# CONTROL STRATEGIES FOR CNC MACHINE TOOLS

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***Abstract*—Computer numerical machines (CNC) has been playing major role in manufacturing industries. Almost it has overcome many automated industries. Computer discovery makes its performance faster and easier for user. Various control techniques is used to control the performance of CNC machines. In ancient times, all the measurements were done by human operators which consists of different types of errors. To overcome the different types of human generated errors control techniques are applied to achieve the better response to get the maximum optimised performance. PID controller techniques is one method to implement with. Further modified form of PD controller is the method for implementation. Fuzzy controller is the method of implementation. In current trend, GENETIC ALGORITHM (GA) is applied to get the response faster and performance with minimum error due to less complex. In this paper, GA controller is linked with PD controller to achieve best outfit value for performance.***

***Keywords*—CNC machine, PD controller ,FUZZY controller ,GENETIC ALGORITHM**

## I. INTRODUCTION

This**CNC** (Computer Numerical Control) machine is developed from NC machine which was discovered by **JOHN T. PARSON** in between 1940s and 1950s.To meet our cultural and societal needs, our production parameters are being changed with effective manner to support advantages in technology over last hundred years[1].That decade was called mechanical era. There are two major portions of a typical CNC machines system, one is servo control and another is interpolator by which machine axial motor is coordinated[2].NC machines were based on G-code(Geometry code).For real time CNC system, always computational method is preferred[3].The operator measures all the three dimensions of object to send the command to NC machines to perform various operations.CNC machines are equipped with many features like interoperability, adaptability, agility and configurability and hence they are highly demanded for manufacturing industry, its main advantage is that it can communicate and exchange their data with latest technologies like CAD,CAM and CAPP[4].It became very helpful for war industry, aeronautics industry. CNC machines help to improve flexibility and productivity and we get perfect dimensional accuracy for parts produced, as we improve machine accuracy and select the good machining process, we get higher quality [5].

The first machine built was hardwired. CNC machine tools are used to produce gears which are mostly made of gears millers as a special tools, some tools examples are shank cutters, half-side milling cutters and ball end mills [6].

There are three basics category of current CNC diagnostics support i.e. start-up, on-line and off-line diagnostics, with the help of CNC machines diagnostics many advantages like optimizing service, repairing, decreasing idle time and reducing flaw can be achieved [7].In 1970s and 1980s, when computer and microprocessor era was started, then NC machines was linked with this latest technology, with computer. Currently, to design the CNC machines tool's appearance quickly, automotive generation system of intelligence algorithm is used as a common method, with this method designers become able to reduce the subjective mistakes, improve the success rate of design and reduce the design duration [8].CNC machines are automated devices where no human assistance is needed, it consists of coded information that goes to computer where it fabricates parts of industries in very precise and accurate manner[9]. It created a wide user interface for user, it was easier to understand the programme and performance with the help of monitor. Now NC machines can be operated by programs, G-code was not necessary to be used, now the it accepted the programming languages of its own, instructions can be given in computer languages. Now the system was connected with feedback system with computer where it can check the generating errors and performance can be enhanced due to overcome errors. The wrong instructions can be modified in computer programming.

## II. PROPOSED WORK

In this paper, we have designed a CNC system and after placing the numerical values of our all block elements, finally we have developed a transfer function. Now we are using here various techniques for control operations on CNC machine like PD CONTROLLER, FUZZY-PD CONTROLLER and GA CONTROLLER. The final response of these controllers are being recorded and analysed. On the basis of these observations, we compare the result and find out the best controller for our plant to achieve the performance faster and without any error generation. For PD controller, all tuning needs calculation and placing the value by user self which is very complex and difficult to resolve and hand tunings method is suitable for output response because it requires lots of value testing which is assigned by the user to perform. Therefore, we are using here performance index method in which there are some techniques to minimize our error i.e. MSE (Mean Square Error), IAE (Integrated Absolute Error), ISE(Integrated Square error), ITAE (Integrated Time weighted

Absolute Error) to optimise our CNC system. Further using FUZZY-PD controller, it enhances the response of system, further using GA controller with PD controller.

## III. SYSTEM MODELLING

In system modelling, our first aim is to design a CNC plant with the help of block diagram of control system block diagram having different machine parameters. The assumptions has been taken that lead skew becomes frictionless.

The block diagram of CNC machine tools is given below in fig3.1 [9]:

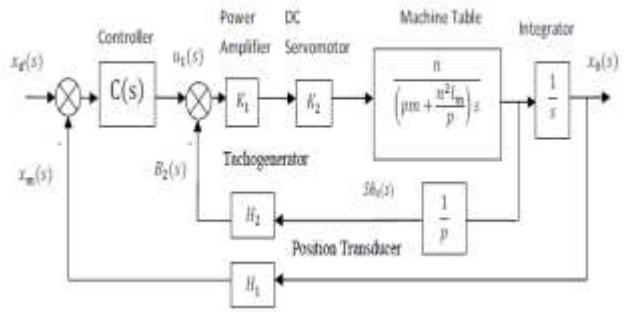



**Fig-3.1:** CNC machine circuit [9]

Let find out the output and input relation of transfer function in control system, the open loop transfer function is derived below in equations 1, 2 and 3 respectively,

$$G(s) = \frac{x_0(s)}{u_1(s)} = \frac{K_1 K_2 np}{(p^2 m + n^2 l_m)s^2 + K_1 K_2 n H_2 s} \dots\dots\dots 1$$

$$G(s) = \frac{x_0(s)}{u_1(s)} = \frac{\frac{K_1 K_2 np}{(p^2 m + n^2 l_m)}}{s^2 + \frac{K_1 K_2 n H_2}{(p^2 m + n^2 l_m)} s} \dots\dots\dots 2$$

Now, the numerical values placed for analysis is given below:

**Table-3.1** Value of Notation [9]

| Constant | Notation | Values |
|---|---|---|
| Power amplifier gain | $K_1$ | 2 V/V |
| DC Servomotor gain | $K_2$ | 4 Nm/V |
| Pitch of the lead screw | P | 0.05m |
| Gear ratio | N | 2:1 |
| Mass of work piece | M | 50 kg |
| Equivalent moment of inertia | $I_m$ | 0.01 kg$m^2$ |
| Feedback gains | $H_1$ & $H_2$ | Unity & 0.1 |

Placing the value from given table 3.1 in the derived equation no.2, finally the our CNC plant in the form of transfer function we get,

$$G(s) = \frac{x_0(s)}{u_1(s)} = \frac{4.484}{s^2 + 10.77s} \dots\dots\dots 3$$

As we have a plant's transfer function, we checked our plant output by giving some input when none of the mentioned controlling technique is applied. As we get our system output we may conclude that our output is not accurate and undetermined .There are high errors and distorted signals present in it hence this system is not optimized. By using various control techniques, we can improve our system response and error signal can be minimized so that we achieve faster and better response that is necessary for our plant to function precisely.

The block diagram of open loop response is given below:

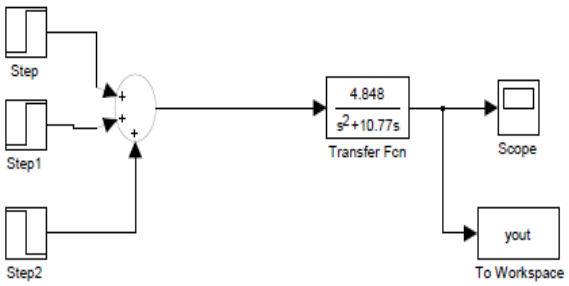



**Fig.3.2:** block diagram of open loop system

The open loop response of CNC plant is shown below:

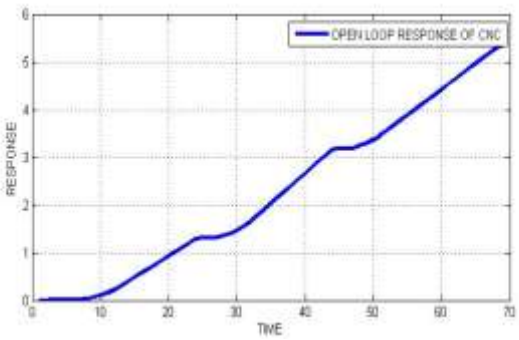



**Fig 3.3**: Open Loop Response of CNC machine System

## IV. CONTROL TECHNIQUES

### A) **PD Controller**

In this control strategy, we are applying proportional and derivative controller (PD controller) in our plant. Let us check our response characteristics. This controller consists of a feedback control system. Proportional gain increases the response of the system and derivative gain minimises the oscillations of the system such that it achieves the minimum settling time.

$$C(s) = K_{p+}K_d s \dots \dots \dots 4$$

The block diagram of PD controller is given below:

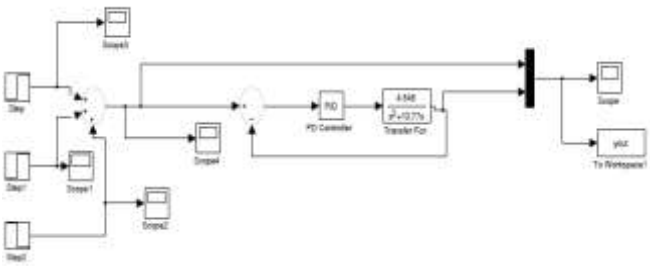
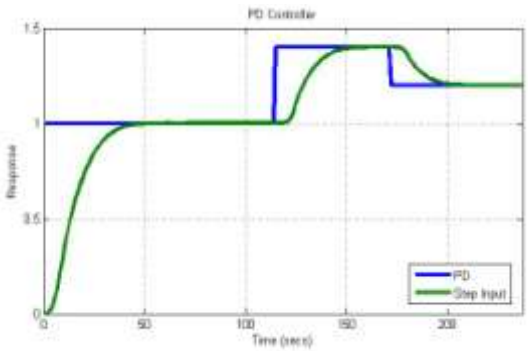


**Fig.4.1:** Block Diagram of System with PD Controller

The proportional-derivative controller response is shown below:




### B) **FUZZY-PD Controller**

As we can see in our previous technique that the response is getting away from our desired settling time that means it still has many errors so we are applying here PD controller with FUZZY interface. Proportional-integral-derivative is a feedback control system. Proportion gain increases the response of the system[11]. It makes response faster. The overshoot problem is minimised by increasing the integral value and the oscillations of the system is minimised by increasing derivative gain. The Fuzzy controller is designed in MATLAB tool, where the fuzzification, rule base, inference engine and defuzzificationis done.

The block diagram of FUZZY-PD controller is given below:

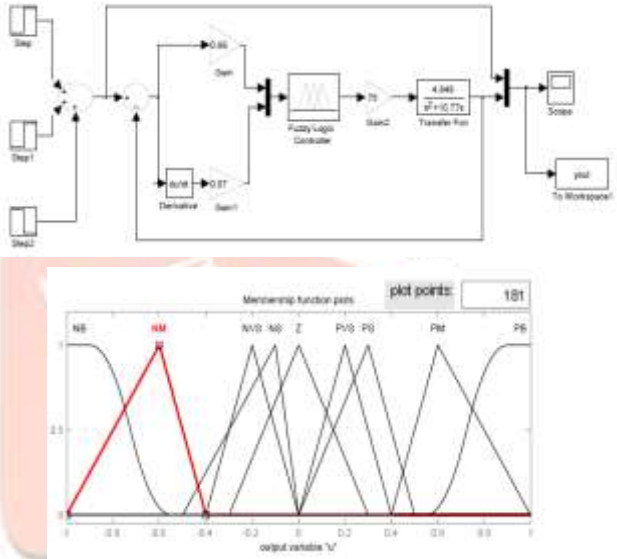



**Fig.4.3:** Block Diagram of System With Fuzzy-PD Controller.

The membership function diagram is given below:

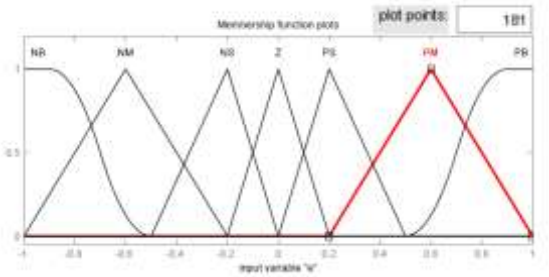



**Fig.4.4:** Figure Of Membership Function Of Input-Output

Fuzzy rule base abbreviations and their input and output limits are listed below in table 4.1,

**Table 4.1**:Fuzzy Rule Base Limit

| ABBREVIATIONS | FULL FORM | LIMITS OF MEMBERSHIP FUNCTIONS |
|---|---|---|
| **NB** | NEGATIVE BELOW | [-0.9,-0.5]**INPUT** [-0.9,-0.55] **OUTPUT** |
| **NM** | NEGATIVE MEDIUM | [-1,-0.6,-0.2]**INPUT** [-1,-0.6,-0.4] **OUTPUT** |
| **NS** | NEGATIVE SMALL | [-0.5,-0.25,0] **INPUT** [-0.5,-0.3,0] **OUTPUT** |
| **NVS** | NEGATIVE VERY SMALL | [-0.4,-0.2,0] **OUTPUT** |
| **Z** | ZERO | [-0.2,0,0.2]**INPUT** [-0.3,0,0.3] **OUTPUT** |
| **PB** | POSITIVE BELOW | [0.5,0.9]**INPUT** [0.55,0.9] **OUTPUT** |
| **PM** | POSITIVE MEDIUM | [0.2,0.6,1]**INPUT** [0.4,0.6,1] **OUTPUT** |
| **PS** | POSITIVE SMALL | [0,0.25,0.5]**INPUT** [0,0.3,0.5] **OUTPUT** |
| **PVS** | POSITIVE VERY SMALL | [0.0.2,0.4]**INPUT** |

The rule base table of these memberhip functions are drawn below in table 3,

**Table 4.2** Fuzzy Rule Base

| Ce / E | NB | NM | NS | Z | PS | PM | PB |
|---|---|---|---|---|---|---|---|
| **NB** | NB | NB | NB | NM | NS | NVS | Z |
| **NM** | NB | NB | NM | NS | NVS | Z | PVS |
| **NS** | NB | NM | NS | NVS | Z | PVS | PS |
| **Z** | NM | NS | NVS | Z | PVS | PS | PM |
| **PS** | NS | NVS | Z | PVS | PS | PM | PB |
| **PM** | NVS | Z | PVS | PS | PM | PB | PB |
| **PB** | Z | PVS | PS | PM | PB | PB | PB |

The response of FUZZY-PD controller is given below:

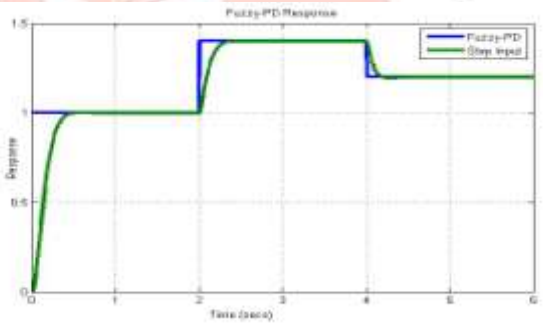



**Fig.4.5:** output response of Fuzzy-PD controller

C) **Genetic Algorithm-PD Controller**

As we can see that response is close to our input but still not perfect and containing many errors therefore in this technique, we are trying to minimise our errors and get our perfect response of our plant. Genetic algorithms are being used to search among different sets of chromosomes data and optimization techniques used on Darwin's principle[10] of natural selection basically, a population based search method, it is useful to solve the tough problem .It is based on the mechanise of biological evolution algorithms[13]. It has been widely used today in business, scientific & engineering circles[14].

Here we will get our value of P&D for genetic algorithm iterations and putting different values in our system and trying to get best optimum response.

The block diagram of GA controller is given below:

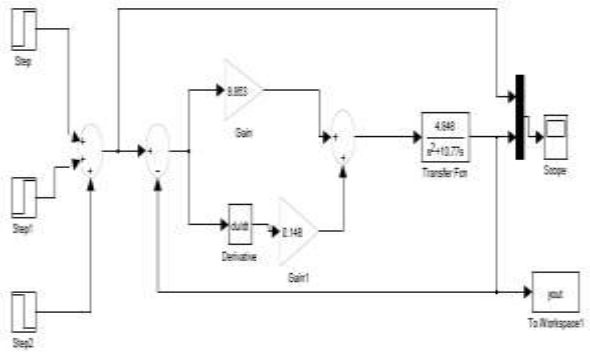



**Fig.4.5:** output response of Fuzzy-PD controller

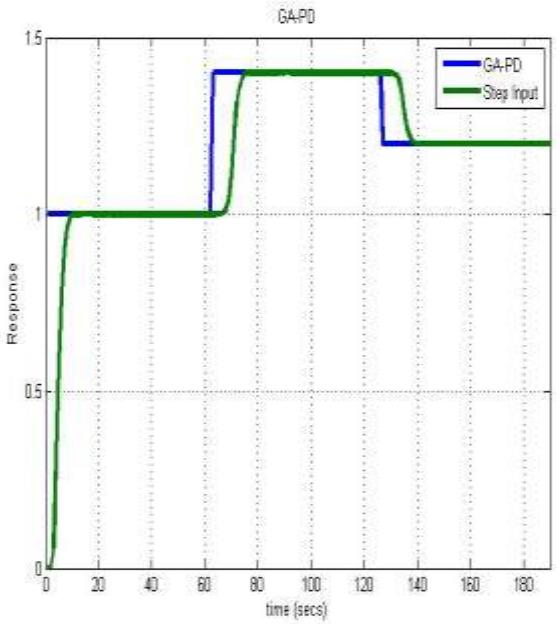



**Fig.4.7** Response of GA-PD controller

## V. CONCLUSION AND RESULT

**OBSERVATION TABLE:**

**MATLAB** has a command **[ yout-step info ]**,we find out the rise time, settling time and overshoot time for our PD controller, Fuzzy-PD controller and GA-PD controller respectively.

Where **'yout'** is calculated as below:

10 second = 336 values

1 value = [10/336] seconds……..5

Now multiplying these values with equation no.5, we get certain values which is listed below in the form of comparison in following table no. 5.1,

**Table 5.1** Comparison Analysis

| S. N | PARAMETERS | PD | FUZZY-PD | GA-PD |
|---|---|---|---|---|
| 1. | SETTLING TIME | **0.6901** | **0.3923** | **0.2787** |
| 2. | OVERSHOOT | **0.0000090** | **0.0001** | **0.00692** |
| 3. | RISE TIME | **0.3931** | **0.2382** | **0.1237** |

**RESULT:**

As we can see that using Genetic Algorithm our system achieves faster response and less settling time. It means that error has been minimized up to its lowest limit. Therefore if we compare our control strategies PD, FUZZY-PD and GA, then Genetic Algorithm is best among them.

As far as overshoot is concerned, **FUZZY-PD CONTROLLER HAS GIVEN THE BEST OUTPUT RESPONSE.** The choice of controller depends on the engineer based on the application.

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