are obtained.

Equation 18. $S_{av} = \frac{\pi \cdot \emptyset_e^2}{4} = \frac{\pi \cdot (25)^2}{4} = 490.873\ mm^2$

Equation 19. $S_{ret} = \frac{\pi \cdot (\emptyset_e^2 - \emptyset_v^2)}{4} = \frac{\pi \cdot ((25)^2 - (10)^2)}{4} = 412.334\ mm^2$

Substituting the values of equations 18, 19 and the piston stroke in equations 4 and 5, equations 20 and 21 are obtained.

Equation 20. $V_{av} = S_{av} * C = (490.873) * (85) = 41\,724.205\ mm^3 \rightarrow 0.0417\ L$

Equation 21. $V_{ret} = S_{ret} * C = (412.334) * (85) = 35\,048.39\ mm^3 \rightarrow 0.0350\ L$

Substituting the values of equations 20 and 21 in eq.6, we obtain eq.22

Equation 22. $V_T = V_{av} + V_{ret} = (41\,724.205) + (35\,048.39) = 76\,772.595\ mm^3 \rightarrow 0.0767\ L$

Substituting the value of eq. 22 and the cylinder operating time in eq. 7 gives eq. 23.

Equation 23. $Q = \frac{V_T}{T} = \frac{(0.0767\ L)}{(0.133\ min)} = 0.576\ {}^{L}/_{min} \rightarrow 0.1522\ gpm$

Cylinder with pressurized air injection

This cylinder will not carry any force, instead it will have to hold the bottle in position once it is placed, it will also have to inject enough pressurized air to eliminate the imperfections of the bottles. The total stroke of this piston will be 30mm, the pressure developed will be 3 to 4 bar [4].

Racero and Spatula Cylinders

These cylinders will not load forces, instead they will have to exert little pressure so that at the moment of passing over the screen they can perform their function well, which will be to print or place ink. They will have a total stroke of 40 mm. See equation 24.

Stem and plunger diameter:

Equation **24.** $\emptyset_v = 4\ mm\ \emptyset_e = 12\ mm$

Substituting the values of eq. 24 in eq. 2 gives equations 25 and 26.

Equation 25. $S_{av} = \frac{\pi \cdot \emptyset_e^2}{4} = \frac{\pi \cdot (12)^2}{4} = 11\ 113.097\ mm^2$

Equation 26. $S_{ret} = \frac{\pi \cdot (\emptyset_e^2 - \emptyset_v^2)}{4} = \frac{\pi \cdot ((12)^2 - (4)^2)}{4} = 100.530\ mm^2$

Substituting the values of equations 25 and 26 and the piston stroke in equations 4 and 5, equations 27 and 28 are obtained.

Equation 27. $V_{av} = S_{av} * C = (113.097) * (40) = 4\,523.88\,mm^3 \rightarrow 0.00452$

Equation 28. $V_{ret} = S_{ret} * C = (100.530) * (40) = 4\,021.2\,mm^3 \rightarrow 0.00402\,L$

Substituting the values of equations 27 and 28 into eq. 6 gives eq. 29.

Equation 29. $V_T = V_{av} + V_{ret} = (4\,523.88) + (4\,021.2) = 8\,545.08\,mm^3 \rightarrow 0.00854\,L$

Substituting the value of eq. 29 and the operating time of the cylinder in eq. 7, we obtain eq. 30

Equation 30. $Q = \frac{V_T}{T} = \frac{(0.00854\,L)}{(0.0333\,min)} = 0.256\,{}^{L}/_{min} \rightarrow 0.0676\,gpm$

ELECTRICAL CONNECTION DIAGRAM

Automation Studio 5.0 software was used to create the electrical diagram, as shown in Figure 2. The diagram is divided into two parts, the first part is the automatic operation circuit and the second part is the manual operation circuit.

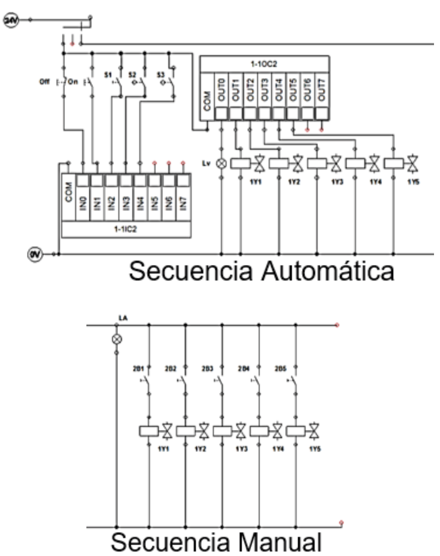

Figure 2. Electrical connection diagram

PNEUMATIC CONNECTION DIAGRAM

Similarly, to perform the pneumatic diagram and simulation that can be seen in Figure 3, Automation Studio 5.0 software was used. This consists of 5 pistons [5].

1. Vertical screen elevation piston.
2. Horizontal screen scrolling piston.
3. Pressurized air injection piston.
4. Squeegee movement piston.
5. Spatula movement piston.

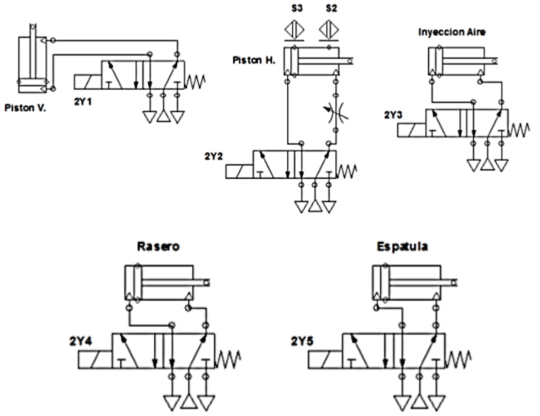

Figure 3. Pneumatic Connection Diagram

PROGRAMMABLE LOGIC CONTROLLER (PLC) PROGRAMMING

Once you have the assignment list, you can start programming the PLC, this was done in the LogixPro software, with the simulator of inputs and outputs to be able to appreciate more easily (Table 1, 2), that in effect, the program reraliza what is desired (Figure 5) [6].

SEMI-AUTOMATIC MACHINE PROTOTYPE

Figure 4 below shows the proposed modifications to be made to the machine and where the devices selected for them will be placed.

Tickets

Address	Usage	Description
I:1/0	Button Startup	Push Button N/A
I:1/1	Stop button	Push Button N/A
I:1/2	Sensor Bottle	Sensor presence
I:1/3	Piston Limit Horizontal	Detector magnetic
I:1/4	Home Piston Horizontal	Detector magnetic

Table 1. Assignment of entries

Exits

Address	Usage	Description
O:2/0	Indicator Ignition of the machine	Indicator light
O:2/1	Vertical Piston	5/2 solenoid valve
O:2/2	Horizontal Piston	5/2 solenoid valve
O:2/3	Piston Injection Air	5/2 solenoid valve
O:2/4	Squeegee Piston	5/2 solenoid valve
O:2/5	Piston Spatula	5/2 solenoid valve

Table 2. Output assignment

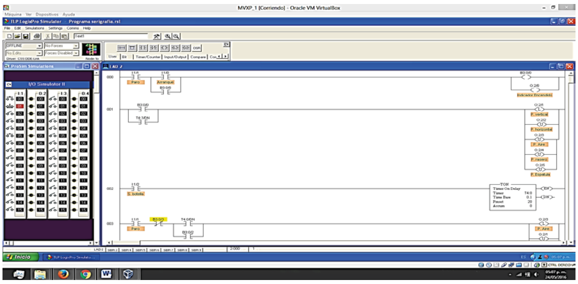

Figure 4. LogixPro Startup Screen

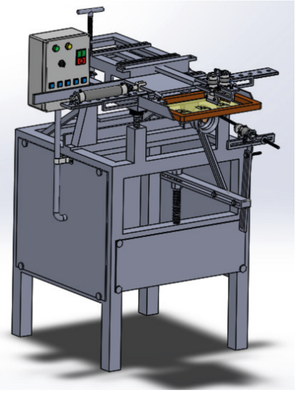

Figure 5. Proposed Semiautomatic Machine

RESULTS AND ANALYSIS

The calculations allow us to obtain a pneumatic cylinder for the horizontal movement with a displacement capacity of 0.0261l and a pressure of 6 bars, likewise, the cylinder for the vertical movement will have a pressure of 6 bars and a displacement of 0.417l in the advance, the cylinder for air injection to the bottles will displace air at a pressure of 4 bars, the cylinders for squeegee and spatula will displace 0.00452l of air at a pressure of 4 bars.00452l of air at a pressure of 4 bars, with this information we developed the pneumatic diagram, then we developed the electrical diagram for the control and apply a programmable logic controller using LogixPro software, to finally develop a proposal through a 3D design program with simulator.

CONCLUSIONS

It was obtained through mathematical calculations, critical reasoning, mathematical modeling, the use of specialized software and the selection of components to arrive at a viable proposal for the automation of the proposed machine.

The automation of the proposed screen printing machine will increase the production of the company by making the production line or prints constant, by partially replacing the human element, the operator will only have to place and remove the bottles, which will minimize the physical effort. Likewise, production costs will be reduced, which can be reflected in higher profits for the company.

The rework reduction margin is the point that will have the greatest impact on this project, since it can be as much as 10 to 30% of total production. This problem will be solved with the injection of pressurized air and will greatly reduce monetary losses and production costs.

REFERENCES

[1] Soria S. (2018), *Sistemas Automáticos Industriales de Eventos Discretos*. México: Alfaomega.

[2] Balcells J. (2016), *Autómatas Programables.* México: Afaomega.

[3] Creus A. (2019), *Neumática e Hidráulica*. México: Alfaomega.

[4] Sánchez R. (2009), Ingeniería de máquinas. [En línea] Disponible en: http://www.uhu.es/rafael.sanchez/ingenieriamaquinas/carpetaapuntes.htm/Trabajos%20IM%202009-10/Carlos%20Tutosaus-introduccion_automatizacion.pdf.

[5] Tutosaus C. (2019), Introducción a la automatización. [En línea] Disponible en: http://www.herrera.unt.edu.ar/eiipc/material/apuntes/Automatas%20Programables.pdf.

[6] Millor N. (1998), Elementos de un proceso a automatizar. [En línea] Disponible en: http://www.infoplc.net/files/documentacion/automatas/infoPLC_net_Teoria_iniciacion_Automata.pdf.