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Design, Development and Simulation of CNC Plasma (or Oxy-Fuel) Cutting Gantry

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***Abstract*: In the developing stages of all convectional machining processes there is a special and most important type of non-convectional machining has been developed during early years of mechanical era. The most important and reliable development is the plasma arc cutting machine due to its high rate of cutting speed and greater accuracy lead to the development of this machining process. The most important aspect of this type is that it can cut any type of harder material through hot jet of plasma. Another main and most important is cost parameter because of material used in this machine is of low cost efficient compared to any other machining processes in the market. The modern framework and body frame of mechanical components has become the heart of the any industry. This paper illustrates the design of plasma cutting machine through set of design considerations.**

The rapid developing technology i.e., plasma cutting machine plays an important role in the industry, the plasma cutting machine uses jet of hot plasma to cut metal pieces using some set of components they are CNC machine, controllers, machine table and most 2D software which used to convert images to some set of CNC codes to operate in specified coordinates.

***Keywords*: Oxyfuel, Plasma CNC machine, Gantry, CNC controller, p2p software.**

1. Introduction

The plasma cutting is a process of cutting in which it uses a jet of plasma through electrically conducting materials, the material includes steel aluminum and other metals. The positive and negative terminals create path between current to pass through a nozzle of varying shape constrict a passage of highly ionized gas i.e., air, oxygen and inert gas. The low amps and low cost create more and more research in the process. The ability to cut metals and to attain higher accuracy and finish, the plasma arc cutting process has useful advantages compared to other machining processes thus it is being carried in industries from large CNC operated machines to small scale industries.

What is plasma?

- Plasma is a fourth state of matter.
- The other three states of matter are Solids, Liquids, & Gases
- When the gas is heated to above saturated temperature the resulted matter is known as PLASMA.

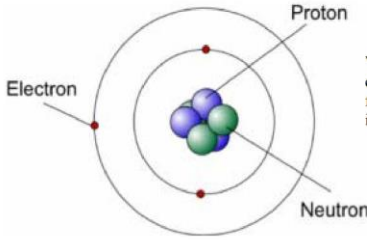


Fig. 1. Atom

Plasma cutting basics:

The plasma cutter includes more & more units the below fig. shows the basic idea of plasma cutter unit.

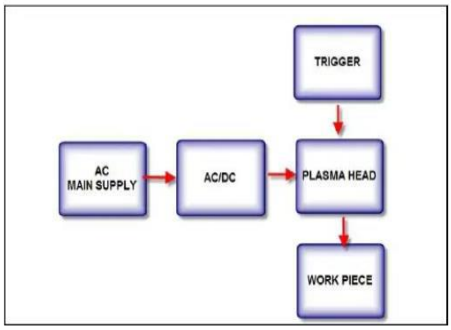


Fig. 2. Plasma cutter unit

The exchange of molecules creates heat that generated heat is then ionized and passed to the torch lifter and then to narrow restricted passage where highly ionized gas transfers into the work piece and removes the metal to the required shape. Around 28.7% of the gas is used to cut the metal and remaining 71.3% is used to remove metal and cooling.

Plasma is the utilization of electricity to expand an ionized gas through space create heat to come up to a temperature that will cut directly through metal. The plasma cutter utilizes compressed air or gas to ionize and create plasma. Once the compressed air or gas make contact with the electrode, it ionizes and creates more pressure, resulting in a stream of pure plasma. This is hot enough to cu directly through materials.

The figure shows the components of plasma head.

1. Plasma gas.
2. Electrode which is connected to the negative DC power supply.
3. Nozzle which is container that focuses the plasma gas around the electrode.

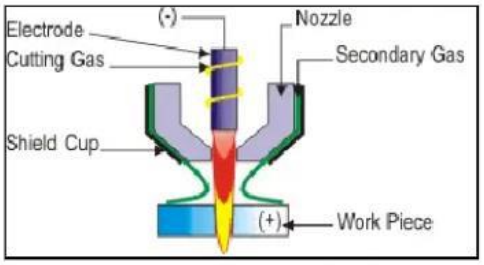


Fig. 3. Plasma head

The plasma cutter circuit includes three major classifications

1. Power circuit
2. Trigger circuit
3. Control circuit

2. CNC Machine and Mechanical Setup

The most important aspect in the machine is design of some useful structures, the main understandings include linear motions & linear bearings. The solid works inventor application is used in the design of this structures.

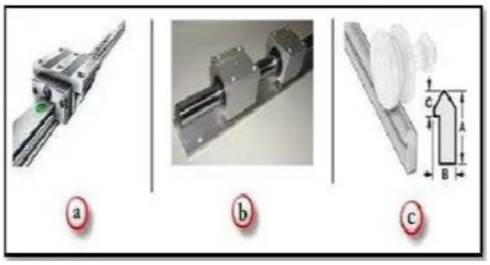
Linear motion (LM) plays a vital role in all linear CNC machines; it is responsible for

Three primary tasks.

1. Support machine components.
2. Guide the machine in a precise linear motion with minimal friction.
3. Support lateral loads.

An LM system is composed of some type of linear bearing and the linear bearing guides.

The most famous types of bearings and guides are in figure below:



(a) Rail &guide (b) rod & bushing (c) v-groove
Fig. 4. Types of linear motion systems

Rods and bushings system is selected for our machine because of it is high load capacity, low friction coefficient, good accuracy, low cost and easy maintenance.

A bearing is a device used to allow constrained relative motion between two or more parts, typically rotation or linear movement.

Types of bearing used are as follows,

1. Ball bearing
2. Thrust bearing
3. Linear bearing

Fig. 5. Types of bearings

Mechanical parts:

The mechanical parts are designed by using solid works inventor software and it includes following parts.,

1. Table
2. Y-axis
3. X-axis
4. Z-axis
5. Plasma head holder

Fig. 6. The plasma CNC machine

Y-axis:

In the Y-axis, rods and bushing are used to facilitate the linear motion as shown in figure below and timing belt is used to drive the axis as shown in figure below.

Timing belts have many advantages:

1. No backslash.
2. Good accuracy.
3. Easy to replace.
4. Low cost.

Fig. 7. Timing belt driver

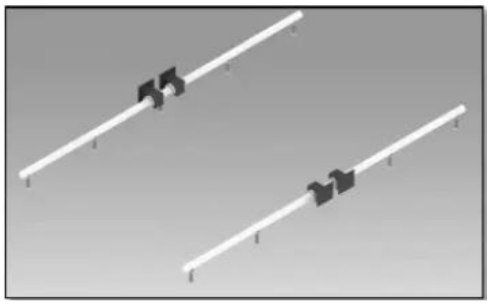


Fig. 8. Rods & bushing for Y-axis

X-axis:

Linear motions for rods and bushing are carried out in X-axis. It makes use of timing belt for driver.

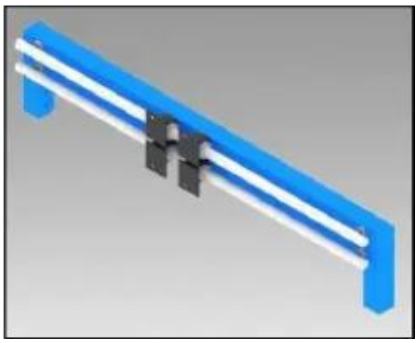


Fig. 9. Rods & bushing for X-axis

Z-axis:

The main part of the machine is the z-axis motion hence it is needed to be carefully & precisely designed. The fig below shows full Z-axis.

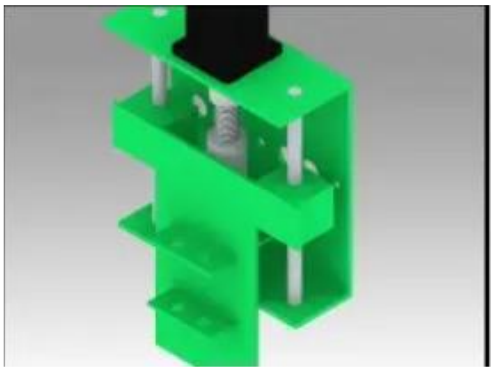


Fig. 10. The full Z-axis

Plasma head holder:

The main problem with CNC plasma is that the distance between plasma holder and a work piece, whenever the Z-axis moves down until it comes in contact with work piece and moves back to upper side until it touches limit switch hence the distance between the both can be found with the help of plasma head holder. The fig below shows the complete plasma head holder assembly.

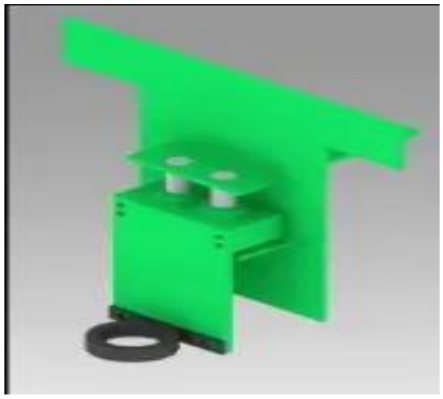


Fig. 11. Plasma head holder

CNC Controller:

The CNC controller has played an important role in the development of this plasma arc cutting gantry because any motion that we carry out requires lot more control over the equipment and hence this can be done through stepper motor placed inside it. It carries out the motions in required amount through number of steps say 200 and specially designed synchronous, brushless electric that convert pulses into mechanical shaft rotations.

Stepper motor:

The figure below shows the stepper motor that industry uses in every aspect of this design due to its high accuracy & high torque at low speeds makes a reason to adopt this stepper motor.

Fig. 12. Stepper motor

The motor uses two types of driver they are as follows,

1. Unipolar
2. Bipolar

In unipolar mode we use 5 wires from the stepper motor where as in the bipolar mode we use 4 wires from the stepper motors in this mode huge torque can be obtained.

Design:

The mechanical design has more specific and important parameter that a designer needs to consider in the development of this plasma cutting machine.

In this paper we designed mainly four parts they are

1. Left support
2. Right support

3. Gantry
4. Assembly

1. Left support:

The rigid body frame which supports the rail assembly & the designed 2D model is shown in fig below

The detailed isometric view is shown in next fig below.

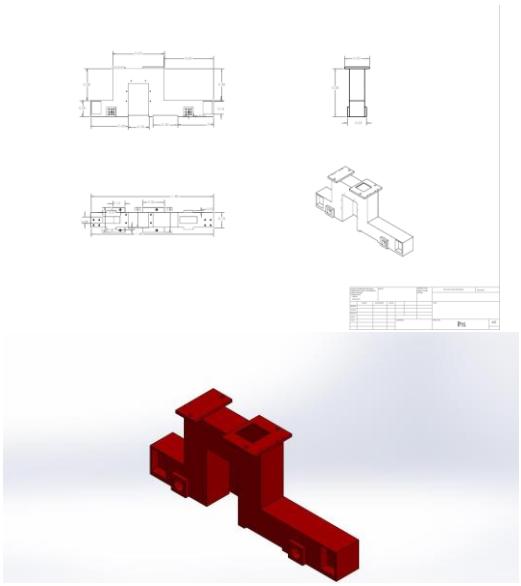


Fig. 13. Left support

2. Right support:

This is the exact mirror image of left support; it also supports the rail assembly in the right side of the machine. The fig below shows the 2D model of the part.

The fig below shows the isometric view of the right support we used solid works inventor software to develop these drawings.

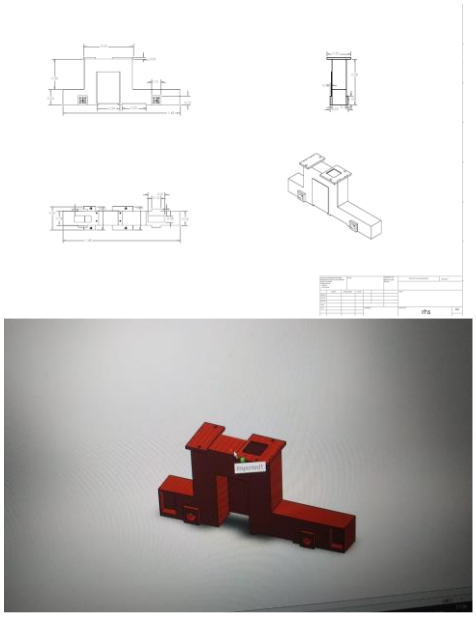


Fig. 14. Right support

3. Gantry:

It houses a different part of the machine components such as torch lifter and plasma head holder, CNC controller units. The fig. below referred to detailed 2D model of the part.

The isometric view is shown below fig illustrates the actual look of the component in 3D view.

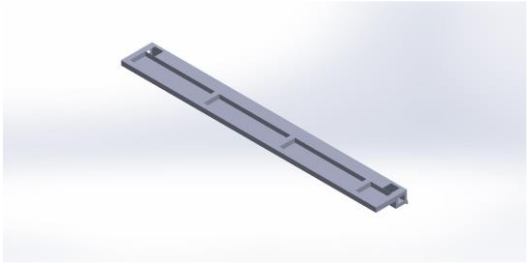


Fig. 15. Gantry

4. Assembly:

The final assembly of the machine component that is plasma arc cutting machine is shown below.

Fig. 16. Assembly

Newly integrated aspects:

- Highly automised.
- No CNC programming is required.
- The programming required is auto generated by the controller.

Working and interface:

The main and important aspect is that how it works in actual practice and what is interface behind this machine.

Plasmas combination of cut quality productivity and versatility make it one of today's most popular industrial cutting processes, but first what is PLASMA?

Plasma is often called fourth state of matter, let's take look at the three other states we are all familiar with they are solid, liquid, and gas. The difference between these states is their energy, when we add energy to ice in the form of heat the ice melts and forms water if we add more energy the water vaporizes and becomes steam, from ice to water to steam but what if we add even more energy to the steam a lot more if we could heat it to 11700'c the steam would break up into a number of component gases it would also become electrically conductive or ionized this high energy ionized gas is called PLASMA. Plasma is created when we expose a gas to very high temperatures.

The mainly it consists of a plasma torch the kind typically used on cutting tables compressed air nitrogen or other gases provide a source for the plasma in this a second inert shield gas is used to protect the work piece and blow of melted metal, the electricity supplies the energy needed to turn the gas into plasma the greater the current the hotter of the plasma. A specially engineered nozzle and electrode constrict and maintain the plasma jet concentrating it into small area so it can be used for cutting

When the operator is ready to cut a start signal is sent to the DC power supply a circuit temporarily connects the nozzle to the positive side of the power supply with the electrode at negative. The high frequency spark ionizes the gas and makes it electrically conductive this creates a current path between the electrode and the nozzle and forms a pilot arc of plasma the work piece is connected to the ground through the cutting table when the pilot arc contacts it the plasma arcs transfer to the work piece melting the metal the high velocity gas blows the molten material away.

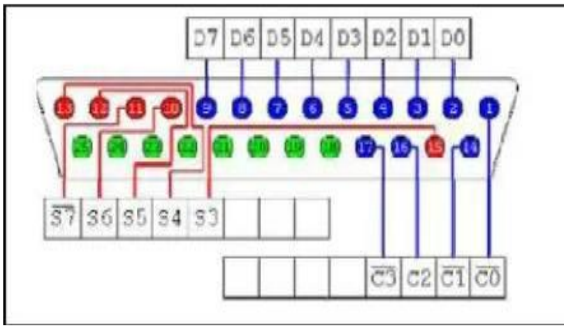


Fig. 17. Parallel port

The interface illustrates the PC which is connected to the CNC through the parallel port. Which uses most 2D software to convert image data to automatically generated G-codes for the motion of the CNC machines and A mach3 software to generate codes for operating the machine axis that is X, Y, & Z coordinates.

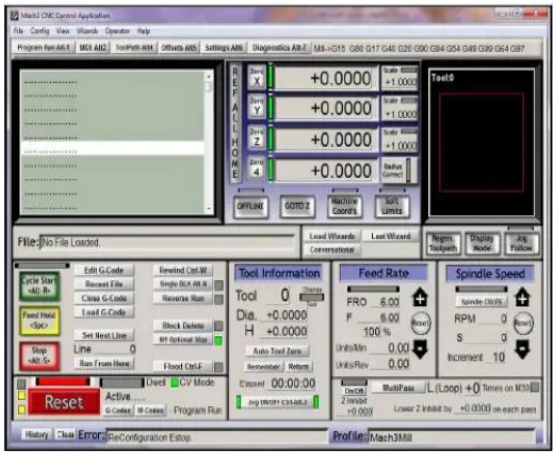


Fig. 18. Mach3 software

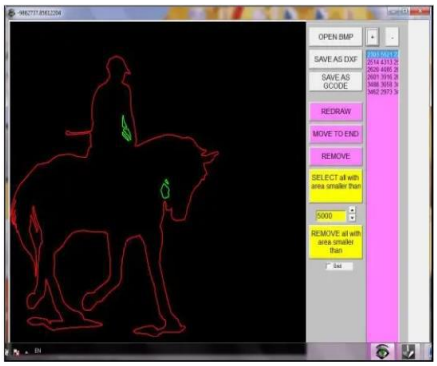


Fig. 19. Plasma trace software

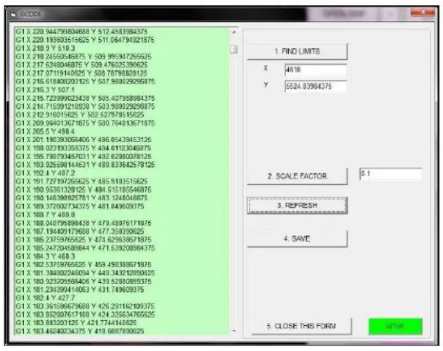


Fig. 20. G-code for generated trace

3. Conclusion

The plasma cutting process is one of the developing and research-oriented topics in all aspects of increasing technology by the implementation of this type cutting process we can enhance productivity and versatility. The main important aspects of the cutting process is that its motion control hence by this we conclude that the development of the plasma arc cutting gantry played vital role and its cutting speed increases or decreases depending on the thickness of the work piece. The user friendly software that is most2D & mach3 software are really helpful in generating automated g-codes for the CNC machine.

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