UNIVERSIDAD RICARDO PALMA

PROFESSIONAL DEPARTMENT OF INDUSTRIAL ENGINEERING

RESEARCH WORK

INDUSTRIAL AUTOMATION

PROTOTYPE OF IRON (PVC) PIPE CUTTING MACHINE CONTROLLED BY A PLC

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LIMA - PERU
2023

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SUMMARY

The present research work consists of the development of a prototype of an iron cutting machine, which as a precaution and simulation, was carried out using PVC pipes; and a programmable logic controller (PLC), respectively.

For the execution of this project, a preliminary study was carried out in order to diagnose the current situation in the manufacturing sector and through planning and application, to be able to provide automated solutions to various activities in the sector that are carried out manually and may be susceptible to automate.

The main objective of this project is to apply automation technologies in real processes and knowledge learned throughout the course and professional career in Industrial Engineering, for the correct operation of the iron cutter. In addition, putting teamwork into practice, which allows us to prepare ourselves as future professionals.

After the application of automated technologies, through the use of sensors, pneumatic/electro-pneumatic actuators controlled by a PLC, it was concluded that the application of these tools will optimize time and expenses in the manual production of iron cuts.

Keywords: Programmable logic controller, automation, cutting machine, PVC pipes.

ABSTRACT

This research work consists in the elaboration of a prototype of an iron cutting machine, which as a precaution and simulation, was carried out through the use of PVC pipes; and a programmable logic controller (PLC), respectively.

For the implementation of this project, a preliminary study was carried out in order to diagnose the current situation in the manufacturing sector and through planning and application, to be able to provide automated solutions to various activities in the field that are carried out manually and may be susceptible to automation.

The main objective of this project is to apply automation technologies in real processes and knowledge learned throughout the course and the professional career of Industrial Engineering, for the correct operation of the iron cutter. In addition to this, to put teamwork into practice, which allows us to prepare ourselves as future professionals.

After the application of automated technologies, through the use of sensors, pneumatic/electro-pneumatic actuators controlled by a PLC, it was concluded that the application of these tools will optimize times and expenses in the manual production of iron cuts.

Keywords: Programmable logic controller, automation, cutting machine, PVC pipes

INTRODUCTION

Manual processes have always been a fundamental part of our daily work for a long time, however; With advances in science and technology and the emergence of automated systems, more and more industries and organizations are choosing to replace manual processes with automated solutions. This transition from manual to automated offers numerous benefits, ranging from increased efficiency and reduced costs to improved accuracy and quality of work performed.

That is why this research work exposes the development of an iron pipe cutting machine (PVC) controlled by a PLC, with the purpose of applying methods, knowledge and, above all, providing automated solutions to various activities in the field. that are done manually and can be automated. It should be noted that automated processes use technology to perform tasks more quickly, efficiently and accurately through the use of specialized software, hardware and algorithms that can replace manual tasks with automated workflows. For this case, we will use a programmable logic controller which involves its own configuration of the PLC.

Likewise, the development of this project aims to improve the process and manual finishing of iron cutting in the manufacturing industry through automation.

CHAPTER I: THEORETICAL FRAMEWORK

1.1 Theoretical foundation

Industrial automation is based on the integration of systems and technologies to autonomously control and operate processes in the industry. In the case of an automated iron pipe cutter, automated devices and components are used to efficiently and accurately monitor and regulate the cutting process.

First of all, industrial automation relies on control systems that play a fundamental role in supervising and regulating industrial processes. These systems use sensors to measure variables such as the position and size of the iron tubes, and actuators to control the movement of the cutter and cutting blades. Using programmable controllers, such as programmable logic controllers (PLC), logical instructions are executed based on previously developed programs. This allows activating or deactivating actuators, performing calculations and reading sensors, among other functions, to carry out the cutting process in an automated manner.

Instrumentation is also essential in the automation of an iron pipe cutter. Instrumentation allows measuring and monitoring variables such as temperature, pressure and flow, providing real-time data that is used to adjust the operation of the processes. In the specific case of the cutter, the instrumentation allows measuring key parameters such as cutting speed and blade pressure, which contributes to obtaining precise and consistent cuts.

Furthermore, industrial networks play a vital role in industrial automation and an automated cutting machine. These networks facilitate the communication and integration of different automation devices and systems, allowing the exchange of data between controllers, sensors, actuators and other devices. This facilitates centralized supervision and control of the iron pipe cutting process.

The interaction between operators and the automated cutter is carried out through human-machine interfaces (HMI). These interfaces, which can be touch screens, control panels or monitoring software, allow operators to monitor the status of the cutting process, receive alarms and make adjustments or interventions as necessary.

In summary, industrial automation and an automated iron pipe cutting machine are based on control systems, instrumentation, industrial networks and human-machine interfaces. These components work together to monitor, regulate and optimize the cutting process, improving efficiency, precision and productivity in the iron pipe cutting industry.

Figure 1: Timeline
Source: self made

1.2 Objectives

1.2.1 General objective

Improve the manual iron cutting process in the metallurgical industry.

1.2.2 Specific objectives

a) Improve the productivity of the iron pipe cutting process without affecting quality.
b) Reduce cycle time to 30 seconds per cut.

CHAPTER II: DETAILED DESCRIPTION OF THE CURRENT PROCESS

2.1 Process description

The tube to be cut must be selected taking into account that it is optimal for the clients, then the desired length of the tube must be measured and mark where the cut should be, then the tube is placed on the base horizontally, and Lower the mower vertically.

Figure 2: Tube marking
Source: Laredo, A. (2013) Cutting of longitudinal iron pipe [Video]. YouTube. https://www.youtube.com/watch?v=Q200DhyVnsM

After cutting, the tube will fall by gravity to the container that is below it, so the operator will then finish the PVC tube or the irons, in order to have them in an appropriate shape, either for construction or metalworking companies that are the ones that need these pieces with their specific measurements required in order to have the function for which they are requested.

Figure 3: Placing the tube on the base and cutting
Source: Laredo, A. (2013) Longitudinal iron tube cutting [Video]. Youtube.
https://www.youtube.com/watch?v=Q200DhyVnsM

2.2 Description and details of production indicators before automation

This cutting process, by conventional or manual means, has a dangerous nature, since when cutting the tubes or irons manually, the operator has a high rate of danger and incidents, since it is not a safe way to carry out a process, Therefore, the grinder is a dangerous tool that can cause damage to the person who operates it. For this reason, a prototype for automated pipe and iron cutting has been designed, increasing production in less time, being more efficient and safer. for the operator, thus avoiding damage to the health of workers and improving their productivity.

Figure 4: Cut of the tube trace
Source: Laredo, A. (2013) Longitudinal iron tube cutting [Video]. Youtube.
https://www.youtube.com/watch?v=Q200DhyVnsM

Cycle Time: This indicator measures the total time required to complete a tube cutting cycle, from tube loading to unloading of the cut tube. The shorter the cycle time, the higher the productivity, so the conventional way of cutting is not efficient in companies since it takes a long time to carry out the cutting manually, causing the company to present bottlenecks in the production thereof and thus generates downtime.
Cycle time is 30 seconds.

Throughput: Throughput is the number of tubes cut in a given period of time. It is generally expressed as a ratio between tubes cut and total tubes processed. Higher performance indicates higher productivity.
The performance in a period of 1 hour is 120 cut pieces.

This recorded performance is not adequate, since in a metalworking company countless pieces are needed in order to satisfy the demand, but with this number it cannot be covered enough, therefore it is necessary to devise some prototype of a cutter in order to be able to cover cutting orders in PVC tubes or iron and thus satisfy the demand and customers who require this product.

CHAPTER III: CURRENT DESIGN OF THE PROCESS

3.1 3D CAD plans of the current situation or video of the current situation

The following link demonstrates the current status of the developed project.
https://www.youtube.com/watch?v=z8fnfs9fJt8

CHAPTER IV: PROPOSAL DESIGN TO AUTOMATE THE PROCESS

4.1 Detailed description of the proposed process

It is mentioned that the objective of our project is the novelty in the tube cutting process. Therefore, the description of the process begins to present:
The process of the tube cutter begins with the movement of the tube, it will fall due to the effect of gravity to the top of the ruler, which will have a previously adapted measurement. After this, the photoreflective sensor will begin its function, detecting the presence of the tube and sending the signal to the PLC; taking into account that if the tube measures differently than the adapted measurement, it will continue to fall into a waste box.
At that moment, the PLC will begin to perform its function, starting with the activation of the solenoid valves.
The solenoid valves will send the compressed air under pressure through the hoses, towards the first actuator, which will cause it to expand and hold the tube, it will continue with the second cylinder, when the grinder expands it will begin to rotate and therefore make the cut.
When the sensor does not detect any presence, it sends a signal, therefore the actuator retracts and the tube falls again to the stop where the cycle is repeated continuously, until all cuts are completed.

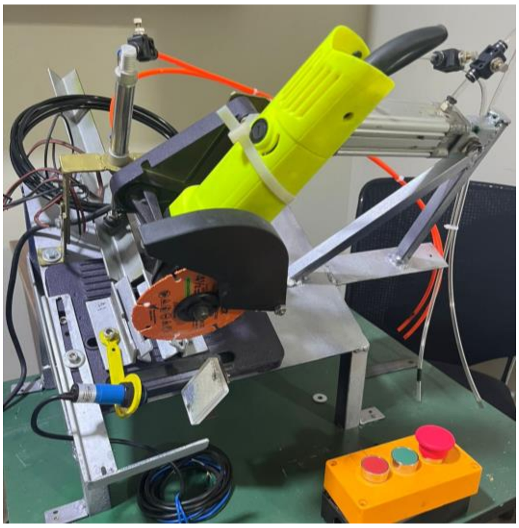

Figure 5: Prototype Tube Cutter
Source: self made

4.2 3D CAD drawings of the chosen proposed situation (must show each component with a different color) or video of the improved situation

The following link demonstrates the improved situation of the developed project.
https://youtu.be/3qVOd6hzcqQ

4.2.1 Double-acting pneumatic cylinder - Piston

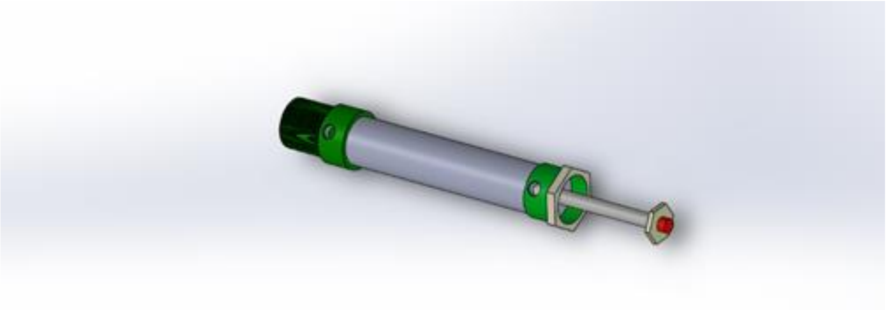

Figure 6: Pneumatic Cylinder
Source: self made

4.2.2 Solenoid valve 1 and 2

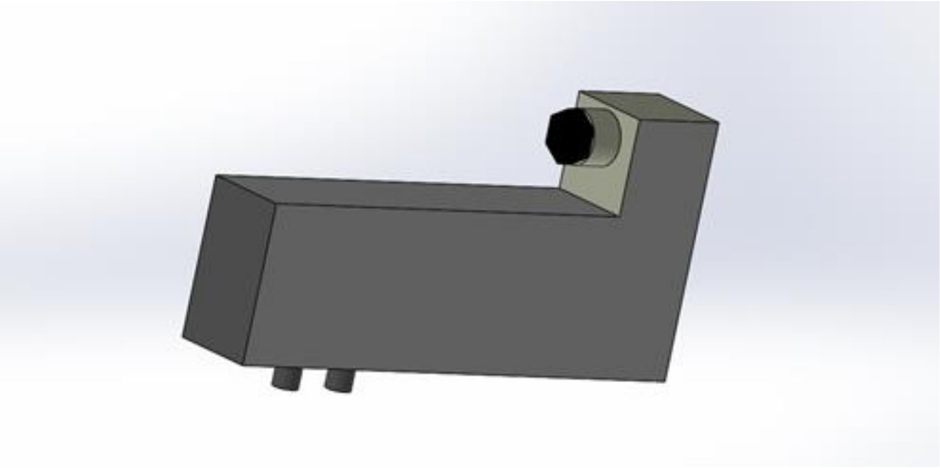

Figure 7: Solenoid valves
Source: self made

4.2.3 Project Basis

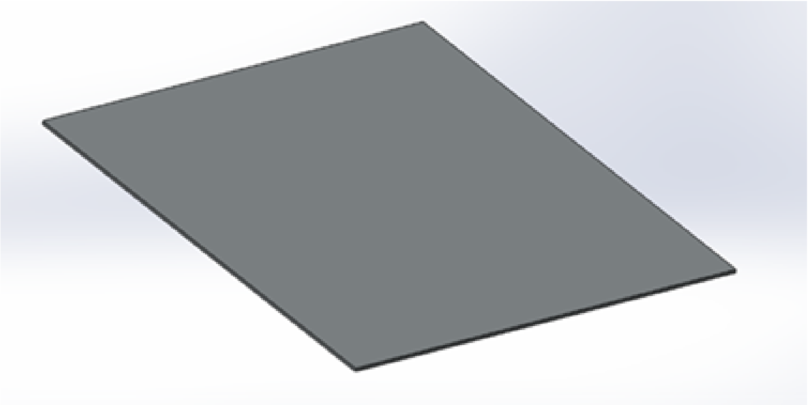

Figure 8: Project basis
Source: self made

4.2.4 Hoses

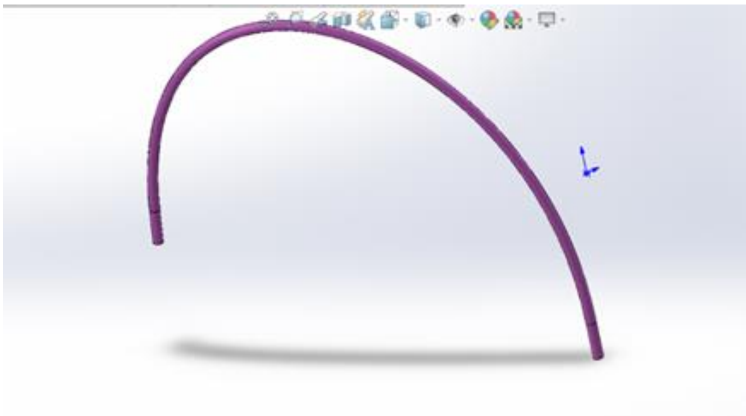

Figure 9: Hoses
Source: self made

4.3 Analysis diagram of the proposed process

4.3.1 Flow Chart

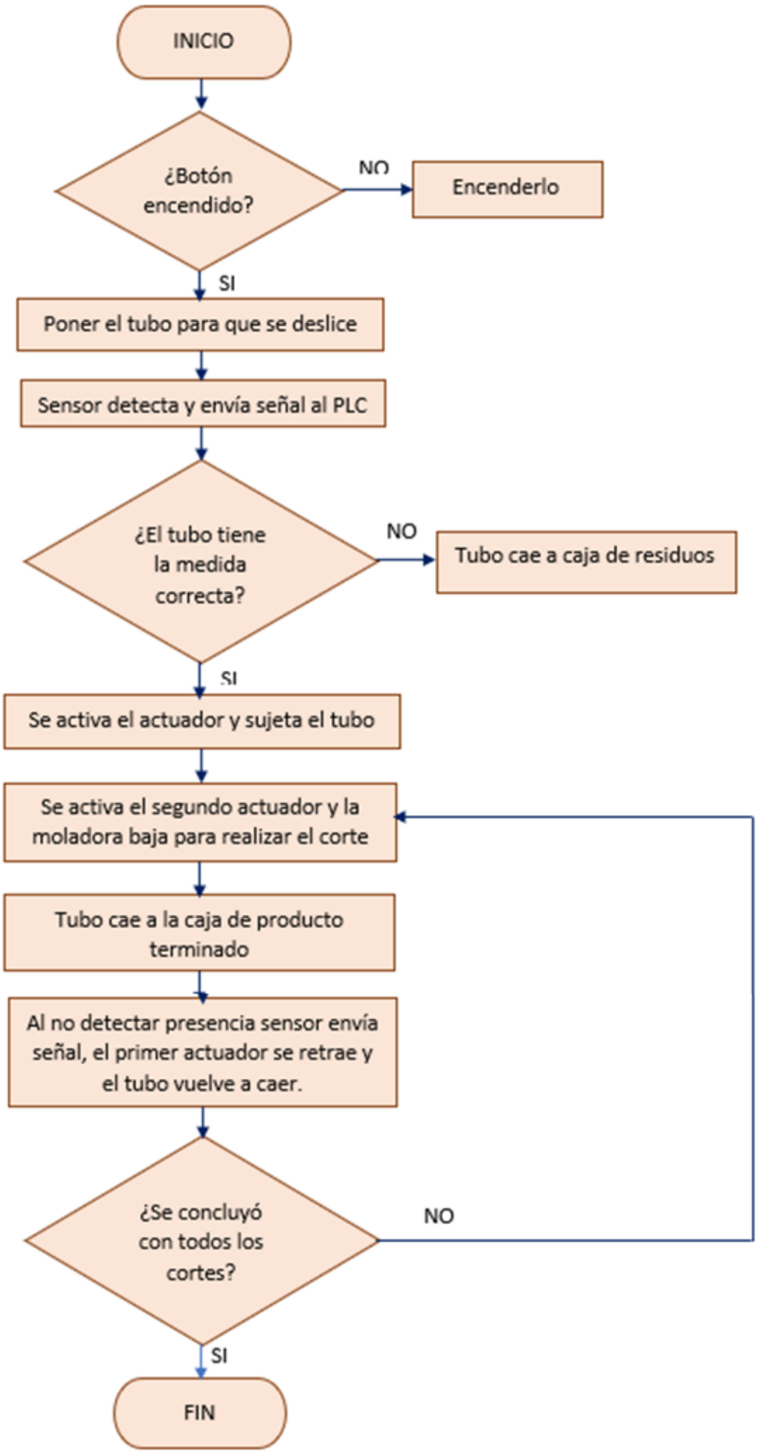

Figure 10: Proposed process flow diagram
Source: self made

4.3.2 Activity Diagram

DAP- PROCESO DEL FUNCIONAMIENTO DE LA CORTADORA DE TUBOS

Ubicación: Universidad Ricardo Palma
Actividad: Diagrama de Actividades
Fecha: 1/07/2023
Operador: Estudiantes de Ing. Industrial

N°	Descripción de las Operaciones							Tiempo (seg)
1	Ingresar el tubo para que se deslice		x					0.1
2	Detectar la presencia del tubo por medio del sensor	x						0.1
3	Generar señal hacia el PLC	x						0.1
4	Activación de las electroválvulas	x						0.1
5	Proporcionar aire a los actuadores a traves de la electrovalvula	x						0.1
6	Activa el primer actuador y presiona el tubo	x						1
7	Activa el segundo actuador y moladora empieza a cortar	x						1
8	Inspecciona el tubo cortado				x			1
9	Se coloca en la caja de producto terminado	x						0.1
10	Se almacena el lote de producto terminado					x		0.1
						Tiempo Total		4
						Tiempo improductivo		0

RESUMEN

Nota:		Simbolo	Descripción	Nro.	El Diagrama comienza en:
Elementos usados en el DAP:	Tubo, Actuadores,PLC, Fuente de Poder, Electroválvulas, Sensor		OPERACIÓN	7	Todos los instrumentos en orden
			TRANSPORTE	1	El Diagrama termina en:
			INSPECCIÓN	1	Máquina termina de realizar su funcion de corte
			ESPERA	0	
			ALMACENAM	1	
			TOTAL		

Figure 11: Activity Diagram
Source: self made

4.4 Detailed description of the materials to be used (sensors, pre-actuators, actuators, motors, PLC, etc.).

Button panel: Allows us to start and end the process.

Figure 12: Button panel
Source: self made

Photo-reflective sensor: Used to detect the light beam reflected from the object.

Figure 13: Photo reflective sensor
Source: self made

Grinder: Object cutter with a circular blade.

Figure 14: Grinder
Source: self made

Double-acting cylinders: They expand and retract in a controlled manner.

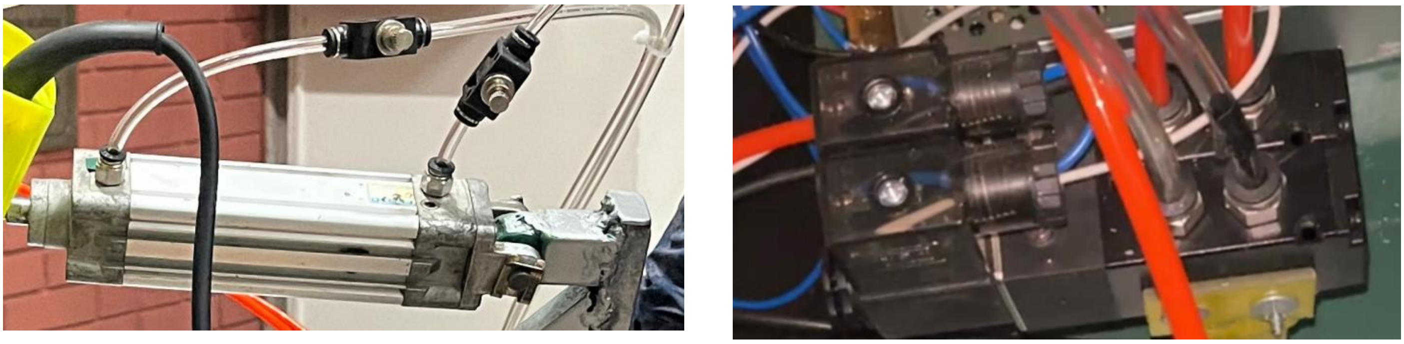

Figure 15: Double acting cylinders
Source: self made

Valve 5/2: Valves through which compressed air enters and exits.

Figure 16: 5/2 Valve
Source: self made

Hoses: Hoses that carry compressed air.

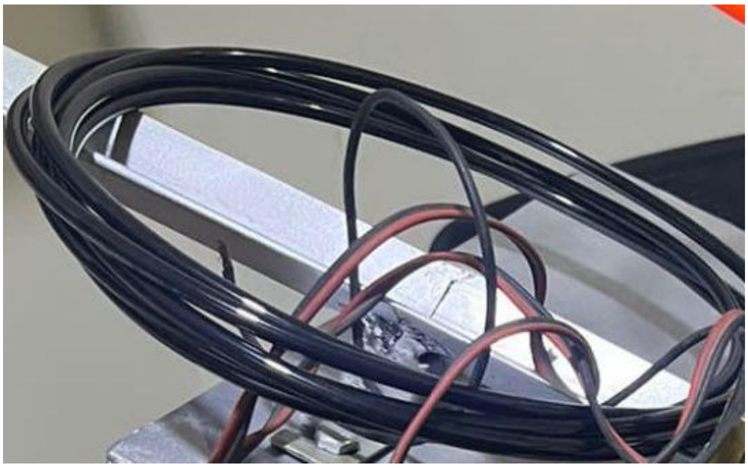

Figure 17: Hoses
Source: self made

Regulators: Regulate the pressure of the compressed air.

Figure 18: Regulators
Source: self made

PLC: Detects various types of process signals, sends and develops actions according to what has been programmed.

Figure 19: Programmable logic programmer
Source: self made

Power Supply: Provides power supply to each component of the system.

Figure 20: Power supply
Source: self made

Relay 24V: Switch whose control is carried out by an electrical circuit, through a coil and an electromagnet, which affects various contacts for the opening or closing of other circuits, which operate independently.

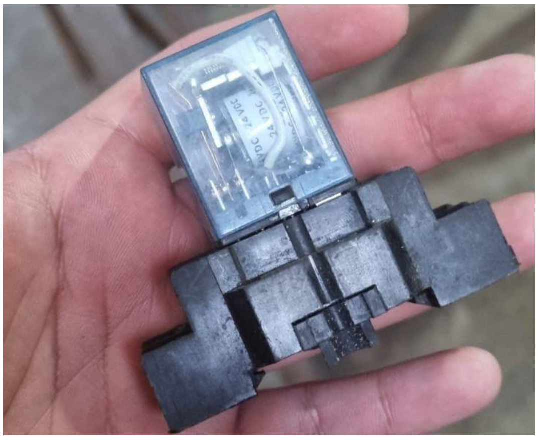

Figure 21: 24V Relay
Source: self made

4.5 Design of the electropneumatic circuit of the proposed process.

We carried out the design of the electropneumatic circuit in Fluidsim; since it is one of the software that can illustrate the pistons and solenoid valves that we use in our project. Here we will use two pistons, the first will hold the tubes in this case so that they do not fall continuously and the second piston will move the grinder that will cut said tubes.
In the first figure, as can be seen, two solenoid valves were also used, which are the ones that will be connected to the PLC and the compressor where it will provide compressed air.

In the second figure, we have the PLC where it will be in charge of controlling the electropneumatic circuit, where the timers will be used to set the time that each piston will be connected.

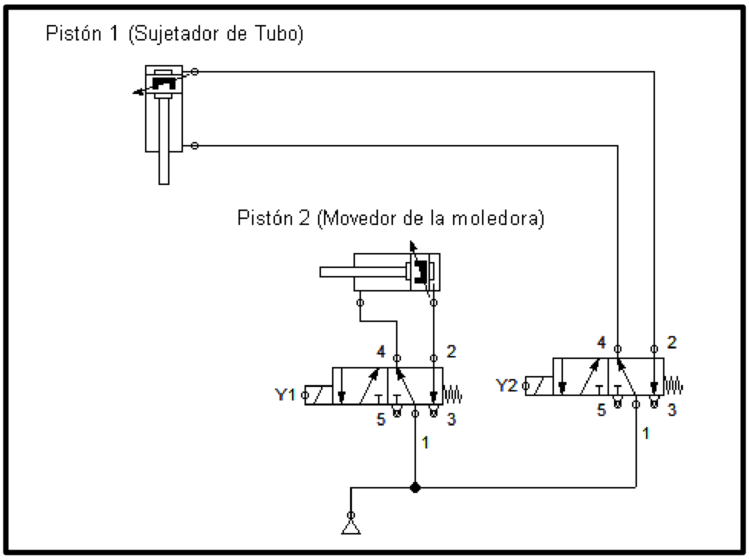

Figure 22: Electropneumatic circuit of the tube cutting machine.
Source: self made

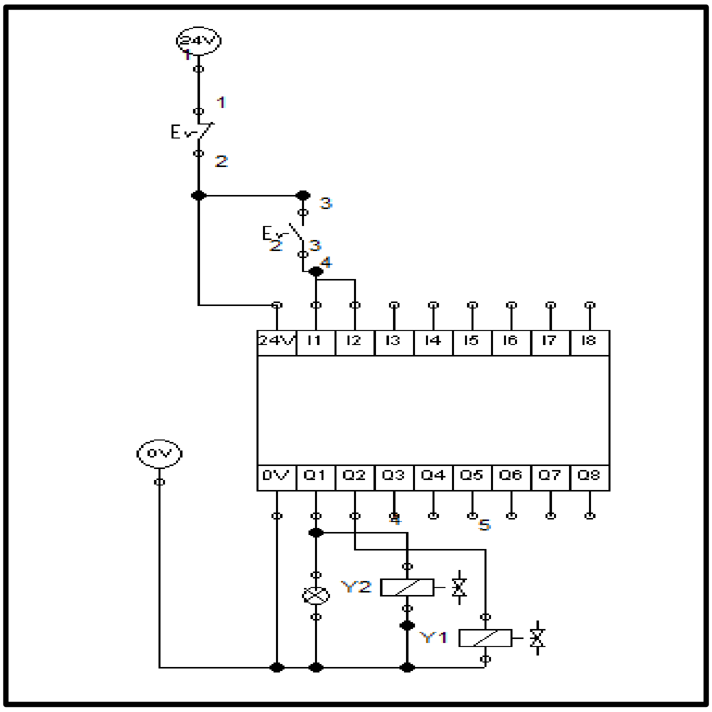

Figure 23: Electro-pneumatic PLC of tube cutting machine
Source: self made.

4.6 Programming in ladder language of the process (comment on each of the segments used in its Ladder programming)

For programming we use the software called LOGO, which is indicated for the type of PLC that we are going to use. The elements that we are going to use are: Normally open contacts, normally closed contacts, self-latching relay, positive edge AND block, disconnection delay timer, coil (represent the actuators) and connection delay timer.

First, we are going to put a normally open contact for turning on and another closed contact for turning off the system. These two are linked to a self-latching relay that will detect the on or off button. Then we connect another normally open contact, which in this case will be the sensor, which, when activated, will cause all the programming to run.

First the piston that will hold the tube will be activated automatically, then the grinder will be activated for 1 second, everything will be done thanks to the connection delay timer; then, the piston will be activated that will move the grinder for another second and finally the system will turn off after 2 seconds thanks to the disconnection delay timer, therefore it will cut off in that time and turn off 2 seconds later because it will be connected to the normally closed contact of the off button.

It should be noted that the entire system is adapted in the software and we found it more practical to do it in Ladder, because in LOGO the block diagram language can also be done.

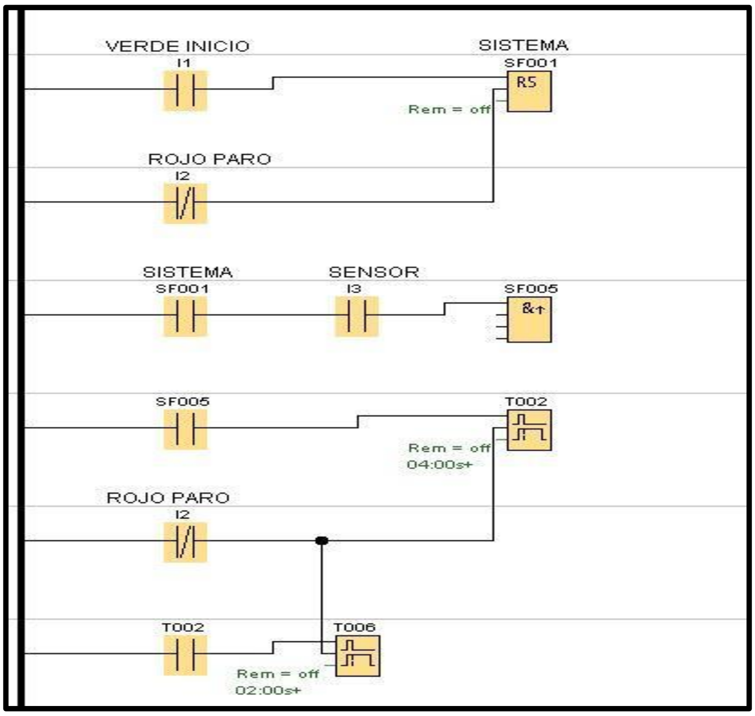

Figure 24: Electropneumatic circuit in LOGO software
Source: self made

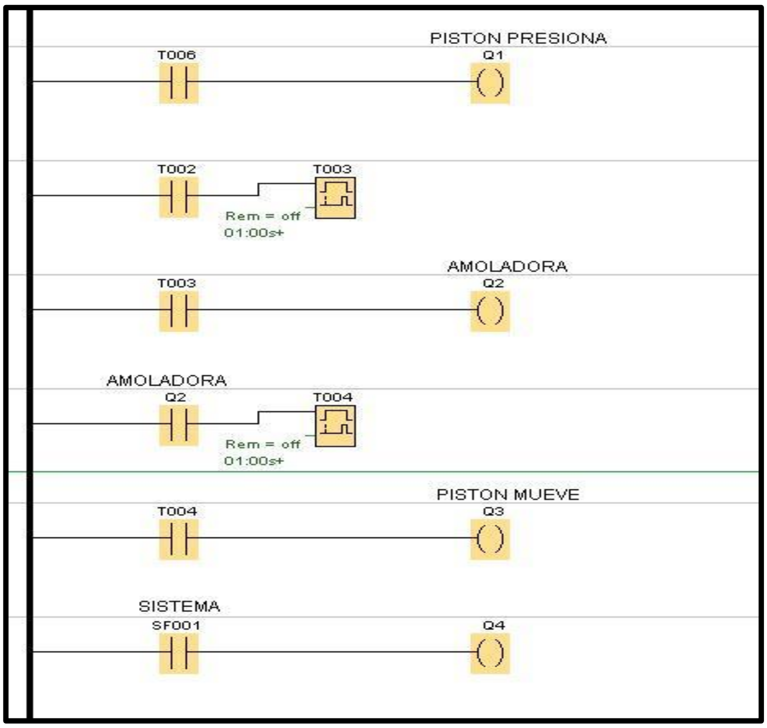

Figure 25: Electropneumatic circuit in LOGO software
Source: self made

4.7 Description and detail of production indicators after automation.

Cycle Time: This indicator measures the total time required to complete a tube cutting cycle, from tube loading to unloading of the cut tube. The shorter the cycle time, the higher the productivity.

The cycle time is 4 seconds.
Throughput: Throughput is the number of tubes successfully cut in a given period of time. It is generally expressed as a ratio between tubes cut and total tubes processed. Higher performance indicates higher productivity.
The performance in a period of 1 hour is 700 cut pieces.

CHAPTER V: INVESTMENT AND OPERATION COSTS

The investment in the automated PVC pipe and iron cutting unit is 950 soles and its sale will be for a value of 1,500 soles, so it was estimated that in the first year 24 units were sold, in the second year 48 units, in the third year 72 units and in the fourth year 96 units were sold, thus covering more of the market as time went by.

5.1 Cash flow

INVERSION INICIAL	22800
COK	20%
TASA DE INFLACION ANUAL	1.80%
RIESGO DEL PROYECTO	2%
INTERES DEL APORTE FINANCIADO	15%
PERIODO	4
INGRESO POR VENTAS	
PRIMER AÑO	36000
SEGUNDO AÑO	72000
TERCER AÑO	108000
CUARTO AÑO	144000
DEPRECIACION	125
CMV	30%
GASTOS OPERATIVOS	10%
TASA IMPOSITIVA	20%

Table N°1: Investment data

Source: self made

EPG AÑO 1		EPG AÑO 2		EPG AÑO 3		EPG AÑO 4	
	ECONOMICO		ECONOMICO		ECONOMICO		ECONOMICO
VENTAS	36,000	VENTAS	72,000	VENTAS	108000	VENTAS	144000
CMV	10,800	CMV	21,600	CMV	32400	CMV	43200
UTILIDAD BRUTA	25,200	UTILIDAD BRUTA	50,400	UTILIDAD BRUTA	75600	UTILIDAD BRUTA	100800
GASTOS	3,600	GASTOS	7,200	GASTOS	10800	GASTOS	14400
DEPRECIACION	125	DEPRECIACION	125	DEPRECIACION	125	DEPRECIACION	125
UAII	21,475	UAII	43,075	UAII	64675	UAII	86275
INTERES	0	INTERES	0	INTERES	0	INTERES	0
UAI	21,475	UAI	43,075	UAI	64675	UAI	86275
IMPUESTOS	4,295	IMPUESTOS	8,615	IMPUESTOS	12935	IMPUESTOS	17255
U. NETA	17,180	U. NETA	34,460	U. NETA	51740	U. NETA	69020

Table N°2: Profit and loss statements

Source: self made

FLUJO DE CAJA ECONOMICO					
	0	1	2	3	4
UTILIDAD NETA ECONOMICA		17,180	34,460	51740	69020
DEPRECIACION		125	125	125	125
INVERSIONES	-22800				
SALDO NETO DE CAJA	-22,800	17,305	34,585	51,865	69,145

Table N°3: Economic cash flow

Source: self made

5.2 Economic viability (VAN, IRR).

FLUJO DE CAJA ECONOMICO					
	0	1	2	3	4
UTILIDAD NETA ECONOMICA		17,180	34,460	51740	69020
DEPRECIACION		125	125	125	125
INVERSIONES	-22800				
SALDO NETO DE CAJA	-22,800	17,305	34,585	51,865	69,145
TASA DE DESCUENTO	24.60%				
VAN:	-22,800	13,888	22,276	26,809	28,684
VAN:	68,857				
TIR:	120%				

Table N°4: NPV and economic IRR of the project

Source: self made

CONCLUSIONS

1. According to the objectives, it is concluded that applying automation in the manual iron cutting process in the metallurgical industry will optimize production times, reducing costs, accidents, errors and increasing productivity, efficiency and quality of the finished product.

2. After the implementation of automation in a manual cutting process, we immediately showed that the implementation of this in the metallurgical industry would be of great benefit for notable reasons such as the resulting profitability in the NPV and the improvement of profitability that exceeds the cost. of the capital demonstrated in the IRR.

3. As a final conclusion, it is indicated that the application of automated technologies in real processes improves productivity, efficiency, increases quality and precision, reduces costs, provides greater security, the process is flexible, can collect and analyze more data, as well as how to show greater innovation and competitiveness in the sector.

RECOMMENDATIONS

According to the application of automated technologies in this research work, the improvement and increase in productivity that the sector would have in the iron cutting process is notably recorded, which mentions the following different steps:

- It is recommended in planning to clearly establish the objectives and requirements of the prototype. Considering aspects such as the diameter and maximum thickness of the tubes that the machine must cut, the precision required in the cuts, the desired cutting speed and any other special characteristics desired.

- It is proposed to incorporate safety features, such as operator protections, emergency stop systems and safety elements in the clamping and cutting mechanisms.

- It is recommended to carry out exhaustive tests to evaluate the performance, precision and durability of the prototype, making the necessary adjustments based on the test results and repeat the process until we are sure and/or find satisfaction with the performance of the prototype.

- It is advisable to keep a detailed record of the entire design, construction and testing process of the prototype, this way it will be useful for future improvements and references.

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