Mechanisms of a 3-axis CNC machine design and experiment

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ABSTRACTS

CNC technology has become a requirement in the industrial world without complying with educational, pedagogical and private ratings. Manufacturers of this type of machine are trying to conform with the marketing requirements in terms of quality, price and quantity, so the CNC machine can meet the requirements and has acquired a leading position. The study and design of the three-axis CNC machine are based on the Fusion 360 software for the design and PROTEUS software for simulation to perfect our device.

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1. INTRODUCTION

The design of devices at the level of research laboratories continues to progress. Each time, prototypes from different disciplines have been continuously designed and developed (Golnabi & Asadpour, 2007; Li, et al., 2019; Khechekhouche, et al., 2019). CNC (Computer Numerical Control) machines have not been shielded from this development; these machines can automatically perform many tasks in various fields of activity: engraving and drilling of printed circuits, the production of small mechanical parts, the tracing and cutting of the various components of the scale models, and much more (Ye, et al., 2018). A growing number of model builders, electronics engineers and other enthusiasts are using digitally controlled machine tools. These small machines, most often milling machines, provide an almost professional quality result. But these machines are often very expensive to purchase, so many people design and build them themselves. Most CNC machines have three axes, but there are models with four or even five axes. Three-axis models are often sufficient in the majority of applications. Today, computer numerical control (CNC) machines, allow great flexibility in industrial production, during recent years, the control of electrical machines, has undergone significant progress, thanks to the technological revolution in electronics and computer science (Keefe & Jeffrey, 1991). A group of researchers used a servo system consisting of a monitor, a multi-axis motion control board, a servo motor, a servo motor and the load was installed. After connecting the various components, the machine edited the command interface software calling the interpolation process, which could realize the simulation control and real-time control of the servo motors. The comparative results indicate that the process simulation of the experiment is higher (Shafieifar, et al., 2017). In this paper, a simulation with the PROTEUS software, a realization with the fusion 360 software, a kinetic study and finally a study of the mechanisms of the X, Y and Z axes of the machine will be made in order to improve the competence of the numerically controlled machine.

2. MATERIALS AND METHODS

2.1. System overview

Three Axis CNC Machine (MOCN) as shown in Figure 1 is a high precision machine designed to engrave a variety of metallic and non-metallic materials. It is a machine driven by stepper motors. These allow the direct conversion of a digital electrical signal into an angular positioning of an incremental character.

![Figure 1. Three-axis CNC machine](image)

2.2. Operating principle of a MOCN

The machine tool is equipped with a numerical control capable of carrying out the calculations of the coordinates of the points defining a path (interpolation), it is said to be
with a computer. It is called CNC (Computer Numerical Control). Most of the MOCNs are CNCs. The numerically controlled machine tool forms an assembly comprising: an operating part and an operating part, as shown in Figure 2.

![Figure 2. Architecture of MOCN](image)

2.3. Characteristic of three axis CNC machine

The kinetic, dynamic, physical and electrical properties of each axis of the CNC machine are gathered in Table 1, while Figure 3 shows the kinematic diagram of the x, y and z axes.

| AXES | KINETICS PROPERTIES | DYNAMIC PROPERTIES | PHYSICAL PROPERTIES | ELECTRICAL PROPERTIES |
|------|---------------------|--------------------|---------------------|-----------------------|
|      | Displacement:       | Torque = 0.1166Nm  | Length = 15 (cm)    | Stepper motor quantity |
|      | Length (cm) = 40    | Strength:          | Width = 8 (cm)      | = 1                   |
|      | max steps = 400     | tangential = 43.59N| Height = 19.5 (cm)  | Nominal voltage = 24V |
|      | max Step = 19200    | Axial load = 51.5N | Weight = 1.2 (kg)   | Nominal current = 1 A |
| X    | Speed:              | Torque = 0.1166Nm  | Power (useful) = 1.072 W |                        |
|      | rotational speed = 1249.98 rpm | Strength:          |                     | Stepper motor quantity |
|      | linear speed = 20.833mm / s | tangential = 43.59N |                     | = 2                   |
|      | Displacement:       | Axial load = 51.5N |                     | Nominal voltage = 24V |
|      | Length (cm) = 46    | friction = 0.06 N  |                     | Nominal current = 1 A |
|      | max steps = 460     | Max axial load = 51.44N |                     | Power = 30.52 W |
|      | max Step = 22080    | Power (useful) = 2.14 W |                     |                       |
| Y    | Speed:              | Torque = 0.1166Nm  | Length = 18 (cm)    | Stepper motor quantity |
|      | rotational speed = 1249.98 rpm | Strength:          | Width = 8 (cm)      | = 1                   |
|      | linear speed = 20.833mm / s | tangential = 43.59N | Height = 12 (cm)    | Nominal voltage = 24V |
|      | Displacement:       | Axial load = 51.5N | Weight = 0.8 (kg)   | Nominal current = 1 A |
|      | Length (cm) = 4     | gravity = 7.85 N   | Power = 15.26 W     | Power = 15.26 W       |
|      | max steps = 40      | Max axial load = 51.44N |                       |                       |
|      | max Step = 19200    | Power (useful) = 0.909 W |                       |                       |
| Z    | Speed:              | Torque = 0.1166Nm  |                     |                       |
|      | rotational speed = 1249.98 rpm | Strength:          |                     |                       |
|      | linear speed = 20.833mm / s | tangential = 43.59N |                     |                       |
|      | Displacement:       | Axial load = 51.5N |                     |                       |
|      | Length (cm) = 4     | gravity = 7.85 N   |                     |                       |
|      | max steps = 40      | Max axial load = 51.44N |                     |                       |
|      | max Step = 19200    | Power (useful) = 0.909 W |                     |                       |
2.4. Design and mechanisms of the X, Y and Z axes

The CNC machine is designed in two parts, an electrical part and a mechanical part. The elements in the assembly gives this machine, are shown in Figure 4. All the elements of the machine are designed beforehand by the Corel DRAW software than they are really manufactured on the basis of this software. Corel DRAW software is a graphics suite developed by software publisher Corel since 1989. Originally, it was Corel DRAW vector drawing software. Over time, other software such as Corel Photo Paint and Corel R.A.V.E were added and the software became a graphics suite.

3. RESULTS AND DISCUSSION

Figure 5 shows the tool used in the experiment. It is a metal punch with a diameter of three mm which we modified to carve on different types of wood. In the experiment, engravings were carried out on different wood panels, and we obtained the following results.
Several calculations have been made on the mechanism of the three axes X, Y, and Z such as the number of steps, angular speed, motor entry and exit power and many others. All the results obtained are presented in Table 2. Based on cutting parameters of each type of wood, practical and concrete results are obtained and summarized in Table 3. We notice that the other numerically controlled machine to perform several cutting shapes on the wood which shows our device is effective.

![Figure 5. Features of the cutting tool](image)

### Table 2. Mechanisms of the X, Y and Z axes

|       | N pas (step) | S\(_\text{max}\) (rad/s) | V (mm/s) | F\(_t\) (N) | F\(_a\) (N) | F\(_f\) (N) | F\(_x\) (N) | P\(_m\) (W) | P\(_u\) (W) | \(\eta\) (%) |
|-------|--------------|--------------------------|----------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|
| Axe X | 400          | 19200                    | 130.89   | 20.833      | 43.59       | 51.5        | 0.06        | 51.44       | 15.26       | 1.072        | 7            |
| Axe Y | 640          | 22080                    | 130.89   | 20.833      | 87.18       | 103.02      | 0.264       | 102.76      | 30.52       | 2.14         | 7            |
| Axe Z | 40           | 1920                     | 130.89   | 20.833      | 43.59       | 51.5        | 7.85        | 43.65       | 15.26       | 0.909        | 6            |

### Table 3. Paramètres de coupe en fonction du type de bois

| Wood       | Cutting parameters                                                                 | The result of the engraving |
|------------|------------------------------------------------------------------------------------|------------------------------|
| MDF        | Rotation frequency \(n = 6500\) rpm, Advance speed \(F = 0.15\) mm / s, Cutting speed \(V_c = 30.6\) m / min, Depth of cut \(a = 0.2\) mm | ![MDF result]                |
| Red Wood   | Rotation frequency \(n = 6500\) rpm, Advance speed \(F = 0.2\) mm / s, Cutting speed \(V_c = 30.6\) m / min, Depth of cut \(a = 0.2\) mm | ![Red Wood result]           |

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| Wood          | Cutting parameters | The result of the engraving |
|--------------|--------------------|-----------------------------|
| Multilayer wood | Rotation frequency 6500 rpm |  |
|               | Advance speed 0.4 mm/s |  |
|               | Cutting speed 30.6 m/min |  |
|               | Depth of cut 0.3 mm   |  |
| Beech wood    | Rotation frequency 6500 rpm |  |
|               | Advance speed 0.1 mm/s |  |
|               | Cutting speed 30.6 m/min |  |
|               | Depth of cut 0.15 mm  |  |

4. CONCLUSION

Our study focused on a 3-axis CNC machine. This expensive device was designed and programmed with two available software and aluminium and iron building materials. After the construction of the machine, the results show that the device perfectly executes the commands entered in the PC. Different geometric shapes were engraved on pieces the different woods with very acceptable precision. With strong structure and powerful motors, this machine can process in future aluminium metal surfaces.

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