

CONSTRUCTION OF A PRINTING MACHINE PRINTED CIRCUIT LABORATORY AUTOMATION INDUSTRIAL RACE MECHATRONICS ENGINEERING.

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Abstract - This paper grade is aimed at building a CNC machine that can print directly onto (copper plate) Bakelite electrical and electronic circuits Basic, for which tool is used as a dispenser of indelible ink. The process of its basic functions can be performed manually using the buttons on the control panel and from a computer automated process through the parallel communication porch. After printing, the printed board should be subjected to a chemical process known as "acid attack", which eliminated all copper not protected by the ink, leaving only the tracks on the circuit designed .Its biggest advantage is saving a file from PC after a process that performs vectorization (mapping matrix) to convert any format you have, to a final format for position indicating movement in the X, Y and Z, allowing repeat print it as often as desired from its final form.

The printing machine has two engines built to facilitate movement far and wide on the horizontal plane and one that raises or lowers the permanent marker. The system consists of a basic control panel features an LCD screen that displays basic machine printer options, limit switch sensors that helps define the work area, parallel communication porch. For automatic control a CNC program is KCAM4 is used, and for the design of tracks and routing, any electronic program that allows the design of printed circuits. For the project has been used PROTEL for routing and testing. Control has programmed in the microcontroller PIC16F628A PICBASIC Pro, allowing the same driving motors, sensors and other electronic elements having.

It then proceeds to execute and analyze the functioning of systems and operational tests in manual mode, automatic mode and machine maintenance printer basic electrical and electronic circuits.

I. INTRODUCTION

The construction of the printing of printed circuits, is an alternative and support for practices carried out in the laboratory for industrial automation Mechatronics Engineering, since the latter years technology for the manufacture of printed circuits and design tools have made great strides so that there are very complex electronic circuits, that a human could not do it with ease.

This printing machine is divided into two systems, electronic and mechanical.

The first consists of a PC, software and control devices, which designs electronic circuits is carried out by placing the components and the corresponding connections. Then send a

communication to parallel interface a set of orders that follow a logical sequence which is a CNC machining program, giving orders or instructions to the machine to print on the copper plate (Bakelite) electronic circuit.

II. DESCRIPTION

The system will be written according to the following components:

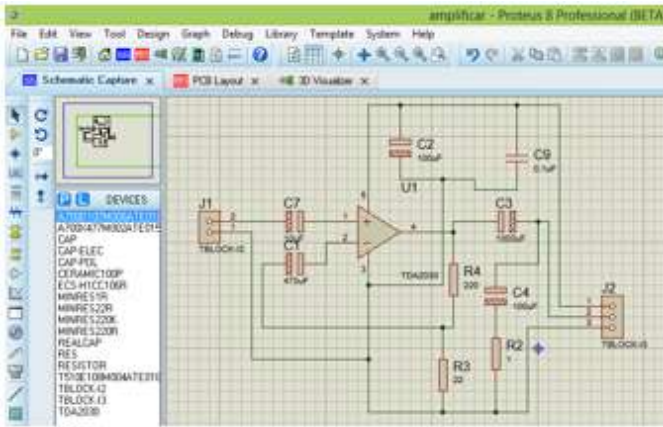
- **Software:** Contains the PCB design, generate and read files described, user interface, communication and visualization of coordinates and other data needed controller via the parallel portico of the Pc.

- **Hardware:** Made up of electronic devices, which is responsible for taking data from the PC and generate control signals for the two positioning axes and for the electromagnet of permanent marker.

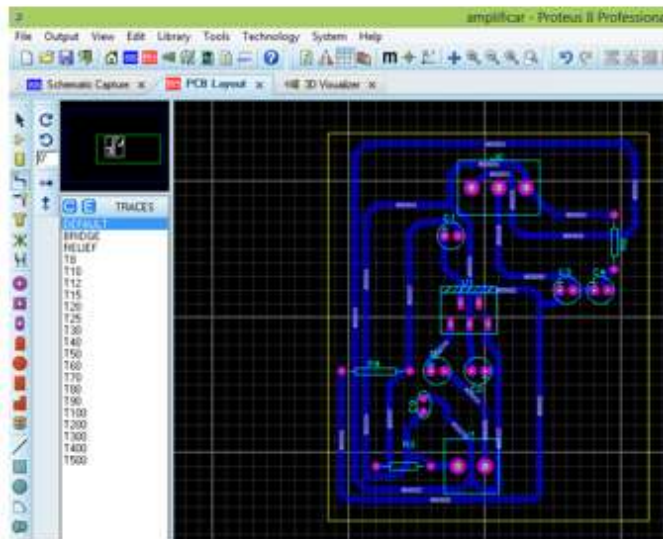
- **mechanical structure:** It is the body of the machine, which consists of two augers positioning with suitable actuators and sensors; as with an electromagnet DC plotting circuit for

II – A. Software

II - A1. PCB design and creation of DXF files: the realization of printed circuits often requires automatic design programs elcetronico to distribute and interconnecting each of the components. Which convert the schematic in a list of nodes and pin circuit, where to is will process the desired ISIS circuitio (Fig. 1a) of the Proteus program is assembled and finally the connected circuit is passed ARES (Fig. 1b) where a track circuit design is created and saved as a set of instructions and data in HPGL, DXF or PDF format. For this application a DXF file is generated.



(a)



(b)

Fig. 1: ISIS circuit diagram (a) and Circuit Design ARES (b)

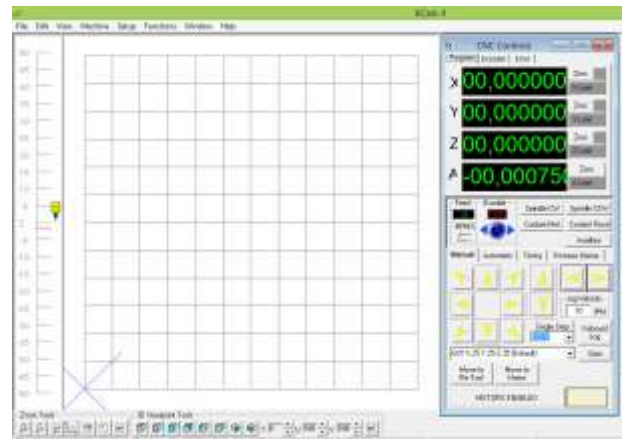
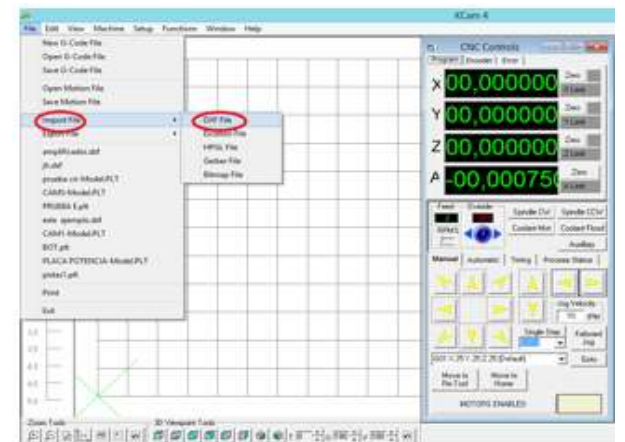
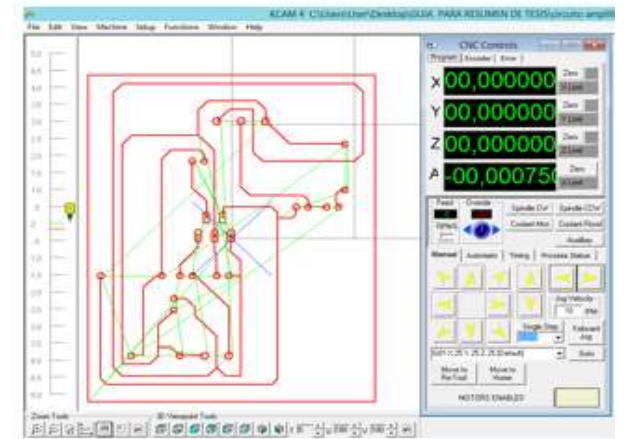


Fig. 1: Platform KCAM4.



(a)



(b)

Fig. 3: Import DXF file (a) and generated file (b).

II - A2. User Interface and read DXF files: The software I can use is the KCAM4 (Fig. 2) that opens DXF (Fig. 3a) files, interpreting the characteristics of the PCB and to realize the reading of the instructions provided, the mapping matrix, the unit of measurement millimeter inch format of the coordinates, the type of movement; ie move plotting, desplazrse without plotting, do jumps and score a point. this information is processed to load the DXF file generated in the software KCAM4 (Fig. 3b).

The process starts with plotting a command located in CNC Controls, where the condition of zero that is generated moves and places the Z axis (permanent marker) at the coordinate (0, 0.0). Once waxed platform a enter occurs in the automatic mode button located on the same screen KCAM4, obiamente the machine must be turned on, then the KCAM4 program sends pulses of each of the coordinates of the axes to

the control circuit and which verifies the respective movements using parallel communication portico.

II-B. Hardware

II - B1. Controller: The controller is constituted by three microcontrollers PIC16F628A, the same taking the coordenadas signals of each of the axes from the program from the PC (fig. 4), which generate respective sequences for activation and movement of electroiman step motors, sensors accompanied quines limit switch limit the workplace, this by portico parallel communication.

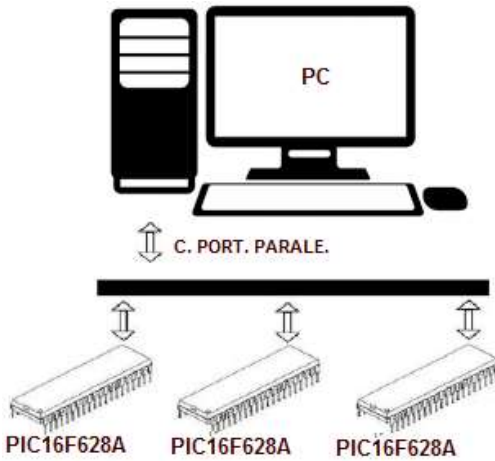


Fig. 4: Communication scheme.

Communication Portico Paralel: Due to the easy operation of the port and for being one of the most applied in the automation industry it was decided to choose for interconecion microcontrollers and PC parallel prtortico, which can carry out their work in two modes different: 1.5 Mbps (low speed) and the other of 12 Mbps (high speed) using the latter for the development of this project, each motor controller must have input CLK connected to a pin on the parallel port. This turns the stepping motor when the pulse ends.

También se requiere una entrada de dirección para indicarle al controlador en qué dirección debe mover al motor. La entrada de habilitación se usa para indicarle al controlador de aplicar o no corriente al motor, la función de habilitación es opcional.

If you have a controller that has an enable input and is is enabled when the motor stop, they go out and protecting them from overheating.

The parallel control through gate, bit by bit lets you designate which pins are CLK control. Address and empowerment, for each motor.

Programming the Microcontroller: The microcontroller firmware development Microcodestudio 16F628A is the basic language with Pic Basic Pro compiler, which contains libraries necessary for communication Portico Paralel, which allows full control of the program, being totally easy programming and transparent to the programmer and admas is much easier

to write and read the language Microchip assembler and others.

II - B2. Power Amplifier:

Stepper motors: This was controlled from the software KCAM4 through 16F628A Pics and in order not to have any problem, damage microcontrollers used optocouplers 4N33 connected at each of its outputs. To connect the motors to the ULN2003 integrated step was used to amfpilficar the coerriente and MOSFET transistors IRFZ44 which served as protection drives and direct management of engines step (Fig. 5).

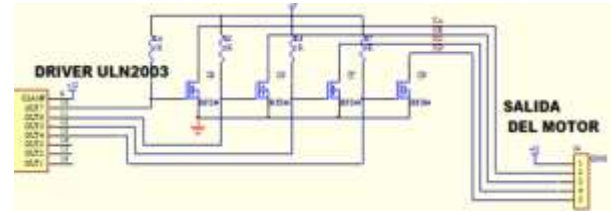


Fig. 5: Connection step motors with the power stage.

II - B3. sensors:

If the limit of work stand these would be operated and would send a pulse to the pics Y - end stroke sensors are located to ensure the working limit within which A4 will move the main carriage and is in the X axis and the machine will automatically alarm and stop would sound as a warning signal to restart the printing machine (Fig. 6).



Fig. 6: Year sensors.

II - C. mechanical device: the mechanical structure of the machine is formed by two augers which are constructed by helical teeth, 2 guides which give cylindrical axis rotational motion, which allow a linear movement which causes movement dezplasmiento motor rotation, these cilindicos axes are also low friction that gives more stability to the movement of the printing machine, in Figure 7, you can see each of the axes implemented in the machine. The rotational axis is formed by simply passing delivering engines to pricipal carriage movement for drawing.

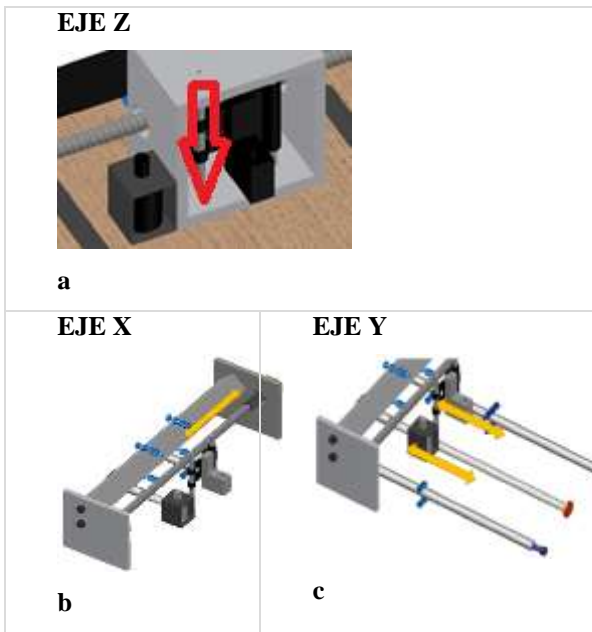


Fig. 7: Set design and worm shafts.

The X and Y axis has an independent movement, offering precision and stability in the main carriage. The helical screws X, Y have a pitch of 1.75 mm and 12 mm in diameter, as engines with a rotational advance of 1.8 degrees per step, with a working speed of 10pulg / min.

The routing tool is a permanent marker readily available and very inexpensive. This presents an optimal performance on the copper trace.

The ubicacion axis corresponds to the architecture of a Cartesian machine (fig. 8) diseñada in AutoCAD 2010.

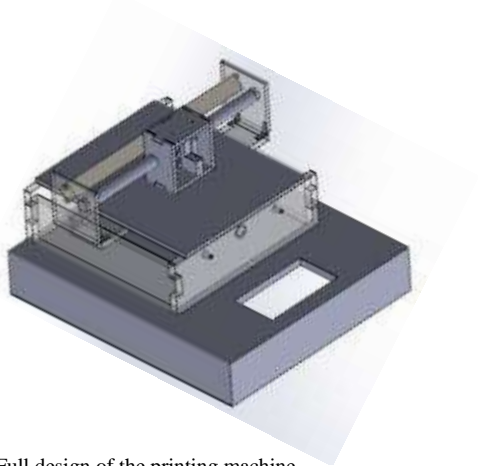


Fig. 8: Full design of the printing machine.

Where the selection of material has the following parameters:

The weight that support the worm is 6,67N (Main carriage) and 3,92N (weight of the screw) According to the physical

condition of screw is selected design endless L = 450 mm and 12 mm in diameter.

Where is the force diagram (Fig. 8).

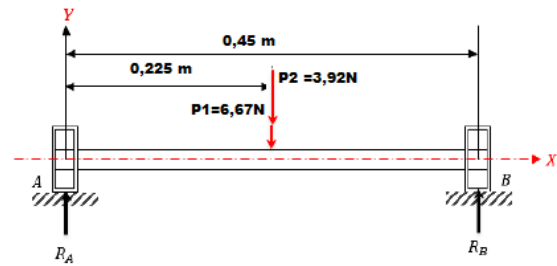


Fig. 8: Free body diagram of the worm.

Where their forces:

$$F_1 = 5,29\text{N}$$

$$F_2 = 5,2932\text{N}$$

Maximum time the worm:

$$M_{max} = 0,871\text{N.m}$$

With the help of the software (MDSolids 4.0) verification is performed forces: shear and bending moment, and likewise proceed to plot their charts, observing (fig. 9).

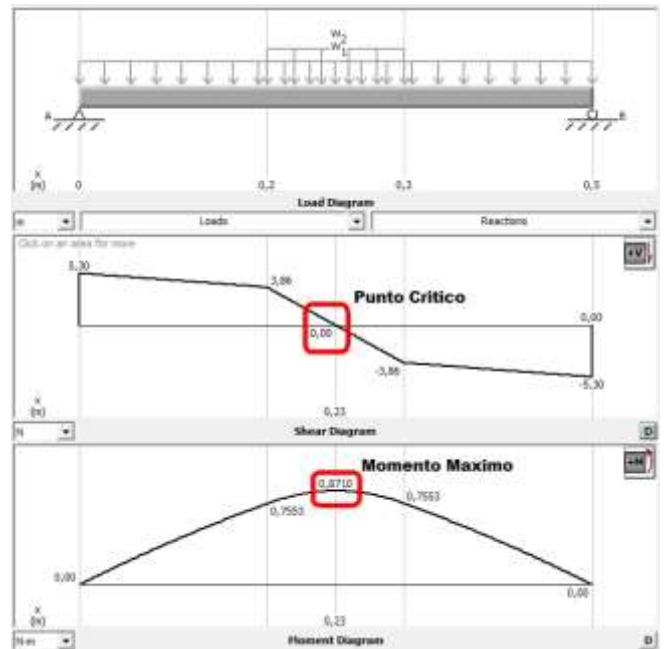


Fig. 9 : Load, shear and bending moment Shear Force Diagram and Bending moment in worm.

Below is the work effort:

$$\sigma_t : \frac{M_{max}}{S}$$

$$\sigma_t : 640KPa$$

Comparing and considering it for a good design work effort or design does not exceed the allowable stress, the maximum value that can be applied to the material.

$$\sigma_t \leq \sigma_{adm}$$

$$640KPa \leq 125 MPa$$

Then the maximum deflection of the shaft caculo:

$$y_{max} = - \frac{Fx L_x^3}{192EI_x}$$

$$y_{max} = - 1,30 \times 10^{-4} m$$

$$y_{max} = - 0,130mm$$

Knowing that the upward deflection is positive (+) and down negative (-), in this case the deflection is down because the weight of the main car is down.

This deflection is found acceptable for the required design of the axes and their functions, the check is made with the software is obtained SolidWords 0.1370 mm (fig.10) the shaft flexes as the calculated value.

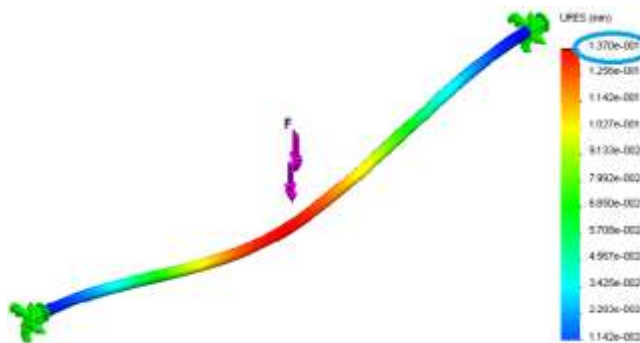


Fig 10 : Deformation analysis axis X, Y.

Tabla I : Shaft deformation.

LONGITUD DEL EJE (mm)	DIAMETRO (mm)	FUERZA EJERCIDA (N.m)	DEFORMACION MAX. (mm)
450	12	10,59	1,370e-001

III. RESULTS

Initially tests were performed on each coordinate of the printing machine to observe: the operating speed of each axis respectively.

On the horizontal axis drawbacks when gauging the speed of movement in the KCAM4 software were presented,

in addition there was a misalignment in the X axis in terms of precision of movement, for which we proceeded to perform the necessary tests detailed in the follows (Table II).

Tabla II

ELEMENTO	PROBLEMA	SOLUCION	PRUEBAS
Kcam4	Velocidad de rotación del tornillo sin fin.	Calibrar la velocidad de rotación del motor X en la pantalla CNC Controls.	7
Movimiento del eje X	Desalineación	Lubricación de los rodamientos	5
		Ajuste de montaje	6 7
		Ajuste de los pernos de sujeción	8
Carro principal	No grafica	Alinear el carro	5
Total			38

The solution of these problems were made after performing 38 tests.

In the Y axis displacement drawbacks with engine speed the same rotating faster than the X axis is presented in addition there was a misalignment in moving and finally the shaft was clogged and not to fulfill its function, thus to solve these problems began to perform the following steps outlined in the following (Table III).

Tabla III

ELEMENTO	PROBLEMA	SOLUCION	PRUEBAS
Kcam4	Velocidad de rotación del tornillo sin fin.	Calibrar la velocidad de rotación del motor Y en la pantalla CNC Controls.	8
Movimiento del eje Y	Desalineación	Lubricación de los rodamientos	6
		Ajuste de montaje	7
		Ajuste las tuercas de sujeción	8
		Ajuste del tornillo guía del eje Y.	9
Total			38

The solution of these problems are solved after performing 38 tests. In the direction Z drawbacks with the electromagnet which got very hot, like power cables to it, as well as material Grilon which will subject the permanent marker were

presented, it does not slip correctly, for which we proceeded to perform the necessary tests shown in the following (Table IV).

Tabla IV

ELEMENTO	PROBLEMA	SOLUCION	PRUEBAS
Pieza de Grilon	Deslizamiento no adecuado	Calibrar utilizando un resorte.	8
		Lubricación de los ejes.	3
		Ajuste de montaje	4
Electroimán	Calentamiento más de lo debido.	Electroimán 38 v	3
Cable de conducción	Se calienta	Cable #18 a 2,66 A	2
Total			20

The solution to these drawbacks of the hello after performing 20 tests, after which we can say that it works correctly.

Immediately after arming their working speed components in the software KCAM4 (Table V) was calibrated.

Tabla V

	PRUEBA 1	PRUEBA 2	PRUEBA 3	PRUEBA 4
VELOCIDAD DE TRABAJO DEL TORNILLO SIN FIN X - Y DESDE KCAM4 (Pulg/min)	7	8	10	12
PRECISION DE POSICIONAMIENTO	0,6pulg/10pulg	0,7pulg/10pulg	0,985pulg/10pulg	0,8pulg/10pulg
EXACTITUD DE DISEÑO (%)	60	70	98,5	80

In the (fig.11) you can see the result with the calibration of working speed of each of the axes

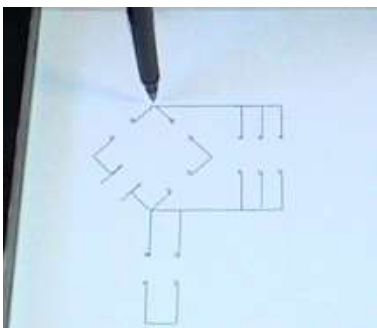


Fig. 11: Test Circuit Design.

Based on tests (Table V) came to readjust the parameters in the software KCAM4, setting the working speed to 10pulg / min of the worm. With which it has a process of plotting the

circuit with an accuracy of 98.5%, as shown in (fig.11) an example of a PCB prepared by the printing machine.

The dimensions of the structure are 510 x 520 mm with a working area A4 and the Z axis desplazamiento 5mm.

After several tests it carries out a readjustment of parámetros software, as well as the card control. The process can be seen plotted in (fig.12), which takes a time of about 16 min to develop a amplifier circuitio 10w DXF file. In the (fig.12) a diagram of a PCB prepared by the printing machine is shown.



Fig. 12: Circuit Graphing Process A.

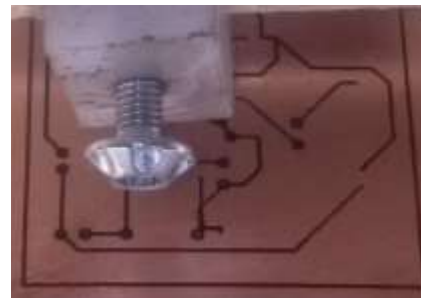


Fig. 13: Result Circuit Design Process.

In order to compare the results, and differentiate elaboracion time a PCB iso the same circuit using the manual manufacturing method, which present some desperfectos in design as you can (fig.14), this is due to print made with the iron.

Obtaining and comparing the results presented by the printing machine it can be said that this makes a PCB with no damage as is the discontinuity of tracks, union between them which almost always presents a PCB made by hand (fig.14), plus the processing time, from importing the KCAM4 design program, a third of the time spent on the manual process was reduced by approximately.



Fig. 14: Printed results manually.

IV. CONCLUSIONS

The main objective raised in this thesis project was to build a printing press that prints on bakelite (copper plate) was successfully achieved

electrical and electronic circuits Basic, in order to be consistent with technological advances that industry CNC computerized numerical control brings.

The control of the printing machine is based on 2 main cards; card processing and motor control card; it made this modular way to separate the stage of processing power and avoid consequent interference.

The best option in a variety of software was KCAM4 open for easy configuration, management, control and ability to generate DXF and HPGL files code.

The mechanical system design using AutoCAD did, MDSolids and Solidworks, achieving perform static stress analysis, fault detection for respective correction and thus fulfilled the needs and study parameters.

It is important to consider the required power circuit when selecting electronic elements necessary for its current and power required to control stepper motors.

According to performance tests conducted with the printing machine it was established that the speed of work generated by the settings in the KCAM4 software for stepper motors is 10 in / min for the main carriage where is located the permanent marker does not cause faults in the design of the track; the increase causes the electronic tracks intersect and lose continuity by reducing the process becomes very slow.

According to performance tests conducted on the printing machine it is determined that it is necessary to place a spring in the Z axis along the marker so this will have winged in the design of electronic track.

According to performance tests conducted it was determined that the printing machine (automatic) printed circuit has a 98.5% accuracy, 100% accuracy and time to design electronic tracks was reduced by 39% compared the manual process.

The proper use of the manual operator is helpful for the smooth operation of the printing machine.

It was possible to control the process of track electronics design, for parallel transmission medium called gantry.

V. RECOMMENDATIONS

To encourage graduates next Mechatronics Engineering, continuing research on computer numerical control in order that the knowledge of this prototype to extend and start the practice.

To achieve more accurate machining of acrylic is recommended laser cutting machines and thus achieve proper finishing of the structure and base of the printer machine.

It is recommended that no more than 1.8 degree motor rotation angle for precise routing tool (permanent marker) and in case you want to manipulate other tool having an excessive weight is recommended to use higher engine torque step.

In the part of electronic design, it is recommended to take into account protection to prevent damage and short circuits.

Operate the printing press provided the axes are properly lubricated and its mode of operation is known, or have read the operating instructions found in this document.

Before operating the printing machine is recommended to place the tool work properly (permanent marker) as if too attached to the board this can create a resistance movement and force the stepper motors or turn if is separated from the plane would not make too much electronic diagram of Bakelite, thus causing blanks that affect the design of basic electronic circuits.

To make designs in manual mode, it is recommended to use the option of moving step by step to very small strokes, since the displacement run option does not allow exact stops, taking into account that this option allows single stroke of geometric figures.

We recommend selecting the proper way to print labels, as these have to be indelible ink to prevent any failure on the print quality of the electronic track.

For a recommended management of the printing machine it is recommended before starting operation check the user manual.

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