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DC Motor Angular Position Control using PID Controller for the porpuse of controlling the Hydraulic Pump

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***Abstract*— In this paper, presents PID controller is applied for control the angular position of dc motor connected to a valve of a hydraulic pump . The valve open and close in a limited range not 360 degree. C code for the PID controller run on atmeaga16 microcontroller. The parameters of a standard PID controller for the dc motor position control system under the investigation is tuned and fixed throughout the control. The results of experiment on the real plant demonstrate that the PID controller is a good choice to suppress the oscillation due to the system and sensors nonlinearity.**

***Keywords*— DC Motor , PID controller, position control, hydraulic pump, robot**

I. Introduction

In this paper, a PID controller design for a DC motor angular position control that open and close a hydraulic pump on an all-terrain vehicle (ATV) is presented.

DC motor angular position systems are usually controlled by proportional integral- derivative (PID) control algorithms with PID coefficients tuned for optimizing operation. The objective of a PID controller in a position control system is to maintain a position set point at a given value and be able to accept new set-point values dynamically. Modern position control environments require controllers that are able to cope with parameter variations and system uncertainties.

To implement a PID controller the proportional gain KP, the integral gain KI and the derivative gain KD must be determined carefully. controlling the DC motor without using the PID controller will give some oscillation in the signal and because the system is nonlinear, controlling by function is the best way to control the nonlinear systems and PID controller is the best choice to achieve this task. Tow DC motors will control the Tow hydraulic pump valves which rotating in limited angle not 360 degree but between certain value. This system mounted on an all-terrain vehicle (ATV) to drive 8 which will describe in detail in the next section. for the system of a hydraulic pump and its valve return spring special torque should be apply from the motor to overcome the valve resistance and has be done by controlling the motor speed. The more motor speed the less torque the less motor speed the more torque .controlling speed has done by using PWM (pulse width modulation) all of this written in c code using avr studio and load it to the atmega16 microcontroller.

II. System Description

DORIS robot (dual media Outdoor Robot Intelligent System) as shown in figure 1, is a research project of the Institute for Real-Time Learning Systems in Siegen university. It is an autonomous acting vehicle for outdoor use under the most difficult conditions. It consists of many subsystems like gas control system ,break control system , steering control system , security system and power train control system which will be the research task ,the hydraulic power train system which drive the wheel forward and backward driven by tow hydraulic pumps one for left and one for right side controlled by two 12V DC motor as shown in figure 2. by rotating the pump valve clockwise allow to drive the wheel forward and rotating the pump valve counter clockwise allow to drive the wheel backward. Two potentiometers connected to the two motors as shown in figure 2 to detect the angular position and send the signal to the atmeaga16 microcontroller to process it and correct the error figure 3 .
a sliding potentiometer used to send the input signal to the atmega16 microcontroller figure 3.

Fig. 1. DORIS robot

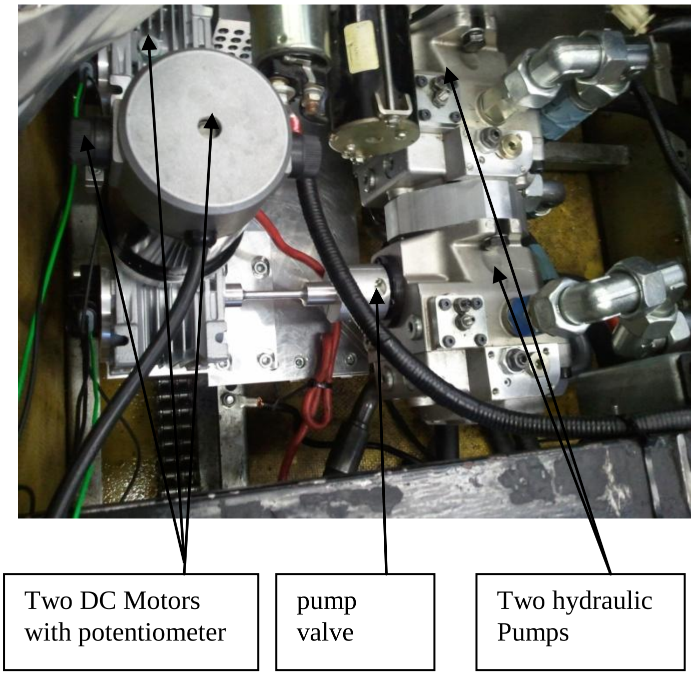

Fig. 2. DC Motors and the Hydraulic pumps

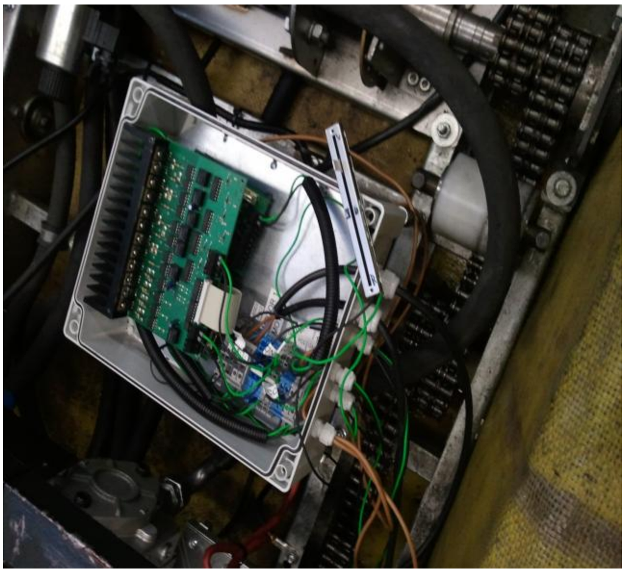

Fig. 3. microcontroller board

III. SYSTEM MATHMATICAL MODEL

As reference we consider a DC motor as shown in figure 4. A simple mathematical relationship between the shaft angular position and voltage input to the DC motor may be derived from physical laws. In the point of control system, DC servo motor can be considered as SISO plant Therefore, complications related to multi-input system

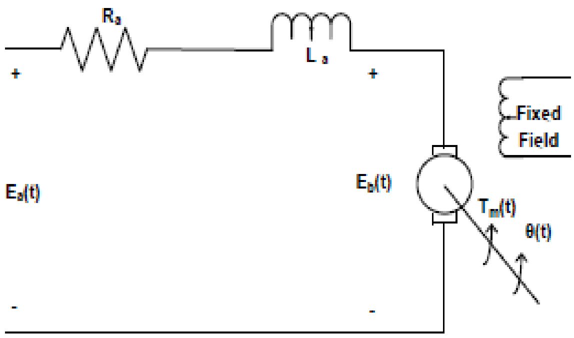

Fig. 4. Schematic Diagram of a DC Motor

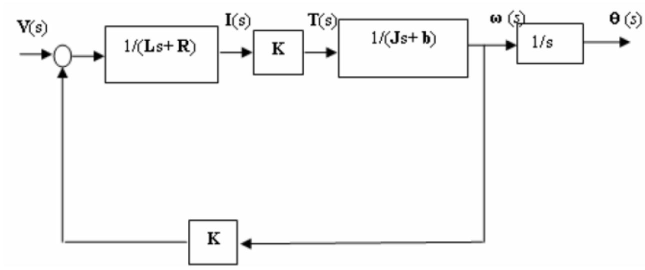

Fig. 5. Block Diagram representation of a DC motor

are discarded. DC servo motors have the field coil in parallel with the armature. The current in the field coil and the armature are independent of one another. As a result, these motors have excellent speed and position. The dynamic behaviour of the DC motor is given by the following equations [1], and can be represented by the block diagram as shown in figure 5.

$$E_a(s) = R_a I_a(s) + L_a s\, I_a(s) + E_a(s)$$

$$T_m(s) = K_t I_a$$

$$E_b(s) = K_b\, s\, \theta(s)$$

$$T_m(s) = (J_m s^2 + D_m s)\theta(s)$$

where,
Ra=Armature resistance in ohm
La=Armature inductance in Henry
ia=Armature current in ampere
ea=Armature voltage in volts
eb=Back EMF in volts
Kb=Back EMF constant in volt/(rad/sec)
Kt=Torque constant in N-m/Ampere

Tm=Torque developed by the motor in N-m
θ(t)=Angular displacement of shaft in radians
J=Moment of inertia of the motor and load in K:gm^2/rad
Dm=Frictional constant of motor and load in Nm/(rad/sec).

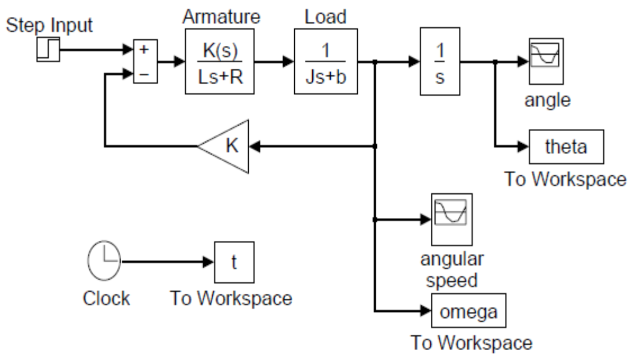

Fig. 6. simulink Block Diagram

After simplification and taking the ratio of $\frac{\theta(s)}{E_a(s)}$ the transfer function will be as below [2],

$$G(s) = \frac{k}{((Js+b)(Ls+R)+K^2*s} \quad (1)$$

with j=0.01 ,b=0.1,l=0.5,R=1,k=0.01 [6] the transfer function will be

$$G(s) = \frac{0.01}{(0.005s^2+0.06s+0.1)} * \frac{1}{s} \quad [2]$$

IV. PID CONTROLLER

Proportional-integral-derivative (PID) controllers [2] are widely used in industrial control systems because of the reduced number of parameters to be tuned. They provide control signals that are proportional to the error between the reference signal and the actual output (proportional action), to the integral of the error (integral action), and to the derivative of the error (derivative action), namely

$$U(t) = K_p\left[e(t) + \frac{1}{T_i}\int_0^t e(\tau)\,d\tau + T_d\frac{d}{dt}e(t)\right] (2)$$

Where u(t) and e(t) denote the control and the error signals respectively, and Kp, 'Ii and Td are the parameters to be tuned. The corresponding transfer function is given as

$$U(s) = K_p\left[1 + \frac{1}{T_i(s)} + T_d\,(s)\right] \quad (3)$$

These functions have been enough to the most control processes. Because the structure of PID controller is simple, it is the most extensive control method to be used in industry so far. The PID controller is mainly to adjust an appropriate proportional gain (K p), integral gain (K I), and differential gain (KD) to achieve the optimal control performance. The PID controller system block diagram of this paper is shown in

Figure 7and the simulink block diagram for the system shown in figure 6 [5]and the block diagram result shows in figure 16.Transfer function can also be expressed as[1]

$$K(s) = \frac{U(s)}{E(s)} = K_p + \frac{K_i}{s} + K_d\,S \quad (4)$$

The main features of PID controllers are the capacity to eliminate steady-state error of the response to a step reference signal (because of integral action) and the ability to anticipate output changes (when derivative action is employed
Tuning the PID controller achieved experimental on the plant .a lot of experiment has done till getting the best result for Kp , Kd and Ki.

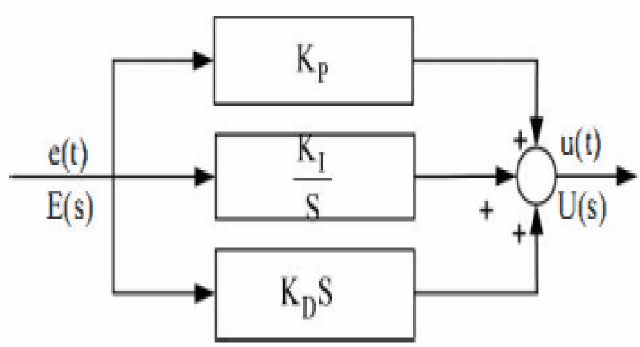

Fig. 7. PID Controller Block Diagram.

and to overcome the effect of the valve torque and according to the relationship between the torque and the motor speed we give a small rotating speed(RPM) by adjusting the OCR (output compare register) in the atmega16 microcontroller to be equal to the desired value.

V. EXPERIMENTAL RESULTS

The experimental results of the proposed position controlled system and comparing the satisfied results obtained. It can observe that the response to the input signal is fast with small error and damped oscillation figure 9. the overshoot of the propose position controlled system is smaller than the overshoot by using a system without PID controller figure 10.

Using of kp= 0.06, kd= 0.02andki= 0.02 will not give a good result with a big error in the beginning figure 13 and by connecting the DC Motor to the pump valve the resistance from the pump valve return spring give an error in the beginning for some millisecond and then be constant figure 14. with several input signal for the DC Motor connected to the hydraulic pump shows also the effect of the valve return spring and the changing from an angle to the other angle takes around 215ms and the step from on sample to the next step is 21.5 microsecond according to the sample rate from signal 1 to signal 2 as shown in figure 12.and the best PID parameters choice that achieved experimentally seen in figure 15 and simulated as in figure 16 with the same parameters .

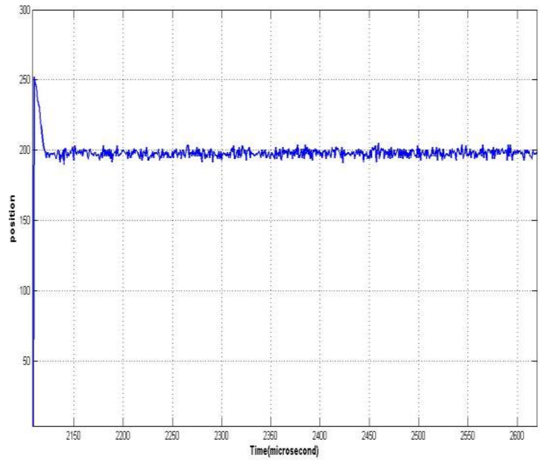

Fig. 9. the response to the input signal

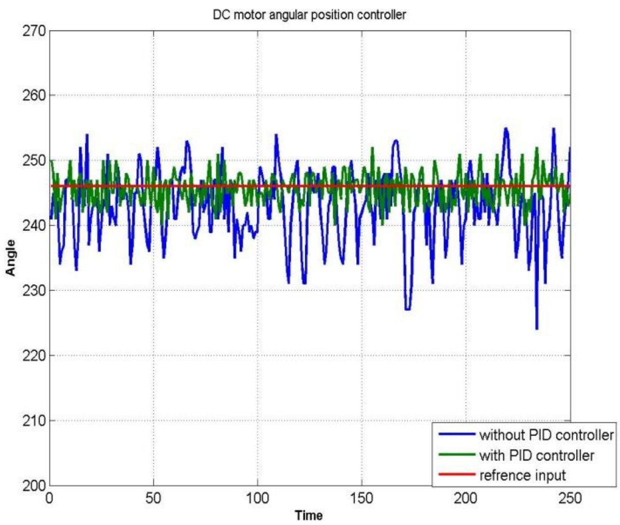

Fig. 10. the system with and without PID

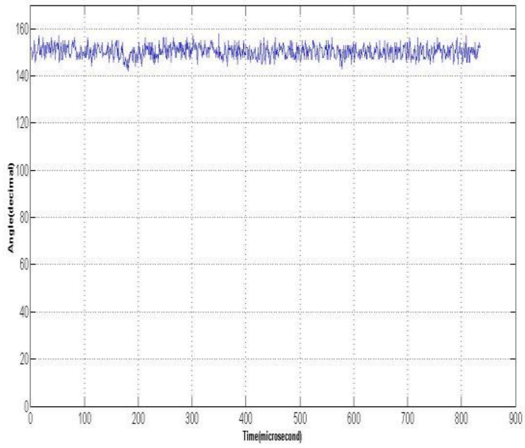

Fig. 11. kp=0.05,kd=0.01,ki=0.01

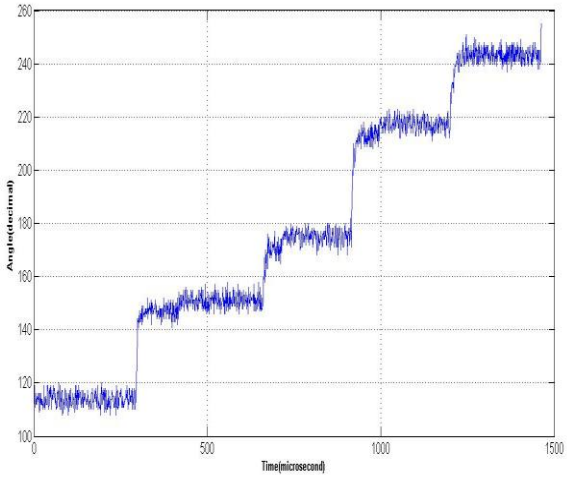

Fig. 12. with several input signal

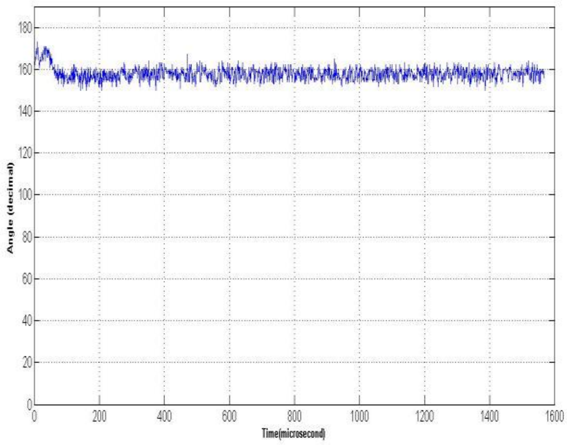

Fig. 13. kp=0.06,kd=0.02,ki=0,02

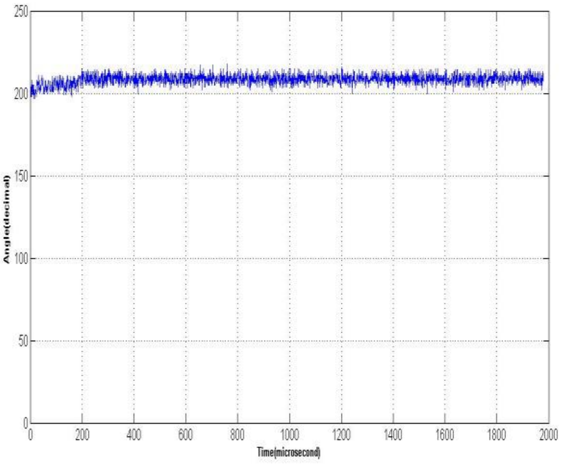

Fig. 14. DC Motor connected to the hydraulic pump

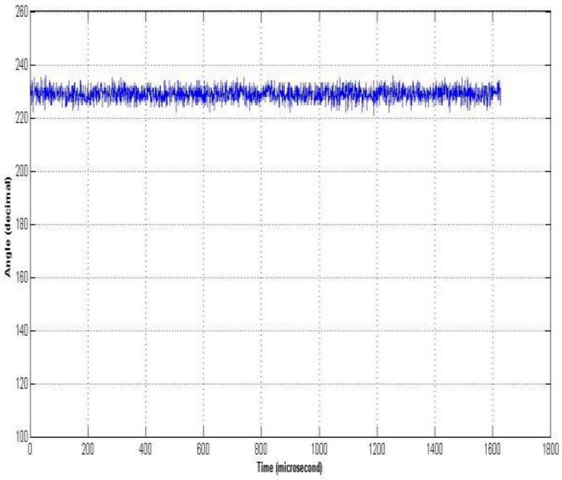

Fig. 15. kp=0.05,kd=0.01,ki=0

VI. CONCOLUSION

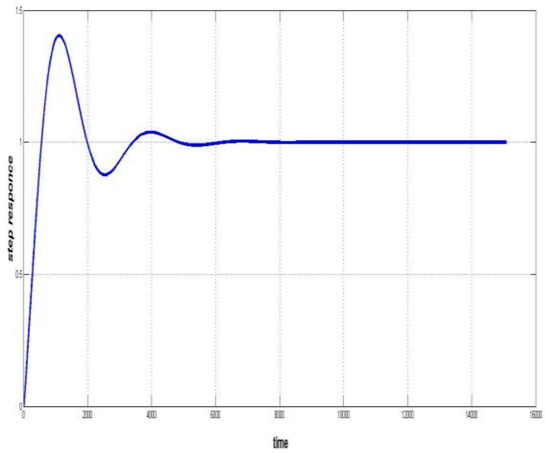

Fig. 16 simulated dc motor with PID controller

In this research, a PID control system for DC Motor angular position was proposed this controller has an advantage in both noise reduction and oscillation reduction and the control system runs well, and has a good system response.

VII. DC MOTOR PARAMETERS

parameters	Motor 1	Motor2	unit
Rotor inertia	52	52	gcm2
Terminal resistance	1.8	1.8	Ohm
Inductance	2.4	2.4	mH
Mech. time constant	15	15	ms
Electr. time constant	1.3	1.3	ms
Speed regulation constant	300	300	rpm/Ncm
Torque constant	2.45	2.45	Ncm/A
Thermal resistance	16	16	K/W
Thermal time constant	10	10	min
Axial play	< 0.01	< 0.01	mm

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