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CNC Machine DC Servo Motor Control

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Abstract

This paper concentrates on computer numerical control (CNC) as one of the modern control system which has a great benefits and Reduced the problems and errors of the traditional machines that depend on operators the main problems of traditional machines are waste of time and effort beside that CNC machines have the capability of producing the complicate pieces in a mass production form in a very limited time as any other machines the CNC machine faces some problem such as technical errors due to high temperature the actuator deviation and finally the error produced by the motor used as motion source one of the CNC error is tracking error from the servo motor using PID controller for position and speed control minimizes this error hence improving the motor performance and increased the quality of the product as desire by the designers.

Keywords: *Computer Numerical Control (CNC), PID Controller*.

1. Introduction

The objectives of the paper are to explain the CNC machines technology and its capabilities in industrial automation and understand of the PID controller capabilities for control in dc servo motor and Decrease error in final product of CNC machines.

The Problem statement on this paper The final product made by CNC machines have not exactly because some problems and errors effective, These errors can be classified as Geometric errors of machine components and structures, Errors induced by thermal distortions, Deflection errors caused by cutting forces and Other errors-for example, those caused by servo errors of machine axes (e.g., tracking errors) or numerical control interpolation algorithmic errors. The Methodology that we use in this paper is Describing the operation of the CNC machines and their probabilities of errors .Using Matlab program to simulate the PID controller using CAD program to drawing and design the shapes.

1.1 General View

Mechatronics are the synergistic integration of sensors, actuators, signal conditioning, power electronics, decision and control algorithms, and computer hardware and software to manage complexity, uncertainty, and communication in engineered systems. Mechatronics are including 40% electricity, 30% mechanics, 20% elctronics and 10% programming so CNC machines are department for applications of mechatronics engineering.

The present day computer can be considered as a direct consequence of the progress in the field of numerical control of machine tools. A real breakthrough was achieved around 1965 when numerical control machines were fitted with minicomputers which introduced the name Computer Numerical Control. The first step in the process of implementing automation in any industry is to manufacture parts or components through automation using machines and machine tools with little human intervention. In order to meet the increasing demand to manufacture complicated components of high accuracy in large quantities, sophisticated technological equipment and machinery have been developed. Production of this components calls for machine tools which can be set up fairly rapidly without much attention. The design and construction of Computer Numerically Controlled (CNC) machines differs greatly from that of conventional machine tools. This difference arises from the requirements of higher performance levels. The CNC machines can be operated automatically using computers. A CNC is specifically defined as "The numerical control system where a dedicated, stored program computer is used to perform some or all of the basic numerical control functions in accordance with control programs stored in read & write memory of the computer" by Electronic Industries Association (EIA).

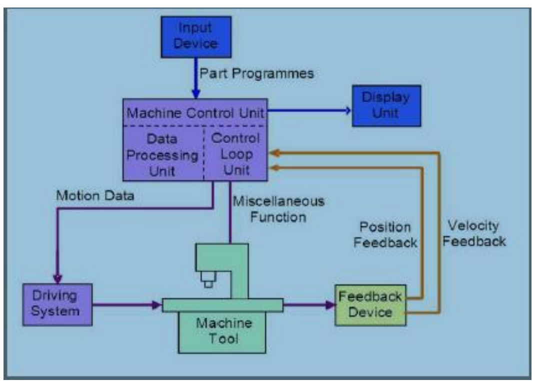

Figure 1: Working Principles of CNC Machines

CNC is a chip based control framework that acknowledges an arrangement of program guidelines, forms and sends yield control data to a machine apparatus, acknowledges criticism data obtained from a transducer set on the machine device and in view of the directions and criticism, guarantees that appropriate movement, speed and operation happen. A portion of the imperative parts of CNC machines are Machine structure, direct ways, bolster drives, shaft and Spindle orientation, measuring frameworks, controls, programming and administrator interface, gaging, instrument observing .The data put away in the PC can be perused via programmed implies and changed over into electrical signs, which work the electrically controlled servo frameworks. Electrically controlled servo frameworks allows the slides of a machine instrument to be driven all the while and at the suitable bolsters and bearing so mind boggling shapes can be cut, regularly with a solitary operation and without the need to reorient the work piece. PC Numerically Control can be connected to processing machines, Lathe machines, Grinding machines, Boring machines, Flame cutters, Drilling machines and so on.

2. Using PID Controller to Control DC Servo Motor

2.1 DC Servo Motors

There are numerous sorts of dc engines being used in ventures dc engines that are utilized as a part of servo framework are called dc servo engines in dc servo engines the rotor idleness have been made little with the outcome that engines with high torque-to-latency proportions are industrially accessible some dc servomotors have greatly little time constants dc servomotors with moderately little power appraisals are utilized as a part of instrument and PC related gear, for example, plate drives tape drives and word processors medium and vast power evaluations are utilized as a part of robot framework numerically controlled processing machines, et cetera

2.2 PID Controller

PID (Proportional (P), the indispensable (I), and the subsidiary (D)) controllers are wherever because of its effortlessness , strength, and phenomenal if not Optimal execution in numerous applications , PID controllers are utilized as a part of More than 95% of shut circle modern procedures [5] .

Corresponding (P), the necessary (I), and the subsidiary (D) control use to acquire a wanted reaction and enhance the transient reaction of DC servo engines.

Numerous procedure plant controlled by PID controllers have comparable progression it has been discovered conceivable to set tasteful controller parameters from not as much as plant data than a total scientific model. These method came to fruition on account of the longing to modify controller parameters in situ with at least exertion , furthermore on account of the conceivable trouble and poor money saving advantage of getting scientific models[5] Consider the accompanying solidarity criticism framework:

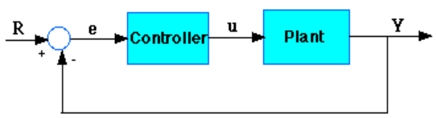

Figure 2: Unity Feedback System

Plant: A system to be controlled, Controller: Provides the excitation for the plant; Designed to control the overall system behavior.

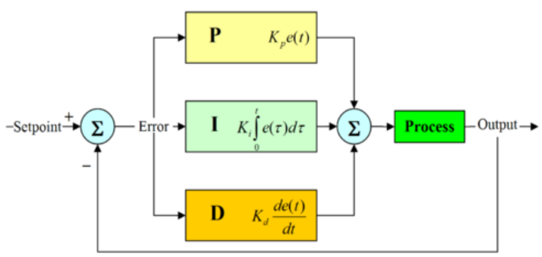

Figure 3: A Block Diagram of a PID Controller

The transfer function of the PID controller looks like the following acknowledgments are also placed here.

$$K_p + \frac{K_I}{S} + K_p = \frac{K_D\, S^2 + K_p\, S + K_I}{S} \ldots\ldots\ldots\ldots\ldots (1)$$

K p = Proportional gain
KI = Integral gain
K d = Derivative gain

2.3 The Characteristics of P, I, and D Controllers

Table 1: The Characteristics of P, I, and D Controllers

cl response	Rise time	Over shoot	Settling time	s-s error
Kp	Decrease	Increase	Small change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small change	Decrease	Decrease	Small change

2.4 Open loop step response in dc servo motor modeling in equation

G(S) = K/ JS^2 + BS
Let that for the parameter:
K = 1 Nm/A   J = 10 kgm2
b = 20 Nm/(rad /sec)
G (S) = 1/ 10S^2 + 20S
Using matlap program:
g = tf ([1] , [10 20 0])
Step(g)

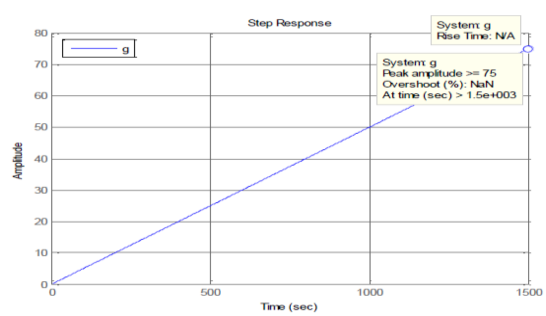

Figure 4: Step Response for Open Loop of DC Servo Motor

2.5 DC Servo Motor by using PID Controller

Servomotors use feedback controller to control the position or the speed, or both. The basic continuous feedback controller is PID controller which possesses good performance.

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2.5.1 Position Control

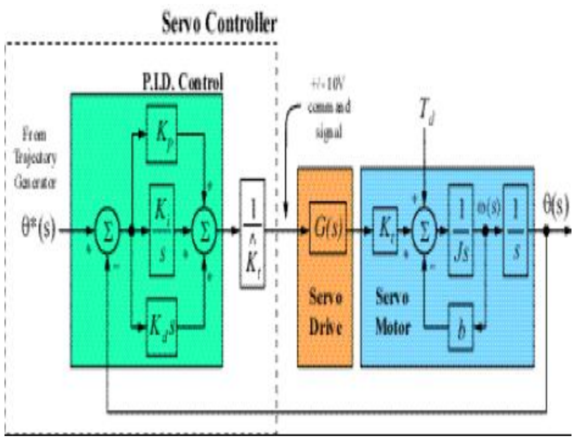

Figure 5: Using PID Controller to Control the Position of DC Servo Motor

2.5.1.1 P Controller

The transfer function of the above system using unity feedback K p controller defined the second order can be written as :
G(s) = K*K p / JS^2 + BS + K*K p
Let that for the parameter :
K =1 Nm/A
j = 10 kgm2
b = 20 Nm/(rad /sec)
k p = 200 Nm/rad
G(S) = 200 / 10S^2 + 20S + 200
Using matlab program :
g = tf ([200] , [10 20 200]) , step (g)

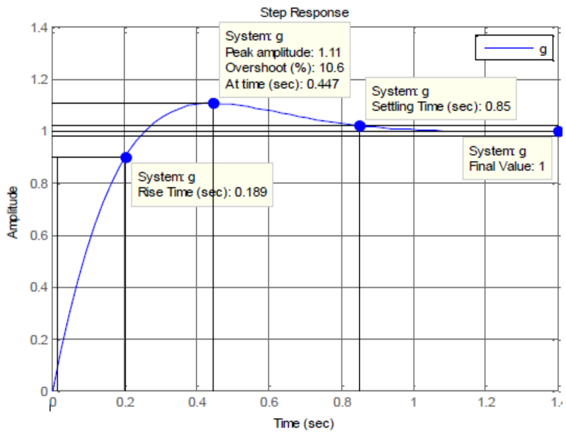

Figure 6: Step Response for PD Controller

2.5.2 PI Controller

The closed-loop transfer function of the given system with a PI controller is:
G(s) = K*[kp S + ki] / JS^3 + bS^2 + kp S + ki
Let that for the parameter:
K = 1 Nm/A
Kp = 130 Nm/rad
Ki = 170 Nm/(rad/sec)
b = 10 Nm/(rad /sec)
j = 0.1 kgm2
G(S) = (130 S + 170) / (0.1 S^3 + 0 S^2 + 130S + 170)
Using matlap programe
g = tf ([130 170] , [0.1 10 130 170])
Step (g)

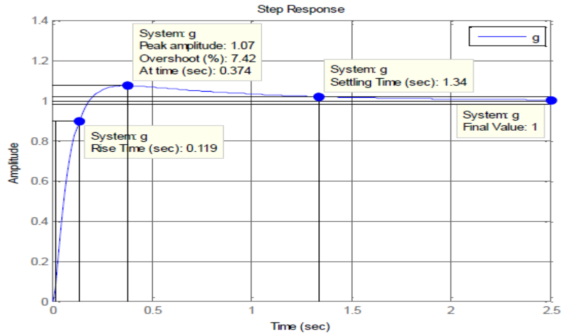

Figure 7: Step Response for PI Controller

2.5.3 PID Controller

For the general PID controller transfer function of the closed loop system dc servo motor its written as:

G (S) = K*[Kd S^2 + Kp S + Ki] / J S^3 + (Kd + B) S^2 + Kp S + Ki
Let that for the parameter:
K = 1 Nm/A Kp = 150 Nm/rad
Kd = 350 Nm/(rad/sec) Ki = 40 Nm/(rad/sec)
b = 20 Nm/(rad /sec) j = 10 kgm2
G(S) = 150 S^2 + 3500 S + 40 / 10 S^3 + 170 S^2 + 350 S + 40
g = tf ([150 350 40] , [10 170 350 40])
step(g)

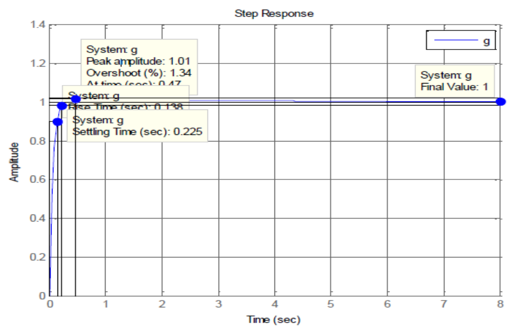

Figure 8: Step Response for PID Controller

3. Matlab Simulink Technology

In the past years became Matlab sumulink technology from the best methods to modeling and represent systems the useful from this system research and user perform to tests needed to build a model or take older model and applied tests or additions.

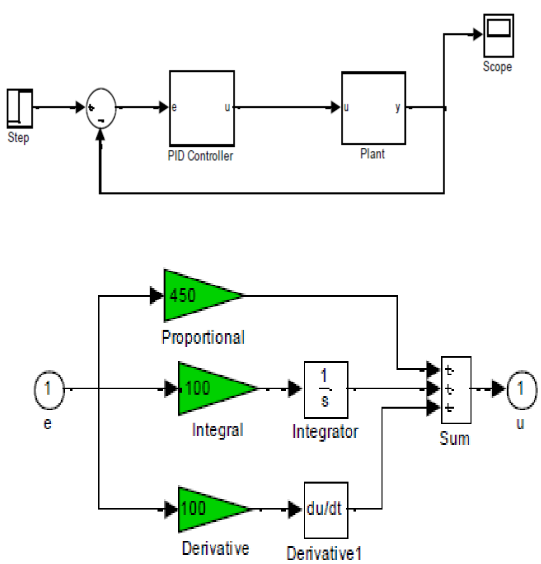

Figure 9: PID Controller

4. Results

Geometric errors of machine components and structures and Errors induced by thermal distortions and Deflection errors caused by cutting forces in this set of error sources can be reduced by improving the mechanical hardware or utilizing compensation techniques, but cannot be reduced by the control techniques discussed in this search.

4.1 Results of Simulation

Table 2: Results of PID Controller Parameters

Close loop	Rise time	Settling time	Over shoot%	Peak amplitude	Steady state
P	0.281	3.78	48.5	1.48	1
PI	0.119	0.34	7.42	1.07	1
PD	0.189	0.85	10.6	1.11	1
PID	0.138	0.225	1.34	1.01	1

5. Conclusion

Finally in this paper and according to the simulations and experimental results, a comparison of these servo controllers is summarized in Table 3.Based on the comparison, the selection of servo-controllers for different machine tool contouring applications and cutting conditions is suggested in the following: The P controller works well only when cutting a contour on a machine with small friction, small cutting loads, small mismatch in axial parameters, and conventional feed rates (e.g., 0.25 m/min ~ 10 I p m).

The PID controller has good disturbance rejection ability and is more robust to mismatched axial parameters. Its drawbacks are poor tracking ability of nonlinear contours and sharp corners, and in addition, it may result in an overshoot at stopping. Therefore, the PID controller is preferred on low-speed machines. Usually, a deceleration is needed at the end of every contour segment in order to avoid the overshooting problem .However, this increases the total cutting time. A special algorithm can be utilized to perform corner tracking: the I component of the PID controller can be turned off before the corner. This, however, can cause undercut and contour errors because of the friction and other disturbances.

6. Recommendations

It is recommended to using adaptive control such as fuzzy logic , artificial neural networks and genetic algorithm (GA) to determine the optimal parameters of the PID controller for the desired system specifications (dc servo motor). It is recommended to processing other errors such as Geometric errors of machine components and structures and Errors induced by thermal distortions and Deflection errors caused by cutting forces these errors can be reduced by improving the mechanical hardware or utilizing compensation techniques, but cannot be reduced by the control techniques discussed in this paper.

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