



## 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.

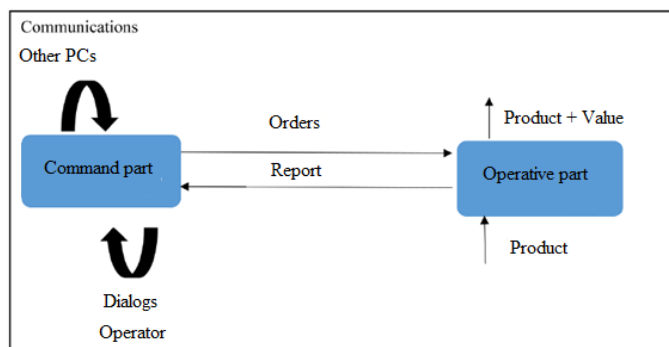


**Figure 1.** Three-axis CNC machine

### 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

### 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.

**Table 1.** Characteristic of 3 axis CNC machine

AXES	KINETICS PROPERTIES	DYNAMIC PROPERTIES	PHYSICAL PROPERTIES	ELECTRICAL PROPERTIES
<b>X</b>	<b>Displacement:</b> Length (cm) = 40 max steps = 400 max Step = 19200 <b>Speed :</b> rotational speed = 1249.98 rpm linear speed = 20.833mm / s	Torque = 0.1166Nm <b>Strength :</b> tangential = 43.59N Axial load = 51.5N friction = 0.06 N Max axial load = 51.44N Power (useful) = 1.072 W	Length = 15 (cm) Width = 8 (cm) Height = 19.5 (cm) Weight= 1.2 (kg)	<b>Stepper motor quantity</b> = 1 Nominal voltage = 24V Nominal current = 1 A Power = 15.26 W
<b>Y</b>	<b>Displacement:</b> Length (cm) = 46 max steps = 460 max Step = 22080 <b>Speed:</b> rotational speed = 1249.98 rpm linear speed = 20.833mm / s	Torque = 0.1166Nm <b>Strength:</b> tangential = 43.59N Axial load = 51.5N friction = 0.06 N Max axial load = 51.44N Power (useful) = 2.14 W	Length = 56.5 (cm) Width= 15 (cm) Height = 18 (cm) Weigh= 2 (kg)	<b>Stepper motor quantity</b> =2 Nominal voltage = 24V Nominal current = 1 A Power = 30.52 W
<b>Z</b>	<b>Displacement:</b> Length (cm) = 4 max steps = 40 max Step = 1920 <b>Speed:</b> rotational speed = 1249.98 rpm linear speed = 20.833mm / s	Torque = 0.1166 Nm <b>Strength:</b> tangential = 43.59N Axial load = 51.5N gravity = 7.85 N Max axial load = 51.44N Power (useful) = 0.909 W	Length = 18 (cm) Width = 8 (cm) Height = 12 (cm) Weight = 0.8 (kg)	<b>Stepper motor quantity</b> = 1 Nominal voltage = 24V Nominal current = 1 A Power = 15.26 W <b>DC motor:</b> Voltage = 12V Current = 1.79A

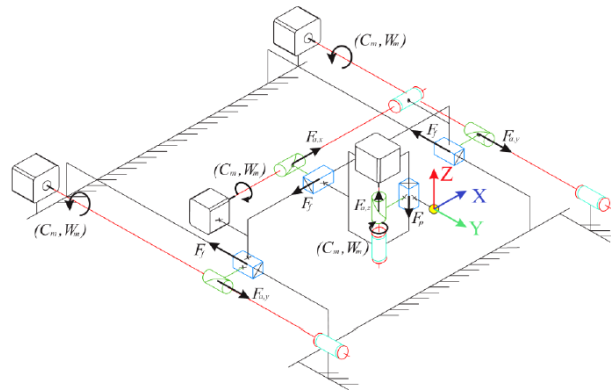


Figure 3. Kinematic diagram of the CNC machine

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.

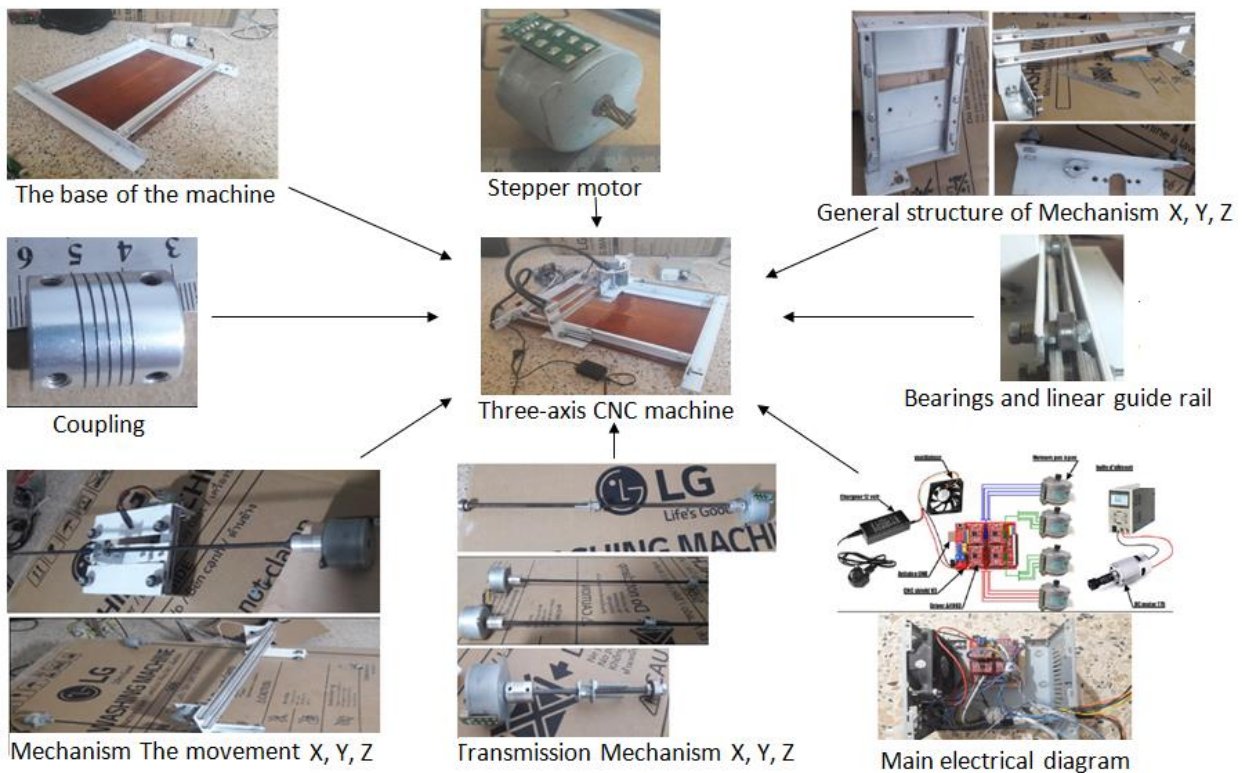
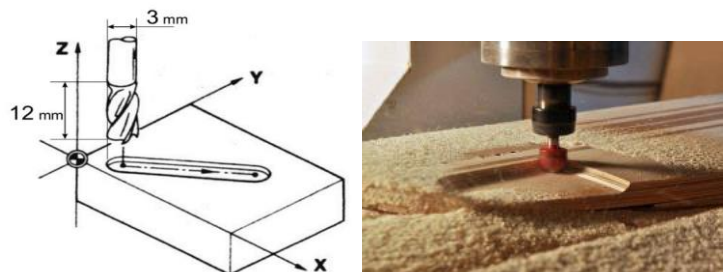


Figure 4. Different parts of the machine CNC

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.






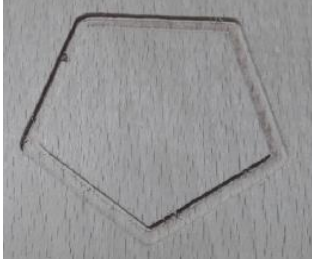
**Figure 5.** Features of the cutting tool

**Table2.** Mechanisms of the X, Y and Z axes

	N pas	S <sub>max</sub> (step)	W <sub>max</sub> (rad/s)	V (mm/s)	F <sub>t</sub> (N)	F <sub>a</sub> (N)	F <sub>f</sub> (N)	F <sub>x</sub> (N)	P <sub>m</sub> (W)	P <sub>u</sub> (W)	η (%)
<b>Axe X</b>	400	19200	130.89	20.833	43.59	51.5	0.06	51.44	15.26	1.072	7
<b>Axe Y</b>	640	22080	130.89	20.833	87.18	103.02	0.264	102.76	30.52	2.14	7
<b>Axe Z</b>	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
<b>MDF</b>	Rotation frequency n = 6500 rpm Advance speed F = 0.15 mm / s Cutting speed Vc = 30.6 m / min Depth of cut a = 0.2 mm	
	Rotation frequency n = 6500 rpm Advance speed F = 0.2 mm / s Cutting speed Vc = 30.6 m / min Depth of cut a = 0.2 mm	

Wood	Cutting parameters	The result of the engraving
<b>Multilayer wood</b>	Rotation frequency n = 6500 rpm	
	Advance speed F = 0.4 mm / s	
<b>Beech wood</b>	Cutting speed Vc = 30.6 m / min	
	Depth of cut a = 0.3 mm	
	Rotation frequency n = 6500 rpm	
	Advance speed F = 0.1 mm / s	
	Cutting speed Vc = 30.6 m / min	
	Depth of cut a = 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.

#### 7. REFERENCES

- Golnabi, H., Asadpour, A. (2007). Design and application of industrial machine vision systems, *Robotics and Computer-Integrated Manufacturing*, 23(6), 630-637.
- Li, J., Weng, J., Xu, H., Zhou, C., Zhang, D., Lu, G. (2019) Design of robotic mannequin formed by flexible belt net. *Computer-Aided Design*, 110(2019), 1-10.
- Khechekhouche, A., Elsharif, N., Kermerchou, I., Sadoun, A. (2019). Construction and performance evaluation of a conventional solar distiller. *Heritage and Sustainable Development*, 1(2), 74-77.
- Ye, Y., Hu, T., Zhang, C. (2018). Design and development of a CNC machining process knowledge base using cloud technology. *The International Journal of Advanced Manufacturing Technology*, 94(2018), 3413–3425.
- Keefe, Jeffrey H. (1991). Numerically controlled machine tools and worker skills. *Industrial and Labor Relations Review*, 44(3), 503–519.
- Shafieifar, M., Farzad, M., and Azizinamini, A. (2017). Experimental and numerical study on mechanical properties of ultra high performance concrete (UHPC). *Construction and Building Materials*, 156(2017), 402-411.