

## Project Didactic of a Mini CNC Milling Machine

José L. Hernández C.<sup>1</sup>, Mariela Hernández V.<sup>2</sup>, Juan Alberto Villegas G.<sup>3</sup>, Ericka Sánchez V.<sup>4</sup>, Omar Ezael Ramírez V.<sup>5</sup>, Jesús Salvador Montiel S.<sup>6</sup>

<sup>1,2,3,4,5,6</sup> Industrial Maintenance Engineering, Technological Tlaxcala University, El Carmen Xalpatlahuaya, Huamantla, Tlaxcala 90500, Mexico.

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**Abstract** - The present investigation shows the results of the construction of a prototype CNC milling machine (Control Numeric Computer). The milling cutter is controlled by a CNC Shield card and an Arduino card. The axes work with stepper motors. The CNC is designed to work with wood, copper and iron plates; it has the option to work with plotter. Copper tracks can be recorded for electronic circuits.

The results show the correct operation at different programmed speeds. The programming of the milling machine is simple, it allows its application in small workshops, and this research has a great opportunity of application at a higher level so that students develop their design skills and can improve it.

Currently there are different types of milling machines that cover up to six axes of work with a design that constantly improves day by day, the advantages of this type of machinery make the machining centers be present in virtually all manufacturing processes, from the most advanced even the most modern to more traditional sectors. The control of the CNC milling machine is carried out through the universal G-code intermediary to establish communication with the Arduino card and the CNC protection card that will be responsible for sending the instructions that the motors must accomplish. For its implementation, machining tests were performed, which showed a statistically satisfactory performance.

**Key Words:** Stepper motors, Universal-G-Code-Sender program, CNC Shield card, Arduino card, Manufacturing,

### 1. INTRODUCTION

The C language performs the drilling operation using computerized machines (CNC), which have a great capacity of automatic reception of the given instructions, by means of software, to manufacture work pieces or moulds by means of complex movements given. It is very important to know the meaning of milling, which is an indispensable tool or tool machine for the realization of machining by removing chips from a piece by the movement of a rotating tool of different cutting edges called milling. [1]

The investigations carried out on the implementation of the CNC in motion machines have established in general terms the main tools and commands necessary for the optimal operation of any CNC machine prototype. For the benefit of the student community, the prototype of a great contribution was implemented for the students of the

industrial maintenance career, who begin to know the way of working of the control languages. [3].

Among the tools we can find: linear cutters, rotation cutters, work pieces and other components. The components of the structure of the tool are described by the Cartesian coordinates system specified by the original point (established point of origin) and three other points selected from the three axes perpendicular to each other. [4] These three points are different from the origin of the machine's coordinate system. On the other hand, the commands used by a CNC system are usually G codes, which contain incremental or absolute positioning data for each axis. [2], [6].

Manipulating this type of machinery is very easy because, knowing the programming language, it allows to design models in two dimensions, like electrical circuits that can be used in different types of future projects, since it will facilitate the recording of the necessary tracks and get the plates. [7] [10]

Since its development in 1980, additive manufacturing has become a powerful facet of manufacturing. [8] that is defined by the American Society for Testing and Materials (ASTM) as "the process of grouping material to create objects from 3D data models". The evolution of the concept in the first decade of the 21st century has made available a large number of processes and materials in the manufacturing industry. [3]

### 1.1 Computer numerical control

The first numerical remote-control machines were built in the 40s and 50s by engineer John T. Parsons. These initial servomechanisms developed rapidly with analog and digital equipment. The cheapening and miniaturization of the processors has generalized the digital electronics in all the types of tools, which gave rise to the denomination of numerical control by computer or numerical computer control (CNC), to differentiate them from the machines that did not have a computer. The principle of common operation of all applications of the numerical control is the control of the relative position of a tool or processing element with respect to the object to be processed. [7]. The application of the numerical control covers a great variety of processes; the applications are divided into two categories: applications with machine tools and applications without machine tools. [7]

The numerical control is a form of programmable automation in which the processing equipment is controlled by numbers, letters and other symbols. These numbers, letters and symbols are coded in an appropriate

format to define a program of instructions to develop a specific task. When the task in question changes, the instructional program changes. [7].

This system has revolutionized the industry due to the cheapening of the microprocessors and the simplification of the programming of the CNC machines. The numerical control by computer (or more commonly known as CNC) is a system that allows to control at all times the position of a physical element. Normally a tool, which is mounted on a machine.

This is achieved through a program and a set of aggregate orders. With both, it can control the position coordinates of a point (the tool that works with the product) with respect to an origin (the position of the machine).

The ability to change the program makes the numerical control appropriate for low or medium production volumes, since it is easier to write new programs than to make changes in the processing equipment.

The research helped the elaboration of the project, which provides knowledge for the students of the Technological University of Tlaxcala, who could design and elaborate printed circuit boards.

## 2. Universal G-code Sender communication with prototype

Once the G-Code files have been created, a program is needed to analyze them and issue the commands to the Shield CNC card. A good open source that works well with Shield CNC (and all GRLB hardware) is Universal G-Code-Sender.

It must vectorize the images or designs intended to make and post-process them to the G code, which is what the machine reads. The theory of stepper motors is simple, when the processing card sends a pulse to the motor controller, it advances one step. This technique is very popular in robotic machines because it lets us know how many pulses, it has sent and how much the machine will advance.

What you need is to move from a pulsed language to something simpler to explain, such as the coordinates of the motors.

The standard way to communicate with a machine of this type is through the use of the G-Code language. Which is a simple text system with the movements of the machine and what it gets with the G-Code language. It is a text file with all the movements of the machine.

The Inkscape program allows to determine the path by stroke of the selected figures and by means of the complete G-Code platform that is used to interact with advanced CNC controllers such as GRBL.

Universal G-Code-Sender is a standalone Java application that includes all external dependencies, which means that, if you have the Java Runtime Environment configuration, UGS provides the rest and we will manage the process in the team.

Figure 1 shows a block the communication process between the PC software and the G-Code-Sender which interacts with the prototype mentioned in this article.

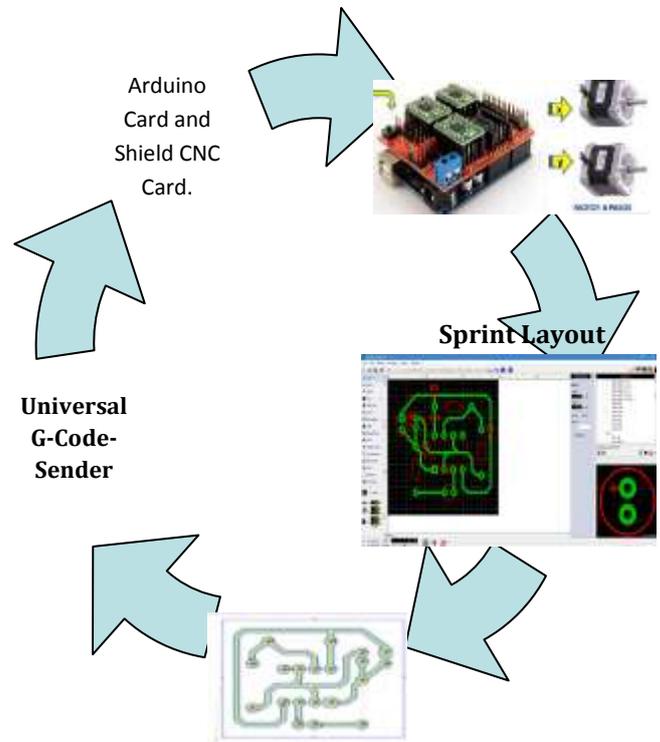


Fig -1: Process Flow Diagram

## 3. Prototype structure and drawing in SolidWorks.

### 3.1. How the CNC is assembled

The project consists of three axes manufactured in a wooden base of plywood of thickness 18 mm, with stepper motors NEMA17, for each axis has a screw of endless double entry, two steely axes that give support of 8 mm, four linear bearings, a bed placed on the Y axis where the process will take place, fasteners, a tower that supports the x axis, has a support box in the mill that moves the z axis to raise and descend.

Each of the axes and the bed are correctly calibrated so that they can move easily without generating friction, thus preventing overheating of the motors and avoiding driver faults.

To begin the construction of the prototype, the measurements were defined based on the realization of the drawing in SolidWorks first, these measurements are shown in the following table.

**Table -1:** Measures for mechanical construction

Measures of the axes				
	No. of pieces	Length	Width	Thickness
X axis	2 nylamid plates	300 mm	70 mm	18 mm
	Shaft support	200mm	100 mm	18 mm
Y axis	4 wood plates	300 mm	70 mm	18 mm
	1 milling bed	200 mm	200 mm	18 mm
Z axis	2 wood plates	100 mm	100 mm	18mm
	Bottom base	100 mm	75 mm	18 mm

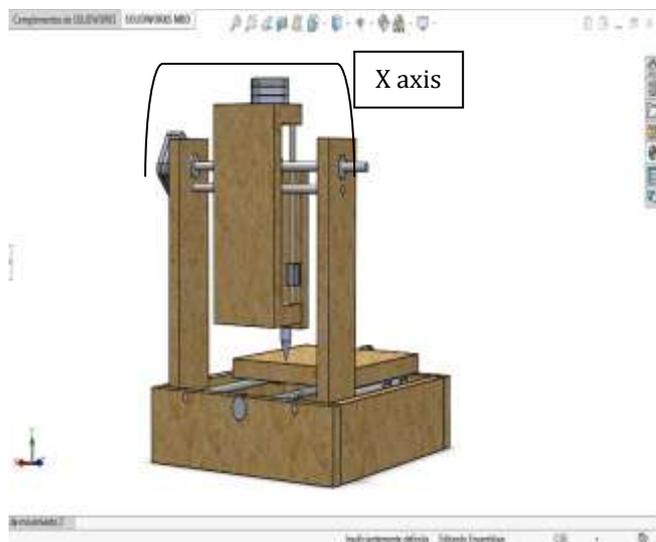
**3.2. Construction of the X axis**

In the base that will support the X axis, two steel shafts are installed and the screw with four linear bearings of 8 mm. The linear bearings will be located 40mm from the center with a separation of one side of 18mm and the other of 24mm.

The stepper motor is installed and fixed in the columns, the couplings and the bearing are located on the support opposite side, observing that it is correctly adjusted and leveled to avoid deviations in the milling.

The structure is fixed together with the base of the X axis. The control interface is preloaded in a data acquisition card of the Arduino family, specifically the UNO model, in which the GRBL program is loaded, with the shield and the driver for handling the engines. The Universal G-Code-Sender program will be the one we will use for programming.

This system is shown completely assembled in Figure 2.



**Fig -2:** X axis

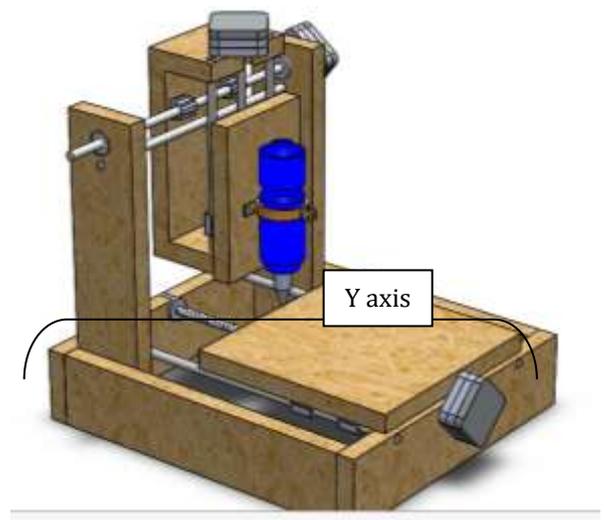
**3.3. Construction of the Y axis**

In this axis, two holes are made through which the two pitch shafts of 8 mm diameter are drilled and in the central part to place the motor step by step, the motor will move the Y axis. The holes are 3 mm diameter and the hole of the arrow of the motor has a diameter of 22 mm, these dimensions allow the movement of the flexible coupling, at the other end there is a bearing that serves as a guide.

The adjustment of the motor plays a very important role, due to the types of displacements that it makes for the cuts. The bearing must be correctly adjusted, since it will support the screw of the Y-axis, we must observe that the screw must turn without problems, as well as the nut of the bushing that moves the bed.

The wooden bed is square with measures of 101 mm per side, the axes are 90 mm from the center to a height of 62 mm. The bed will be placed on 8 mm steel shafts, since each one has two linear bearings, which will help us to give support, stability and easy sliding to carry out the development of the program we want to send.

This system is shown completely assembled in Figure 3.



**Fig -3:** Y axis

**3.4. Construction of the Z axis**

The Z axis consists of a top and a bottom lid, the base that will support the milling tool. In the upper section, the lid is drilled in the center of 10cm, we make hole holders for the motor where the 8 mm axes go, the length of each axis is 20cm.

The tool holder is thickness of 15 mm and width of 100 mm. The lower base is thickness of 18 mm, width of 100 mm and depth of 75 mm. The tool holder must be correctly centered.

The linear bearings are the ones that support the two 8 mm axes and all these fits into the base that supports the milling tool. In the upper base the flexible coupling and the stepper motor are placed. In the lower base the bearing is placed. This system is shown completely assembled in figure 4.

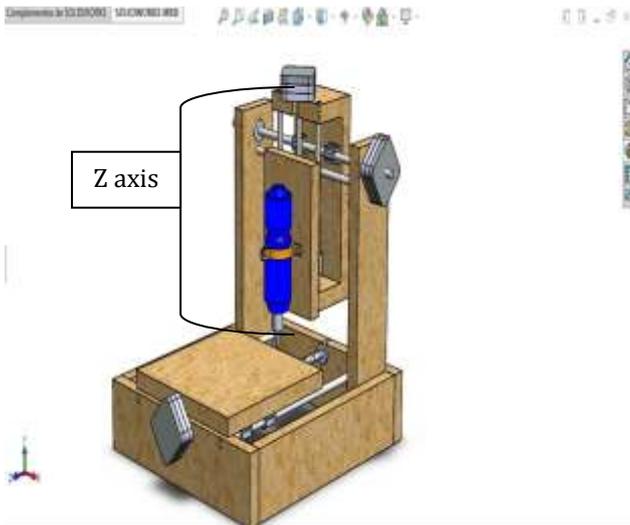


Fig -4: Z axis

#### 4. Prototype control

The control is done with the Arduino UNO card and the Shield CNC, the latter has the A4988 drivers, to increase the current and voltage of the stepper motors.

The designs of the circuits are carried out in programs such as Sprint Layout 6 or Easy EDA in which we can design the tracks for the circuits that are intended to be made, the difference is that the latter is worked for free, but with internet to save circuits. Once the G-Code files have been created, a program is needed to analyze them and issue the commands to the Shield CNC card. This system is shown completely assembled in figure 5.

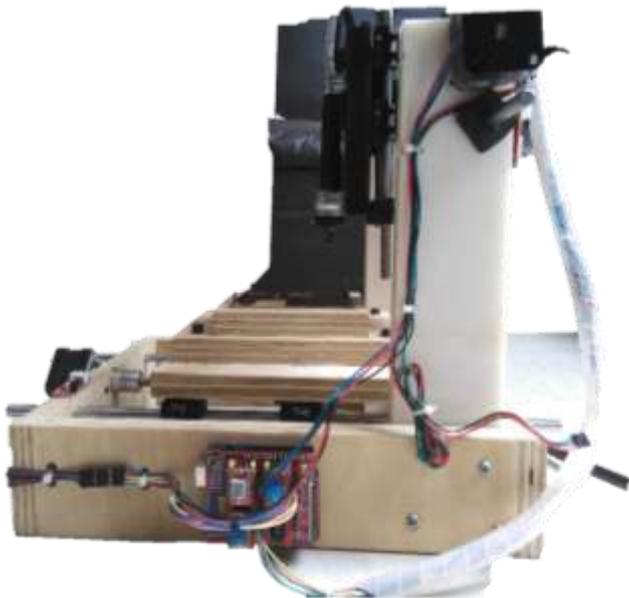


Fig -5: Location of the control card

#### 4.1. Setting the A4988 drivers

The voltage of each complete bridge is given by a current control circuit, pulse width modulation (also known as PWM, pulse-width modulation) of fixed disconnection time that limits the load current to a value

wanted. Initially, outputs with field effect transistors or FET (Field Electric Transistor) from the source and current are activated diagonally and current flows through the motor winding and the current sensing resistor RSx.

When the voltage across RSx is equal to the digital output voltage to analogue converter (DAC), the current sense comparator resets the PWM latch. Then, the latch deactivates the appropriate origin controller and initiates a fixed time reduction mode. [5]. The data with which they are recommended work this type of controllers is shown in table 2.

Table -2: Characteristics of the A4988 driver

Characteristics of the A4988 driver	
Minimum voltage	3 V
Maximum voltage	5.5 V
Maximum current per phase	2 A
Continuous current per phase	1 A
Minimum voltage operation	5 V
Maximum voltage operation	35 V



The maximum value of the current limitation is established by the selection of RSx and the voltage on the Reference Voltage (Vref) pin. [5]

The transconductance function is approximated by the maximum value of the current limitation, I<sub>TripMAX</sub> (A), which is established by:

The values of the SMD resistors and the drivers is 0.2 Ohm (R200). Applying the formula of the datasheet of the drivers A4899

$$I_{max} = V_{ref} / (8 \times R_s) \tag{1}$$

$$V_{ref} = 1.5 \times (8 \times 0.2) = 2.4 \text{ V} \tag{2}$$

$$V_{ref} = 2.4 \text{ V} \tag{3}$$

To this data it is necessary to apply the 70% that gives 1.68V.

The problem is with the voltage values that are measured when the potentiometer of the controllers is turned. The minimum that was achieved is 4.2 V and the maximum is 7 V.

#### 5. Results.

The physical structure was improved to have better accuracy in the engraving and thus make the circuits more accurate.

We show the development of a circuit that gives the pulses of a led with an integrated circuit 555. We will develop step by step the explanation of the load and the program, how the tracks were designed and they became a C language for the engines to carry out the process

The software for the realization of printed circuit boards (PCB) is easy, fast and useful. The logical and understandable structure of Sprint-Layout is very easy to learn. The logical and understandable structure of Sprint-Layout is very easy to learn.

Tracing of tracks is achieved by verifying their dimensions. In the same edition of the tracks the elements of the circuit were placed to obtain the precise measurements.

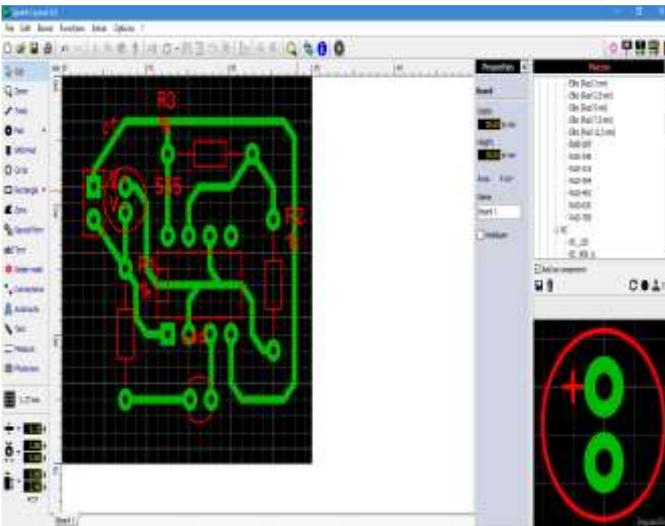


Fig -6: Sprint-Layout program circuit.

At the end of the design, the tracks are vectorized in the FlatCAM program that allows you to take your designs to a CNC router. It is open source, written in Python and runs smoothly on most platforms. In this program we will generate the cutting path that the prototype will carry out.

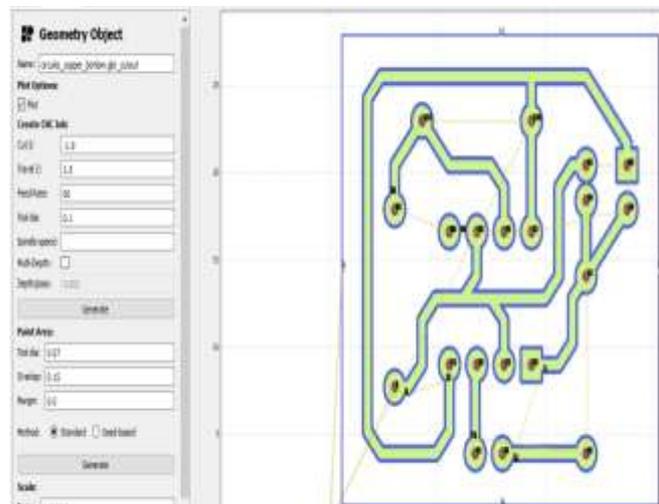


Fig -7: Circuit in the FlatCAM program

Later, the files will be sent to the Universal G-Code-Sender to load them, these files will be divided into three parts, the first will be the tracks for the components, the

second will mark the positions of the holes to be made and finally a frame will be made that will cut the plate section.

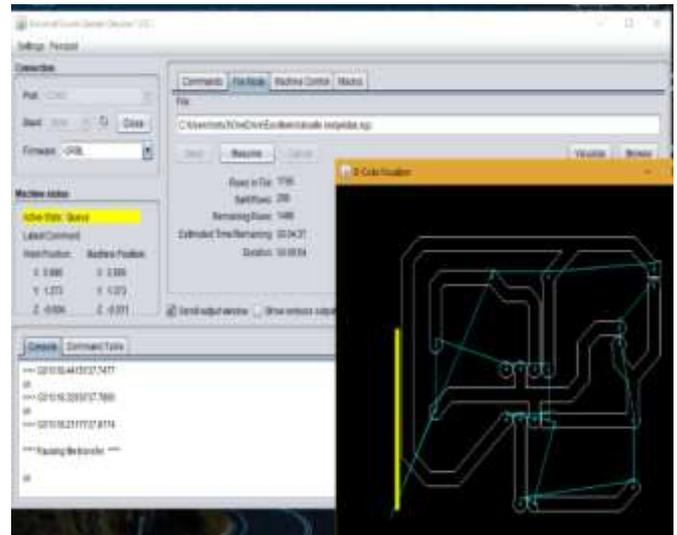


Fig -8: Displaying tracks in G-Code-Sender

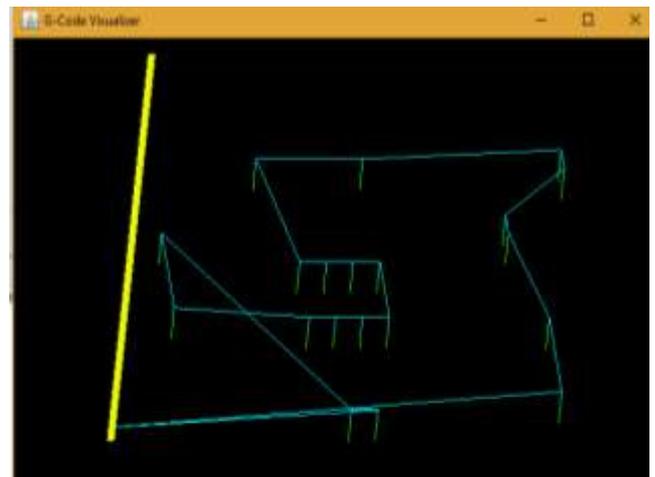
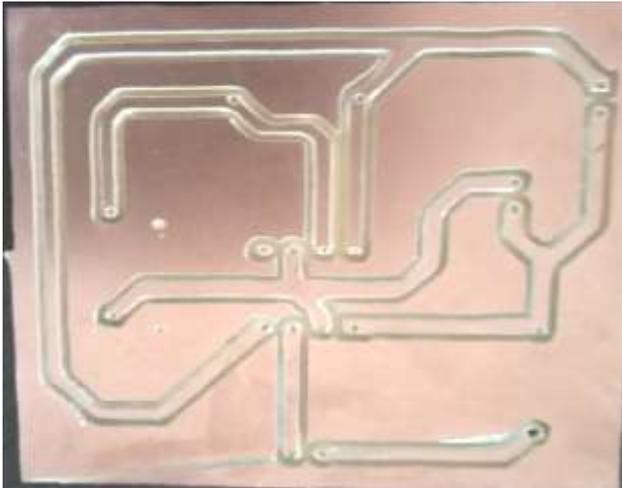


Fig -9: G- Viewing perforations in G-Code-Sender

The code is loaded into the machine, which executes all previously performed routes. The figure represents the displacement on the X axis, the figure on the Y axis and the figure on the Z axis. Therefore, the working plane is three-dimensional.



Fig -10: Process in the prototype



**Fig -11:** Electronic circuit terminated

## 6. CONCLUSIONS

The present project of the CNC contains many advantages, especially the control system, that is what makes it more important. With regard to the time it takes to generate a model, the process of cutting by a CNC is much shorter than doing it by hand, besides not requiring labor, only one operator for the machine.

The control system has a very efficient communication with the computer software that sends the code. The mechanical system has a functionality for the movements in the programmed cutting axis. The mechanical control system and the software work together, resulting in a prototype useful for slabs in soft materials and high precision.

The control system also comprises the power stage for the motors. In the same way the system includes the Software that contains the G code and will send it to the microcontroller of the control system.

In the elaboration of this project we understood how to calibrate each one of the bases of each axis, since this influences the elaboration of the tracks. We understood how to make the interface of the machine with the software, manipulate this system is not of such complexity. The set of these systems results in the roughing of materials such as acrylic and wood. It allows us to record the tracks of the circuits previously made in the program.

It is proposed as a posterior investigation the adaptation of a plastic injection system that allows the realization of 3D figures.

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## BIOGRAPHIES



**José Luis H. Corona** Candidate for a PhD from the Autonomous University of Tlaxcala, Research Professor in the area of Industrial Maintenance, Desirable Profile before the PROMEP, responsible for the CA of Industrial Maintenance at the Technological University of Tlaxcala.



**Mariela Hernandez Vásquez** "Student of Industrial maintenance engineering. T.S.U. In industrial maintenance by the Technological University of Tlaxcala."



**Juan Alberto Villegas Gomez** "Student of Industrial maintenance engineering. T.S.U. In industrial maintenance by the Technological University of Tlaxcala."



**Ericka Sanchez Vazquez** "Student of Industrial maintenance engineering. T.S.U. In industrial maintenance by the Technological University of Tlaxcala."



**Omar Ezael Ramírez Vera** “Student of Industrial maintenance engineering. T.S.U. In industrial maintenance by the Technological University of Tlaxcala. “



**Jesús Salvador Montiel Soto** “Student of Industrial maintenance engineering. T.S.U. In industrial maintenance by the Technological University of Tlaxcala. “ “