UNIVERSIDAD RICARDO PALMA

ENGINEERING FACULTY

PROFESSIONAL SCHOOL OF INDUSTRIAL ENGINEERING

INDUSTRIAL AUTOMATION

RESEARCH WORK

"Automation for productivity improvement with focus on pneumatic recycling can crusher can crusher."

MEMBERS

- **Amaro Granados, Julia Yadira**
- **Ataucchi Palomino, Willy Alexander**
- **Celis Zea, David Israel**
- **Rios Rios, Gerardo Daniel**
- **Correa Gonzales, Joel Renzo**
- **Laredo Palma, Alejandra Valeria**

Professor: Dr. José Antonio Velásquez

CostaLima - Peru

2022 - I

Summary

The increase in automation is a growing trend in correlation with technological progress. This is reflected in the day to day, and mostly its use in the industrial sector. Likewise, pollution is a daily thing, and it is also growing. That is why our project is focused on environmental care and promotion of recycling. The project consists of the development and manufacture of a can recycling machine. This project seeks to offer the market a system that can be used in any space, whether in industries, shopping malls, supermarkets, offices, homes, bars, streets, among others. The difference of this machine, with a garbage can, is that it will no longer be necessary to go to store and crush the can in another area.

By using this can recycling machine, we improve the efficiency, effectiveness and reduce the transformation time of the cans; since in the same place where the cans are deposited, they will be crushed and stored for sale or recycling.

In this project, we will have a research, embodied in various diagrams that substantiated in detail the creation, sequence and improvements (through production indicators) that will lead to the use of this product.

Keywords: can, crushing, recycling and automation.

Abstract

The increase in automation is an increasing trend in correlation with technological advancement. This is reflected in the day to day, and mostly its use in the industrial sector.as well as, pollution is a matter of day to day, and in the same way it is increasing.that is why our project is focused on environmental care and promotion of recycling.the project consists of the elaboration and manufacture of a can recycling machine.This present project seeks to offer the market, a system that can be used in any space, whether in industries, shopping centers, supermarkets, offices, houses, bars, street, among others.The difference of this machine, with a garbage can, is that it will no longer be necessary to go to store and crush the can in another area.

Using this can recycling machine, we improve efficiency, effectiveness and reduce can transformation time; since in the same place that the cans are deposited, they will be crushed and stored, for sale or recycled.

In this present project, we will have an investigation, reflected in various diagrams that detailed the creation, sequence and improvements (through production indicators) that will be taken to use this product.

Keywords: can, crushed, recycling and automation.

INDEX

INDEX OF FIGURES

INTRODUCTION

This project will propose the manufacture of an automated can crushing machine, because nowadays these machines are of great importance for different countries that aim to take care of their ecosystem, as they help to crush the cans faster to use them as raw material for other products or to reduce spaces.

Recycling is not currently a priority in Peru, so the percentage of recycling is minimal, where what is mostly recycled are beer cans; however, once compacted, these are not used as raw material for other products.

In addition to the fact that its process is still not optimal so its technology can be improved by implementing automation, since this process of crushing cans is mostly done manually with a simple machine, which generates loss of time, more money costs, more staff and low production, so we believe that the best solution is that the Peruvian industry should implement automated crushing machines.

The implementation of this project will improve the efficiency of the process by reducing the investment of time and human effort in compressing the cans that are reused for recycling.

CHAPTER I - THEORETICAL FRAMEWORK

1. Theoretical Framework

1.1. Theoretical basis

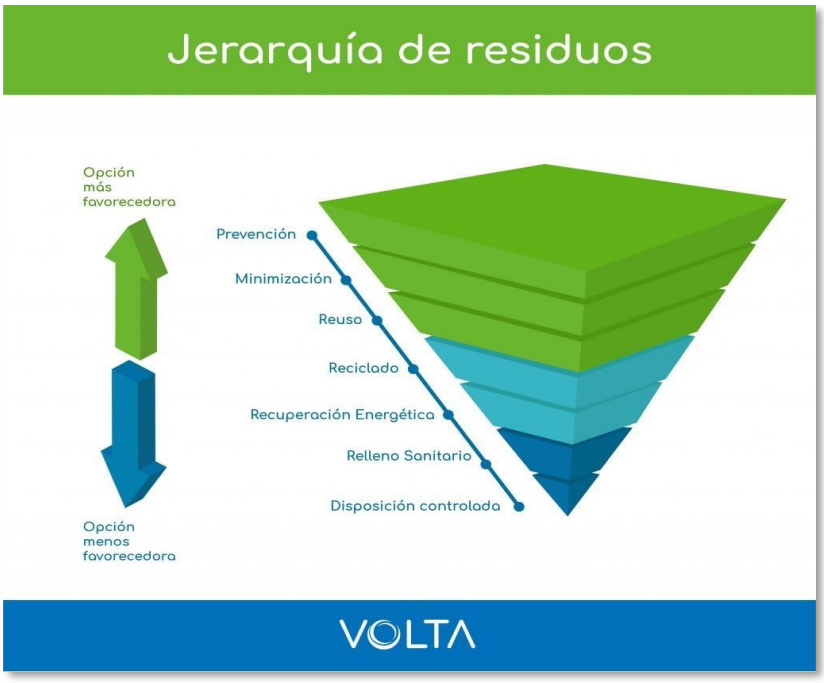
1.1.1. Rationale for recycling

According to The Three Rs Law (2028) mentions that "reduce, reuse and recycle, a policy to control the daily production of millions of tons of waste produced on the planet."

- The fundamental principle is to reduce the consumption of pollutants and unneeded elements as this essentially controls the production of unnecessary waste that is found in landfills and is a potential environmental problem.

- Reuse as much as possible and use something for a purpose other than destruction or reprocessing. Reuse also means using materials from nature. Through reuse, we are free to be creative, decrease the use of raw materials and energy, and turn unneeded things into new objects or products.

- Recycling involves the use of waste that is not reused, but the process requires energy to be collected, transported, sorted and disposed of. This process is ideal only for items that have completely reached the end of their useful life so we avoid contamination.



Waste hierarchy Source: Voltachile

1.1.2. Metal recycling

Metal recycling helps us to use metals that have reached the end of their useful life, in order to use them as raw material for new products.

Metal recycling is a process that occurs first when the person separates the waste, then takes and classifies by the type of metal, in order to separate them.

These cans, separated into aluminum and steel, will be crushed in order to be transported to the recycling plant. Then they will be crushed, so that the steel and aluminum material can be separated with a magnet. Subsequently, each metal will continue with a different process. For example, molten aluminum can be turned into ingots for new cans or other objects, while molten steel will be used for food preserves.

Figure N° 2. References for recycling cans

Source: tom19275

1.1.3. Advantages of automatic recycling

- Instantaneous division of household waste for recycling.
- Try to reduce as much as possible the number of errors when recycling is performed.
- It is a simple process to perform and can be used in any type of location.
- Space: thanks to the waste crushers we can reduce the size of different waste materials, so that we can give more space to the personnel to perform their work in an optimal way.
- Time: waste crushing machines do this process of crushing materials quickly, which gives us extra time to move on to other activities.
- Economy: This material crushing machine would bring savings to any company, since it would not require more than one personnel and it would do the process in a short time, with higher production.

Figure N° 3. Recycled cans

Source: carenas1

1.1.4. Concepts for work

- **Automation:** According to Logicbus (n.d.), automation is "the set of computer, mechanical and electromechanical elements or processes that operate with minimal or no human intervention. These are normally used to optimize and improve the operation of an industrial plant, but automation can also be used in a stadium, a farm or even in the infrastructure of cities".
- **FluidSIM:** In the blog of Arencibia (2015) notes that "FluidSIM 4 is an application designed for the creation, simulation, instruction and study of electro-pneumatic, electro-hydraulic and digital circuits. The program will allow us to create circuits very easily using the classic drag-and-drop procedure. We just have to carry the circuit elements from one place to another and connect them manually. Simple and effective."
- **Simulation of industrial processes:** VLD engineering (n.d.) says "The simulation of industrial processes is a tool that allows to virtually reproduce the processes and study their behavior, to analyze the impact of the different variables that may intervene in it, or to compare different design alternatives, without the

high cost of full-scale experiments. This is of great help in reducing risks and optimizing decision making, as well as in planning, analyzing and improving company processes."

- **Logo soft comfort:** Aula 21 (n.d.) mentions that "This software allows the simple creation of switching programs in function diagram (FBD) or ladder diagram (LD) and enables the creation of user programs by selecting the respective functions and connecting them through drag-and-drop in individual and network mode".
- **Autodesk Inventor:** According to, Team Marketing NKE. (2021) "is a 3D parametric solid modeling software. y It allows the integration of 2D and 3D data in the same environment creating a virtual representation of the final product, so that the product's performance can be inspected and adjusted at any time during the design phase."
- **Process:** According to Westreicher, G. (2020) "is a sequence of actions that are carried out to achieve a certain end. It is a concept applicable to many fields, to business, chemistry, computer science, biology, chemistry, among others".
- **Ladder language:** According to S. (2020) it is known as a "c| diagram that we actually program by means of electrical contacts that, joined together, end up forming a logical sentence".
- **Project simulation:** According to Netinbag (n. d.) "is a process in which a proposed project or idea is run through a simulation to get an idea of what might happen if it were implemented."
- **Recycling**: According to BBVA (2022) "is the process of collecting and transforming materials into new products that would otherwise be discarded as waste."
- **AutoCAD**: According to AUTODESK (n.d.) "is a computer-aided design (CAD) software used to accurately draw, design and model in 2D and 3D with solids, surfaces, mesh objects, documentation functions, etc."
- **SolidWorks**: According to ADR Formation (2022), it is a "CAD-type mechanical design software, which, using a graphical environment based on

Microsoft Windows enables intuitive and fast creation of 3D Solid Models, Assemblies and Drawings."

- **Electro-pneumatics**: According to Luis R., J. (2021) "is an automation technique in which electrical energy replaces pneumatic energy in control and command systems, both for generation and control transmissions".
- **Programming**: According to, Meanings (n.d.) is "Electro-pneumatics: According to, Luis R., J. (2021, 3 August). Electropneumatics "is an automation technique in which electrical energy replaces pneumatic energy in control and command systems, both for generation and control transmissions."

1.2. Objectives

1.2.1. General Objective

To apply automation in the can crushing process in order to increase production in a company dedicated to this industry.

1.2.2. Specific objectives

a) To make the manufacture of these machines simple and affordable.
b) To create an automated can crushing machine that provides the greatest safety to users.
c) Use the minimum amount of parts in the can crushing machine.

CHAPTER II - CURRENT MANUAL CRUSHER PROCESS

2. Detailed description of the current process

2.1. Description of the process

1. We started this process with the collection of cans obtained from different places.
2. They will then be stored for cleaning or removal of any debris they may contain such as garbage, grease, etc.
3. Once this cleaning process is completed, the cans will be taken to the drainage area so that the operator in charge can manually empty the liquid content of the can.
4. After this activity there will be a waiting time for the cans to dry well.
5. The dry cans are then taken to the crushing or compacting area for the operator to manually direct the cans to a table using a pulley to crush them and collect them in a dumpster.
6. The crushed cans are transported to the recycling area.
7. Finally, they are stored to be sold or used for other products.

2.2. Flowchart

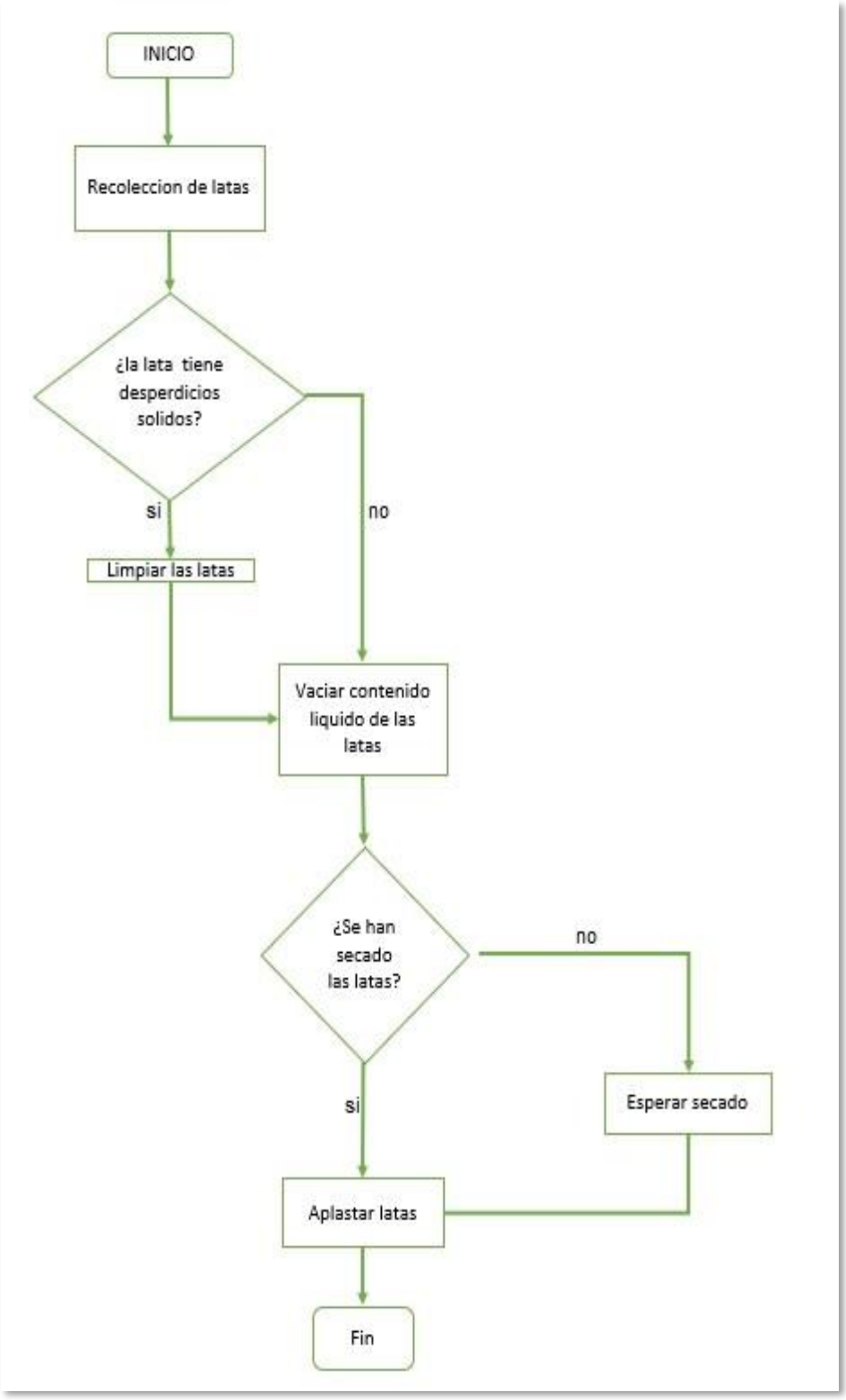


Figure N° 4. Flow diagram of the Manual Can Crusher Source: Own elaboration

2.3. Operations Diagram

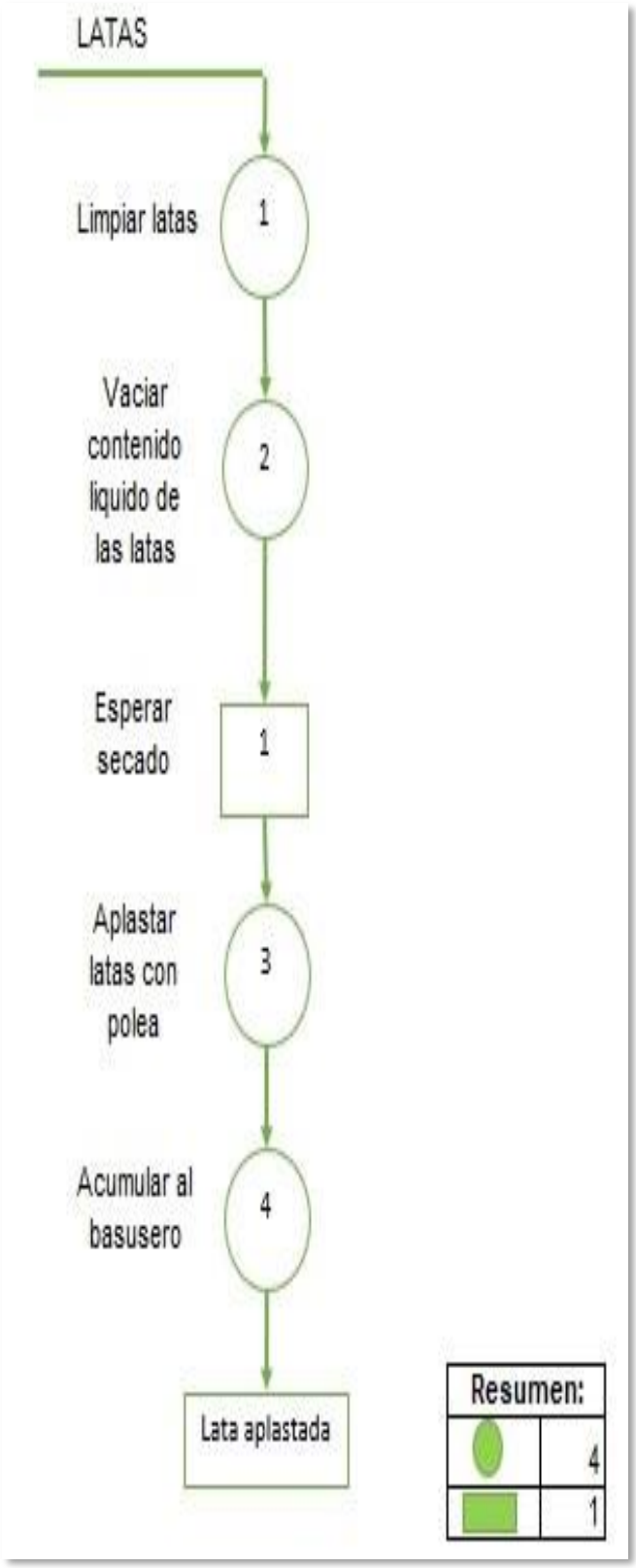


Figure N° 5. Operations Diagram of the Manual Can Crusher Source: Own elaboration

2.4. Process analysis diagram

Diagram of the basic can crusher process, before implementing an automatic crushing process.

DIAGRAMA DE ACTIVIDADES DEL PROCESO (DAP)

Area : Reciclado y aplastado de latas
Máquina y/o equipos : Polea
Operación : Proceso de la aplastacion de una lata

N°	Descripción de las Operaciones	cant. (kg)	dist. (m)	tiempo (m)	Operaciones	Transportes	Inspecciones	Esperas	Almacenamiento	MIXTO
1	Obtener latas	20	50	29	○	⇨	□	D	▽	◇
2	Llevar las latas al area de limpieza		0.5	1	○	⇨	□	D	▽	◇
3	Limpiar las latas (quitarle la basura que tenga)			5	●	⇨	□	D	▽	◇
4	Llevar las latas al area de drenado		0.5	1	○	⇨	□	D	▽	◇
5	Vaciar el contenido liquido de las latas			1	●	⇨	□	D	▽	◇
6	Esperar a que sequen las latas			3	○	⇨	□	D	▽	◇
7	Llevar al area de aplastado o compacto		0.5	1	○	⇨	□	D	▽	◇
8	El operario aplasta las latas con una polea			1	●	⇨	□	D	▽	◇
9	Las latas aplastadas son acumuladas en un basurero			1	●	⇨	□	D	▽	◇
10	Se trasnporta las latas a el area de reciclaje		0.5	1	○	⇨	□	D	▽	◇
11	Se almacenan las latas para ser vendidas o usadas para otro producto.			1	○	⇨	□	D	▽	◇
	TOTAL	20	52	45	5	4	0	1	2	0

Figure N° 6. Process analysis diagram Source:
Own elaboration

2.5. Automation plan Gantt

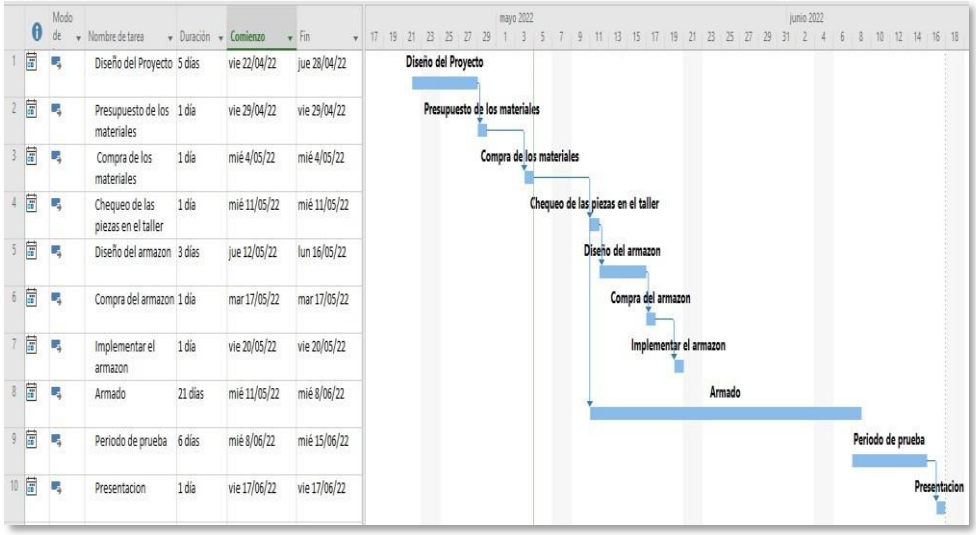


Figure N° 7. Gantt of the automation plan
Source: Own elaboration

2.6. Description and detail of production indicators before automation

2.6.1. Overtime

As it is a manual task to crush the cans, the production of the worker in the 8 hours of work he/she does would have to be seen to measure the cost and the employee's performance.

Therefore, by making it an automated process, it would have a better production and would be paid only by the hour.

2.6.2. Labor effectiveness

Labor effectiveness is based on how a business employing the right amount of personnel and number of shifts employed uses them correctly to have a high efficiency in its business.

By making the process automatic, the number of personnel would be reduced, which generates more income for the company, and the only thing that would have to be taken into account would be the work shifts, since only one operator would be needed per shift.

2.6.3. Quality control

Quality control is an indicator that provides very important information, since it helps to prevent risks, so it is necessary that all areas of the companies know about it. Thanks to this we can obtain correct products, satisfied customers, less personnel accidents, lower costs, etc.

With an automated can crushing machine, there will be fewer errors in the process so quality control will be reduced.

2.6.4. Employee turnover rate

The employee turnover rate is very common in different companies, since sometimes it is beneficial that all employees are multifaceted for when another employee is absent or resigns, so that he/she can replace him/her quickly without affecting the company. But in turn to do this would have to make constant training for all employees.

employees know how to handle most processes, which sometimes also generates more costs.

However, with an automatic machine there will be no need to rotate personnel, since it will be a single, automated process, which will reduce training.

2.6.5. Sales growth

In order to know the sales in a business, the performance of each employee must be measured individually, but this depends first on the production obtained with manual can crushing, which would not be very large.

However, with an automated crusher, this production would be increased, which would allow a higher demand to be met and the vendors to perform better.

CHAPTER III - DESIGN OF THE MANUAL CRUSHER

3. Current process design

3.1. 3D CAD drawings of the current situation

Here we have a manual can crusher, which was designed by SOLIDWORKS 3D CAD software.

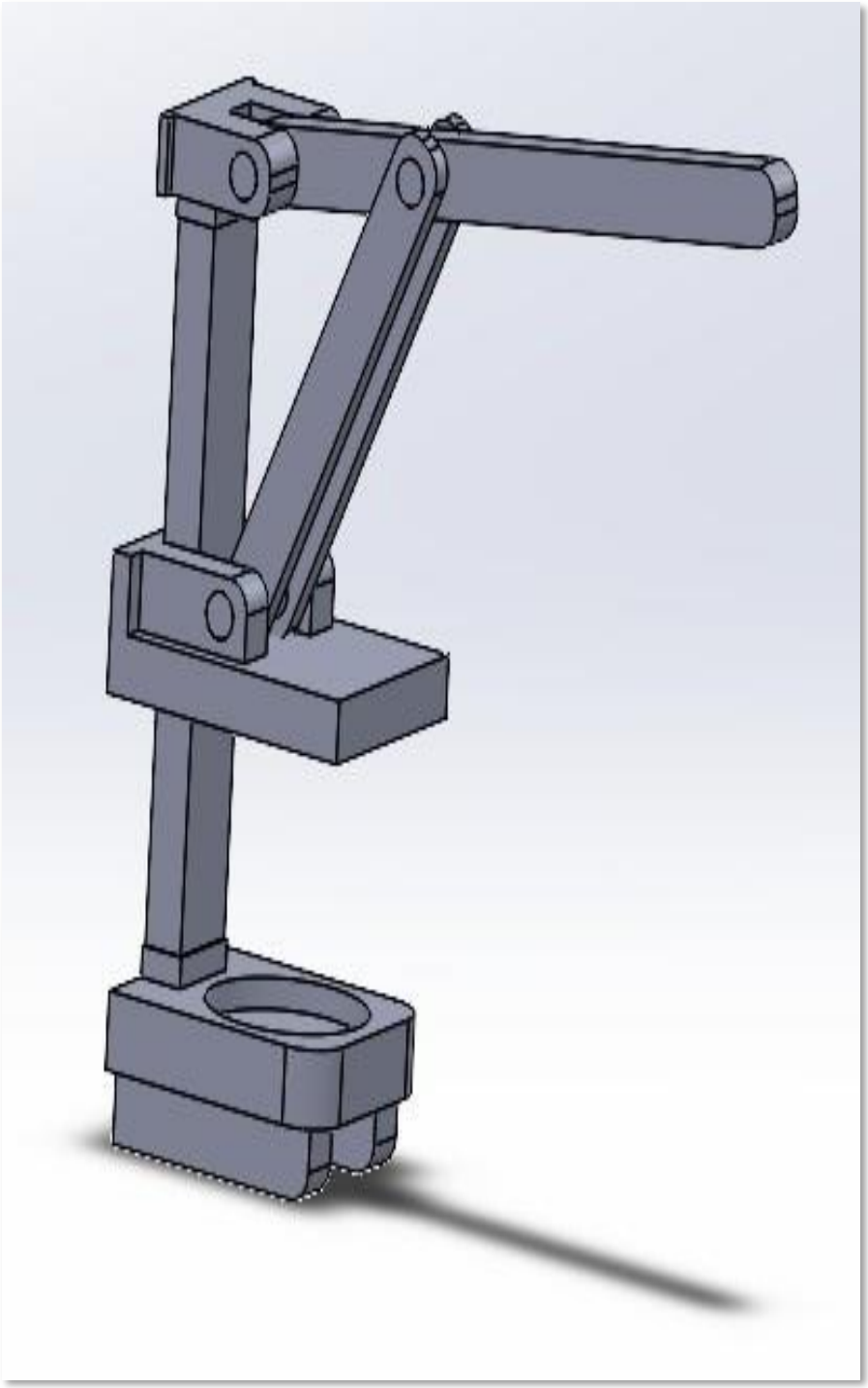


Figure N° 8. 3D manual can crusher Source: Own elaboration

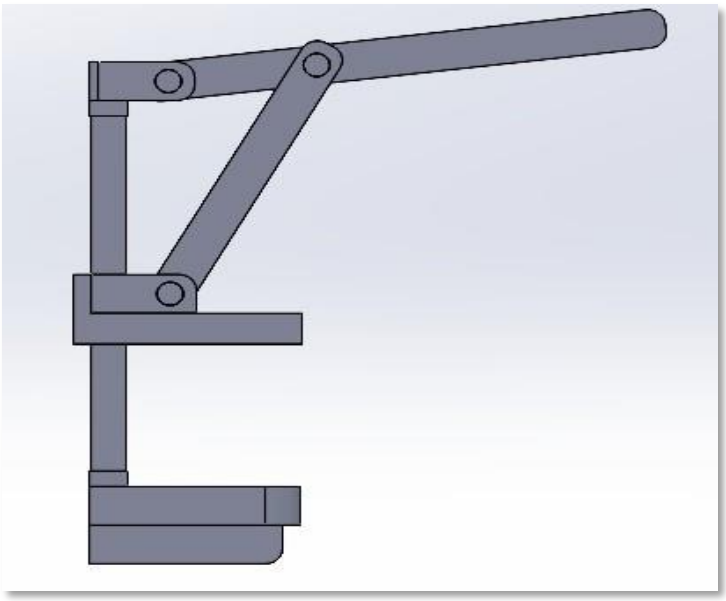


Figure N° 9. Manual side can crusher in 3D Source: Own elaboration

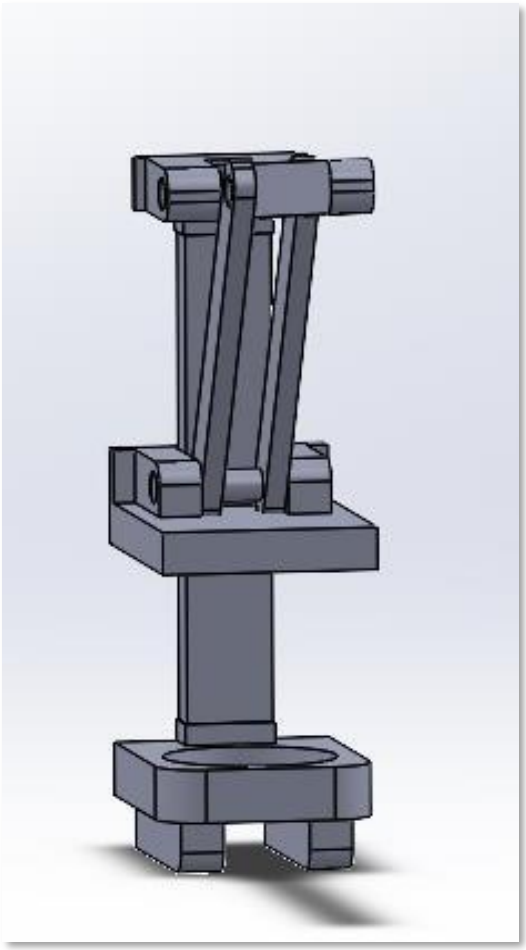


Figure N° 10. 3D manual front can crusher Source: Own elaboration

CHAPTER IV - DESIGN OF THE AUTOMATED CRUSHER

4. Design of proposal to automate the process

4.1. Detailed description of the proposed process

1. First the crusher is plugged in.
2. Secondly, the thermal key is turned on.
3. Third, press the pushbutton on cylinder 2, which will hold all the cans.
4. Fourth, the cans are placed on the ramp.
5. Fifth, press the pushbutton on cylinder 1 to hold the second can and the cans that follow behind it.
6. Sixth, the pushbutton on cylinder 2 is released so that the first can falls.
7. Seventh, the cylinder 3 pushbutton is pressed to crush the can.
8. Eighth, the can falls into a garbage can, and so the process is repeated continuously.

4.2. 3D CAD drawings of the selected proposed location

In this case we designed a pneumatic can crusher with Autodesk Inventor 2022 software.

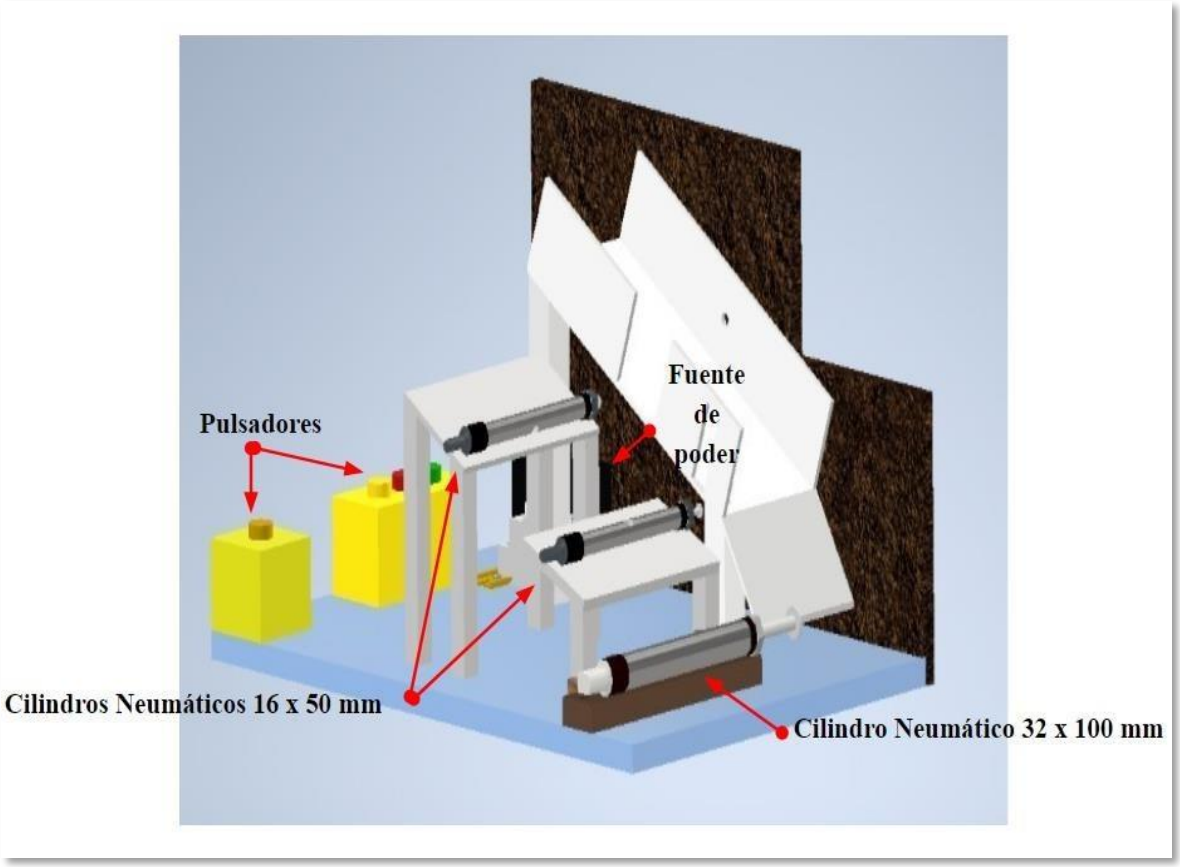
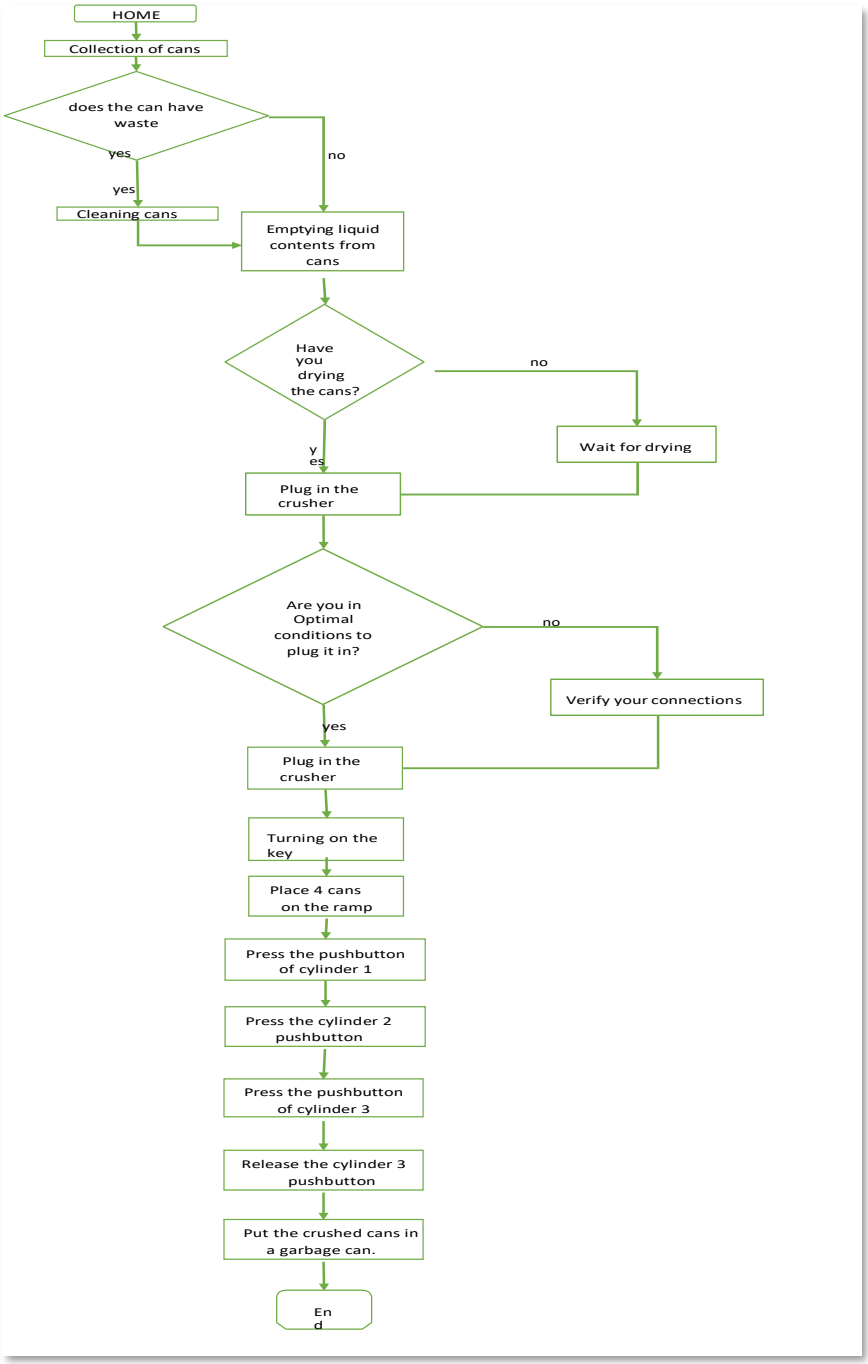


Figure N° 11. Automated 3D can crusher. Source: Own elaboration

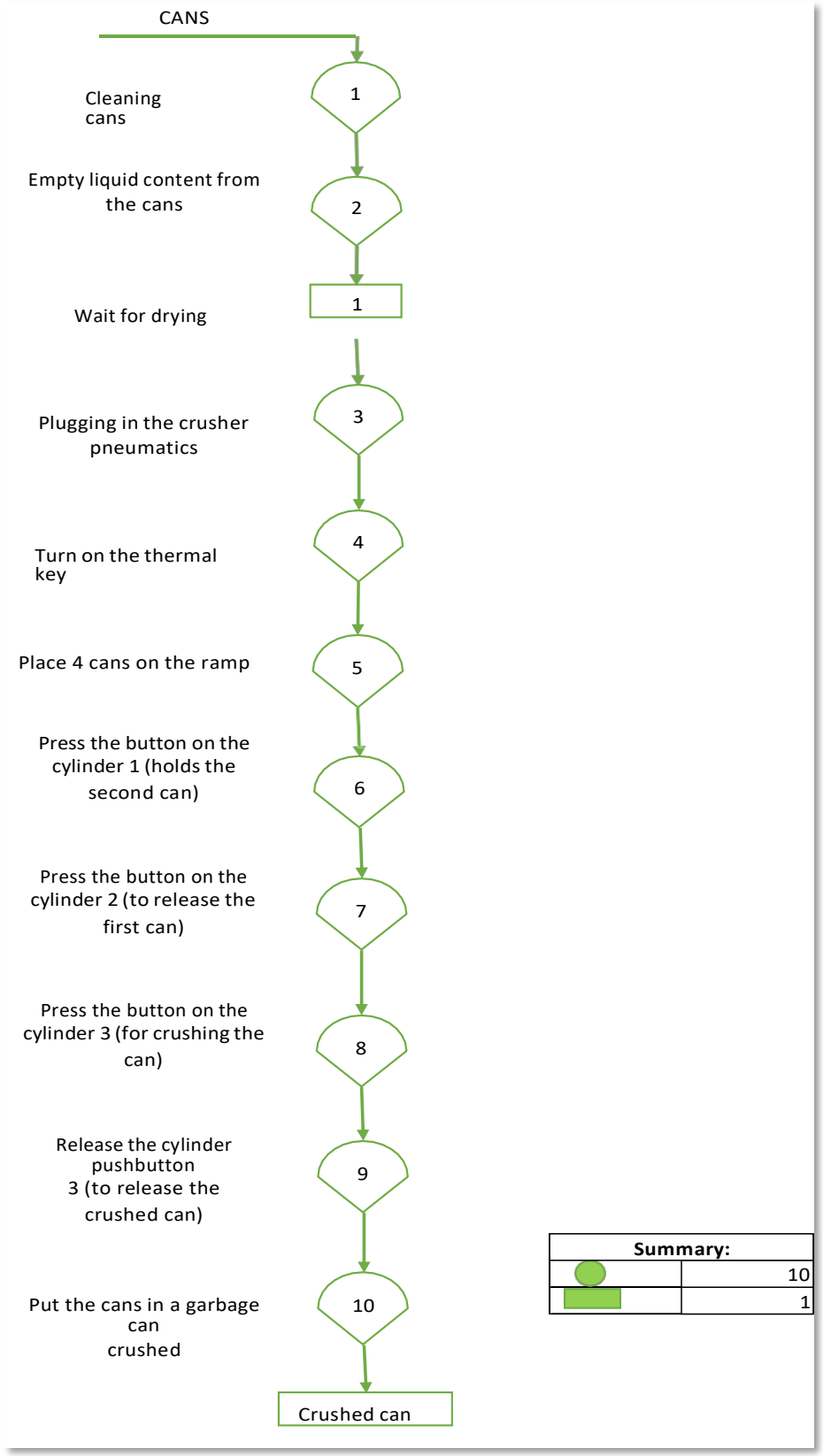
Figure 11 shows some components such as pneumatic cylinders, push buttons, power supply and the thermomagnetic switch mounted together in the system. The base shown in the 3D design is a wooden base as well as the one on the lateral side, which gives stability to the machine due to the pressure exerted by the pneumatic cylinders.

4.3. Flow diagrams of the proposed process



Flow diagram of the Automated Can Crusher Source: Own elaboration

4.4. Operations Diagram of the proposed process



Operations Diagram of the Automated Can Crusher Source: Own elaboration

4.5. Process analysis diagram of the proposed process

PROCESS ACTIVITY DIAGRAM (DAP)

Area : Recycling and crushing of cans
Machine and/or equipment : Pulley
Operation : Crushing process of a can

N°	Description of Operations	qty (kg)	dist. (m)	time (m)	Operations	Transportation	Inspections	Esperas	Storage	MIXED
1	Obtaining cans	20	50	29						
2	Take the cans to the cleaning area		0.5	1						
3	Clean cans (remove any debris)			5						
4	Separating ferrous and non-ferrous cans			3						
5	Take the cans to the drainage area.		0.5	1						
6	Emptying the liquid content of the cans			1						
7	Wait for the cans to dry			3						
8	Take to the crushing or compacting area.		0.5	1						
9	Operator plugs in the crushing machine			0.5						
10	The opearirio turns on the thermal key			0.5						
11	Operator places 4 cans on ramp		0.5	1						
12	The operator presses the pushbutton on cylinder 1 to hold the second can.			1.5						
13	The operator presses the pushbutton on cylinder 2 to release the first can.			1						
14	The operator presses the cylinder 3 pushbutton to crush the can.			0.3						
15	The operator releases the pushbutton on cylinder 3 to release the crushed can.			0.2						
15	Crushed cans are piled up in a dumpster			0.5						
17	The cans are transported to the recycling area.			1						
18	Cans are stored to be sold or used for another product.			1						
	TOTAL	20	52	51.5	11	4	0	1	2	0

Figure N° 14. Process analysis diagram

Source: Own elaboration

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

4.6.1. Pneumatic cylinder 16 x 50 mm

Two 16 x 50 mm cylinders were used for this project. Each one fulfilled a different task. The model of the pneumatic cylinder is the Airtac brand MAL aluminum alloy mini cylinder as shown in Figure 15.

One of them is used to hold the can, to which a circular piece of metal with a diameter of XX mm was welded to facilitate the holding of the base of the can. The other cylinder was used to prevent the can from passing into the crushing zone and to prevent accumulation of the can.

Figure N° 15. 16*50mm double-acting cylinder

Source: Own elaboration

4.6.2. Pneumatic Cylinder 32 x 100 mm

A 32 x 100 mm pneumatic cylinder was used for this project. The model of the pneumatic cylinder is Airtac model MAL aluminum alloy mini cylinder as shown in Figure 16.

A larger cylinder than the previous ones was chosen because a higher pressure force is required to crush the can in order to accomplish the required task.

Figure N° 16. 32*100mm double-acting cylinder

Source: Own elaboration

4.6.3. Power supply

A Delta Electronics brand 24V/2.5A DIN power supply was used for this project to provide overvoltage, overload and thermal protection. Also, with multiple terminals for easy wiring and installation as can be seen in Figure XX.

Figure N° 17. 24 volt power supply Source: Own elaboration

4.6.4. Thermomagnetic circuit breaker

Black handle 220-400 V thermomagnetic switch for turning on and off devices as shown in figure XX. It contains safety shutters and internal silver connectors, air flow on the side for better ventilation, protection to electrical installations from overloads and short circuits. It also includes supplementary two-pole C-curve protectors that trip instantaneously when the current load exceeds five to ten times the rated capacity of the device.

Figure N° 18. Thermomagnetic circuit breaker
Source: Own elaboration

4.6.5. Solenoid valve

Pneumatic valves are mechanical devices for air regulation and control. Three 24VDC monostable 5/2 solenoid valves of the ALITAIR brand were used for this project whose main function is to control the passage of air in the installation, starting or stopping the passage of air flow. When the button is pressed, compressed air is allowed to pass from the supply of pipe 1 to pipe 2 which is connected to the pneumatic cylinder. The model of the solenoid valve used can be seen in figure XX.

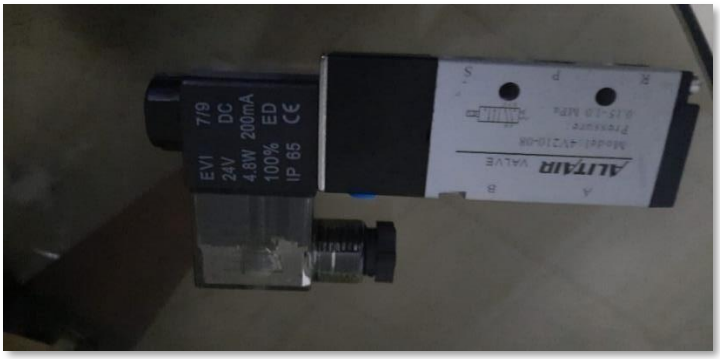


Figure N° 19. Solenoid valve Source: Own elaboration

4.6.6. Pushbutton

It is an electrical component that allows or prevents the passage of electric current when pressed or depressed. The push button only opens or closes when the user presses and holds it down. When released, it returns to its initial position. Figure 20 below shows the pushbuttons used.

Figure N° 20. Three-button pushbutton
Source: Own elaboration

4.6.7. TEE

For this project, two 8 mm TEE tubes were used as shown in Figure 21.

Figure N° 21. TEE
Source: Own elaboration

4.6.8. Flow regulators

The use of flow regulators in the air ducts has the final objective of ensuring the ventilation flow rates, increasing the efficiency of the system. One of the main elements that allow us to ventilate are the ventilation ducts, which are intended to conduct the extraction or supply air in the building to be finally discharged outside. Six ⅛ x 8 mm flow dampers were used in this project as can be seen in Figure 22.

Figure N° 22. Flow regulators. Source:
Own elaboration

4.6.9. Fitting straight

Twelve straight fittings of ¼ x 8 mm as shown in Figure 23 were used in this project whose main function is to join two conduits whose type of union is quick coupling.

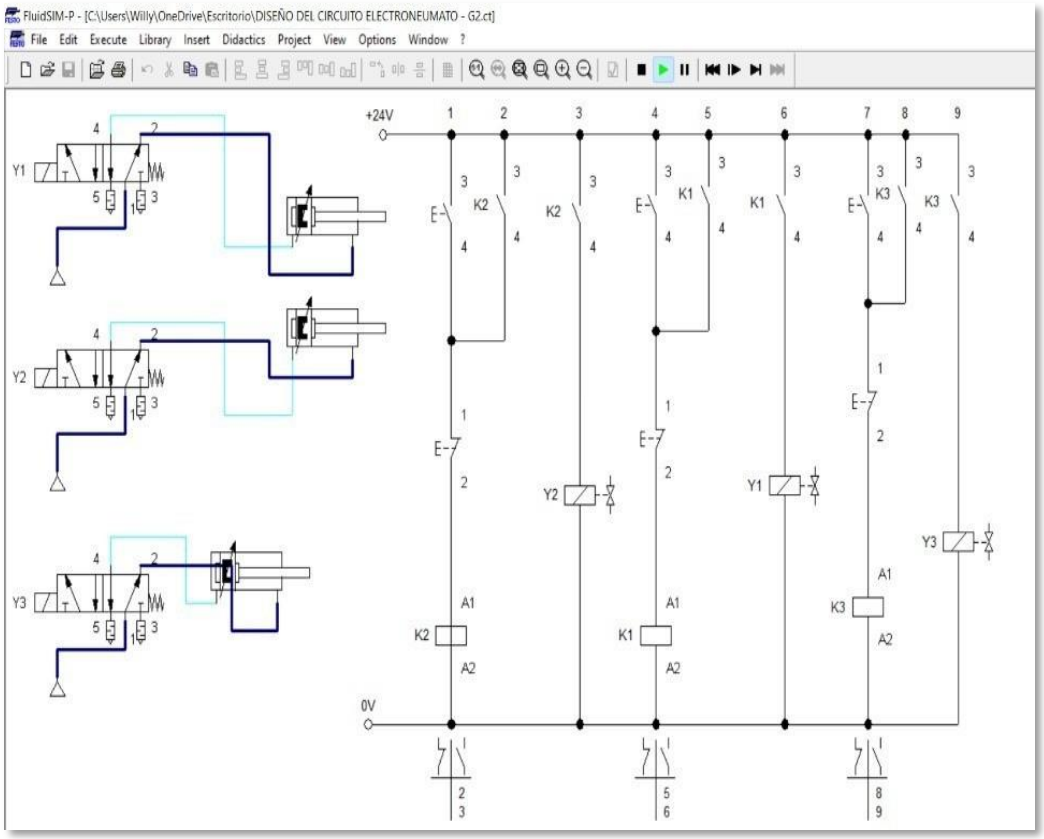
Figure N° 23. Straight fitting Source: Own elaboration

4.7. Design of the electro-pneumatic circuit of the process.

To make the circuit we use the FluidSIM program, where we use the following materials:

1. First we place an air compressor (triangle symbol).
2. Second, we placed 3 double-acting actuators.
3. Third, we put 3 solenoid valves 5/2. with 0silencers.
4. Fourth we put a 24V power supply.
5. Fifth, we insert 3 pushbuttons for each cylinder.
6. Sixth, we occupy 3 solenoid valves
7. Seventh we place 3 relays per cylinder

The formula to be used would be A+B-C+C-B+A-, where letter+ equals extend and letter- equals retract.



Electro-pneumatic circuit of the pneumatic can crushing process.

Source: Own elaboration

4.8. Ladder programming of the process (comment on each of the segments used in your ladder programming).

In the PLC we create a circuit where by means of pushbuttons the can crushing process is done.

For the simulation and explanation of the operation in case of automation, the following simulation of the 3 cylinders was carried out.

1. First the pusher (I1) is pressed to hold from the second can to the fourth can.
2. Second, the pushbutton (I2) is pressed to release the first can.
3. Third, press the pushbutton (I3) to crush the first can.
4. Fourth, release the pushbutton (I3) to make it fly back to its place and at the same time release the pushbutton (I2) to grab the other missing cans.
5. Fifth, the pushbutton (I1) is released to release the second can and it becomes the first can.

6. And so this process is repeated successively.

Once these pushbuttons have been left active by cycling through the work loops, the automatic operation of the system is displayed.

The first cylinder (I1) functions as a retainer, the second cylinder (I2) functions as a passing beam and the third cylinder (I3) functions as a crusher.

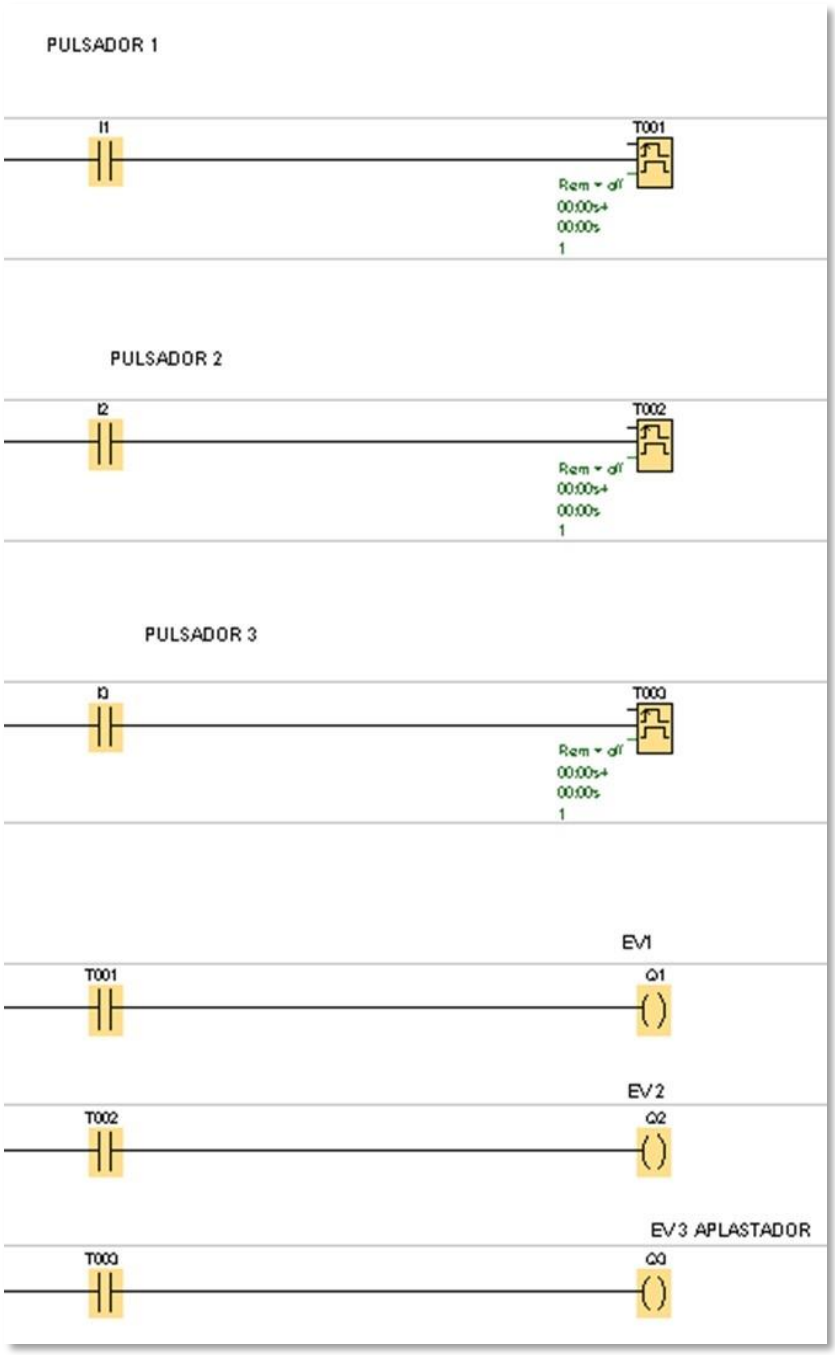


Figure N° 25. PLC circuit of the pneumatic can crusher Source:
Own elaboration

4.9. Description and detail of production indicators after automation.

4.9.1. Overtime

The automation of the can crushing process improved productivity because the workers were able to reach the required daily production goal more easily. As a result, the excess of work outside the maximum working day established by law, which stipulates that a worker may work a maximum of 8 hours per day, was reduced.

Likewise, the costs of paying workers for overtime because they did not meet the required production per day were considerably reduced, bringing a great benefit to the company, reflected in its monthly profits. In addition, thanks to the automation of the process, the workload of the workers was significantly reduced, thus avoiding labor overload.

4.9.2. Productivity

With the implementation of the automated can crushing machine, productivity in production was increased due to the increase in production volume using fewer resources, compared to the method previously used in which a manual procedure was used in the can crushing process.

4.9.3. Quality control

By implementing the automated can crushing machine, errors in the crushing process were reduced, which improved the quality of the crushing process by eliminating the errors made by the workers when performing the process manually. Likewise, reprocessing was eliminated due to defective products that had to go back to the manual crushing process because they were not crushed correctly.

4.9.4. Sales growth

With the automation of the can crushing process, it was possible to increase the production of crushed cans due to a reduction in the number of cans crushed.

This increased the amount of cans crushed per day, which increased the production capacity.

As a result, the company was able to generate more income because it was able to offer a larger quantity of the product to its main customers, resulting in an increase in sales compared to previous months.

4.10. Industrial safety aspects after the implementation of the proposal.

4.10.1. Safety in automated processes

Automated processes are understood as processes in which the operation of the machine is independent, automatic and is solved by programming for more efficient work. Because of this, safety for this type of situation is generally enabled in the testing phase, as well as in maintenance, reprogramming, repair, adjustment or initial start-up after a shutdown and not in a normal operating situation of the equipment. Since there is a decrease in the direct work of the worker with the same process.

4.10.2. Types of accidents

1. **Mechanical contact accident**

   Risks can be categorized as mechanical as they can be caused by collisions with the machine, compression by a valve, trapping of limbs or objects attached to the body such as clothing. This can also be found by the slipping of some misplaced object, this can be a component part of the machine or product worked due to poor programming, unforeseen failure outside the limits of control or some failure due to poor handling of the operator in the location of the product.

2. **Accidents due to human error**

   Human accidents are part of the error due to poor handling or programming of the system. These errors are also due to poor communication between engineers or operators, not visualizing the wear of peripheral equipment, poorly implemented input and output connections,

Unforeseen movements due to fatigue, boredom or poor preparation in the knowledge of the operation of the machines that can finally cause injuries to the same personnel, to a co-worker or finally to the machine due to its sudden stop.

4.10.3. Prevention Measures

1. **Delimitation of the work area**

   The working area of the machine must be delimited by visual signs either on the ground with yellow bands for an interpretation of the working perimeter or with signs or stickers on the adjacent walls or on surfaces of the machine itself that do not overheat. The area can also be made foolproof by implementing safety fencing or a perimeter fence around the work area to prevent unintentional approach by operators. In our work, if the project were implemented in larger sizes and with an industrial character, we would provide wall signs in the compression area with the main cylinder, as well as delimit the working area of the machine and fence if possible the front part of the equipment.

2. **Implementation of safety devices**

   The external zone to the development of the process by the machine can be implemented with automatic warning devices at the moment of being infringed by any object or person. These devices can be sensors or delimiters that prevent the operation of the machine while an object is in the danger zone as well as prevent the start of the initial operation. These would be directly connected to the central system. In our case, when installing the machine in an already delimited zone, it is also possible to implement a couple of alternate sensors in the compression and crushing zone, as well as in the automatic dispenser zone after the filling and arrival of the cans to the ramp.

3. **Operator Training**

   A safety measure is the knowledge that the shift operator has at the time of handling or joining the process developed by the machine, both in the ergonomic area, related to the postures in the work area, as well as in the functional area for handling or assistance in the filling process. In our case, if we do not add any machine

The support of an auxiliary operator would be needed for the dispersion of the cans towards the selector, which functions as a predecessor to the compression process.

4. **Use of safety equipment**

   The use of safety implements is mandatory in plant work. Even more, if you are working with automated machines that generate certain work effort and imminent danger to the operator. In a mechanical work machine, the use of gloves is mandatory, as well as the use of helmets and shoes, whether dielectric or steel-toed, according to the industrial safety regulations in the sector in which the work is being performed. In our case, the use of these implements is not considered indispensable since the products worked are not of a heavy nature, but it is possible that the use of gloves and goggles is recommended to avoid cuts or shearing or crushing.

5. **Reduction of workload.**

   The reduction of the workload is considered when the operator is involved in the support process as an auxiliary agent either in the supply area for the correct operation of the machine. This occurs in assembly work where the automated process has the leading role, leaving the operator for supervision or finalizing action. If the operator had to share his attention with several other processes, as if he were in a work cell, this could generate a risk of accident. In our case, the workload is already part of the administration that generates the functions that each operator has. In principle, the machine was designed for the crushing of aluminum cans with an auxiliary support of an operator for dispensing. This operator would also be obviated if a conveyor belt or dispensing machine was implemented by means of sensors, thus eliminating this risk.

6. **Machinery maintenance process**

   For the maintenance of the machine, which is performed by an operator either in the greasing of the component parts or cleaning by dust interference, be generated by well-trained operators and with all safety implements. The process must be programmed with a continuous schedule to avoid untimely failures that generate a production stoppage.

generating additional costs, as well as damage to the equipment itself or even some damage to the operator due to poor planning. In our case, it is recommended to schedule the days of physical maintenance of the can crusher, whether it is a cleaning of the valves or maintenance of the support structure with the indications in a manual for the knowledge of the operator and thus have standardized processes with all the safety measures.

7. **Programming Maintenance Process**

   The programming testing process is performed by a technician specialized in code supported by a testing assistant who will develop the physical part of the test with the machines. For this process it is also recommended the use of safety implements, as well as sufficient knowledge of the work of the machines to avoid accidents. In our case, it is proposed that the support assistant be the same can supply operator for the correct use and development of the process.

8. **Implementation of labor standards**

   Safety standards always help, whether they are not directly involved in bad practice, but in the knowledge and prevention of accidents in the operation process or in the maintenance process. It must be stipulated in advance the conditions in which the machine must be and the distances for the support or accompaniment of the production. Likewise, the conditions in which the machine must be, in the case of maintenance, must be written down. For example, having the connections disabled, or that the process has no workers in the operation area, as well as possibly also work elements more than those that will be used for testing. In our case, it is considered relevant to generate a guide with rules detailing the external characteristics for the start of operations, as well as maintenance determined by the engineer on duty.

CHAPTER V - Budget for the investment of can crushing machines

5. Investment and operating cost

5.1. Cash flow

We are a group of university classmates who created a pneumatic can crusher machine in which we spent an average of 1300 soles as an investment counting transport of the machine, but now we want to industrialize this project so we plan to make 5 more machines (2 machines for every 2 months), for which we will need a staff (which will be paid the minimum wage), so it will leave an initial investment for this of 22006.50 soles, however we do not have the 14084.16 soles needed to complete this project so we will resort to financing, to see if this is convenient or not, we will make a statement of results, and an economic cash flow, based on sales revenue, cost of sales, expenses, among others and this will be seen below:

Figure N°26. Income statement of the pneumatic can crusher manufacturing company

ESTADO DE RESULTADOS - PROYECTADO

Expresado en soles

	Año 1	Año 2	Año 3	Año 4	Año 5
Ingresos por Ventas	71,186.44	122,203.39	176,217.29	233,362.04	293,776.88
Costos de Ventas	34,163.12	46,256.19	73,509.22	85,503.78	97,464.90
Ganancia/Perdida Bruta	**37,023.32**	**75,947.20**	**102,708.07**	**147,858.25**	**196,311.97**
Gastos de Ventas	16,850.75	17,355.91	17,876.23	18,412.16	18,964.16
Gastos de Administraciòn	17,280.75	17,789.81	18,314.15	18,854.21	19,110.48
Ganancia/Perdida Operativa	**2,891.82**	**40,801.48**	**66,517.69**	**110,591.89**	**158,237.33**
Gastos Financieros	2,262.64	1,491.62	567.09	0.00	0.00
Ganancia/Perdida Antes de Impuestos	**629.18**	**39,309.86**	**65,950.60**	**110,591.89**	**158,237.33**
Impuesto a la Renta	188.75	11,792.96	19,785.18	33,177.57	47,471.20
Resultado del Ejercicio	**440.42**	**27,516.90**	**46,165.42**	**77,414.32**	**110,766.13**
Utilidades (20%)	88.08	5,503.38	9,233.08	15,482.86	22,153.23

Source: Own elaboration

FLUJO DE EFECTIVO						
Expresado en Soles						
Descripciòn	**Año 0**	**Año 1**	**Año 2**	**Año 3**	**Año 4**	**Año 5**
Ingresos por Ventas			122,203.39	176,217.29	233,362.04	293,776.88
Costo de Ventas		34,163.12	46,256.19	73,509.22	85,503.78	97,464.90
Gastos de Ventas		16,850.75	17,355.91	17,876.23	18,412.16	18,964.16
Gastos de Administraciòn		17,280.75	17,789.81	18,314.15	18,854.21	19,110.48
Ganancia Antes de Impuestos		**2,891.82**	**40,801.48**	**66,517.69**	**110,591.89**	**158,237.33**
Impuesto a la Renta		867.55	12,240.44	19,955.31	33,177.57	47,471.20
Depreciacion + Amortizaciòn		493.50	497.00	500.59	504.30	208.12
Flujo de Caja Operativo -FCO		**2,517.77**	**29,058.03**	**47,062.98**	**77,918.62**	**110,974.26**
INVERSIONES						
Activos Fijos	-1,790.00					
Recupero de Activos Fijos	0.00	0.00	0.00	0.00	0.00	1,025.00
Herramientas	-116.50	-120.00	-123.59	-127.30	-131.12	0.00
Capital de Trabajo	-20,100.00					
Recupero de Capital de Trabajo						20,100.00
Flujo de Inversiones - FI	**-22,006.50**	**-120.00**	**-123.59**	**-127.30**	**-131.12**	**21,125.00**
Flujo de Caja Economico - FCE	**-22,006.50**	**2,397.78**	**28,934.44**	**46,935.68**	**77,787.50**	**132,099.26**

TIRE	104%
COK	36%
VANE	65,189.85

Figure N° 27. Economic Cash Flow of the pneumatic can crusher manufacturing company.

Source: Own elaboration

The EIRR was 104%>36%, therefore, this project is feasible with equity capital, since the income is greater than the investments.

The NPV was 65189.65>0, therefore, the project is accepted because it is profitable.

5.2. Economic viability.

For the economic feasibility, a 5-year project is presented in which a workshop was implemented in which the crusher will be produced for trade in small companies seeking to implement an automated solution for the recycling procedure.

For this project, a 5-year horizon was considered, with an investment of S/. 22,006, which includes the acquisition of machinery, work tables, safety implements, additional tools for maximum productivity and safety systems.

For the sales forecast we considered an estimate of 12 to 44 machines sold during the execution of the project at a price of S/ 7,000 to S/ 7,878 soles each, increasing due to the quality of work and image that the company maintains with our values. For the direct cost of production we considered the materials that make up the crusher such as cylinders, pistons, solenoid valves, hoses, regulators, tees, etc. In addition, also within the fixed costs we considered the rent of the premises since for a project of the duration that we estimate we do not consider the best option to buy one.

A straight-line depreciation was considered for both the investment and t h e equipment purchased and was calculated at a rate of 10% per annum for the indicators.

According to indicators such as the net present value and the internal rate of return, it is estimated that the project will return S/. 65,190 soles on the investment and has a rate of return of 114% if we manage to consolidate the estimated sales. Therefore, if we continue with the estimated expenses and projected sales, the system is considered profitable.

DEBT SERVICE

Concept	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Loan	14,084.16	10,211.63	5,568.08	0.00		
Amortization		3,872.53	4,643.55	5,568.08		
Interests		2,262.64	1,491.62	567.09		
Payment		6,135.17	6,135.17	6,135.17		
FINANCIAL CASH FLOW						
Economic Cash Flow - FCE	-22,006.50	2,397.78	28,934.44	46,935.68	77,787.50	132,099.26
Loan	14,084.16					
Amortization		-3,872.53	-4,643.55	-5,568.08		
Interests		-2,262.64	-1,491.62	-567.09		
Financial Cash Flow - FCF	-7,922.34	-3,737.39	22,799.27	40,800.51	77,787.50	132,099.26

TIRF	152%
COK	36%
VANF	69,006.84

Figure N° 28. Economic cash flow of the pneumatic can crusher manufacturing company.
Source: Own elaboration

INDICATORS

Profitability	FORMULA	Year0	Year1	Year2	Year3	Year4	Year5
Gross Margin (%)	G.B./SALES		52.0%	62.1%	58.3%	63.4%	66.8%
OperatingMargin(EBIT)(%)	G.O./SALES		4.06%	33.39%	37.75%	47.39%	53.86%
NetMargin(%)	R.E./SALES		0.62%	22.52%	26.20%	33.17%	37.70%
ROE(%)	R.E./HERITAGE		5.27%	77.65%	85.35%	90.72%	93.33%
ROA(%)	(G.O.- IMP)/ASSETS		12.97%	63.75%	53.08%	46.52%	39.81%
EBITDA (S/)	GO+DEP+AMORT.		3,385	41,298	67,018	111,096	158,445

TIRF	152%
VANF	69007

Figure N° 29. Indicators of the pneumatic can crusher manufacturing company.
Source: Own elaboration

CONCLUSIONS

- This is a project that will allow to generate machines that can be implemented in a greater quantity due to its practicality of use, as well as the care for the environmental identity bringing greater productivity and care of the operator for the same ergonomics in the positioning and safety to be a constant work that will be automated.
- The production of this automated crusher is a breakthrough both to reduce costs for the company that acquires it and to save time and safety, as well as care for the environment.
- As for the development project, by financing and investing certain capital for the development of the mass production company, it is considered that a return on capital would be generated, as well as obtaining profits at the end of the fiscal year after 4 years. Therefore, the production of this machinery is considered profitable.

RECOMMENDATIONS

- It is recommended to check the operation of each element to be used before assembling the system as a whole. It is also recommended to test the components one by one and then as a whole to rule out errors in the machine.
- It is recommended to review the operating manuals of the pneumatic cylinders, solenoid valves and other devices involved in the system to facilitate their implementation.
- It is recommended to have knowledge about the operation of the equipment involved, in order to avoid failures in their implementation.

BIBLIOGRAPHY .

The law of the three Rs | Environment (2008, June 28). Environment | Another VANGUARDIA.COM Blogs site. Retrieved April 18, 2022, from https://blogs.vanguardia.com/medio-ambiente/general/23-la-ley-de-las-tres-r#:%7E:text=Reduce%2C%20reuse%20and%20recycle%2C%20one,by%20of%20the%20third%2C%20para%20todos%20nosotros.

Logicbus (n. d.) What is automation? Retrieved April 20, 2022, from https://www.logicbus.com.mx/automatizacion.php

Arencibia, J. (2015, February 22). *Technology Blog - IES José Arencibia Gil - Telde*. FluidSim. Retrieved April 21, 2022, from https://www3.gobiernodecanarias.org/medusa/ecoblog/fsancac/2015/02/22/fluidsim/

VLD engineering (2021, June 30): WHAT DO WE MEAN BY SIMULATION? OF INDUSTRIAL PROCESSES? Retrieved April 19, 2022, from https://www.vld-eng.com/blog/simulacion-procesos-industriales/

Aula 21. (n. d.). Siemens LOGO!: What it is and how it works. Retrieved April 18, 2022, from https://www.cursosaula21.com/logo-de-siemens-que-es-y-como-funciona/#:~:text=c%C3%B3mo%20se%20program%3F-,El%20software%20LOGO!,servidor%20web%20integrado%20en%20LOGO!

NIKE. (2021, July 13). Autodesk Inventor: what it is and its advantages. Retrieved June 26, 2022, from https://www.nke360.es/autodesk-inventor-que-es-y-ventajas/

Westreicher, G. (2020, August 2). *Economipedia*. Process. Retrieved June 20, 2022, from https://economipedia.com/definiciones/proceso.html

Satoshi (2020, March 23). *Opiron*. Ladder language and fundamental concepts. Retrieved June 20, 2022, from https://www.opiron.com/lenguaje-ladder-y-conceptos-fundamentals/#What_is_the_Ladder_language.

Netinbag. (n. d.). https://www.netinbag.com/es/business/what-is-project-simulation.html. Retrieved June 25, 2022, from https://www.netinbag.com/es/business/what-is-project-simulation.html.

AUTODESK (n. d.). AutoCAD: the 2D and 3D CAD software trusted by millions of users to draw, create and automate designs anytime, anywhere. Retrieved 29 from June 29, from 2022, from https://www.autodesk.es/products/autocad/overview?term=1-YEAR&tab=subscription

adr training (n. d.) What is SolidWorks? Retrieved June 25, 2022, from https://www.adrformacion.com/knowledge/ingenieria-y-projects/_what_is_solidworks_.html.

Luis, J. (2021, August 3). *How It Works*. https://como-funciona.co/electroneumatica/. Retrieved June 27, 2022, from https://como-funciona.co/electroneumatica/.

Meanings (n. d.). Meaning of Programming. Retrieved June 29, 2022, from https://www.significados.com/programacion/#:~:text=Programming%C3%B3n%20is%20it%20la%20acci%C3%B3n%20de,mundo%20inform%C3%A1tico%20de%20las%20computadoras.

ANNEXES

Annex N° 1. Table of material expenses

Gastos de materiales			
Compra	**Monto**	**Fecha**	**Dia**
Malvinas componentes	603	5/05/2022	Jueves
Primeros materiales richi	55.9	11/05/2022	Miercoles
Madera	15	11/05/2022	Miercoles
Cortado de madera	15	11/05/2022	Miercoles
Pintado de madera	50	11/05/2022	Miercoles
Recaudar de caudal	60	11/05/2022	Miercoles
2 latas	6	11/05/2022	Miercoles
Periodico	3	11/05/2022	Miercoles
Material (pincel, etc)	28	11/05/2022	Miercoles
Bolsa gruesa negra	4	11/05/2022	Miercoles
Periodico	3	12/05/2022	Jueves
Materiales galeria richi	39.5	12/05/2022	Jueves
Bisagra galeria richi	8	12/05/2022	Jueves
Clavos grandes ferreteria	3.5	12/05/2022	Jueves
Pernos Y clavos chicos	3.2	12/05/2022	Jueves
Materiales de ferreteria	17.1	13/05/2022	Viernes
Fuente de alimentacion	120	13/05/2022	Viernes
TOTAL DE GASTOS	**1034.2**		

Figure N° 30. Main expenses for the elaboration of the model

Source: Own elaboration

Annex N°02. Quotation in the ACOPROM gallery on April 3, 2022.

Figure N° 31. ACOPROM Gallery

Source: Own elaboration

Annex N°03. First face-to-face meeting with the teacher on April 13, 2022.

Figure N° 32. University corridor Source:

Own elaboration

Annex N°04. Project outline of April 22, 2022.

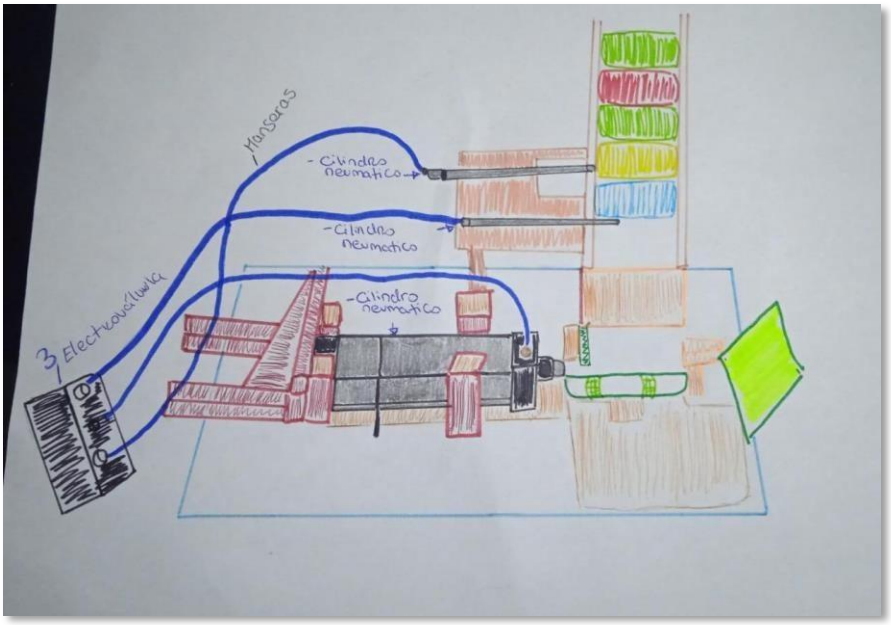


Figure N° 33. Hand-drawn model Source:
Own elaboration

Annex N°05. Second face-to-face meeting to find out which materials to purchase on May 2, 2022.

Figure N° 34. Route to the university
Source: Own elaboration

Annex N°06. Third meeting to purchase materials in the Falklands on May 5, 2022.

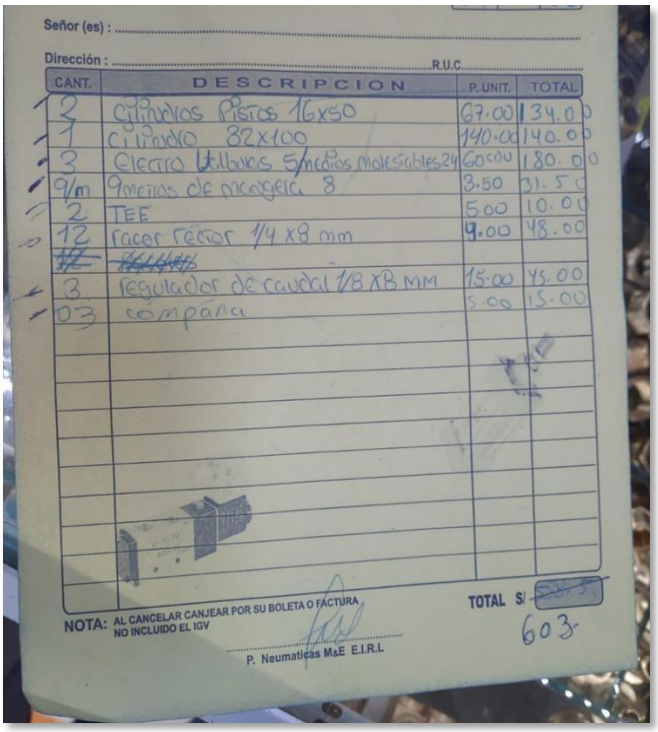


Figure N° 35. Payment slip 1 Source:

Own elaboration

Annex N°07. Fourth meeting going to buy materials to start the assembly of the model on May 11, 2022.

Figure N° 36. Table for making the model Source:

Own elaboration

Annex N°08. Fifth face-to-face meeting at the university to follow up the assembly of the model on May 12, 2022.

Figure N° 37. Students gathered to make the model, part 2 Source:
Own elaboration

Annex N°9. Sixth meeting at the university to assemble the model for May 13, 2022.

Figure N° 38. Students gathered to make the model, part 3 Source:
Own elaboration

Annex N°10. Seventh meeting at the university to put the materials in the model on May 20, 2022.

Figure N° 39. Students gathered to make the model, part 4 Source:
Own elaboration

Annex N°11. First finish of the can crushing model.

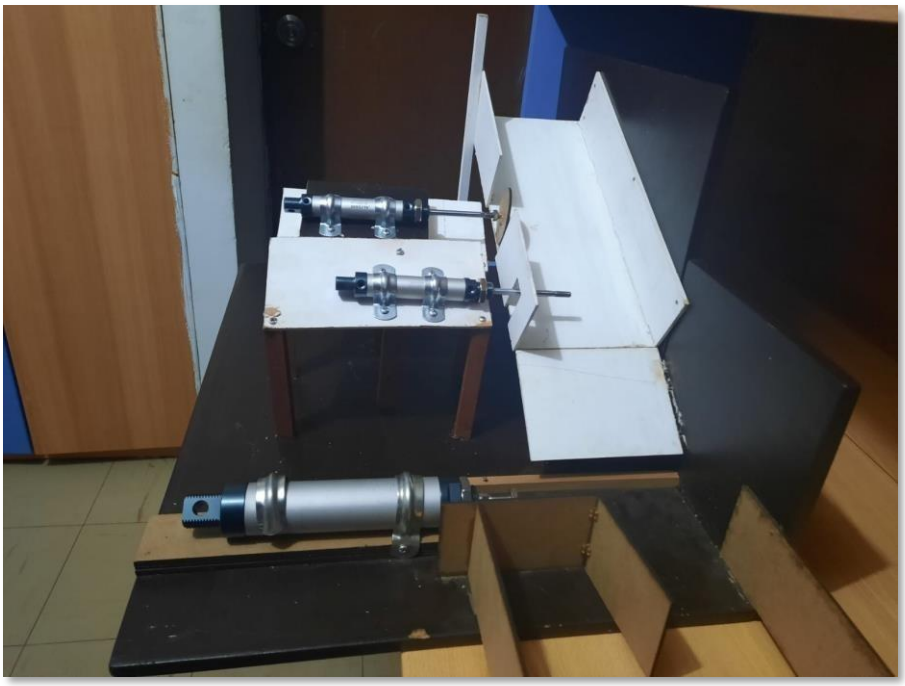


Figure N° 40. Finishing of model 1
Source: Own elaboration

Annex N°12. Purchase of adapters for 16*50 cylinders in the Malvinas on May 26, 2022.

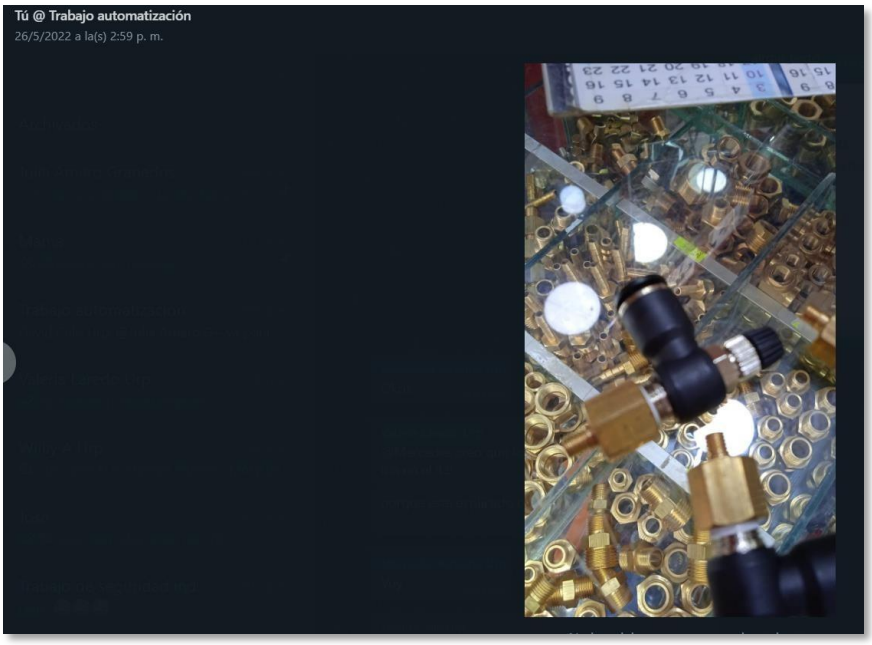


Figure N° 41. Purchase of flow regulators Source:
Own elaboration

Annex N°13. Eighth meeting at the university to put the hoses on the model on May 27, 2022.

Figure N° 42. Students gathered to make the model part 5.1
Source: Own elaboration

Annex N°14. Eighth meeting at the university to put the hoses on the model on May 27, 2022.

Figure N° 43. Students gathered to make the model part 5.2

Source: Own elaboration

Annex N°15. Advance of the 3D design

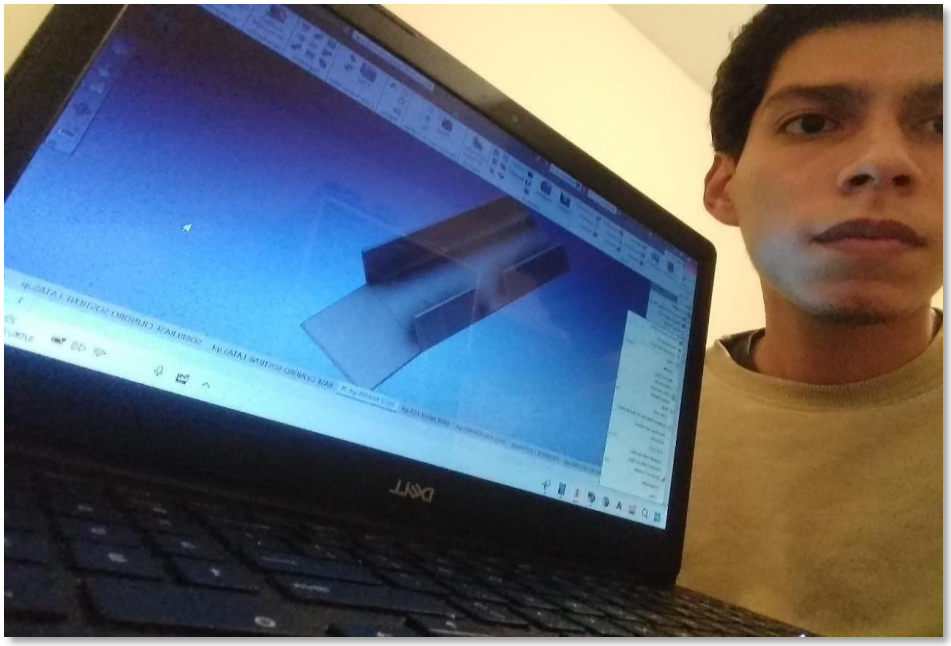
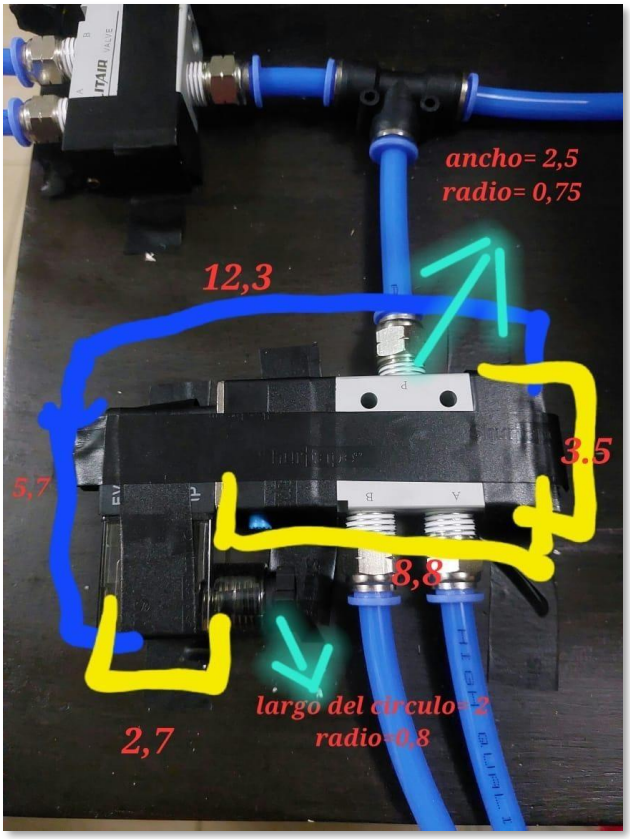


Figure N° 44. Students gathered to make the model part 6.1

Source: Own elaboration

Annex N°16. Taking measurements to make the 3D design



Solenoid valve measurements Source: Own elaboration

Annex N°17. Ninth meeting at David's house to lay the cables in the model on June 3, 2022.

Figure N° 46. Students gathered to make the model part 6.2
Source: Own elaboration

Annex N°18. Ninth meeting at David's house to lay the cables in the model on June 3, 2022.

Figure N° 47. Students gathered to make the model part 6.3
Source: Own elaboration

Annex N°19. Second finishing of the can crusher model.

Figure N° 48. Finishing of model 2
Source: Own elaboration

Annex N°20. Third finish of the can crusher model.

Figure N° 49. Finishing of model 3

Source: Own elaboration

Annex N°21. Tenth meeting at the university to test if air comes out of the model on June 10, 2022.

Figure N° 50. Students gathered to make the model, part 7 Source:

Own elaboration

Annex N°22. Project with turnitin on June 10, 2022.

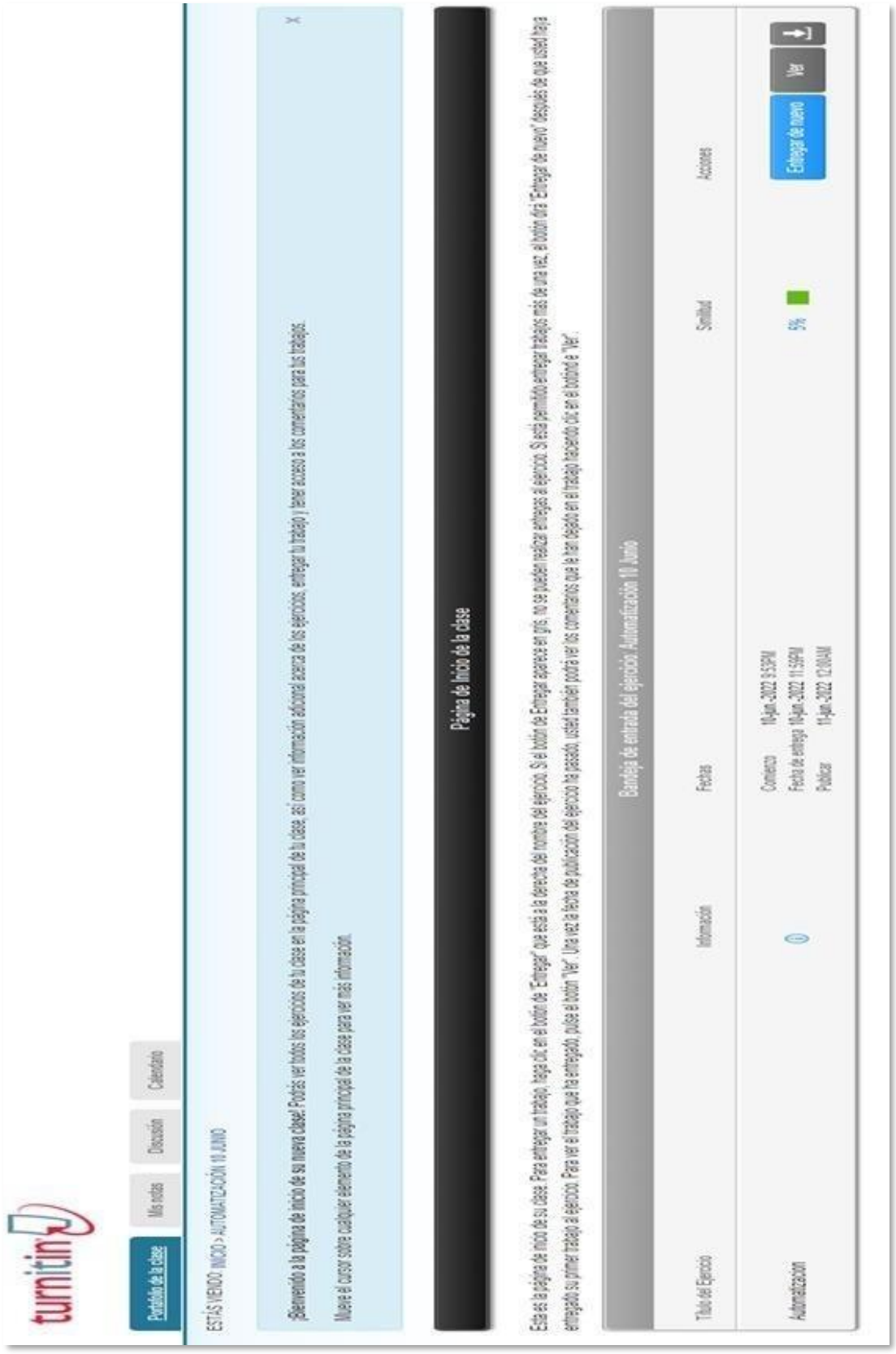


Figure N° 51. Turnitin

Source: Own elaboration

Annex N°23. Turnitin with 5%.

Figure N° 52. Turnitin 5%

Source: Own elaboration

Annex N°24. Eleventh meeting at the university to put the iron circles on the cylinders of the model on June 15, 2022.

Figure N° 53. Students gathered to make the model part 8.1

Source: Own elaboration

Annex N°25. Eleventh meeting at the university to put the iron circles on the cylinders of the model on June 15, 2022.

Figure N° 54. Students gathered to make the model part 8.2

Source: Own elaboration

Annex N°26. Eleventh meeting at the university to put the iron circles on the cylinders of the model on June 15, 2022.

Figure N° 55. Students gathered to make the model part 8.3

Source: Own elaboration

Annex N°27. Fourth finish of the can crusher model.

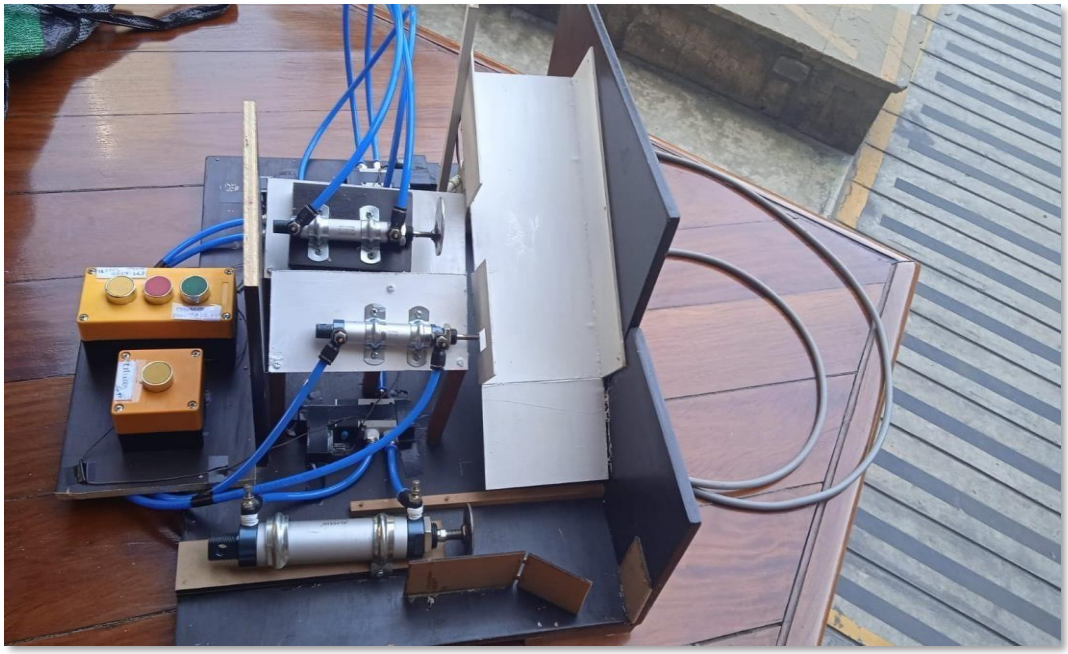


Figure N° 56. Finishing of model 4

Source: Own elaboration

Annex N°28. Twelfth meeting at the university to test the model on June 15, 2022.

Figure N° 57. Students gathered to make the model part 9.1

Source: Own elaboration

Annex N°29. Twelfth meeting at the university to test the model on June 15, 2022.

Figure N° 58. Finishing of model 5

Source: Own elaboration

Annex N°30. Twelfth meeting at the university to test the model on June 15, 2022.

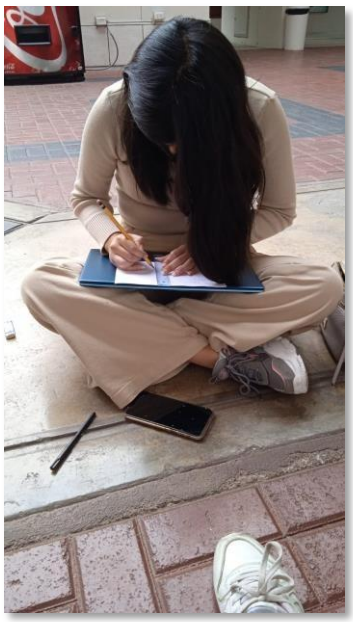


Figure N° 59. Students gathered to make the model part 9.2

Source: Own elaboration

Annex N°31. Twelfth meeting at the university to test the model on June 15, 2022.

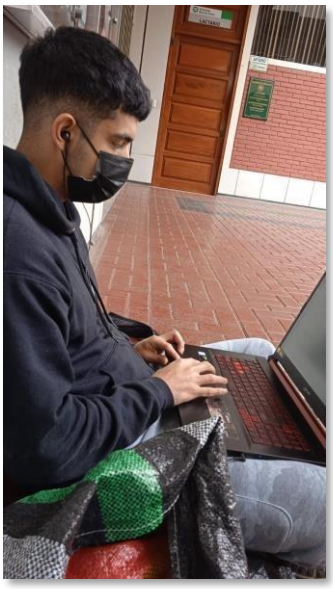


Figure N° 60. Students gathered to make the model part 9.3

Source: Own elaboration

Annex N°32. Twelfth meeting at the university to test the model on June 15, 2022.

Figure N° 61. Students gathered to make the model part 9.4

Source: Own elaboration

Annex N°33. Turnitin of chapter 4 of June 17, 2022.

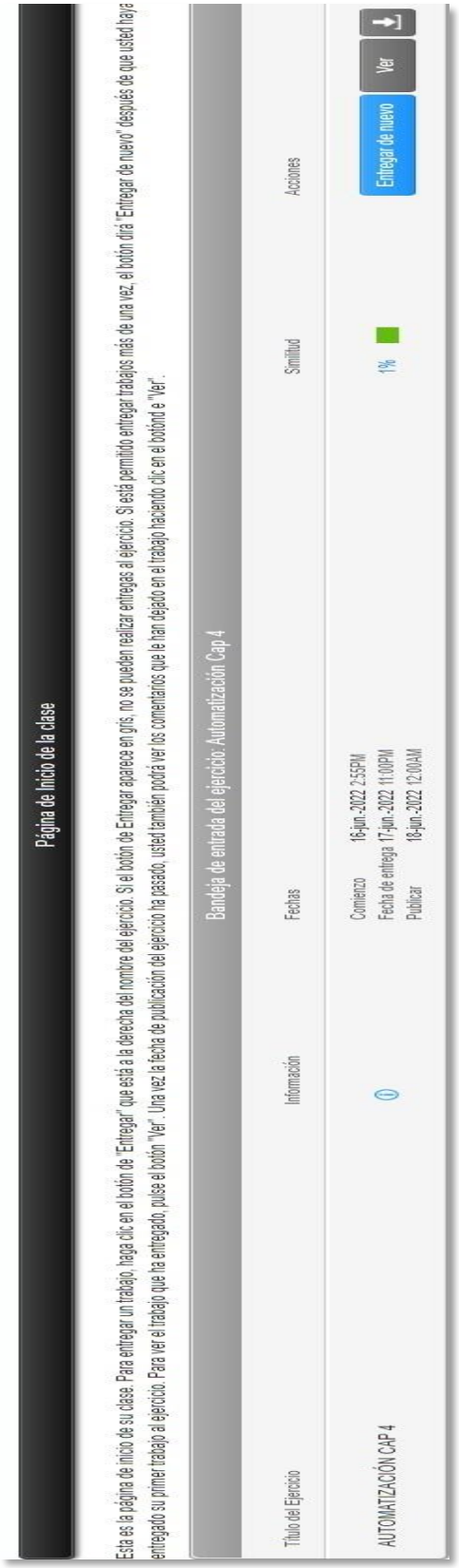


Figure N° 62. Turnitin chapter 4

Source: Own elaboration

Annex N°34. Turnitin of chapter 4 with 1%.