"Design and Analysis of speed control of Bipolar Stepper Motor by using GA with PID Approach Technique"

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Abstract- A stepper motor (or step motor) is a brushless DCelectric motor that divides a full rotation into anumber of equal steps. A stepper motor is a good choice whenever controlled movement is required. Stepper motor is most commonly usedwhere there is a need to control rotation angle, speed, position and synchronism for variable speed drive application because of following advantages over DC drives that is; low maintenance cost, high efficiency; robust operation; and can be used in any environmental conditions.

In this work Stepper motor closed loop position control is being developed and Proportional Integral Derivative (PID) control is used to tunethe parameters of PID.There aretwo tuning method are used to evaluate the parameters of PID controller, first one is Ziegler-Nichols and other one is genetic Algorithm which tunes the parameters of PID. Tuned parameters give the optimum solution that gives converges to a solution having minimum error. Minimum error gives a response of the system in terms of maximum over shoot, Settling time, Rise time & Steady State Error. The designed PID with the Genetic Algorithm has much faster response than the classical method.

Keyword- Stepper Motor,PID,Ziegler–Nichols, Genetic Algorithms

I. INTRODUCTION

A stepper motor is a brushless dc motor that generates rotation in a particular angular increment when its stator coils are energized in a programmed manner. Rotation happens due to the magnetic interaction between poles of the sequentially energized stator windings and rotor poles. The rotor has no electrical coils, but has salient and magnetized poles. A stepper motor moves in steps, rather than rotating smoothly as a conventional motor. Increment size is calculated in mechanical degrees and depending on the system application, it can vary.

A stepper motor internal structure permits a very simple control system. Step motor has several special features that make it an ideal candidate for using as a positioning control device.

- Frequency is proportional to the Speed and the amount of rotation and number of the input pulses. So speed has a wide rotational range which can be achieved and accurate positioning is possible with small angular steps increment.
- Precise operation can be provided with open loop control because positional error is non-cumulative and the accuracy of a stepper motor is very high.
- Very reliable machine device.
- Device starting, stopping and reversing process are easy.

A. BASICS OF STEPPER MOTOR

A stepper motor is generally a brushless dc motor. The rotor of a stepper motor is composed of permanent magnets with poles and a stator with windings. The rotor is formed using a single magnet mounted in alignment with the rotor axis and two pole pieces with many teeth. The teeth are staggered to produce many salient poles. It is easy to use stepper motor for positioning and moves in step by step based on pulses which was supplied to the stator windings part. The direction of rotation can be changed by reversing the pulse sequence and speed is controlled by the frequency of pulses or pulse rate. As the rotor aligns with one of the stator poles, the second phase is energized. The two phases alternate on and off and also reverse polarity.

There are mainly four steps. One phase lags the other phase by one step. This is equivalent to one fourth of an electrical cycle or 90°. The angle of each rotational movement obviously depends on the rotor teeth and the number of stator of the stepper motor.The stepper motoris known by its important property to convert a train of input pulses (typically square wave pulses) into a precisely defined increment in the shaft position. Each pulse moves the shaft through a fixed angle. Steppermotors effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron.The electromagnets are energized by an external control circuit, such as a microcontroller. To make the motor shaft turn, first, one electromagnet is given power, which magnetically attracts the gear's teeth.When the gear's teeth are aligned to the first electromagnet, they are slightly offset from the next electromagnet.

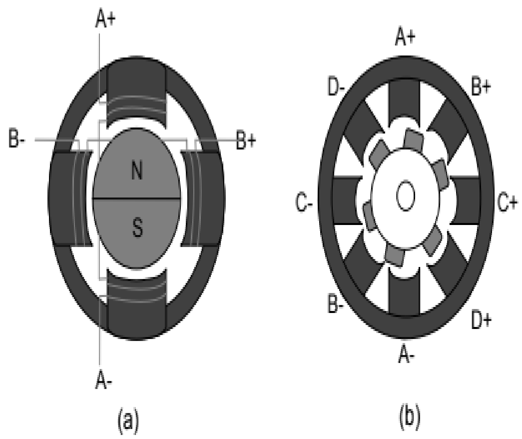

Fig.1: Stator and rotor design of stepper motors
(a) Two-phase Permanent-magnet (PM) stepper motor, and
(b) Four-phase Variable reluctance (VR) stepper motor

This means that when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one.From there the process is repeated. Each of those rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle In addition to being classified by their step angle stepper motors are also classified according to frame sizes which correspond to the diameter of the body ofthe motor.

B.TYPES OF STEPPER MOTOR

The operating principle of stepper motor is very simple as the rotor rest position adjusts with a fixed angle rotation by using excitation switches from one section to any other. This is the basic concept for all the types of stepper motor. However based on the machine structure and operation principle stepper motor has three types. These are:

i. Variable Reluctance Motor (VRM)
ii. Permanent Magnet Stepper Motor (PMSM)
iii. Hybrid Stepper Motor (HSM)

C.TWO PHASE STEPPER MOTOR

There are two basic winding arrangements for theelectromagnetic coils in a two phase stepper motor:Unipolar and Bipolar

Unipolar Stepper Motor

The unipolar stepper motor has five or six wires and four coils (actually two coils divided by center connections on each coil). The center connections of the coils are tied together and used as the power connection. They are called unipolar steppers because power always comes in on this one pole.

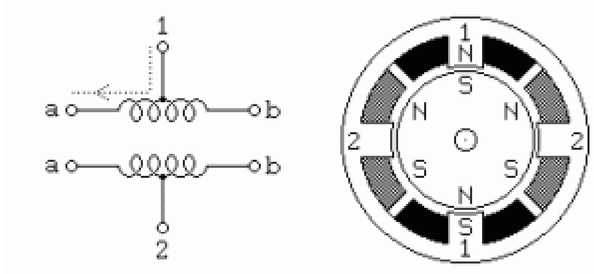

Fig.2: Schematic and Pin diagram of the unipolar stepper motor

Bipolar Stepper Motor

Bipolar steppers have no common center connection. The motor usually has four wires coming out of it. It has two other independent sets of coils. These two coils mainly distinguish them fromunipolar steppers which are cable of measuring the resistance between the wires and two pairs of wires are of equal resistance.

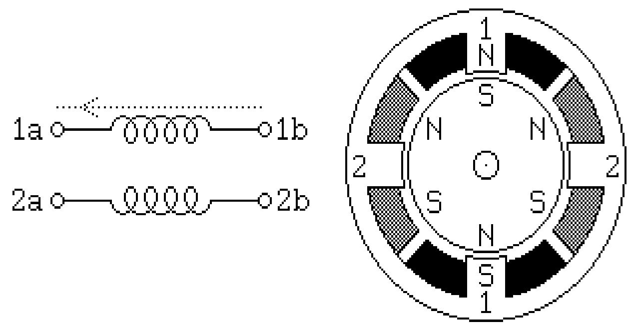

Fig.3: Schematic and Pin diagram of the bipolar stepper motor

D.HYBRID METHOD PID &GENETIC ALGORITHM

PID control strategy is a regular feedback controlling technology and it covers 90% of regular controllers in engineering sector. The function of the controller is to implement an algorithm based on the control input and therefore output is maintained at certain point to make negligible discrepancy between the system method variable and the setpoint.Proper functioning of a system highly depends on PID parameters, so they should be optimized and tuned wisely. Many standard methods are introduced for parameter tuning includes Ziegler-Nichols Ultimate-cycle tuning. In addition to this motor drive should also follow real time load change. Proportional-Integral Derivative (PID) controllers because of their easy and good controlling performance are used for this purpose. Conventional methods like Ziegler-Nichols, frequency domain and Time domain approaches of tuning PID for agiven control system have their certain limitations. Therefore, this paper develops a design using Genetic Algorithm (G.A) in MATLAB tool box.

A genetic algorithm (G.A) is an experimental quest or search model that is motivated by Charles Darwin's theory of natural evolution. This algorithm has a set of rules that gives the information of natural process of selection in which the best or fittest entities are designated work of reproduction to produce new offspring for the next generation.By using genetic algorithms for tuning the controller will provide the best and most optimized result for the given control system when being evaluated every time. The main objective of this research is to reveal that when GA is employed for tuning purpose to any system , an optimized tuning parameter values can be realized.

II. METHODS USED

1. TUNING OF PID CONTROLLER USING CONVENTIONAL APPROACH

Ziegler–Nichols step response method for PID control

A Conventional approach is used to tune the parameters of PID. As shown in Fig 4, the parameters are obtained by using SISO tool in MATLAB. Because of the widespread use of PID control it is highly desirable to have efficient manual and automatic methods of tuning the controllers.A good insight into PID tuning is also useful in developing more schemes for automatic tuning and loop assessment. Practically all books on process control have a chapter on tuning of PID controllers. The Ziegler–Nichols rules for tuning PID controller have been very influential.

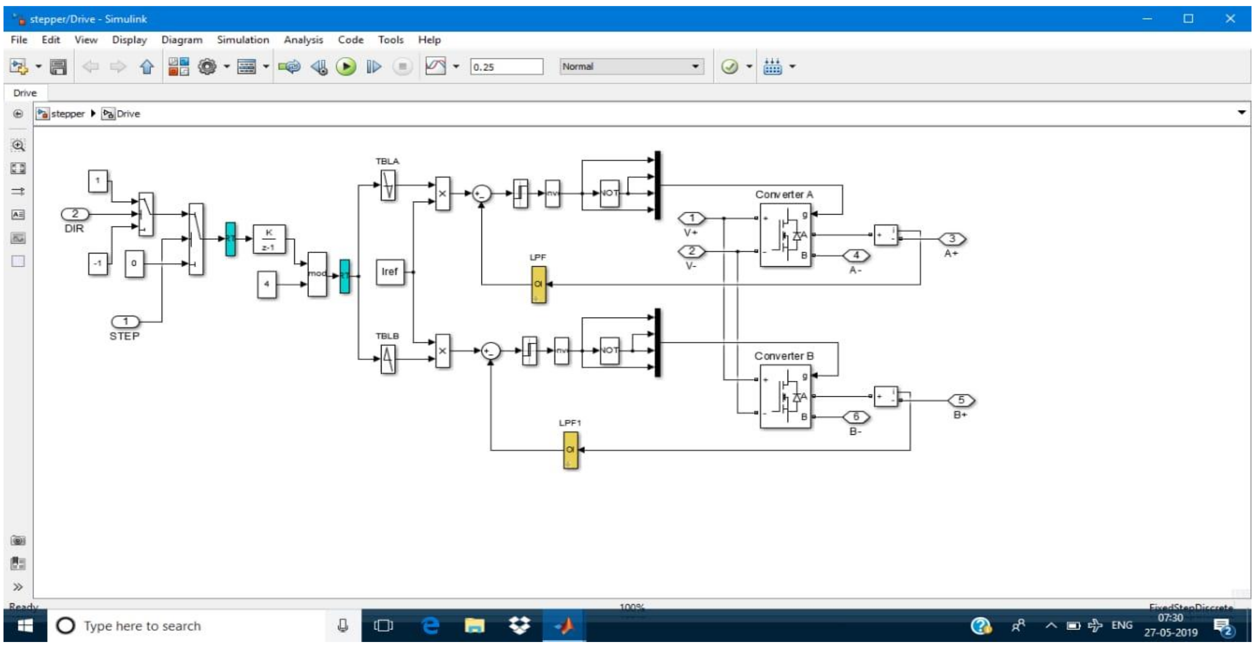

Fig.4: MATLAB model of Stepper Motor Drive

The rules do, however, have severe drawbacks, they use insufficient process information and the design criterion gives closed loop systems with poor robustness [1]. Ziegler and Nichols presented two methods, a step response method and a frequency response method. In this paper we willinvestigate the step response method.

2. OPTIMIZATION TECHNIQUES WITH STEPPER MOTOR

In mathematics, optimization is the selection of a best element under some constraints from some set of available solutions. Optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. The generalization of optimization theory and techniques to other formulations comprises a large area of applied mathematics. More generally, optimization includes finding "best available" values of some objective function given a defined domain or a set of constraints.

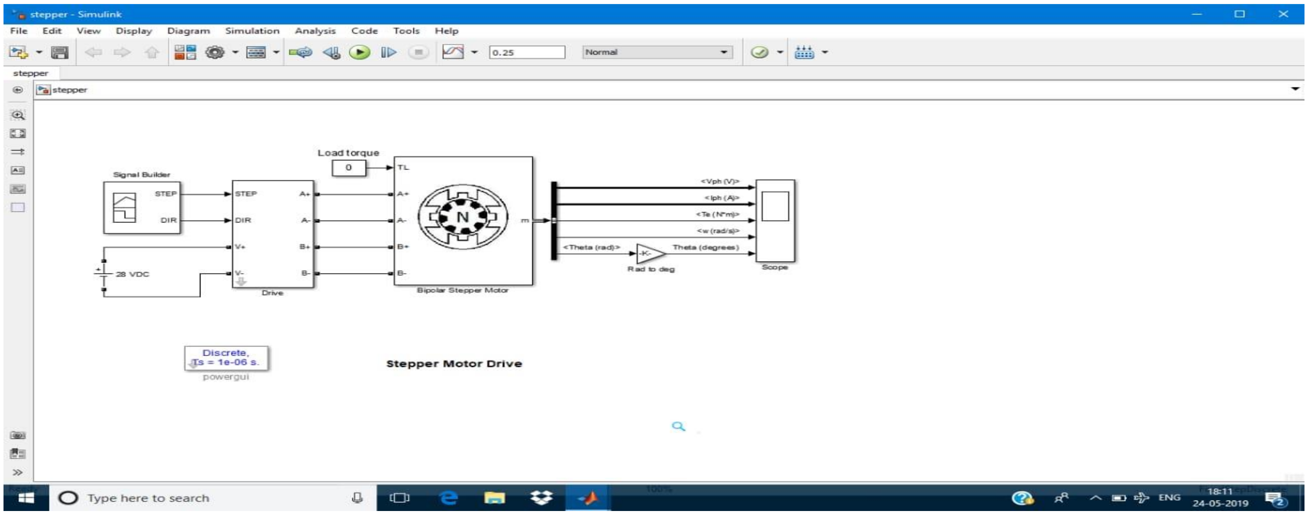

Fig.5: Optimization Techniques with Stepper Motor

3.CLASSICAL OPTIMIZATION TECHNIQUES

The classical optimization techniques are useful in finding the optimum solution or unconstrained maxima or minima of continuous and differentiable functions. These are analytical methods and make use of differential calculus in locating the optimum solution. The classical methods have limited scope in practical applications as some of them involve objective functions which are not continuous and/or differentiable. Yet, the study of these classical techniques of optimization form a basis for developing most of the numerical techniques that have evolved into advanced techniques more suitable for today's practical problems.

III. GENETIC ALGORITHM

A genetic algorithm is a search technique used to find approximate solution to optimization and search problem. Genetic algorithm is a particular class of evolutionary algorithm that use technique inspired by evolutionary biology such as inheritance, mutation, crossover and selection. The evolution starts from a population of completely random individuals and occurs in generations. In each generation, the fitness of the whole population is evaluated. Multiple individuals are stochastically selected from the current population, and modified to form a new population. The new population is then used in the next iteration of the algorithm.

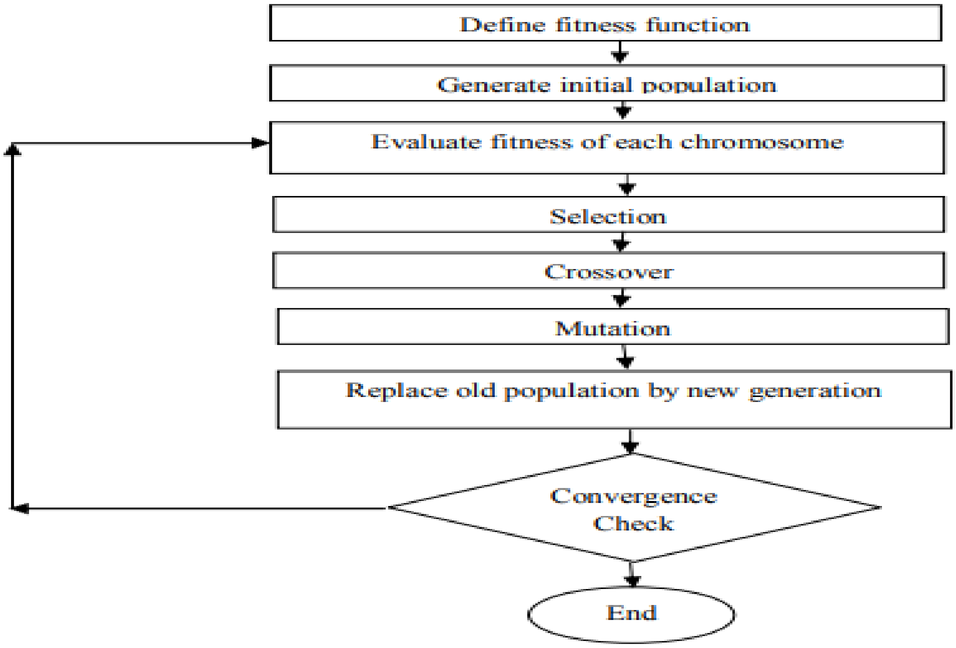

Fig.6: Flow chart for GA

1. WORKING PRINCIPLE OF GENETIC ALGORITHM

Genetic algorithm maintains a population of individuals, say P (t), for generation t. Each individual represents a potential solution to the problem at hand. Each individual is evaluated to give some measure of its fitness. Some individuals undergo stochastic transformations by means of genetic operations to form new individuals. There are three steps:-

1. Selection, which selects the best chromosomes according to their fitness values.
2. Crossover, which creates new individuals by combining parts from two individuals. A new population is formed by selecting the more fit individuals from the parent population and offspring population.

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3. Mutation, which creates new individuals by making changes in a single individual.

After several generations, genetic algorithm converges to the best individual, which hopefully represents an optimal or suboptimal solution to the problem.

IV. RESULTS

In this work design and analysis of speed control of bipolar stepper motor is done by using Genetic algorithm with PID approach. The model of stepper motor drive is discussed above gives the following results.

These graphs represents the phase voltage (V_{ph}), Phase current (I_{ph}), Torque Vs Time and the Angular frequency based outputs

Fig.7: output wave-forms of stepper motor drive

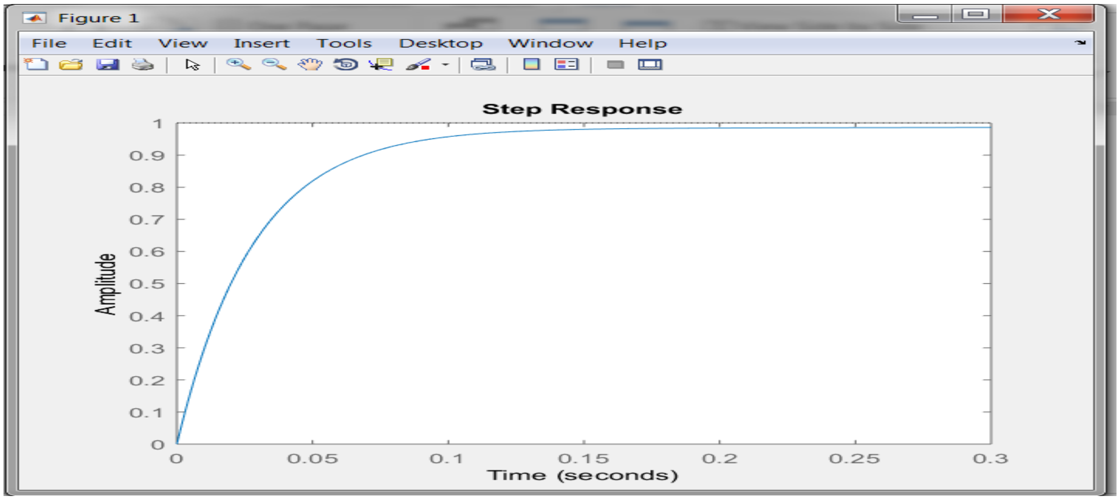

Fig.8: Ziegler–Nichols step response for PID control

2. GA RESULTS

The procedure described in the previous sections has been applied to the design helical gear pair. It presents an approach for combining mechanical component design models with non-traditional optimization techniques namely Genetic algorithms and Fmincon procedures. It is shown that the problem may be posed as a non-linear optimization problem, wherein the fitness function changes over successive generations. Results are presented for the optimal design problem of a helical gear set, where its volume as the objective functions is subjected to constraints.

The results recorded after implementing the optimization process on the input data.

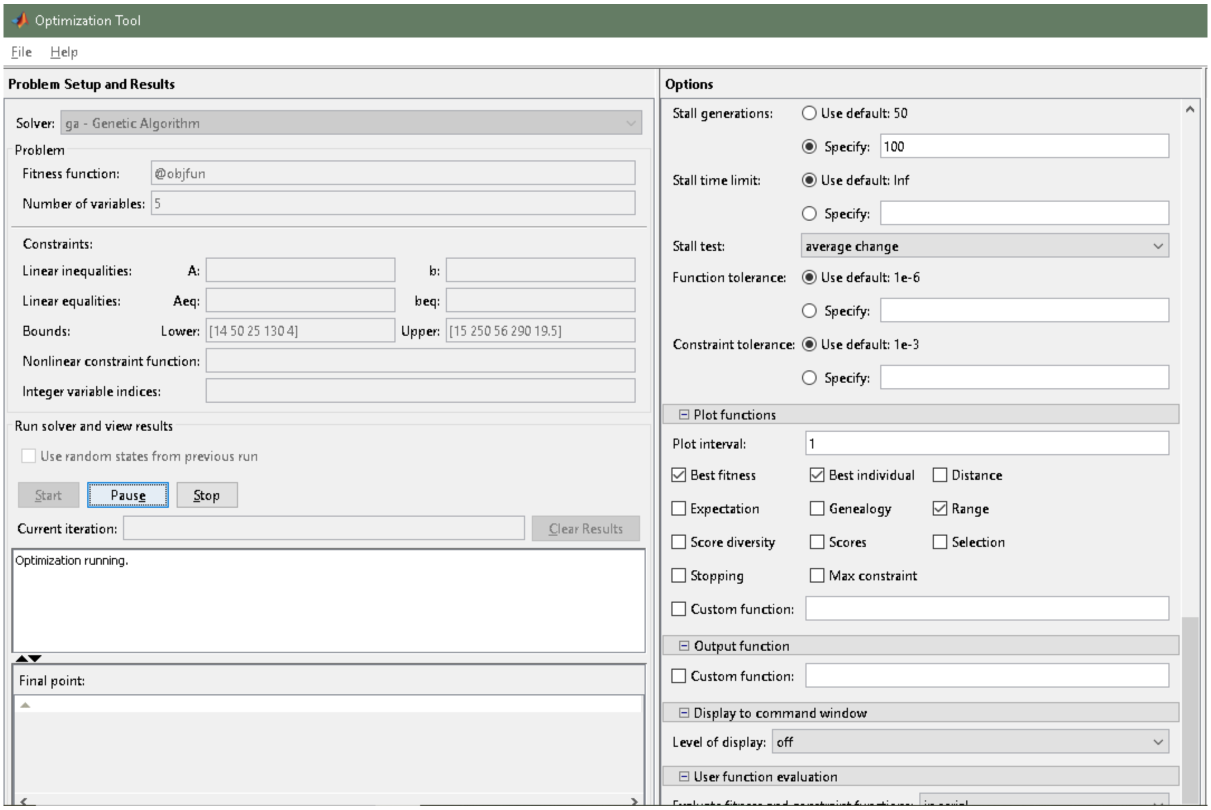

Fig.9: GA implementation

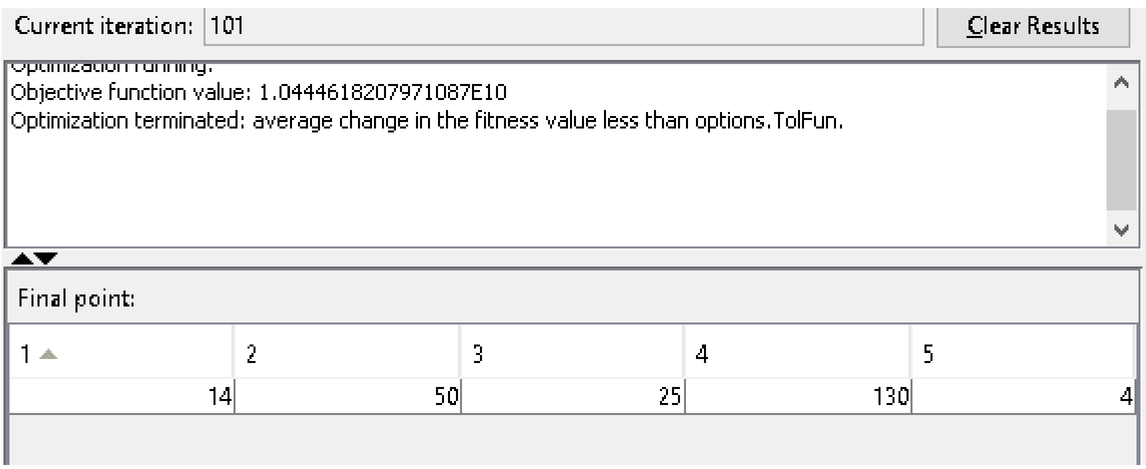

Fig.10: Optimised results at 100 iteration

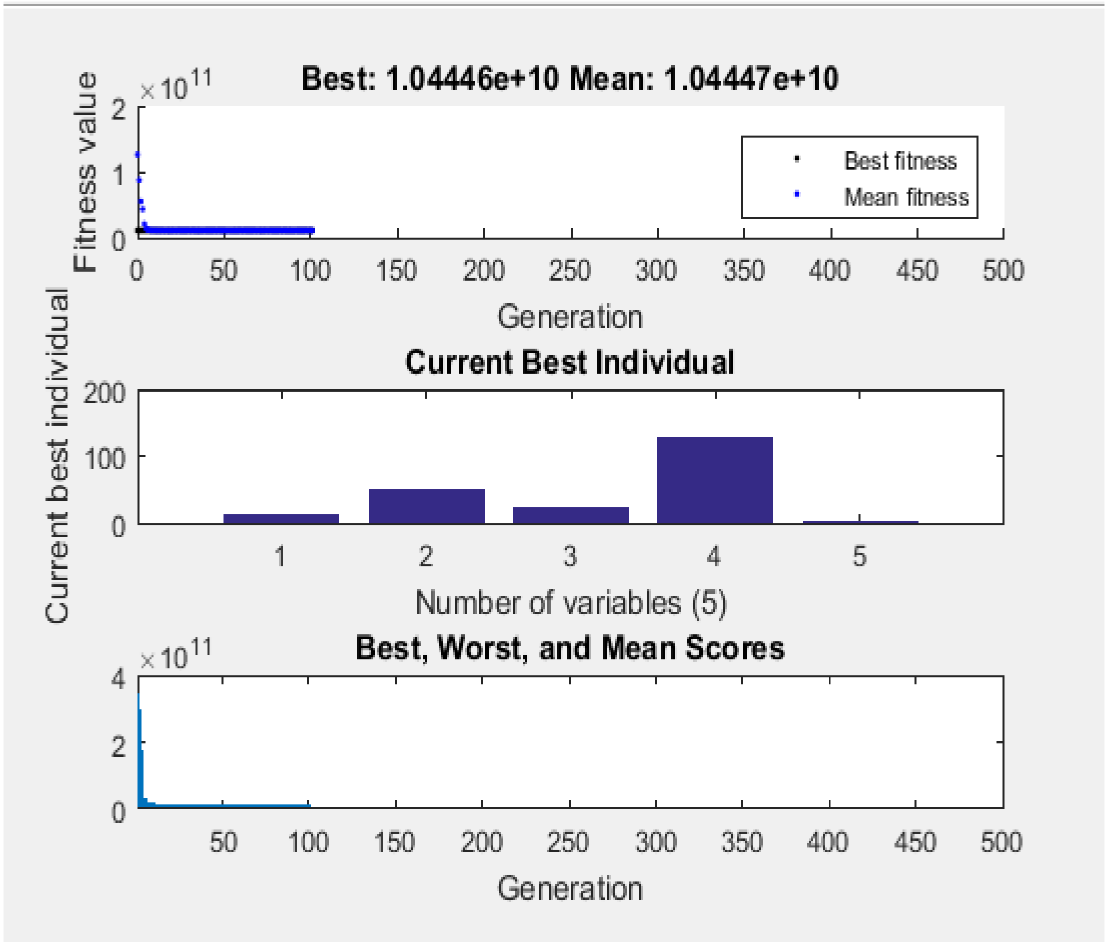

Fig.11: Function value at 100 iteration

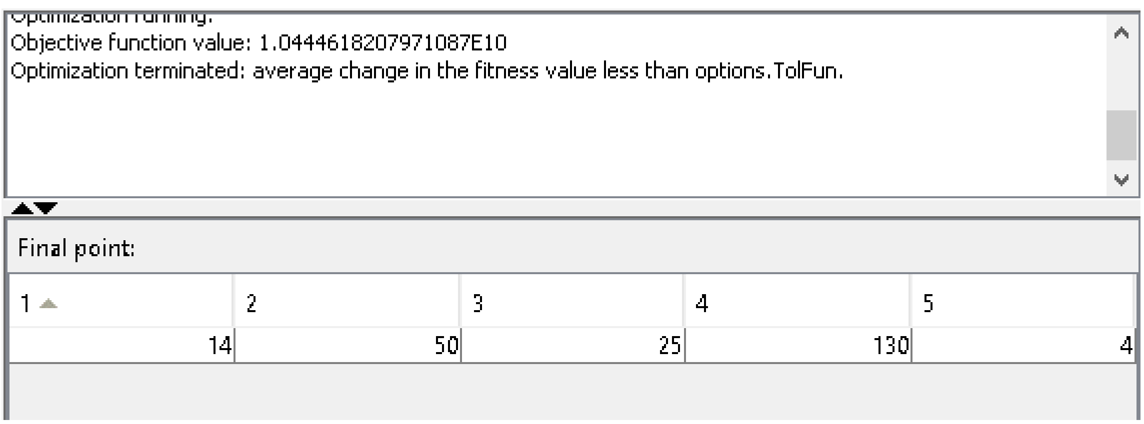

Fig.12: Optimised results at 200 iteration

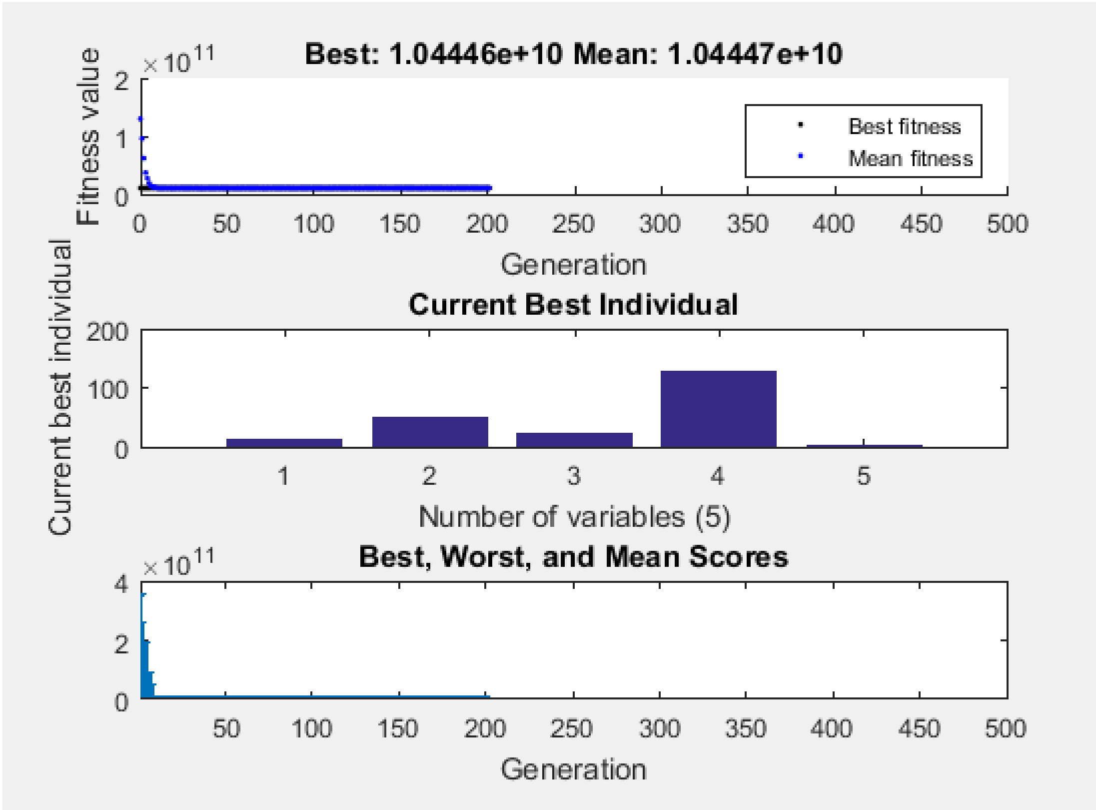

Fig.13: Function value at 200 iteration

V. CONCLUSION

In this work the bipolar stepper motor is analysed with a brief discussion and desired control process.PID controllers can work surprisingly well, especially considering how little information is provided for the design. The satisfactory results is produced by PID tuning procedures that presents an approach for combining mechanical component design models with non-traditional optimization techniques namely Genetic algorithms and Fmincon procedures. It is shown that the problem may be posed as a non-linear optimization problem, wherein the fitness function changes over successive generations. Results are presented for the optimal design. The design of stepper motor drive circuit for position controlling is done by using MATLABalso the optimization technique the MATLAB program for GA has been run on i7 Intel(R) Core(TM) processor with 4 GB RAM and 64-bit operating system.

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