

Investigation of the Performance of PID Control Scheme for Linear Conveyor System of Manufacturing Shopfloor

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ABSTRACT – Conveyor systems have been utilized widely in the manufacturing shop floor as well as in the production line. It is ideals in enhancing productivity and maximizes the operation of a warehouse. However, the performance of the conveyor system can be influenced by a controller as well as the DC motor itself in providing the best response. Therefore, this paper will discuss the performance of the conveyor system that applied PID controller tuned by the Ziegler-Nichols tuning method. To validate the performance of the proposed controller and tuning method on the conveyor system, it will be compared with the DC motor without implement any controller as well as tested onto the prototype of the linear conveyor system. Performances from both different conditions of conveyor system will be evaluated in terms of transient response that are, rise time, settling time and time constant for the simulation part that will be done in MATLAB/Simulink software while position and time will be the other characteristics in evaluating the performance by using the hardware. At the end of the study, by considering both simulation and experimental results, the DC motor with a PID controller shows a better performance for the conveyor system compared to the DC motor without applying any controller.

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INTRODUCTION

In this generation, there are a lot of controllers that are usually implemented in the industry. A controller is important and responsible for the control system. There are two types of control systems open-loop and closed-loop systems [1-2]. The specification of a good control system is an increased accuracy for any error, sensitivity to the input, and a small or constant oscillation of output can be stable to the systems. The uses of the controller can enhance steady-state accuracy. It works as a device that maintains the value of the regulated variable at a set point. A proportional integral derivative controller (PID) is usually used in industrial control applications. To develop intricate automatic systems utilized for energy generation, transportation, and manufacturing, PID controller is frequently integrated with logic, sequential machines, selectors, and basic function blocks [3]. The PID controller is used in feedback control that uses data from the measurement. Feedback control has two main types which are positive feedback to increment the size of the input and negative feedback to reduce the size of the input [4].

This controller uses control loop feedback the most precise and stable controller to keep the setpoint output as possible. Besides, the first system component is an actuator to convert hydraulic, pneumatic, or electric energy into mechanical motion. The electric motor is the type of actuator and is classified as either AC or DC motor. AC motors have more advantages than DC motors. AC motors are more consistent but DC motors also have their specification which has the speed-control capability, even their direction of rotation able to be changed at any time [5-6].

A conveyor system that is highly automated in manufacturing factories for assembly's transport material from one place to another [7]. Many types of conveyor frames can support the product to move from one place to another which is belt, wheels, or rollers. Referring to [8], the authors mentioned that this conveyor system can help the warehouse or the manufacturing factories in enhancing productivity as well as maximizing operations.

A belt conveyor is one of the types of conveyor systems that are commonly being used due to its great efficiency and enormous conveying capacity, as well as its simple construction and low maintenance requirements [9]. The belt is very versatile that is a common type of conveyor. In belt conveyor systems, a few important parts of the system are belts, motors, as well as pulleys [10]. There are three items that important in choosing a belt which is size, the weight of the product, and its shape. The coefficients of friction of the belt can remain low. The advantage of the belt is a long distance can be more economical [11]. The electric motor is included for moving the conveyor.

The main goal of this paper is to examine the performance of the DC motor on a linear conveyor system by implementing a controller that is a PID controller where the parameters were tuned by the Ziegler-Nichols method. Then, to justify the performance of the proposed controller and tuned method, it will be compared with the DC motor without any controller and tested on the prototype of the linear conveyor system.

METHODOLOGY

DC motor transfer function analysis

A standard test model is considered for the DC motor analysis with the Z-N tuning controller. DC motor driving an inertia load block diagram shows in Figure 1 below.

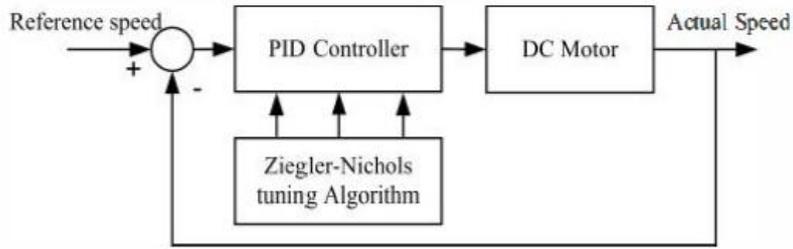


Figure 1. DC motor control system block diagram.

Figure 2 shows the Simulink of the model of the DC motor. The parameters of the DC motor are shown in Table 1.

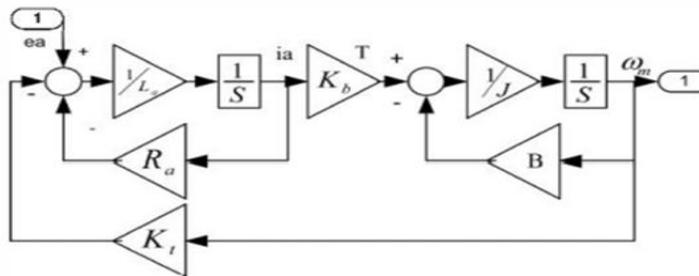


Figure 2. Armature control of DC motor MATLAB Simulink model.

Table 1. DC motor parameters

Parameters	Motor
Armature Resistance, R_a (Ω)	2
Armature Inductance, L_a (H)	0.5
Moment of Inertia, J (Kgm^2)	0.02
Friction constant, B (Nms)	0.2
Torque constant, K_T (Nm/A)	0.015
EMF constant, K_B (V_s/rad)	0.01

The transfer function of the DC motor is generated as,

$$G(s) = \frac{0.015}{0.01s^2 + 0.14s + 0.40015} \tag{1}$$

Simulink block diagram

Simulation for the comparison of the performance between DC motor with PID control and DC motor without PID control will be performed using Simulink in MATLAB. Two main parameters that must be considered during designing the simulation which is:

1. Block diagram of the DC motor without PID control.
2. Block diagram of the DC motor with PID control.

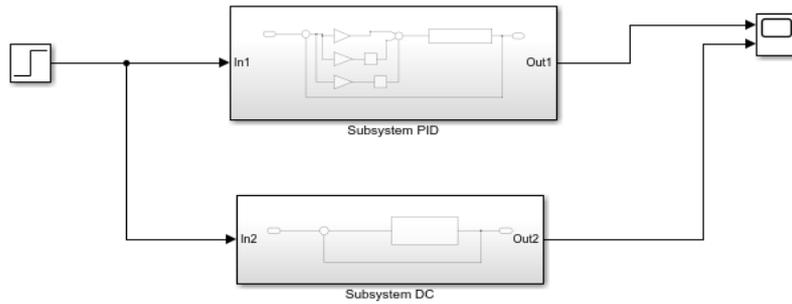


Figure 3. Block diagram of the subsystem for DC motor with PID controller and DC motor without PID controller.

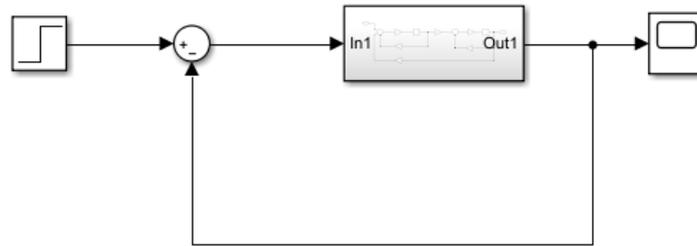


Figure 4. Block diagram of the DC motor without PID controller.

The value of the DC motor transfer function which consists of a numerator coefficient and denominator coefficient that has been derived as well as the parameter of the PID controller will be used in the block diagram in the Simulink software. Figure 3 shows the block diagram of the DC motor with PID controller and DC motor without the controller while Figure 4 shows the block diagram of the DC motor without PID controller.

RESULTS AND DISCUSSION

Simulation in Simulink

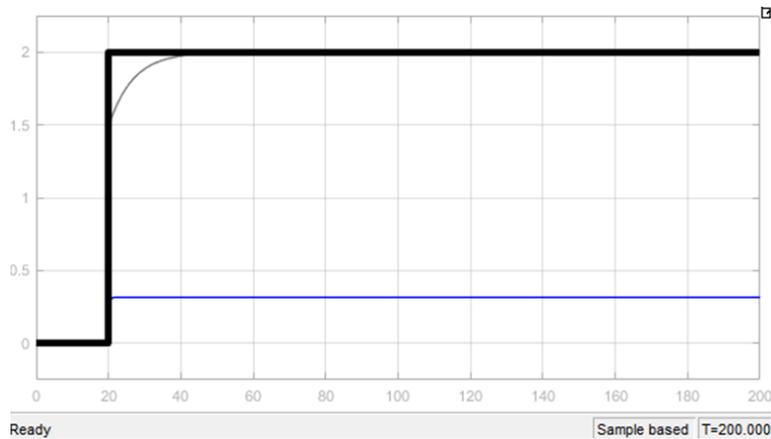


Figure 5. Simulation graph for step input of 2mm.

Table 2. Transient response parameters

Type of controllers	Transient response		
	Time constant (s)	Rise time (s)	Settling time (s)
DC motor without PID controller	20.254	4.227	20.077
DC motor with PID controller	20.344	6.112	37.918

The simulation graph for step input of 2 mm of DC motor with PID controller and DC motor without PID controller is shown in Figure 5 above. Based on Figure 5 the line blue was referred to as DC motor without PID control while the line grey refers to DC motor with PID control and the black line refers to step. The basics of the Ziegler-Nichols method are briefly explained. The DC motor with a PID controller and the DC motor without any controller was simulated in the Simulink software. The response of the DC motor is recorded and the performance of the DC motor without PID controller and DC motor with PID controller parameters such as rise time, settling time, and the time constant is calculated.

To improve the rise time, proportional control needs to be added. A derivative control also needs to be added to reduce the overshoot and lastly, to reduce the steady-state error must add an integral control. Based on the result that has been obtained, the result in terms of the transient response characteristics was tabulated as in Table 2 above for both conditions of the DC motor. Unfortunately, the value of the DC motor controlled by PID is higher than the value of the DC motor without a PID controller. The value of the rise time and the settling time of the DC motor controlled by PID should be lower. It is maybe the parameters of the DC motor are not suitable and must change to other parameters. It is also because instability and the parameter are not satisfied the system needed in the discrete-time domain. But, this DC motor with PID controlled has zero overshoot. Overall, the PID controller shows the best speed response.

Fabrication of a prototype linear conveyor system

The prototype of the conveyor was successfully developed. Figure 6 below shows the proposed design that has been designed using Catia v5 software.

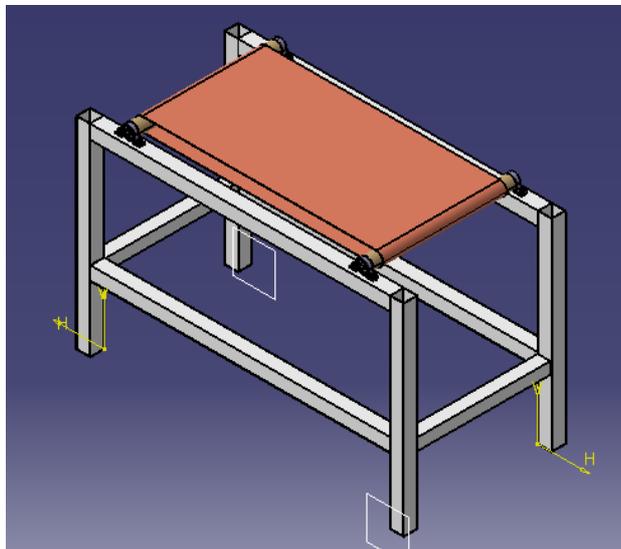


Figure 6. Conveyor designed using CATIA software.

The aluminium profile 40 x 40 mm was chosen for the body part conveyor because of its dimension which is 1020 mm x 450 mm x 584 mm. Bolt and nuts were used to combine each part of the conveyor. Other than that, the diameter of the shaft was 15 mm and used the aluminium rod for the material. It is being cut by a lathe machine.

For the bearing, there are a few characteristics that must be considered to choose the right bearing included the load that applied on the conveyor. For this project, a pillow bearing kp001 was chosen. Besides, a banner 773 mm x 330 mm was used as a conveyor belt. The aluminium sheet has also been used to accommodate the things that we put on the conveyor. The other characteristic was a timing pulley.

The teeth width of the motor shaft timing pulley and conveyor shaft timing pulley must be the same to avoid slip when running. Slip will also occur when the timing pulley was loose. As for this project, a 2GT timing pulley with 16 teeth is being implemented. The diameter of the motor shaft timing pulley was 5 mm while the conveyor shaft timing pulley was 12 mm which is the same as the diameter pillow bearing.

Experimental on the conveyor

The developed DC motor with a PID controller was tested in real conveyor applications. The conveyor was fabricated to investigate the performance of DC motor with PID controller and DC motor without PID controller. Arduino UNO and motor driver MD10C have been used to control the DC motor that has an encoder. This experiment was observed by the time taken for a bottle to reach the specific position which is 40 cm.

Table 3. The DC motor without PID controller for 40cm position.

Position (cm)	Time taken (s)
0	0
5	1.560
10	1.789
15	2.109
20	2.098
25	2.159
30	2.243
35	2.401
40	2.579

Table 4. The DC motor with PID controller for 40cm position.

Position (cm)	Time taken (s)
0	0
5	0.967
10	1.364
15	1.578
20	1.746
25	1.960
30	2.130
35	2.276
40	2.301

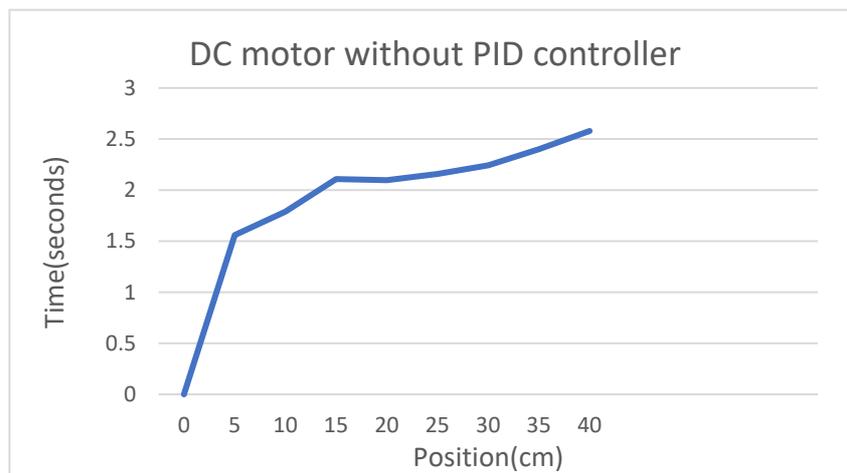


Figure 7. Graph of time against the position for DC motor without PID controller at 40cm.

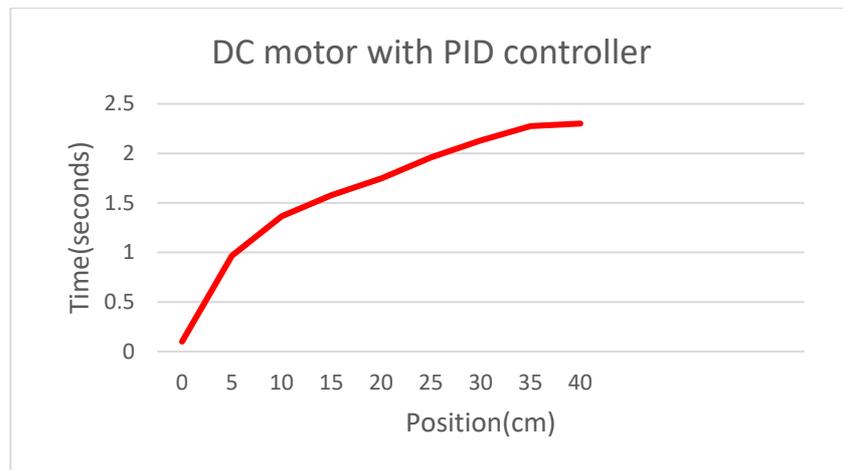


Figure 8. Graph of time against the position for DC motor with PID controller at 40cm.

Table 3 shows the results obtained for the DC motor without PID controller for 40 cm position while Table 4 shows the results obtained for the DC motor with PID controller at 40cm position. This data was obtained from the serial monitor Arduino UNO after it has been programmed by the DC motor programming and PID controller programming. Then, the graph was plotted.

The first point on each graph from both Figure 7 and Figure 8 shows the initial position of the bottle on the conveyor. After the conveyor has run, the DC motor without PID controller takes 1.560s to move to the next position while the DC motor with PID control when the bottle at the initial position takes 0.967s to move to the next position.

The DC motor with a PID controller runs very smoothly and shows better results compared to the DC motor without a PID controller. At position 15 cm, DC motor without PID controller started doing a jerky motion but it is normal characteristics of a DC motor. Last but not least, the DC motor with PID controller only takes 2.301s to get to the final position compared to the DC motor without PID controller which is a little bit late as it takes 2.579s to reach the final position.

CONCLUSION

At the end of the research, the Proportional Integral Derivative (PID) controller was successfully designed using MATLAB. The simulation of the DC motor with PID controller and DC motor without PID controller was also successfully done in MATLAB/Simulink software. From the experimental result, the DC motor with PID controller shows better performance in terms of time taken and accuracy to reach a certain position compare with the DC motor without PID controller.

But in the simulation result, shows that the DC motor is better because of the instability. As for the linear conveyor system, it has been successfully fabricated. In the actual experiment by using the conveyor system, the DC motor that was programmed with a PID controller in the Arduino programming language also shows a better result compared to the DC motor without any controller. The DC motor without the PID controller also shows the motor has jerks when running the conveyor.

There is a marginal difference between the simulation results and experiment results. This happened because the simulation assumes the motor will run in good condition which is never transpiring in a real experiment. Last but not least, the pattern between simulation and experiment step response shows the same pattern. Therefore, it can be concluded that the DC motor with PID controller performed an outperform performance compared to the DC motor without PID controller.

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