CNC MACHINE FOR WOOD CHOPPING.

Haro Yépez Jairo Mauricio
jmharoy@utn.edu.ec
Universidad Técnica del Norte

Abstract - The present work shows the design and construction of a wood milling machine, mobile bridge type for the "Arte y Madera" carpentry workshop located in the parish of San Antonio de Ibarra, which is recognized by the realization of works in wood of artisan and industrial nature.

For the design and construction of this machine was considered the voice of the customer, from which information was obtained for the operation desired by the same.

The machine consists of 3 movable axles, which use threaded rods for the transmission of force, and steel and iron guides in which the Z, Y, X cars seat.

The electrical system is combined with a mechanical system by means of permanent magnet hybrid step motors, which are controlled by the Arduino electronic board loaded with the free CNC firmware, GRBL version 9.0j, which can be controlled from a computer with very basic technical features using free software such as the Universal GCode Sender program.

The tool for the realization of the machining of the wood is a tupi own of the workshop, and its use for the construction of this machine is a requirement on the part of the owner of the workshop.

I. INTRODUCTION

Years ago, carpentry in the sector of San Antonio was developed basically with the knowledge that was acquired in what today is the Higher Technological Institute of Plastic Arts "Daniel Reyes" whose inheritance both in carving and painting come from the Escuela Quiteña, when Don Daniel Reyes, a native of San Antonio de Ibarra, returned to his homeland where he founded, in 1880, an Artistic Lyceum.

Currently, in the carpentry industry in San Antonio de Ibarra, many workshops carve engravings not only in handicrafts, but in products such as doors, tables, shelves, furniture in general, manually or semi-automatic, so that the its activity is related as a craft, this being a limitation for small industries to grow in production capacity and quality that are now demanded.

According to the superintendence of companies more than 90% of the industry dedicated to the production of furniture is located in the provinces of Pichincha, Guayas, Azuay and Manabí. [1]

Being the parish of San Antonio de Ibarra a sector of furniture and wood handicrafts within the province of Imbabura, it is convenient to implement technological development strategies to compete with producers in the provinces with greater production.

The "Arte y Madera" carpentry workshop located in the parish of San Antonio de Ibarra offers decorations on doors and basic general furniture, simple and repeated in the market, which represents a competitive disadvantage for the workshop, and at the same time an opportunity to which the workshop can benefit, so that with the equipment to be implemented is intended to automate the process of thinning artistic figures on flat wood surfaces for the production of doors and other furniture.

II. CHAPTER I
THEORETICAL FRAMEWORK

Wood has been one of the first raw materials from which mankind has benefited, by its characteristics, for a long time has become the main material for construction, fuel, weapons, hunting and many other activities of the man that we has led to our days.
Even today, it is difficult to imagine a home without the wood or its derivatives being present in different shapes, sizes and uses.

Classification of wood

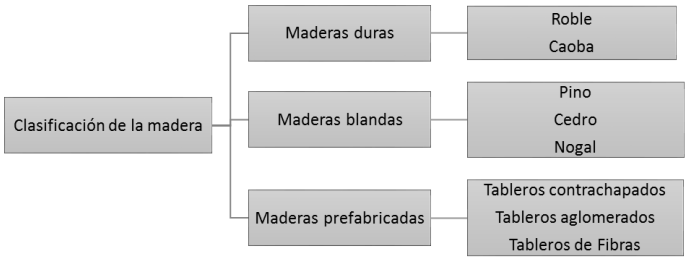


Fig. 1 Classification of wood

The Milling

It is a process of machining by chip removal by means of a tool called a milling cutter, which can have one or several cutting edges, coupled to a rotary cutting tool.

The cutting of the material is done by combining the rotation of the rotary tool with longitudinal movements in different axes of the tool or the workpiece [2].
The machine tool that performs the milling is called the milling machine, and can be classified as shown in the following figure.

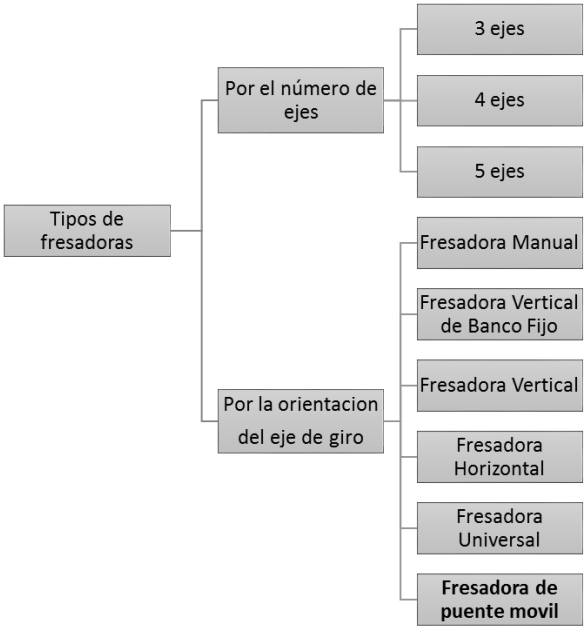


Fig. 2 Classification of milling machines

Mobile bridge milling machine are milling machines in which the table remains immobile and the movement happens in the tool, which slides along the piece to be machined, by means of a structure like that of a crane bridge.
Its main use is the machining of large parts.

It is important to know that this type of milling machine does not have much flexibility, since they usually have one or two large motors, intended to move the weight of the crane bridge [3].

CNC computer numerical control is an automation system used in machine tools. The instructions and commands to perform a work in a numerical control system are coded with alphanumeric characters, which, with the help of a processor, are interpreted to generate signals to actuator controllers which by means of mechanisms makes precise movements on a surface or space.

Advantages of CNC machines include:

- Integration of manufacturing operations to improve product quality and uniformity
- Minimize cycle times and efforts and thus reduce labor costs.
- Improve productivity, reducing manufacturing costs through better production control.
- Improve the quality of end products using more repeatable processes.
- Reduce human intervention, minimizing human error.
- Reduce damage to parts caused by improper handling.
- Increase the level of safety for personnel especially under heavy duty conditions.
- Free the worker from routine tedious and dangerous tasks.

As disadvantages of CNC machines are:

- High initial cost
- Need for knowledge of G-code programming
- Specialized maintenance
- Risk conditions

CNC Programming

Machine tools using CNC controllers are handled with an ISO standardized programming language consisting of alphanumeric symbology, although some manufacturers of controllers add their own special codes for special functions.

CAD (computer-aided design) computer-aided design are computational tools that design 2D drawings and 3D models to obtain a pre-visualization of the product.

CAM (computer-aided manufacturing) computer-aided manufacturing, are computational tools with which to simulate and / or control machine tools to produce work pieces being a post-CAD process.

III. CHAPTER II
METODOLOGY

For this work an investigation is made of the work parameters that the client requires, to obtain general information of operation and to present proposals of solution based on mechatronics engineering for its later construction.

Tabla 1. *Requerimientos del cliente*

Diseñador: Jairo Haro	Producto: CNC para desbaste de madera		Máquina	Cliente: Taller de carpintería ‘‘Arte y Madera’’
Concepto	Propone	R/D	Descripción	
Funcionalidad	C	R	Área de trabajo de 1000x900mm	
	C	R	30 mm de máxima profundidad de trabajo en pasos	
	C	R	Altura máxima de material de trabajo 50mm	
	C	R	Extractor de viruta: no	
	C	R	Material de trabajo MDF, Melamínico.	
	C	R	Energía eléctrica 110V	
	C	R	Porta-herramienta Dewalt DWE6000	
Automatización	C	R	Ingreso del material manual	
	C	R	Sujeción del material por mordazas	
	C	D	PC para el control	
Precisión	C	R	Precisión de trabajo +-2,5mm	
Costo	C	R	2000 USD	
Mantenimiento	C	D	Preventivo superficial	

Design by functional analysis.

For the application of this method of design it is necessary to identify the global function the same one that is defined by the desire of the client, in this case to realize the roughing of wood by means of a computerized system.

The subfunctions allow the realization of the global function, the relation between these are called interfaces whose nature can be mechanical, energy, transfer of material or signals.

The subfunctions are obtained by increasing the level of the global function, taking as a starting point the level zero that is composed of a primitive level and under a single function presented below [4].

The following figure demonstrates the development of modularity at level 0 of the machine.

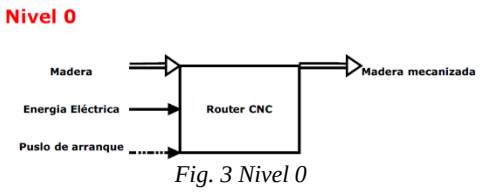


Fig. 3 Nivel 0

The modular development up to level 2 shows a sufficiently complete scheme which is shown below divided by modules:

Module 1

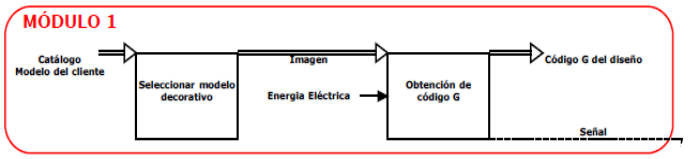


Fig. 4 Module 1

Module 2

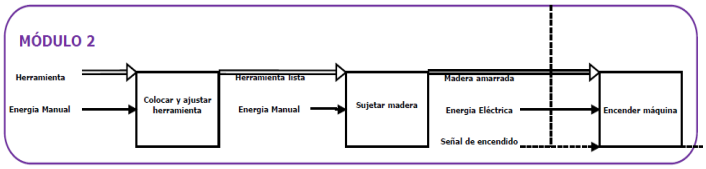


Fig. 5 Module 2

Module 3

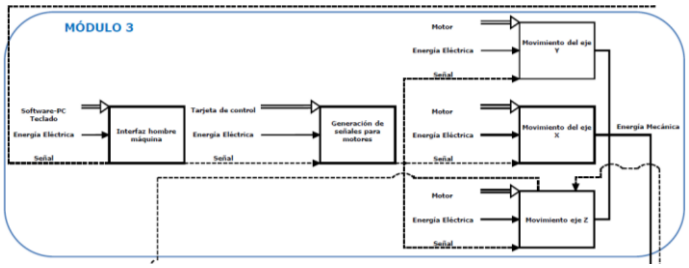


Fig. 6 Module 3

Module 4

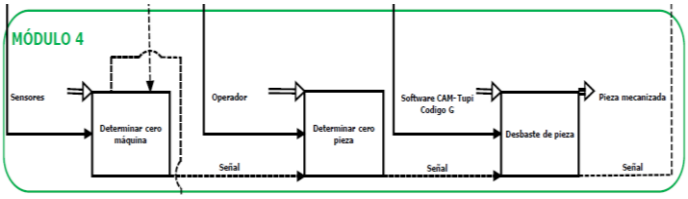


Fig. 7 Module 4

Módulo 5

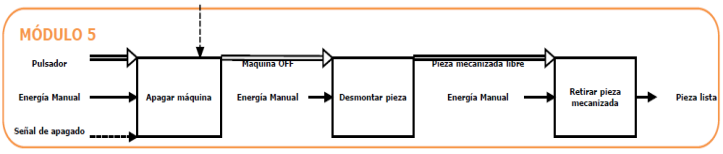


Fig. 8 Module 5

Next, it is proposed to propose possible solutions that can satisfy the needs of each module from the point of view of mechatronics engineering considering the needs of the client and using the method of weighted criteria are selected the most suitable solutions for their construction.

Alternatives and selection of module 1 solutions.

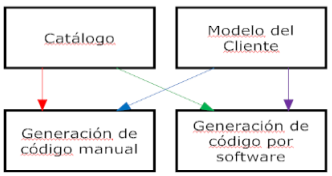
Función	Componente
Selección de modelo artístico	
Obtención de código G	

Fig. 9 Combination of solutions of module 1

For module 1 the appropriate solution obtained by weighted criteria method throws out alternatives 2 and 4.

Alternatives and selection of module 2 solutions.

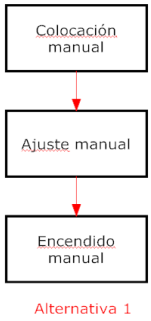
Función	Componente
Colocación de la herramienta en el porta-herramienta	
Ajuste de la herramienta	
Encendido de la máquina	

Fig. 10 Combination of solutions of module 2

For module 2, the development of the method of criteria weighted by a single solution is omitted.

In this module you can appreciate the importance and incidence of the voice of the client in the project as it reduces possible solutions to suit your needs.

Alternatives and selection of module 3 solutions.

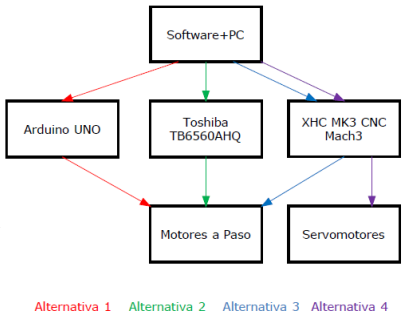
Función	Componente
Interfaz hombre máquina	
Control de movimientos	
Movimientos de la máquina	

Fig. 11 Combination of solutions of module 3

For module 3, the appropriate solution obtained by means of a weighted criterion yields alternative 1 as the most indicated.

Alternatives and selection of module 4 solutions.

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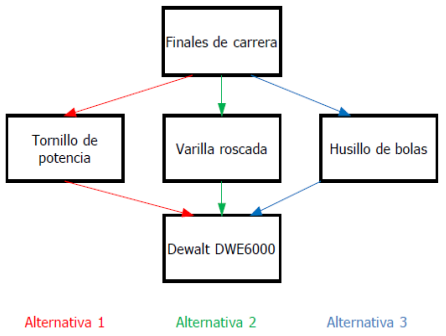
Función	Componente
Puesta a punto de la máquina	
Desbaste de madera	

Fig. 12 Combination of solutions of module 4

For module 4, the appropriate solution obtained by means of a weighted criterion yields alternative 2 as the most indicated.

Alternatives and selection of module 5 solutions.

For the removal of the machined part the machine is switched off, the machined part is untied and removed from the work table manually.

In this module, the selection method is ignored because it has only one solution.

From this analysis we obtain the operation and main parts of which the machine to be developed to be developed is presented below.

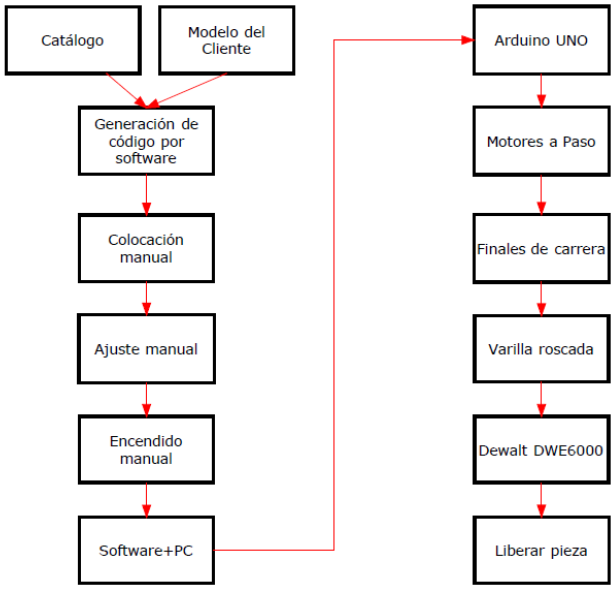


Fig. 13 Combination of final solutions

Design of the mechanical system:

With the information obtained previously, a functional-structural scheme of the machine is realized with the help of a design software which is presented in the figure below.

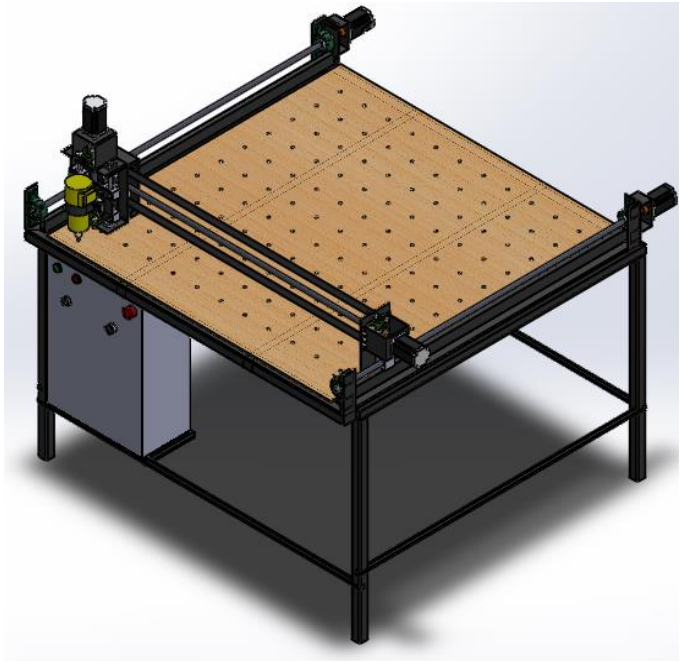


Fig. 14 General shape of the machine

The cutting force appears when the tool pierces the surface of a material and tears it, therefore, this force must be considered for the design of the machine.
For a conservative design, the cutting force will be obtained with critical machine and material conditions.

Design of the carriage on the Z axis

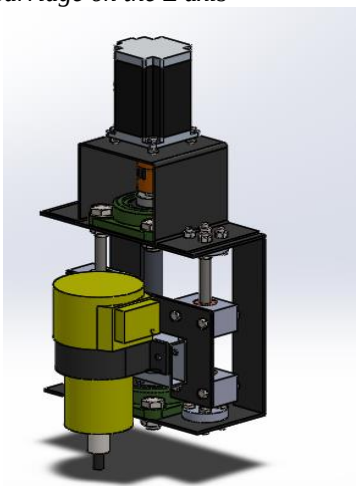


Fig. 15 Z-axis carriage

Figure 15 shows the main parts of the Z axis as:
• The tool holder (tupi).
• A clamp for the tool holder.
• An iron to support the tool holder.
• Four horns to support the iron.
• Two axes to support the horns and at the same time to guide them.
• A threaded rod and a nut for movement on the Z axis.
• Two floor bearings to support the threaded rod and allow it to rotate.
• A stepper motor and a lovejoy coupling to transmit power to the threaded rod.

For the design of the sliding axes, it is necessary to consider the loads to which they are subjected, in this case these loads are generated by the cutting force, and the weight that supports
The moment progression method calculates the reactions caused in the axes by the loads involved for the selection of material and geometry of the axes.

Design of the carriage on the Y axis

Fig. 16 Y-axis carriage

The figure shows the main parts of the Y axis as they are:

- A mobile cart consisting of bearings and angular profiles
- Two square tubes as shafts and guides for the car
- A threaded rod and nut for horizontal movement
- A stepper motor and a lovejoy coupling for power transmission
- Two floor bearings to support the threaded rod and allow it to rotate.
- Two plates to support the shafts and bearings with bearings for movement on the Y axis

Likewise, the moment progression method calculates the reactions provoked in the axes by the loads involved for the selection of the material and geometry of the axes.

Design of the carriage on the X axis

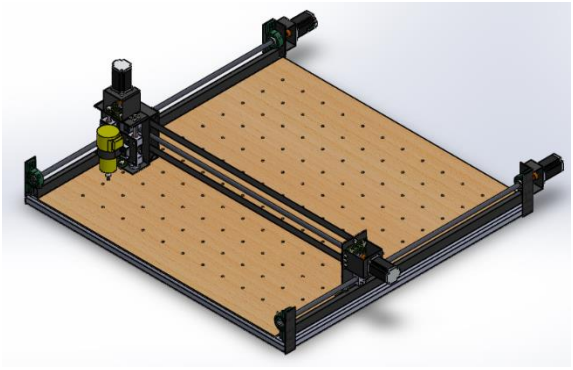


Fig. 17 X-axis carriage

The figure shows the main parts of the X axis as they are:

- Two square profile tubes as shafts and guides for the car
- Two threaded rods and two nuts for horizontal movement
- Two stepper motors with lovejoy couplings for power transmission
- Four wall bearings to support the threaded rods and allow their rotation.
- A structural frame where the pieces and wooden table are seated.

Likewise, by means of the moment progression method the reactions provoked in the axes by the loads involved for the selection of the material and geometry of the axes are calculated

Design of the electronic system:

It consists of automation devices and power required to perform the CNC code reading, make precise and ordered movements in the three axes and for the control of the tool for thinning the wood.

To make the electronic system, the controller card, in this case the Arduino card, is loaded with the GRBL firmware version 0.9j.

Electric scheme

In the following figure, a general single-line diagram of the electrical system connections of the machine is shown.

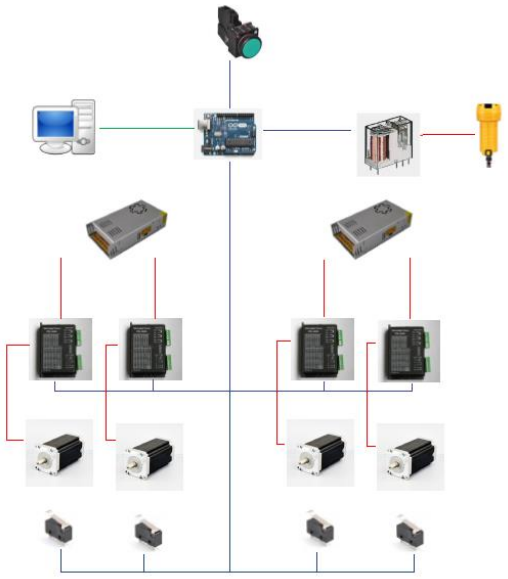


Fig. 18 Single-line diagram of the electrical system

Auxiliary cards.
There are three auxiliary boards necessary for the operation of the CNC machine which are:

Auxiliary board for X-axis limits (TA1).

The GRBL 0.9j firmware loaded in the Arduino offers the ability to detect a limit sensor for each axis, X, Y, Z.
Since the proposed procedure has two motors in the X-axis, a system for detecting end-of-stroke sensors of the movements of these two motors is required in a unique way, and integrates them with the Home function (machine zero detection).
firmware GRBL, important for this type of machines, for which use is made of operational gates that obey a previously analyzed logic.

Auxiliary card for fan (TA2)

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Inside the electrical cabinet are located the drivers for the four motors at a time, so it is generated inside it, an increase in temperature, for which an artificial ventilation system based on a fan is proposed which dissipates the heat generated by the drivers and other electronic components inside the cabinet. For the activation of this, a card is proposed that allows the regulation of the activation and deactivation of the fan using potentiometers and a timer 555 for the regulation of the time, the regulation of the activation and deactivation time is done by means of experimentation as required by the machine and within normal temperature parameters.

Auxiliary card for tupi activation (TA3).

The rotary tool (tupi) works with 110VAC, so it is necessary a power stage that allows its activation with the signal of 5VDC delivered by the pin 11 of the Arduino, since there is a relay of 120V with the ability to switch the tupi, an auxiliary card is made that allows to conjugate the signal of the Arduino with this relay
For the activation of the relay coil, a triac and an optotriac are used.

Electrical cabinet parts.

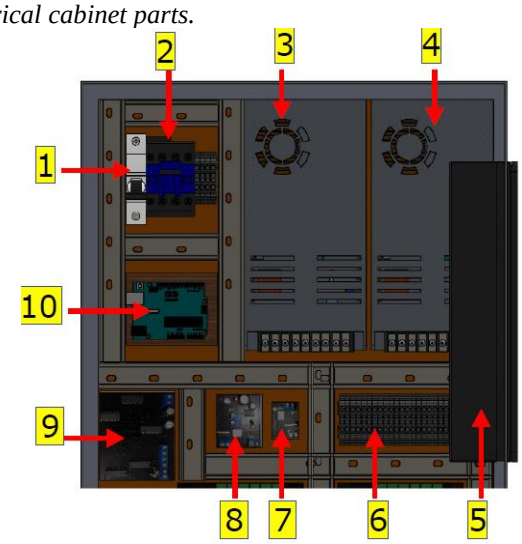

Fig. 19 Top of the electrical cabinet.

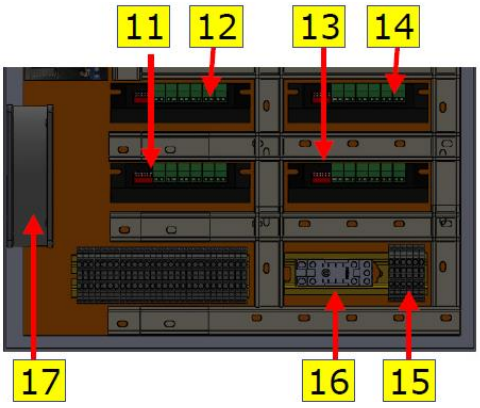

Fig. 20 Bottom of electrical cabinet

Tabla 2. *Partes del gabinete eléctrico.*

Número	Dispositivo
1	Breaker de alimentación
2	Contactor
3-4	Fuente de poder conmutada
5	Filtro de aire
6-15	Borneras
7	TA3
8	TA2
9	TA1
10	Arduino
11-12-13-14	Drivers motores a paso
16	Relé para tupi
17	Ventilador

IV. CHAPTER III
FUNCIONALITY TEST

To check the correct operation of the machine it is necessary to make an engraving that contains varied forms.
For this, the G code generation of the drawing is performed in the first instance.

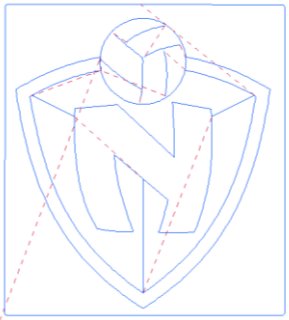

Fig. 21 Visualization of G code generated by Inkscape

Subsequently, an agglomerated wooden board is placed and the machining is carried out.

Fig. 22 Machining of the test figure

At the end of the machining process, the workpiece is removed and a short finishing process is carried out using a fine sandpaper.

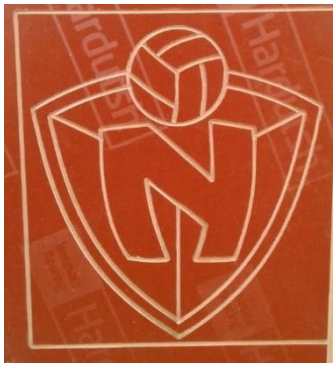

Fig. 23 Finished test piece

At the end of the process, a satisfactory aesthetic engraving is obtained before the eyes of the client.

V. CHAPTER IV

CONCLUSIONS AND RECOMMENDATION

Conclusions:

- A CNC milling machine for wood trimming was designed and built for the "Art and Wood" carpentry workshop with a working volume of 100 x 90 x 6 cm.
- The customer's voice shown in Table 1 was decisive for the performance of the work, as it provided important guidelines for the design and construction of the machine, which was used to determine materials and elements suitable for the construction of the machine. machine.
- The mechanical design of the machine was adjusted to the needs and the cost of its construction is within the established budget.
- The most critical parts of the machine control system such as the Arduino card and the stepper motors provided a satisfactory performance for the needs presented by the customer.
- Inkscape software, Universal Gcode Sender, and GRBL 9.0j firmware, meet the needs both when designing artistic figures and when machining them.
- The operation tests verified the proper functioning of the machine as they were satisfactory and pleasing to the customer.
- The operation and maintenance manual was carried out for the joint delivery of the machine to the owner of the "Arte y Madera" carpentry workshop.

Recommendations:

- Design the mechanical and electrical system in as much detail as possible to avoid unnecessary expenses and design alterations.
- For the construction of machines of CNC type of medium and long dimensions it is recommended to consider the rack-and-pinion system with which a greater speed of advance is obtained.
- Make an empirical table that relates speed of advance and materials with the help of the experience of the master carpentry and paste it in a visible place in the working position of the operator.
- Correct use of the operating and maintenance manual of the machine will allow the safety of the operator and the machine.
- Research and development of linear motion systems with closed loop control in the mechatronics engineering career is recommended.
- Research and development of an interface for controllers based on the GRBL platform is recommended to omit the presence of a computer in the work environment.

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Autor.
JAIRO MAURICIO HARO YÉPEZ

Born in the city of Atuntaqui -Imbabura - Ecuador, on June 03, 1993.
University studies carried out at the Universidad Técnica del Norte. Mechatronics Engineering Degree.