Automated Gas Cutting Machine Using Open CNC

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Abstract. This is to develop & investigate into an open CNC based gas cutting machine using freeware support to perform gas cutting operations on steel plates. A prototype for a low cost automation solution is proposed which will study the feasibility of a two axis CNC machine to improve the accuracy in implementation of gas cutting. The fundamental concept of CNC is still preserved but the operation is manipulated by a motion control system consisting of microcontrollers. This machine will provide a motion control system that provides the tool the freedom to be interpolated to interpolate various profiles. It is the independent system that allows integration of application programs, microcontrollers and drive circuits as well as G code interpreters. It is portable and user friendly hence suitable for all fabrication and production-oriented.

1. Introduction

Computer Numerical Control or CNC refers to the automation of machine tools with the use of pre-programmed sequence of the codes for machine control commands by using computers system. A CNC program is used to control, automate and monitor the movement of the machine. CNC controller works with a drive component and a combination of motors to control and move the machine axes in the requisite path thereby performing programmed motions. The Gas Cutting machines have been the necessity in manufacturing world. Consequently, there have been a lot of improvements and developments in gas cutting machine with respect to its ease in use and considering the human safety. But the traditional methods were time consuming, less accurate and inefficient. Hence, to overcome the disadvantages of traditional gas cutting machine, the automated gas cutting machine is taken into consideration. Also, a major advantage of cutting thicker plates of steel, brass and/or other electrically conductive metals like aluminum is served with better accuracy.

Figure. 1 indicates the basic schema involved in the prototype made
With the development of new technology open CNC architecture is gaining popularity to overcome the difficulties with proprietary controllers. The objective is to automate the gas cutting process especially in intricate contours besides supplementing with proper feed and speed to ensure the cut quality. This is an attempt to bring the freeware to create an open platform to replace proprietary controllers.

Georgi M. Martinova et al. (2014) observed that it was initially difficult to control the tasks of non-traditional processes like additive manufacturing, as certain limits of classical CNC systems do not allow them to be used to solve the range of new tasks. A solution matrix for the synthesis of specialized CNC systems have been put together and a set of hardware, software devices, components and new technologies have been defined. The example of a machine selective laser sintering and a five axis water jet cutting machine would illustrate the synthesis of specialized CNC systems[1]. M. M. Goud et al. (2007) stated that flame cutting machines (which are also known as burning machines) are the machines used for cutting plates and most of these have a high end computerized or optical control with multiple cutting stations. Due to these machines, the complicated shapes are performed quickly and precisely. The procedure is rather simple, but the actual performance is a skill of science[2]. Dound Pramod et al. (2016) elaborated on stability of cutting oxygen flow, cutting speed and preheated flame is all that a flame cutter requires. In the research, experiments were performed to determine appropriate setting of nozzle size, heating oxygen pressure, cutting parameter, cutting speed and acetylene pressure to achieve the highly finished cuts for unalloyed steels upto 0.35% carbon with the help of 99.1% of oxygen which is different for different sheet thickness. One of the necessary machine tools in a workshop is the portable multipurpose electromagnetic profile machine[3]. Practically, all the metal cutting and fabrication is carried out at the shop floor where gas cutting required for different operations. The goal of Portable Multipurpose electromagnetic profile machine is to reduce cutting time of intricate curvature shapes &profiles and decrease cutting time will be a significant step towards reducing the cycle time. This will in turn improve working conditions, reduce fatigue of operator and improve accuracy at the shop floor. Xihui Yang (2017), suggested an industrial design plan for CNC machines. The design concept includes ergonomics, HMI and UED besides industrial design policies and the implementation is done through the virtual machine engines [4]. M.-Y. Yang et al. (2002) have proposed an OAC for Wire electric discharge machining. NURBS was interpolated with Taylor’s series expansion [9]. Kartz, Rueven et al. (2000) have explained the available open architectural control technology by leading research groups like OMAC, OSACA, JOP, The university of Michigan etc.& Globalization of OAC standards [10]. Jorge Correa et al. (2016) proposed hardware & software for interpolation based on open source electronics. They introduced unique finite state machine (FSM) algorithms in the architecture [11]. Peng Yuhai et al. (2010) defined openness in three stages. Open protocols &communication interface of HMI, ability to replace proprietary controls for different purposes& topological structure of control equipment [12].

2. Design Features of Gas Cutting Machine

2.1. Structure

A design of XY stage gas cutting machine has been built which serves the requirements of the objective. The design model consists of a basic frame, XY axes sliders, base of sliding arrangements, lead screw, jaw couplings, motor mounting hub and holding device. The Gas Cutter (or say, in this case a tracer) is connected perpendicularly to the working table with the help of a vertical stand mounted on the Y axis. This design is robust with its arrangement. The CAD model is drawn using SolidWorks 2016 software and the 3D model of the same is generated and represented as figure 2.
2.2. Design Specification

The hardware basically consists of two linear actuators for two axes driven by 2 Phase Hybrid Stepper Motor (NEMA 23) with step resolution 1.8° and torque 0.39N.m. The lead screw used is of diameter 12 mm, Length 350 mm. The available working area is 125X125 mm. The controllers are Arduino Uno of Atmega 328. The drive circuit DM542 is selected as the motor specifications which provides the current of 4 A.

In the gas cutting process, the intricate contour to be executed is derived through a mathematical formulation like Bezier curve. These curves can be modeled by any 3D CAD modelling software or may be generated by freeware like Inkscape and the tool path is generated by Universal G code sender and through G code interpreter the motion control is executed by Arduino controllers. Inkscape is a free and open-source vector graphics editor which gives many primitive shapes besides Bezier curves for the above said purpose. Inkscape generates a file in Scalable Vector Graphics (SVG). Many other formats are compatible. Universal G code sender takes the input from Inkscape in SVG and publishes the requisite G code for GRBL/TinyG which is a G code interpreter. Then GRBL/TinyG G code interpreters will pass on the instructions to microcontrollers with the required interpolated position values, feed and speed. Arduino behaves like the brain of the system, i.e., from controlling the coordinates to executing the path to be traced. Once the data is retrieved from the processors, the trace begins.

2.3. Cutting Parameters

Richard, l. little (1973) has specified all necessary components and processes which are required during gas cutting. Also, the basic features and selection of gases are determined. The oxyacetylene cutting torch has same basic components that of welding torch: an acetylene cylinder, an oxygen cylinder, regulator (oxygen and acetylene), sufficient hosing, and a torch body. A cutting head attached to the torch body is designed to have preheated orifices in the cutting tip as well as a passage for the high-pressure and pure oxygen. Cutting torches maybe of head-mixed or premixed type. In head mixed type, the most likely used type where in the oxygen and fuel (acetylene) is mixed just before entering the tip. In premixed type, the oxygen and fuel (acetylene) are mixed in the body of the torch itself. Torches can also be classified further as medium-pressure torches, in which acetylene is used in the range of 1 to 15 psi, where the acetylene is 1 psi or less. The pressure classifications are the same as those used for welding torches [5].

| Plate Thickness (mm) | Nozzle Size (mm) | Acetylene Gas Pressure (bar) | Oxygen Gas Pressure (bar) |
|----------------------|------------------|-----------------------------|---------------------------|
| 100                  | 2.0              | 0.14                        | 5.37                      |

*Table 1. Cutting Parameter for Selected Nozzle Size*
Bhatia A. et al. (1998) explains the difference between cutting torch and welding torch. It is distinguished in two ways where in the cutting torch consist of a high-pressure valve which is simulated by a trigger, lever or button. In addition to acetylene and oxygen adjustment valves, when the high-pressure oxygen valve is triggered, the oxygen is released through the tip. The second difference is that the cutting torch has multiple numbers of orifice tips where in, the welding torch has just one orifice tip arrangement. Cutting torch tips have preheated orifice facility and one centrally arranged orifice directs the flow of oxygen during the cutting operation [6]. Linde A.G (2012) evaluated various fuels and the advantages and disadvantages are enumerated. Also, the high efficiency of acetylene is easy to explain: Because of the favorable molecular structure of the acetylene, the energy released during combustion, the flame propagation rate of the oxy-acetylene flame, and the high flame temperature is achieved. Also the molecular energy is being released during the breakdown of acetylene, as compared to other hydrocarbons; this is the so called formation enthalpy or energy of formation.

3. Proposed Architecture of Motion Control System

3.1. Proposed Architecture 1: System with Separate Drive Circuit Arrangement

In this system, the mechanical system (axes) are connected to the stepper motors and then to the drive circuit – DM542. The DM542 is a fully digital stepper drive developed with advanced DSP control algorithm based on the latest motion control technology. Its motor auto-identification and parameter auto-configuration feature offers quick setup to optimal modes with different motors. Compared with traditional analogue drives, DM542 can drive a stepper motor at much lower noise, lower heating, and smoother movement. Its unique features make DM542 an ideal choice for high requirement applications. The DM542 is then attached to the Arduino which is connected to the input software. The block diagram for System with Drive Circuit Arrangement is shown in Figure 3(a).

![Figure 3(a) System with Separate Drive Circuit Arrangement](image)

3.2. Numbering Proposed Architecture 2: System with GRBL Shield Arrangement

In this system, the mechanical systems (axes) are connected to stepper motors and then to the Arduino on which the GRBL Shield is placed. The Arduino CNC Shield makes it easy to for the CNC to run for a few hours. It generally uses open (A, 1998)source firmware on Arduino to control the stepper motor. Usually, all the GRBL Shield are easily compatible with all the stepper motors and so this is one of the cheapest arrangements for the CNC machines. The block diagram for System with GRBL Shield arrangement is as shown in Figure 3(b).

CNC shield also known as GRBL shield is connected with the Arduino UNO board with proper orientation of the input polarity. The shield provides ease as the basic configuration of attaching the drive circuit is already attached to it. The arrangement in proposed design 2, thus gives us a compact system.
4. Result and Analysis

The two-axis CNC structure developed for gas cutting was tested for geometrical and dimensional accuracy. Following are the various profile traced, the results and analysis for the same are stated below. Figure 4(a) shows a square profile of 60x60 mm, whereas figure 4(b) shows a circular profile of 60 mm diameter. A constant feed rate of 45 mm/min was followed during the trace. Figure 5 represents the actual setup of the gas cutting machine.

![Figure 4(a). Square Profile (60x60 mm)](image1)

![Figure 4(b). Circular Profile (60 mm diameter)](image2)

5. Conclusion

The XY stage CNC structure is developed for Gas Cutting. An open CNC system is implemented for linear, circular and contour interpolations. Two architectures consisting of drive circuit, microcontroller and GRBL shield is tested. The system with drivers mounted separately is found to be
giving better results with a higher level of accuracy than that of GRBL shield. Various contours are tested successfully. Polygons were accurately plotted. Errors in circular interpolation are attributed due to errors in structural design. Specified feed rates are obtained with an error of ±0.6 percentage. While experimentation, it was found that the required profile have been drawn according to the dimensions by the end-effector accurately. Maximum feed at which the machine performed accurately is about 80 mm/min, whereas, above the feed of 80 mm/min, the profile is not accurate. The setup was tested successfully with minimum errors. Thus, this gas cutting machine will satisfy its requirements within the above specified ranges.

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