3-Axis Motion Control of CNC Machine based on G-Code, M-Code using FPGA and also Apply Bezier Curve

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Abstract—This paper present design and implementation idea about axis motion control of CNC machine based on G code and M code using FPGA. G code and M code are the majority part of the motion action of CNC machine and with the other term motion curves and trajectory formula and interpolation.

Keywords- component, block diagram and flowchart of process, G and M code and functional algorithm and Bezier curve.

I. INTRODUCTION

In the automation industry we need to accuracy regarding a proper motion of machine or CNC machine for manufacturing a product this is done by moving a perfect control of axis motion. This paper presents 3 axis motion control of CNC machine based on FPGA for industrial purpose with minimum cost and minimum power consumption of the system. It includes Bezier curve fro smooth motion of axis and its minimize the error and giving fast response. it can combine the machine language with Bezier curve and super formula.

G code and M code is CNC machine language that generate the command for motion and direction according to parameter used. These commands have wide range of value so by this it can change the motion of axis. The command generate with higher level language like C, C++ and VC++ and by CNC simulator. With advance technology in graphics design parameter processing very important component of computation.

The algorithms are required to be calculated such as interpolation, feed rate, velocity ratio, speed control, jerk monitor which are accomplished by use of FPGA for logic operations. The complex functionality required number of logic blocks to design such system for determines the cost of the system.

The FPGA-based motion controller delivers a fast sampling rate with lower power consumption. FPGA-based motion controller offers advantages such as high speed, complex functionality, and low power consumption [1].

II. BLOCK DIAGRAM AND FLOW CHART OF THE PROCESS

The implementation of axis motion control based on G and M code required main three blocks to control the process are code designing equipment, FPGA kit module and CNC machine for output testing.

Figure 1 shows general block diagram and figure 2 shows flow chart of process. Below are the steps of implementation.

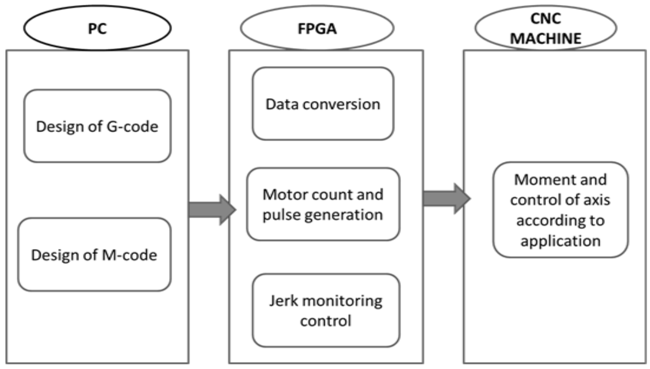

Fig. 1: Block diagram of axis motion control using FPGA

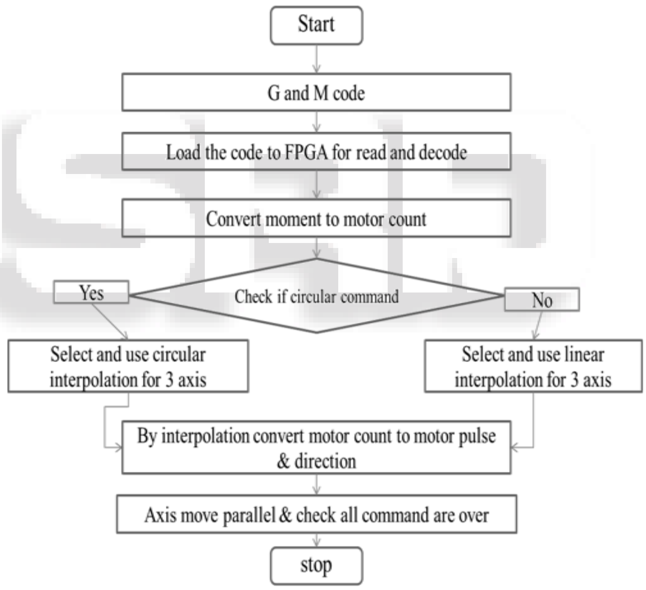

Fig. 2: Flow chart of the axis motion control

Step 1: Design G & M code for input with parameter value.
Step 2: Load code into memory of FPGA card for execution step by step via serial port..
Step 3: Convert the code into moment according to input parameter value using algorithm/logic function.
Step 4: Check all command for whether its a circular command or not
Step 5: If yes then select and use circular interpolation for acceleration/decelerations of axis moment.
Step 6: If no then use linear interpolation to convert count to motor pulse
Step 7: According to interpolation and parameter value convert motor count to motor pulse & direction for CNC axis to motion.
Step 8: All axis move parallel with respect to motor pulse.

III. G AND M CODE WITH FUNCTIONAL ALGORITHM

G-code is used for computer numerical control (CNC) programming language Used mainly in automation industry. G-code is a language in which people tell computerized machine tools what kind of move and how to move. The type of motion mostly defined by instructions tells the direction and movement. The situation is according to these instructions giving in the value of parameter used. G commands tell the control what kind of motion is wanted such like rapid positioning, linear motion, and circular motion. G-code began as a limited type of language that lacked constructs such as loops, conditional operators, and programmer-declared variables with natural-word-including names. Majority it is a code that gives command to the machine tool what type of motion to perform such as Rapid move move in a straight line or circular arc, Series of controlled feed moves, Switch coordinate systems. M code are user define code and it can be manage by manually. The control command of M code can be change according to control needed and the code will varies from machine to machine.

Various G and M code as follows[2]:

- G00-Rapid positioning
- G01-Linear interpolation
- G02 & G03 -Circular interpolation
- G09-Exact stop
- G12 & G13- Full-circle interpolation
- M00- Compulsory stop
- M02- End of program
- M06- Automatic tool change

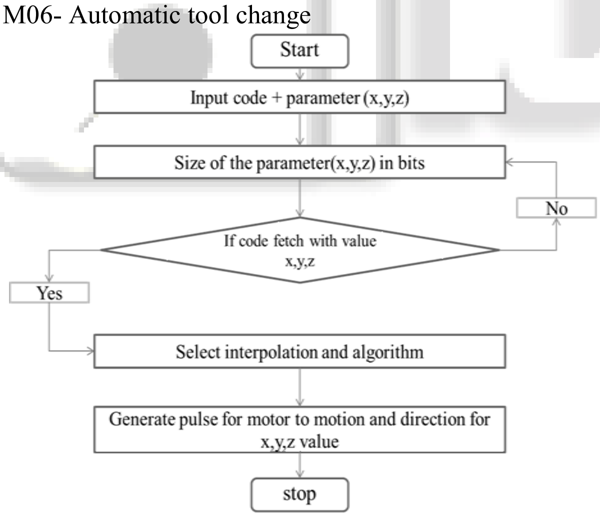

Fig. 3: Flow chart of the functional algorithm

Implementation of axis motion control of CNC machine based on the functional algorithm with specific value of particular parameter x, y, z of axis of machine. In this algorithm set the size of the parameter x, y, z in bits either it may be 32 bit, 64 bit, 128bit. The control action take place with the help of FPGA based control card and all command function pass through controller of system it include selection of the accept proper code, parameter size x, y, z, selection of interpolation if require, convert motor count to generate pulse for servo motor and control pass to servo controller for jerk monitoring process for safety of product, machine tools and more important things is to minimization of power consumption and reduction in vibration of machine module. Figure 3 shows the flow chart of the function algorithm. Below is the step for function algorithm.

Step 1: Input the code convert into integer value with parameter value x, y and z
Step 2: select the size for parameter value in bit
Step 3: Code is fetch then select interpolation use algorithm and calls the different logic function according to the parameter value.
Step 4: If no then return call the function step 3
Step 5: According to the parameter value functions call to calculate and generate the pulse for motor count to moment and the direction of axis.

IV. BEZIER CURVE

Bezier is one of the polynomial and important tool for interpolation because it is easy to compute and is also very stable. One of the main approaches to robot motion is through the use of Quadratic and Cubic Bezier spline functions. Bezier curve include cubic and quadratic curve and function are to change whole shape which look like smooth and interactive curve by determine the constraints so curve only touch the constraint line which are useful for path planning of diamond cutting and in other complex application to making accurate shape.

Let $(Pi = (xi, yi), i = 0, 1, 2, ..., n)$ be the control points of Bezier curve (BC). The BC of degree 'n' can be defined as

$$p(t) = \sum_{n=0}^{i} B_i^n(t) p(i) \quad 0 \le t \le 1$$

Where

$B_n^i(t) = \binom{n}{i} t^n (1-t)^{n-1}, i = 0,1,2 \ldots \ldots n$ are Bernstein polynomials of degree n[3].

V. SIMULATION RESULTS AND PERORMANCE ANYLASIS

Figure 6 shows the simulation result of Bezier curve interpolation. The inputs *x* and *y* are shown in hexadecimal and so is the output *mult*. Figure 4 and 5show Output of G and M code and its show a design according to parameter value *x, y, z.*

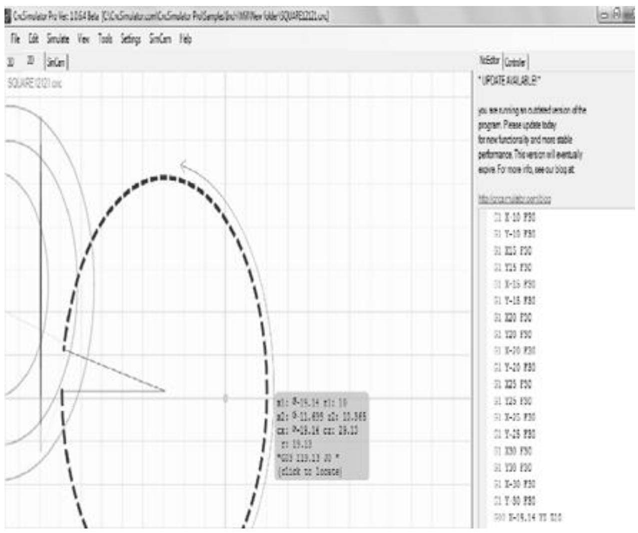

Fig. 4: output of G and M code

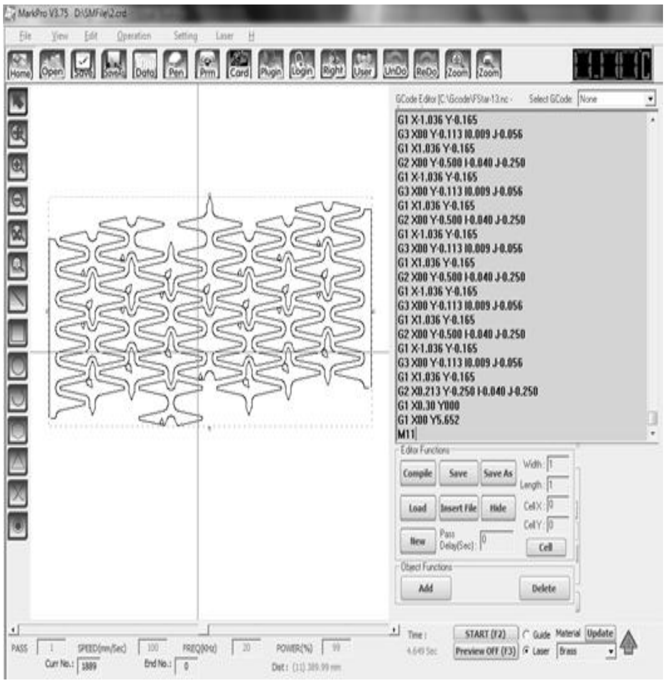

Fig. 5: output of G and M code

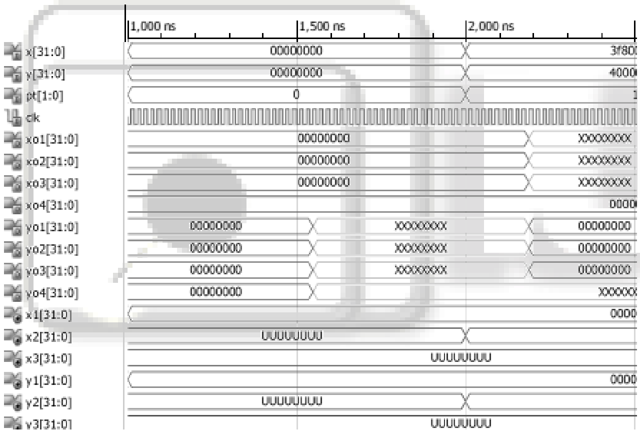

Fig. 6: Simulation result of bezier curve

CONCLUSION

By performing analysis of results, it can be conclude that according axis motion algorithm the output of G code are accurate so axis motion are control efficiently and responsible for smooth motion of axis so it consume less power. Output of Bezier curve shows the fast and smooth response towards motion control finally overall system performance cost is reduce.

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