UNIVERSIDAD RICARDO PALMA

ENGINEERING FACULTY

PROFESSIONAL SCHOOL OF INDUSTRIAL ENGINEERING

INDUSTRIAL AUTOMATION

RESEARCH WORK

"Design and application of PLC on a part drilling machine within awoodworking shop."

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SUMMARY

The objective of this work is to improve the automation of a drilling machine, which will drill a part in 4 points of equal distance. In order to make this proposal, a study of the current process of the process, which is performed entirely manually, was previously made. To perform the current process the worker must first mark the correct location to the point to which you want to drill, then place on the drill table a drill, which must be aligned using the view to then make the drilling process. As can be identified this process is simple and repetitive, but at the same time it requires a lot of precision. The proposal is to design a machine that performs this process automatically.

Key words: Drilling, automation, drilling machine.

ABSTRACT

In this work, the objective is to improve the automation of a drilling machine, which will drill a piece in 4 points of equal distance. To make this proposal, a study was previously made on the current process, which is carried out entirely manually. To carry out the current process, the worker must first mark the correct location at the point to which it is desired to drill, then place a drill bit on the drill table, which must be aligned using the view to then carry out the drilling process. As can be identified, this process is simple and repetitive, but at the same time, it requires a lot of precision. The proposal to design a machine that performs this process automatically is proposed.

Keywords: Drilling, automation, drilling machine.

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CHAPTER 1: THEORETICAL FRAMEWORK

1.1 Theoretical Basis

1.1.1 Pneumatics and Hydraulics

Pneumatics can be defined as a science that with the help of implementing gases and air will cause a pressure that will make a machine move and run. On the other hand, hydraulics uses liquids and gases for the same purpose, the main difference being that the former is for transferring energy, while the latter is for transferring power. Generally, as mentioned, compressed air is used, but there are also other options such as nitrogen, helium, argon, among others (Areatecnologia, n.d.).

1.1.2 Valves

According to Pneumax (2018) defines that "in pneumatics the valve is the device that intercepts and distributes compressed air or regulates its flow."

1.1.3 Distributor Valves

The directional control valves, also called directional control valves, are part of the air flow path. In addition, they serve to effect the direction of flow and stop. The directional control valves have several holes and help to follow the direction of the compressed air. These holes are from two to six, depending on the function to be used (Industrial Automation, 2010).

1.1.4 Bistable solenoid valve

According to Pneumax (2018) states that "for operation they need two external signals. They are valves with operators of the stable type, such as pneumatic or 2-position pushbutton, which, in the absence of the second external signal, remain in the position in which they are located."

1.1.5 Monostable solenoid valve

According to Pneumax (2018) "for their operation they need only one external signal. They are valves with the unstable type repositioning operator that does not need external signal, but reposition itself upon lack of signal from the opposite operator."

1.1.6 PLC

Murillo (2013) defines that "the Programmable Logic Controller is an electronic digital device with a programmable memory for the storage of instructions, allowing the implementation of specific functions such as: logical, sequential, timed, arithmetic counting; in order to control machines and processes".

Fields of application

Nowadays it is known that the fields of application of the PLC are very varied, from a house to an industrial application, it can control simple production processes to the most complicated ones; for example:

- Industrial wood furniture machines
- Machinery in the plastics industry
- Processes with display of environment variables.
- Processes with reduced physical space
- Thermal process installations
- Lighting system of a house, etc.

PLC applications are varied, it should be taken into account that they are the most used electronic devices in the control of sequential processes and at the same time, they facilitate the development of heavy or repetitive work where the integrity of the human being could be put at risk (González, 2015).

Programmable control

According to Vasquez (2010) to achieve the automation of industrial processes is necessary to implement the PLC. The programmed control replaces the use of electromechanical relays to define the automation process, thus saving material costs. Therefore, any changes required in the programming logic are reduced to making changes in the code without creating physical changes. PLC programming is done empirically, so there may be similar programmers, but the PLCs can be programmed in a variety of ways.

with different structures. As a result, future modifications to the code will be difficult to make and will need to be redone.

1.2 Objectives

1.2.1 Main Objective

Implement the automation upgrade of a drilling machine.

1.2.2 Specific Objectives

- Simplify the drilling process in order to automate simple processes.
- Standardize drilled parts, reducing failed parts and speeding up the activity.

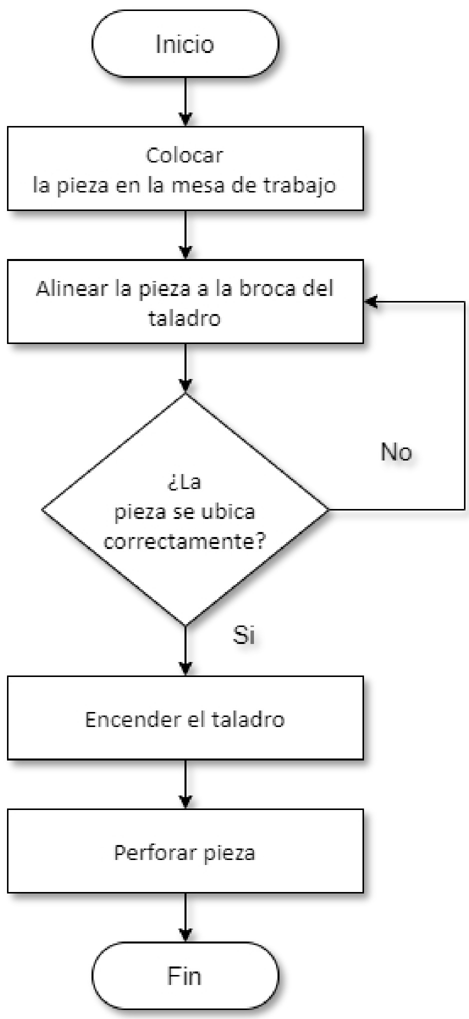
CHAPTER 2: DETAILED DESCRIPTION OF THE CURRENT PROCESS

2.1 Description of the Current Process

The whole process is done manually, it consists first of placing the piece on the drill table to make the drilling process, the worker must mark in advance to avoid errors. After that, the table drilling machine is turned on to perform the process. This process is done several times since this is a repetitive process.

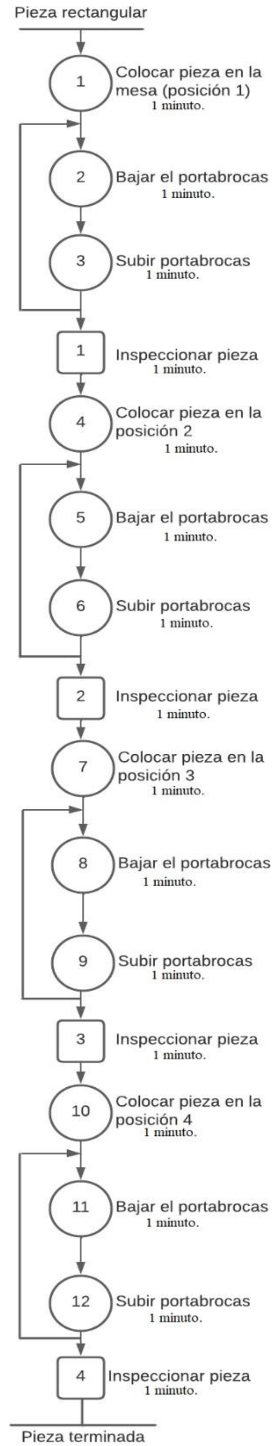
2.2 Flow Diagram of the Current Process of a Drilling Machine

Figure 1:
Flow diagram of the current process of a drilling machine
Source: Own elaboration



2.3 Current Operations Diagram of a Drilling Machine

Figure 2:
Diagram of current operations of a drilling machine
Source: Own elaboration



2.4 Current Process Analysis Diagram for a Drilling Machine

Figure 3:
Diagram of analysis of the current process of a drilling machine
Source: Own elaboration

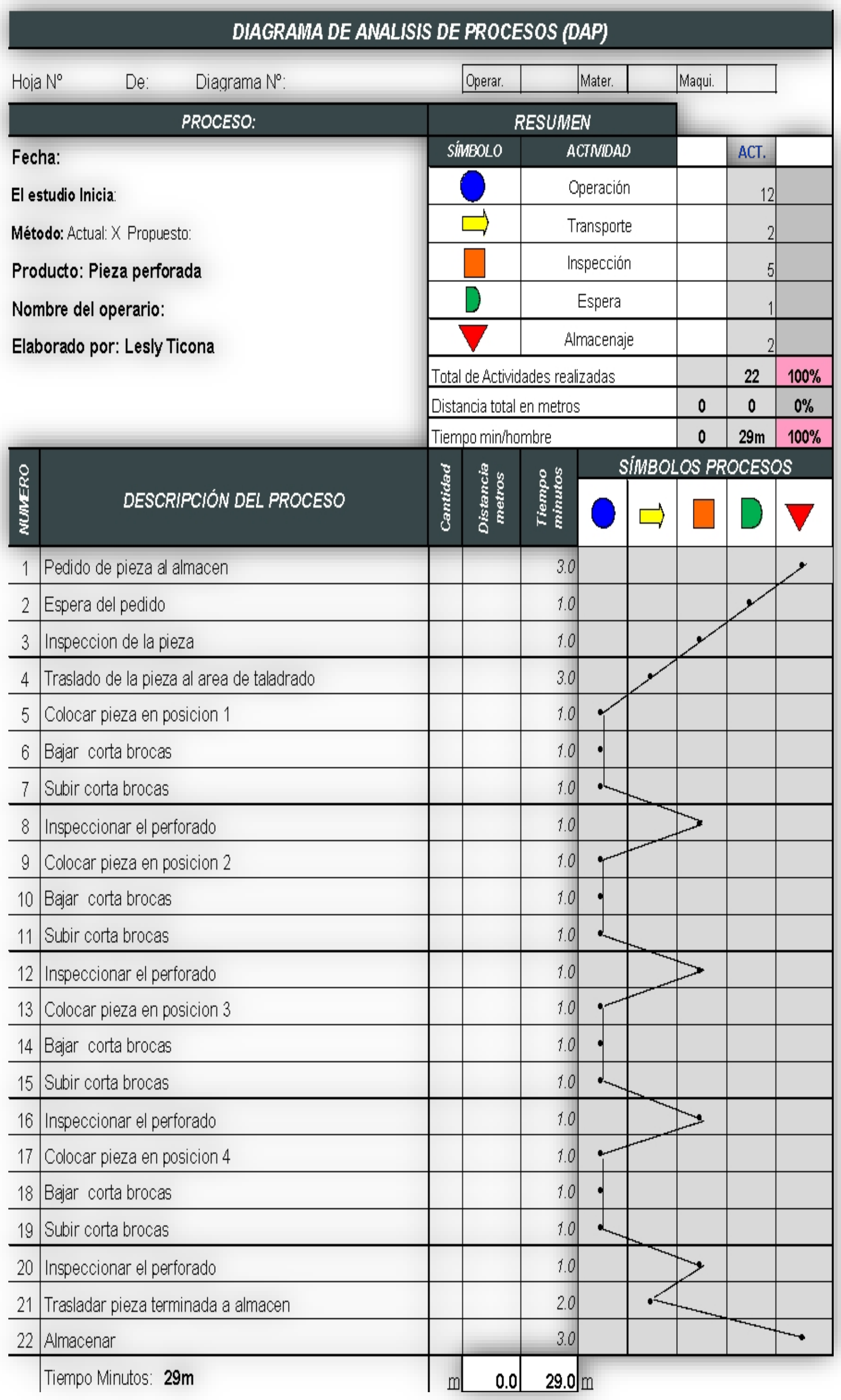


DIAGRAMA DE ANALISIS DE PROCESOS (DAP)

Hoja N° De: Diagrama N°: Operar. Mater. Maqui.

PROCESO:

Fecha:
El estudio Inicia:
Método: Actual: X Propuesto:
Producto: Pieza perforada
Nombre del operario:
Elaborado por: Lesly Ticona

RESUMEN				
SÍMBOLO	ACTIVIDAD		ACT.	
●	Operación		12	
⇨	Transporte		2	
■	Inspección		5	
D	Espera		1	
▼	Almacenaje		2	
Total de Actividades realizadas			22	100%
Distancia total en metros		0	0	0%
Tiempo min/hombre		0	29m	100%

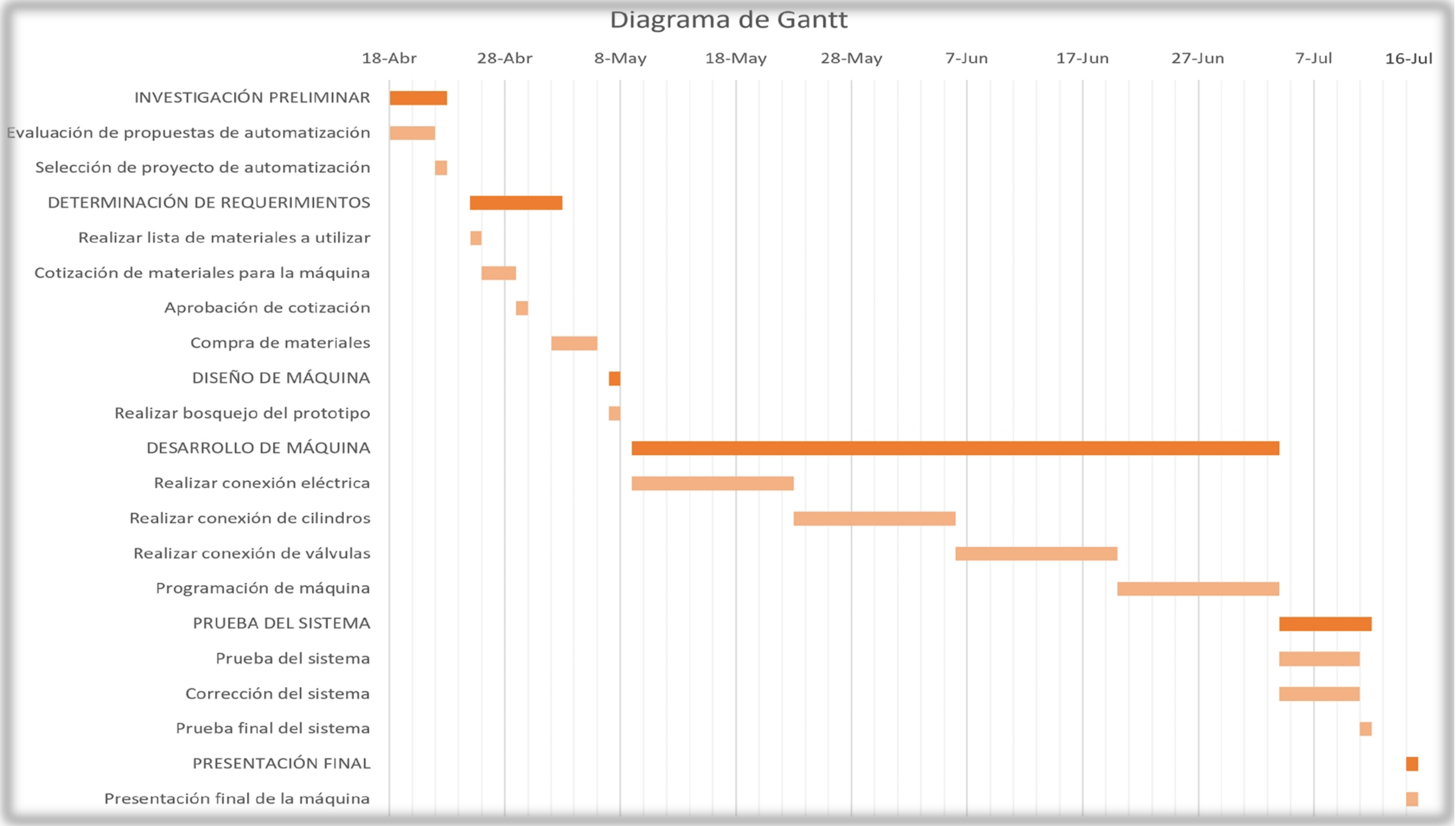
NUMERO	DESCRIPCIÓN DEL PROCESO	Cantidad	Distancia metros	Tiempo minutos	●	⇨	■	D	▼
1	Pedido de pieza al almacen			3.0					•
2	Espera del pedido			1.0				•	
3	Inspeccion de la pieza			1.0			•		
4	Traslado de la pieza al area de taladrado			3.0		•			
5	Colocar pieza en posicion 1			1.0	•				
6	Bajar corta brocas			1.0	•				
7	Subir corta brocas			1.0	•				
8	Inspeccionar el perforado			1.0			•		
9	Colocar pieza en posicion 2			1.0	•				
10	Bajar corta brocas			1.0	•				
11	Subir corta brocas			1.0	•				
12	Inspeccionar el perforado			1.0			•		
13	Colocar pieza en posicion 3			1.0	•				
14	Bajar corta brocas			1.0	•				
15	Subir corta brocas			1.0	•				
16	Inspeccionar el perforado			1.0			•		
17	Colocar pieza en posicion 4			1.0	•				
18	Bajar corta brocas			1.0	•				
19	Subir corta brocas			1.0	•				
20	Inspeccionar el perforado			1.0			•		
21	Trasladar pieza terminada a almacen			2.0		•			
22	Almacenar			3.0					•
	Tiempo Minutos: **29m**	m	0.0	29.0 m					

2.5 Automation Plan Gantt

Table 1:
Project automation schedule Source: Own elaboration

Name of activity	Start date	Duration in days	End date
RESEARCH PRELIMINARY	**18-Apr**	**5**	**23-Apr**
Evaluation of proposals for automation	18-Apr	4	22-Apr
Project selection of automation	22-Apr	1	23-Apr
DETERMINATION OF REQUIREMENTS	**25-Apr**	**8**	**6-May**
Create a list of materials to be used	25-Apr	1	26-Apr
Quotation of materials for the machine	26-Apr	3	29-Apr
Approval of quotation	29-Apr	1	30-Apr
Purchase of materials	2-May	4	6-May
MACHINE DESIGN	**7-May**	**1**	**8-May**
Sketch the prototype	7-May	1	8-May
MACHINE DEVELOPMENT	**9-May**	**56**	**21-May**
Make electrical connection	9-May	14	23-May
Connecting cylinders	23-May	14	6-Jun
Connect valves	6-Jun	14	20-Jun
Machine programming	20-Jun	14	4-Jul
SYSTEM TEST	**4-Jul**	**8**	**15-Jul**
System test	4-Jul	7	11-Jul
System correction	4-Jul	7	11-Jul
Final system test	11-Jul	1	15-Jul
FINAL PRESENTATION	**15-Jul**	**1**	**16-Jul**
Final machine presentation	15-Jul	1	16-Jul

Figure 4:
Gantt chart of the project automation plan Source: Own elaboration.



2.6 Description and Detail of Production Indicators Before Automation

2.6.1 Production

In an ordinary carpenter's shop, a conventional table drill is used for daily drilling, the work shift corresponds to 8 hours for 5 days a week. Its production level is 180 holes per day.

2.6.2 Physical efficiency

$$\text{Production} = \frac{360 \text{ min / day}}{2 \text{ min / day}}$$

This indicator is determined by the time it takes to carry out the operations, in a few words, it is the time it would take an operator to perform the drilling.

2.6.3 Designed capacity

According to the Delphi Method (n.d.) "The designed capacity of the machine is the maximum theoretical capacity that can be obtained under ideal conditions".

In reference to the proposed designed capacity for the project, we consider that the appropriate capacity for this drill is 100 pieces/hour.

2.6.4 Idle capacity

What defines this idle capacity indicator is equal to the difference of effective capacity minus the designed capacity, which is 50 pieces/hour.

2.6.5 Effective capacity

What defines this indicator is known as the highest production number obtained with the minimum number of resources, which gives us 20 pieces/hour.

CHAPTER 3: CURRENT PROCESS DESIGN

As mentioned in previous chapters, the process was done manually with a conventional table drill.

3.1 3D CAD drawings of the current situation

Figure 5:
3D plan of the current situation
Source: Own elaboration.

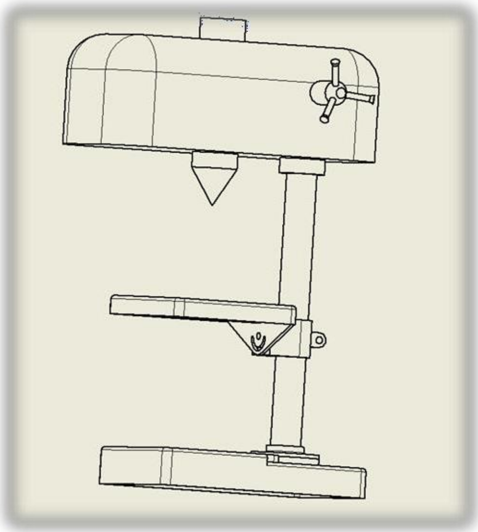
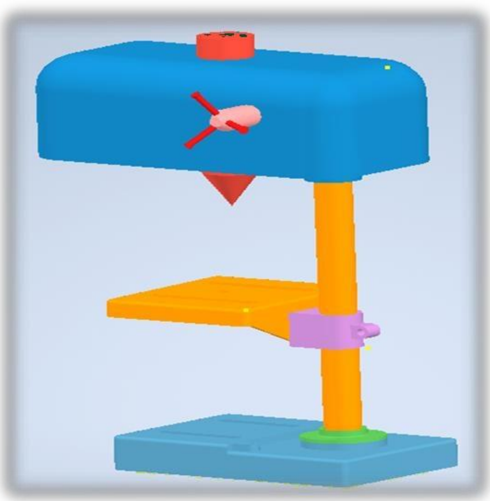


Figure 6:
3D plan of the current situation
Source: Own elaboration.



CHAPTER 4: PROPOSAL DESIGN TO AUTOMATE THE PROCESS

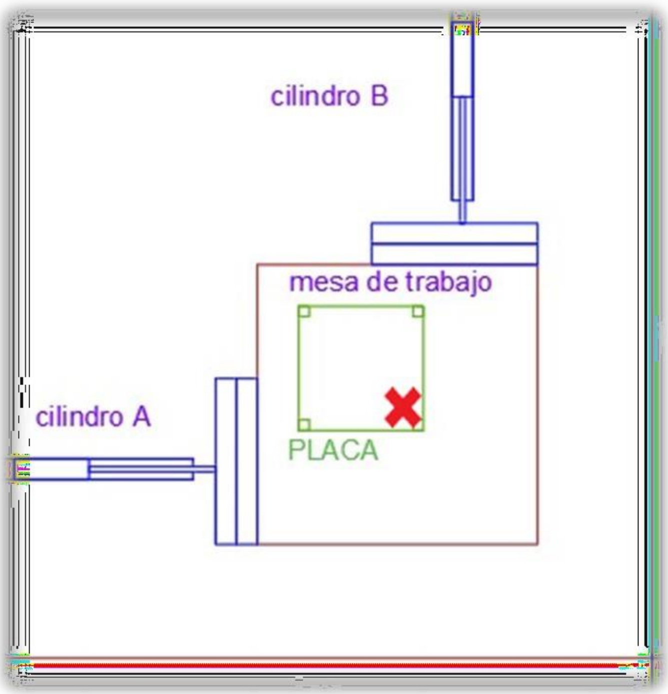
4.1 Detailed description of the proposed process

The process starts with the positioning of the piece to be drilled (wood) on the working surface of the drilling machine.

Once the piece of wood to be drilled has been verified that it is correctly positioned, the drilling machine is turned on and starts its operation.

Once the drilling machine is turned on in its starting position with both cylinders (A and B) compressed, the drilling machine starts drilling at point 1 of the piece of wood to be drilled. (See Figure 7).

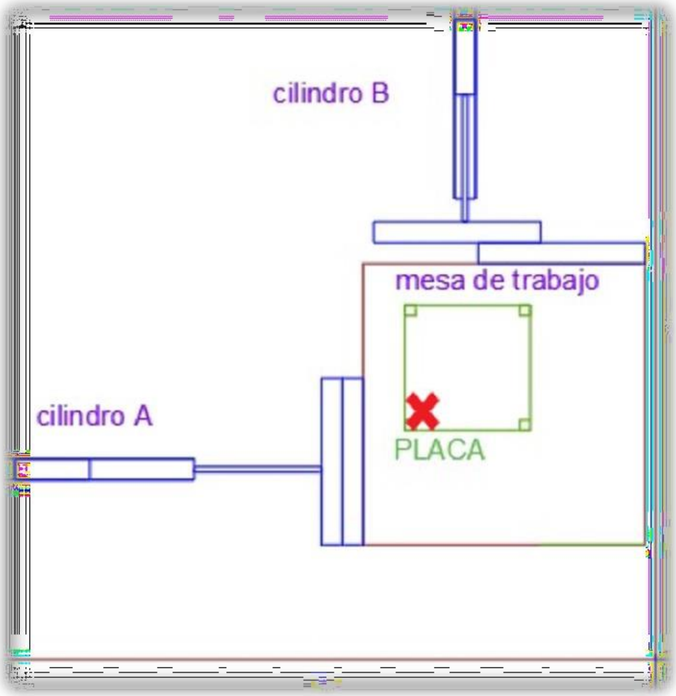
Figure 7:
Base structure point 1



Note*:* The image represents the projection of the drilling machine for the drilling of the first point to be drilled prepared in AutoCAD. Own elaboration.

Next step Cylinder A expands, and once Cylinder A is fully expanded (Cylinder A expanded and Cylinder B compressed), the drill starts drilling at point 2 of the piece of wood to be drilled. (See Figure 8).

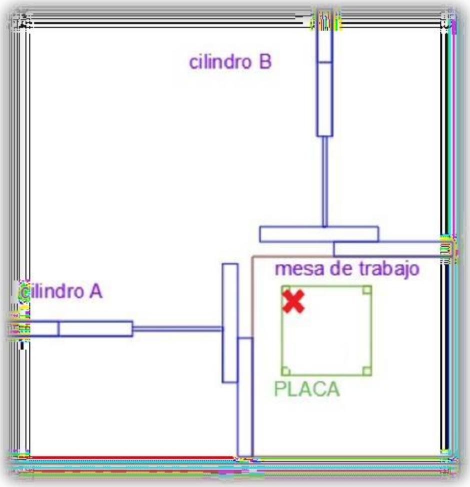
Figure 8:
Base structure point 2



Note: The image represents the projection of the drilling machine for the drilling of the second point to be drilled prepared in AutoCAD. Own elaboration.

Once point 2 of the piece is drilled, cylinder B expands; once Cylinder B is fully expanded (Cylinder A and Cylinder B expanded), the drill begins to act on point 3 of the piece of wood to be drilled. (See Figure 9).

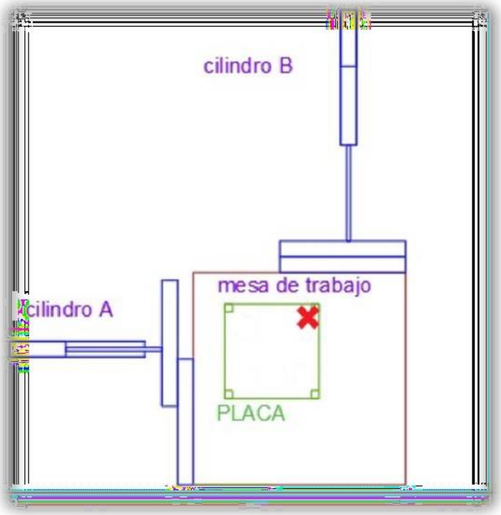
Figure 9:
Base structure point 3



Note*:* The image represents the projection of the drilling machine for the drilling of the third point to be drilled prepared in AutoCAD. Own elaboration.

Once point 3 of the piece is completely drilled, cylinder A is compressed (Cylinder A compressed and Cylinder B expanded), and drilling begins at point 4 of the piece of wood to be drilled. (See Figure 10).

Figure 10:
Base structure point 4



Note*:* The image represents the projection of the drilling machine for the drilling of the fourth point to be drilled elaborated in AutoCAD. Own elaboration.

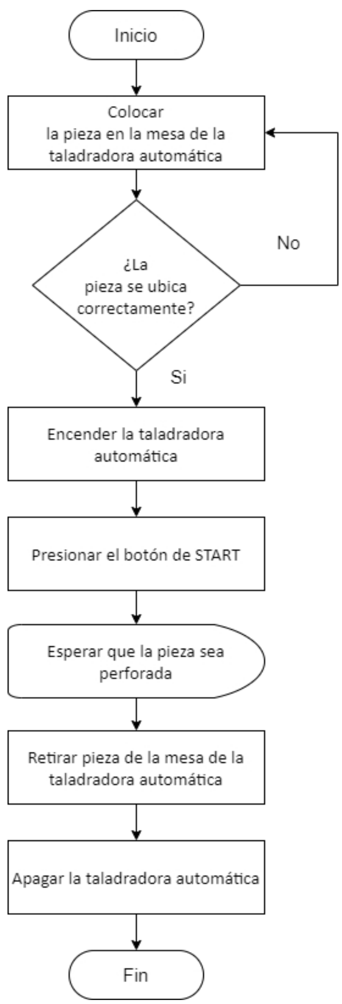
Once the 4 points have been drilled, cylinder B is compressed (Cylinder A and Cylinder B compressed) returning to its starting point, resulting in the desired part.

4.2 3D CAD drawings of the selected proposed location

See Annexes 1, 2, 3 and 4.

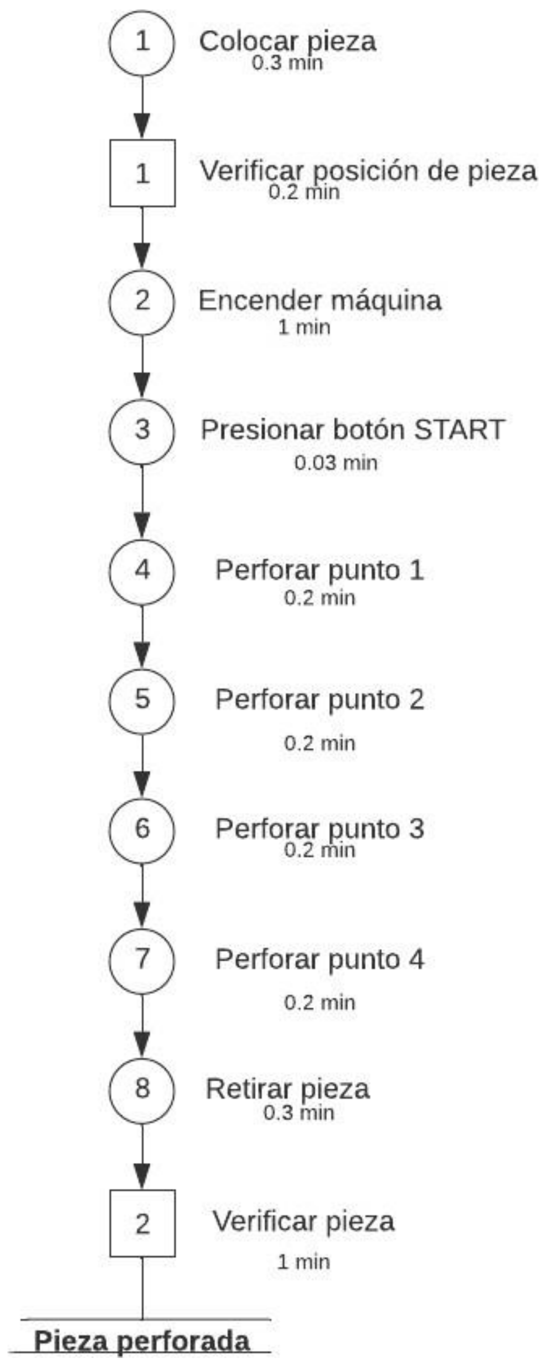
4.3 Flowchart of the Proposed Process

Figure 11:
Flow diagram of the proposed process of a drilling machine
Source: Own elaboration.



4.4 Operations Diagram of the Proposed Process

Figure 12:
Diagram of operations of the improved process of a drilling machine Source: Own elaboration.



Caption:

Table 2:
Summary of proposed PDO

Activity	Quantity	Time (min)
Operation	8	2.43
Inspection	2	1.20
TOTAL	**10**	**3.63**

4.5 Process Analysis Diagram of the Proposed Process

Figure 13:
Diagram of analysis of the proposed process of a drilling machine
Note*:* Own elaboration.

DIAGRAMA DE ANALISIS DE PROCESOS (DAP)

Hoja N°_____ De:____ Diagrama N°:____ Operar. Mater. Maqui.

PROCESO:	RESUMEN				
Fecha:	SÍMBOLO	ACTIVIDAD		ACT.	
El estudio Inicia:	●	Operación		3	
Método: Actual:____ Propuesto:__x__	⇨	Transporte		2	
Producto: Pieza perforada por maquina taladradora autom.	■	Inspección		3	
Nombre del operario:	D	Espera		2	
Elaborado por:	▼	Almacenaje		2	
Tamaño del Lote:	Total de Actividades realizadas			12	100%
	Distancia total en metros		0	0	0%
	Tiempo min/hombre		0	11	100%

NUMERO	DESCRIPCIÓN DEL PROCESO	Cantidad	Distancia metros	Tiempo minutos	●	⇨	■	D	▼
1	Pedido de pieza al almacen			3.0					●
2	Espera del pedido			2.0				●	
3	Traslado de la pieza al area de taladrado			1.0			●		
4	Colocar pieza en maquina			0.3		●			
5	Verificar posicion de pieza			0.2			●		
6	Encender maquina			1.0	●				
7	Presionar boton START			0.03	●				
8	Espera de perforado de pieza			0.8				●	
9	Retirar pieza de maquina			0.3	●				
10	Verificar pieza			0.2			●		
11	Trasladar pieza terminada a almacen			1.0		●			
12	Almacenar			1.0					●
	Tiempo Minutos: **10.9**	m	**0.0**	**10.9** m					

4.6 Detailed description of the materials to be used

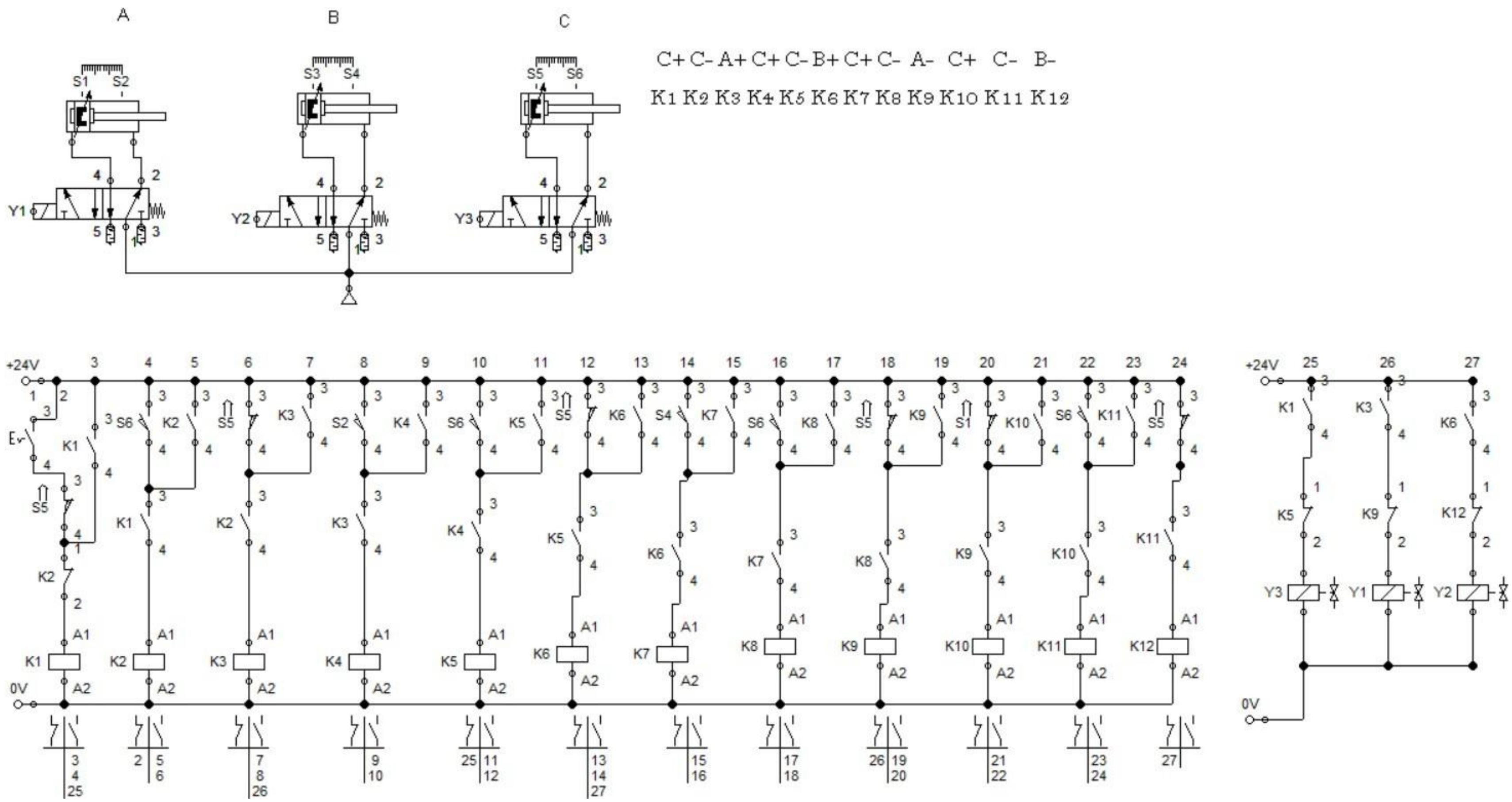
Table 3:
Materials used in the project prototype Source: Own elaboration

		
Power Supply	Pneumatic cylinders (16 x 100)	Solenoid valve
		
PLC	Pneumatic Cylinders (16x100 and 20x50)	Pneumatic hose
		
Flow Regulator	Connectors	Thermal key

	
Pushbutton	Melamine

4.7 Process Electropneumatic Circuit Design

Figure 14:
Electropneumatic Circuit of the Process
Source: Own elaborationa



4.8 Ladder Process Programming

In this part the steps of process programming in Ladder language will be explained.

Commands used:

- Normally open contact
- Coil
- Flank-triggered sweep relay

Process Description:

The process cycle lasts 48 seconds in total, it will start by pressing the switch (I1). After 5 seconds of pressing the switch, the PLC sends a signal to solenoid valve C, this will keep cylinder C expanded for 2 seconds. 12 seconds after pressing the switch, a signal is sent to solenoid valve A, so that cylinder A starts to expand, the cylinder will remain expanded for 24 seconds.

In the second 17 of pressing the switch, a signal will be sent to the solenoid valve C which will expand the cylinder C and remain so for 2 seconds.

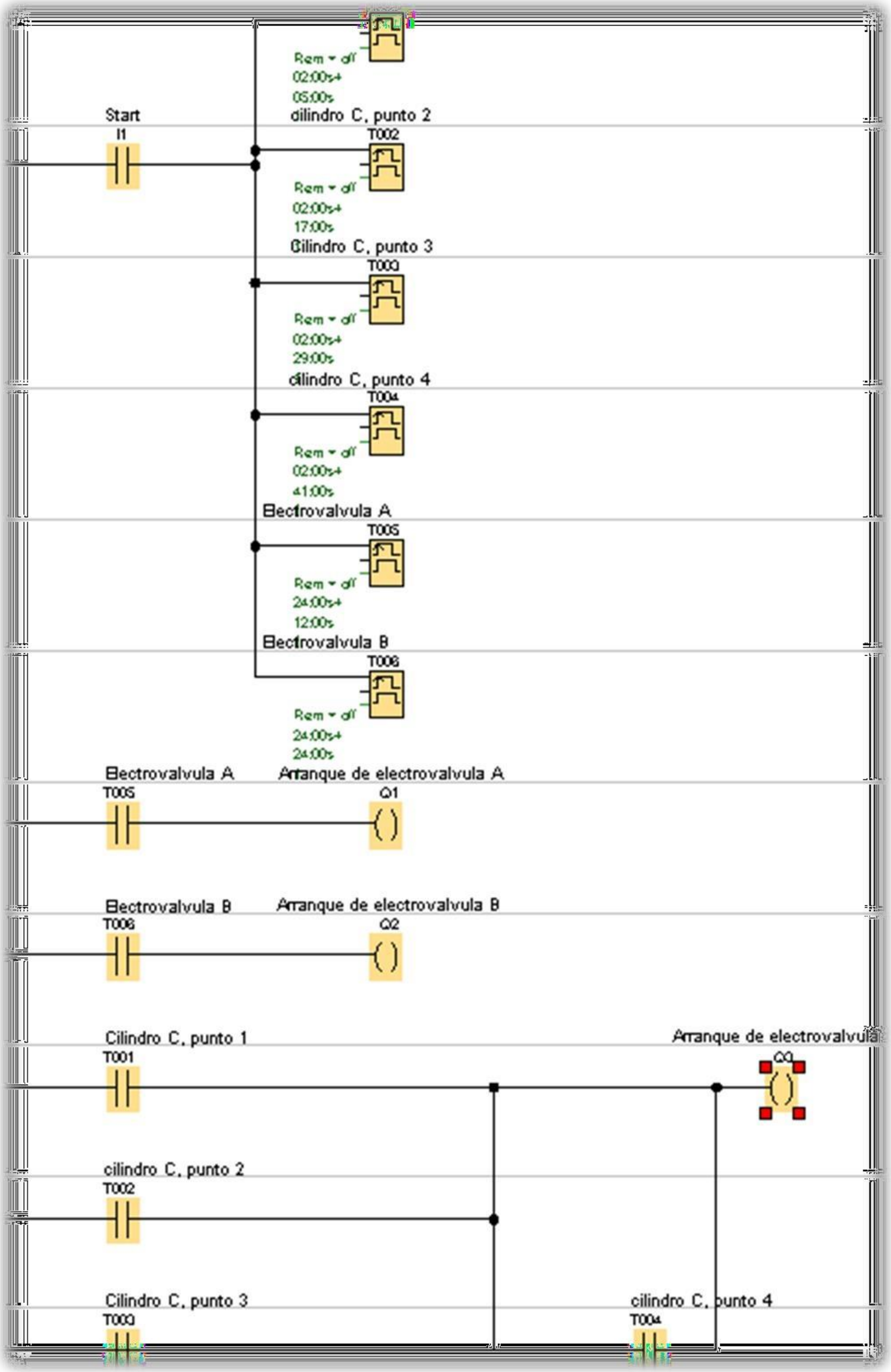
After 24 seconds of pressing the switch, the PLC will send a signal to solenoid valve B, causing cylinder B to expand, the cylinder will remain expanded for 24 seconds.

The second 29 seconds after pressing the switch, a signal will be sent to solenoid valve C which will expand cylinder C and hold for 2 seconds.

The second 36 seconds after pressing the switch, the PLC will stop sending a signal to solenoid valve A, causing cylinder A to contract.

At 41 seconds after pressing the switch, the PLC sends a signal t o solenoid valve C, this will cause cylinder C to stay expanded for 2 seconds. At 48 seconds after pressing the switch, the PLC will stop sending a signal to solenoid valve B, causing cylinder B to contract. Culminating with the end of the automatic boring machine process.

Figure 15:
Process programming in Ladder language Source:
Own elaboration



4.9 Description and detail of production indicators after automation

4.9.1 Production

After the automation of the process we can observe that it makes more precise perforations, but at a much higher speed, allowing us to increase our production and giving a final product of higher quality and finish.

4.9.2 Physical efficiency

This indicator determines the time it would take an operator to drill the holes manually. However, with the automation of the process, only the supervision of the operator and the calibration of the machine is enough. This reduces the effort and execution time.

4.9.3 Designed capacity

In reference to the proposed designed capacity for the project, we took the theoretical maximum capacity under previous conditions. However, with the automation of the process, the maximum capacity increased, which led us to allocate a larger space for the storage of the parts. The current maximum capacity is 120 parts per day.

4.9.4 Excess capacity

The excess capacity is the difference between the designed capacity and the effective capacity. With the automation of the process we improved the efficiency and effective capacity, which led us to produce very close to the maximum capacity. The effective capacity is 100 pieces per day and the excess capacity would be 20 pieces per day.

4.9.5 Effective capacity

With the automation of the process, the effective capacity indicator was improved, since it was very common to observe stops in the process manually due to the human factor, and with these improvements it is only executed according to what is programmed.

4.10 Industrial safety aspects after implementation of the proposal

The automatic drill that has been designed is intended to be implemented in a timber mill, therefore, it is necessary to define the industrial safety measures that must be complied with before using it:

- The drill consists of a power supply, which can cause electric shocks if you do not know how to handle it.
- It is important that the power supply cables are insulated, as bare wires can create a risk of electrocution or fire.

Before using or being near the drilling area it is important to put on personal protective equipment:

Proper work clothing: When using the drill, it is best to wear tight-fitting clothing that does not have hanging threads or straps that can become entangled when in close proximity to perform a test or check any of the movements in function.

Hearing protection: In case the operator is close to the drilling area, he should wear protective headphones, this will prevent the loud noise from causing hearing problems such as hearing loss.

Safety footwear: If a tool or sharp piece such as a drill bit or drill itself falls, it is important to wear steel-toed boots to avoid foot injuries.

Respiratory protection: The materials that are drilled usually release residues. In this case, since it is a lumber mill, the wood releases small shavings that can enter through the nostrils and cause bronchial allergies; therefore, it is recommended to use masks.

Safety glasses: The glasses, as well as the mask, serve as a shield to protect the eyes from the remains of the wood (shavings, dust), since they are small or imperceptible and can enter more easily causing eye damage.

Gloves: When manually maneuvering the automatic drill, either to clean any part, it is necessary to wear cowhide gloves, since this material is thick, which prevents cuts or transfer of any splinters that may have been left in the work environment. (Asura, n.d.)

Preventive measures:

- Remove accessories such as jewelry before being near the automatic drill.
- Put on personal protective equipment correctly.
- Verify that all cables are insulated, without any stripping.
- In case of cleaning or repairing the drill, it should only be handled by authorized and trained personnel.

- All tools such as drills should be checked before use, in case they are worn or broken it is better to discard them and replace them with new ones.
- Verify the stability of where the drill is located.
- Perform preventive maintenance periodically.

CHAPTER 5: INVESTMENT AND OPERATING COSTS

5.1 Cash flow

For the elaboration of the cash flow we must consider:

- **Project investment:** Table 4 shows the manufacturing costs for the project.

Table 4:
Investment costs in materials Source:
Own elaboration

MATERIAL INVESTMENT COSTS			
MATERIALS	**QUANTITY**	**UNIT PRICE**	**TOTAL**
24V power supplies	1	S/ 120.00	S/ 120.00
PLC	1	S/ 600.00	S/ 600.00
Cylinder 16 x 100	2	S/ 70.00	S/ 140.00
Cylinder 20 x 50	1	S/ 75.00	S/ 75.00
Solenoid valves	3	S/ 60.00	S/ 180.00
Hose #8 mm (x meters)	9	S/ 3.50	S/ 31.50
Connectors	15	S/ 4.00	S/ 60.00
T connectors	5	S/ 5.00	S/ 25.00
Flow regulator	6	S/ 15.00	S/ 90.00
Adapters	4	S/ 5.00	S/ 20.00
Melamine 63x63	1	S/ 50.00	S/ 50.00
Solderimix glue	1	S/ 10.00	S/ 10.00
Small L-joints	1	S/ 8.00	S/ 8.00
Large L-joints	1	S/ 6.00	S/ 6.00
Wood (x m2)	13	S/ 1.00	S/ 13.00
Clamp	12	S/ 1.00	S/ 12.00

MDF board	1	S/ 45.00	S/ 45.00
Other materials	1	S/ 12.00	S/ 12.00
	TOTAL		**S/ 1497.50**

- **Depreciation:** The equipment will be depreciated by the LR method, where its useful life is 8 years, the project. will last 6 years where the VR of the equipment is 200 soles.

Table 5:
Straight line method Source:
Own elaboration

- **Recovery Value**

To calculate the recovery value in year 6, the RAF at 6 years = 200 soles.

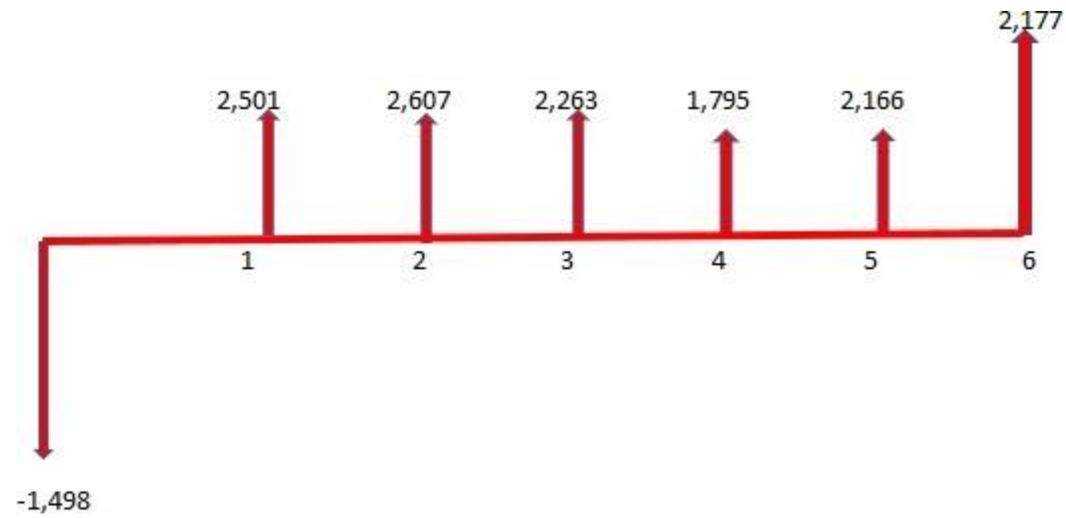
Description	0	1	2	3	4	5	6	7	8
VL	1,497.50	1,335.31	1,173.13	1,010.94	848.75	686.56	**524.38**	362.19	200.00
		162.19	162.19	162.19	162.19	162.19	**162.19**	162.19	162.19

- **Economic cash flow**

Table 6:
Economic cash flow Source:
Prepared by: Own preparation

	0	1	2	3	4	5	6
INCOME		5,000	5,222	4,800	4,200	4,800	4,600
INVESTMENT	-1,497.5						
PRODUCTION COSTS		-2,000	-2,000	-2,000	-2,000	-2,000	-2,000
Depreciation		-1,335	-1,173	-1,011	-849	-687	-524
GROSS PROFIT		1,665	2,049	1,789	1,351	2,113	2,076
Income tax (T%)		499	615	537	405	634	623
AVAILABLE PROFIT		1,165	1,434	1,252	946	1,479	1,453
Depreciation		1,335	1,173	1,011	849	687	524
RAF							200
NET CASH FLOW	**-1,497.5**	**2,501**	**2,607**	**2,263**	**1,795**	**2,166**	**2,177**

Figure 16:
Flowchart
Source: Own elaboration



5.2 Economic viability

As can be seen in the following data, we can conclude the following:

Table 7:
Economic feasibility analysis Source:
Own elaboration

IRR	1.64802841
Ke	50.00%
VAN	2829.85482
PRI =	1.85367616

- The NPV being 2529.85 > 0 shows that the project is viable.
- Investment payback in 1.85 years

CONCLUSIONS

- The implementation of the automatic drilling machine will contribute to increase the production of parts required in any conventional carpentry, due to the speed with which the drillings will be executed.
- By automating a drilling machine, a reduction in the number of operations as well as the time required for the drilling process is achieved. In this project, the number of operations was reduced from 12 to 8 and the time required was reduced from 12 minutes to 2.43 minutes.
- We conclude that the drilling machine achieves the drilling of a piece chosen by the operator from any material allowed for the operation, resulting in a new product in accordance with the purpose for which it is to be used.
- The implementation of the drilling machine is beneficial for the process since, according to cash flow, it shows that it is beneficial and easy to recover compared to its useful life.

RECOMMENDATIONS

- It is recommended to use pneumatic hoses smaller than 8, because during the execution of the prototype it was evidenced that when using a hose number 8 three obstacles were presented, one, that it occupied a lot of space, two, aesthetically it did not look good, and three, that, being of a larger diameter, it would need more air, for such reason, it is recommended a hose number 6 or 4.
- It is recommended to have a supervisor at the machine in order to monitor that the operations performed by the machine are carried out correctly and continuously.
- It is recommended to have a certain degree of prevention with respect to the pressure exerted on the tool as it can generate some unforeseen failures and incidents during the automated process.

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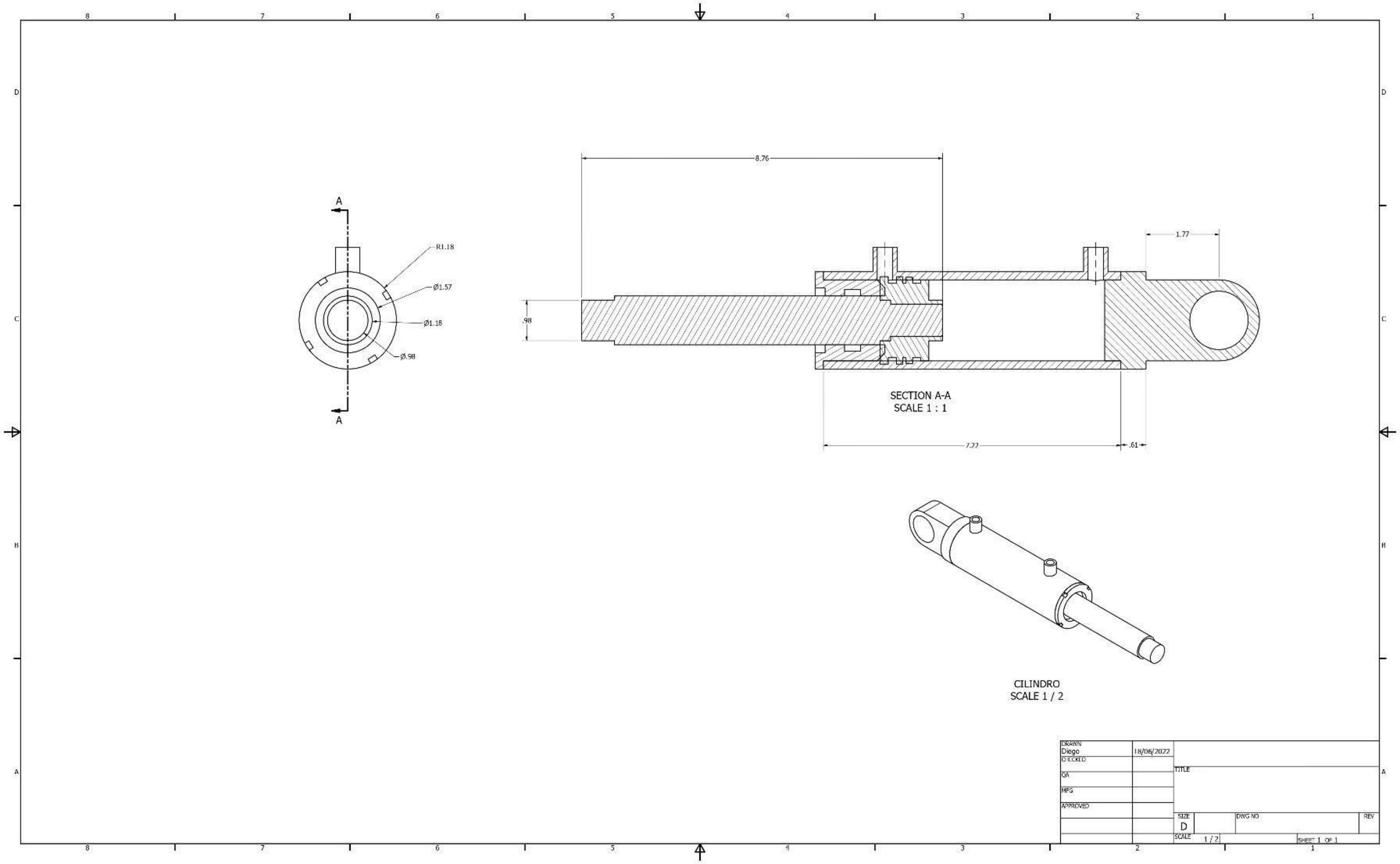
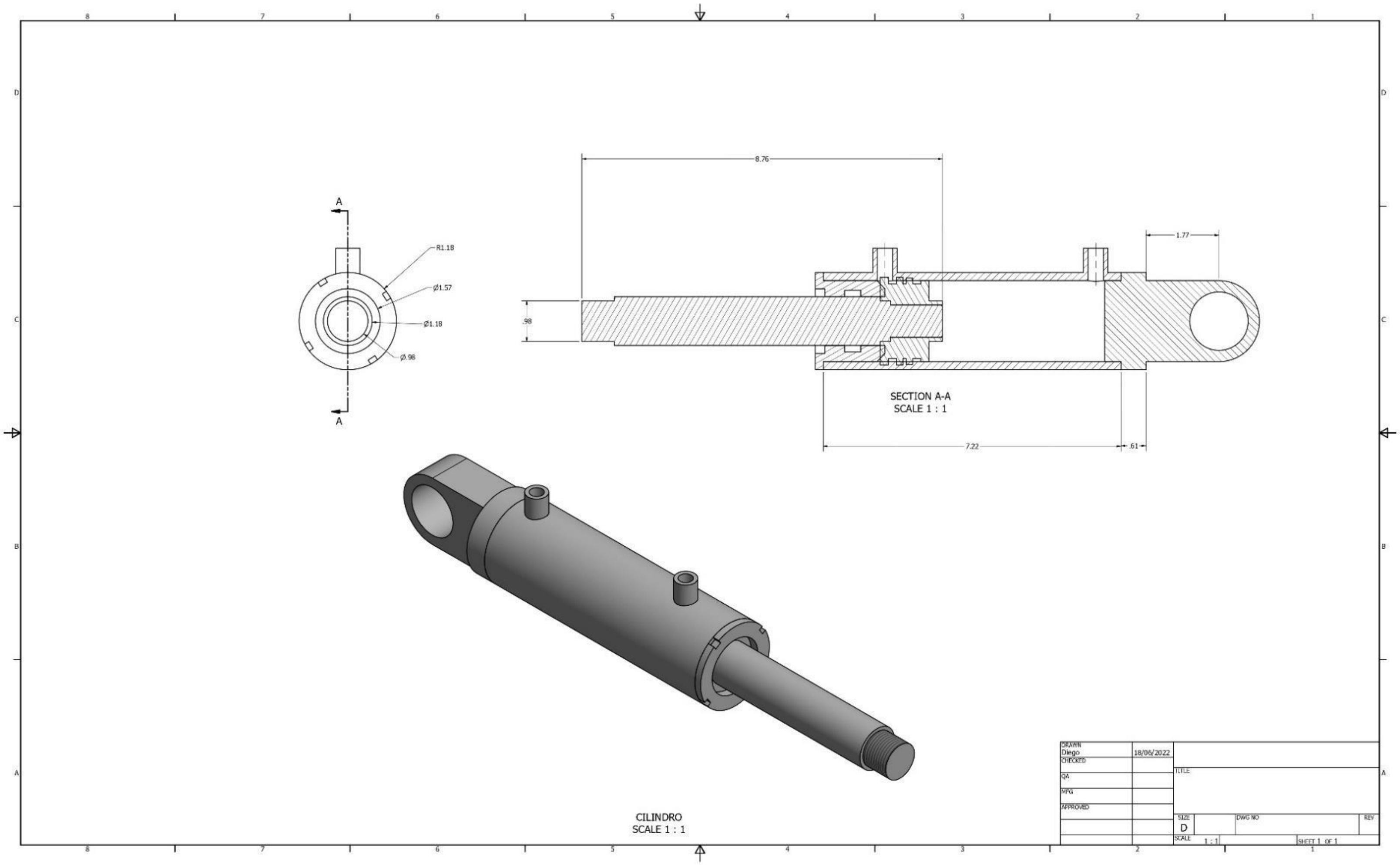
ANNEXES

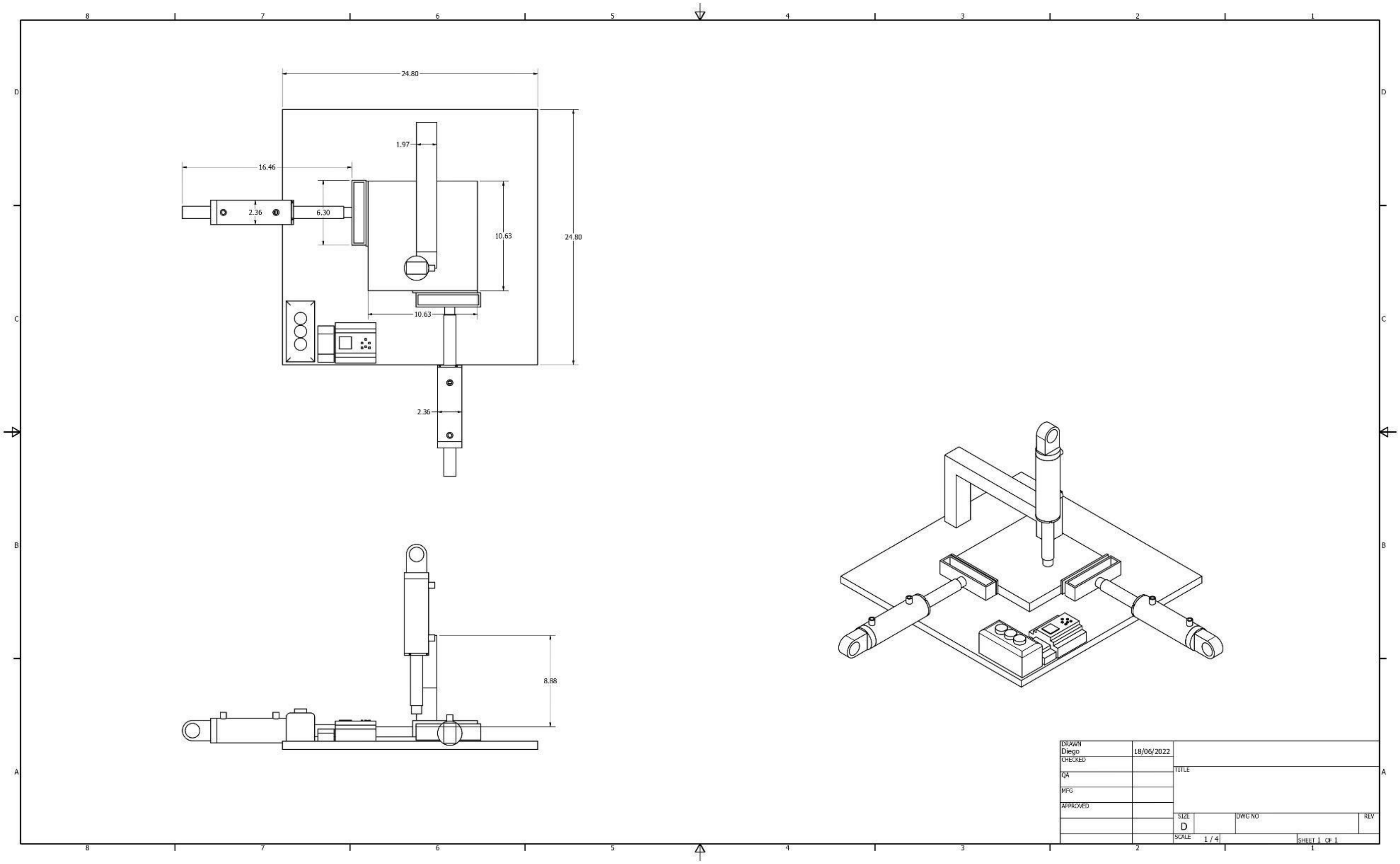
Annex 1: Assembled cylinder created in AutoCAD



Annex 2: Assembled cylinder created in AutoCAD



Appendix 3: Prototype of a drilling machine created in AutoCAD



Annex 4: Prototype of a drilling machine created in AutoCAD