PID TUNING METHODS OF BRUSHED DC MOTOR FOR CART FOLLOWER

Zhi Ling Low[1], S.S.N. Alhady[1], A.A.M. Zahir[1], W.A.F.W. Othman[1], A.A.A. Wahab[1] and A.A.A. Wahab[1]

[1] School of Electrical & Electronic Engineering
Engineering Campus Universiti Sains Malaysia
14300 Nibong Tebal, Penang, Malaysia.

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Corresponding Author's Email: sahal@usm.my

ABSTRACT: Proportional Integral Derivative (PID) tuning methods are simple and can be used for motor velocity control. The velocity control criteria of the cart follower are important since the safety and performance issues appear as the main objective for the cart follower in this paper. The plant transfer function is modeled using System Identification Method in MATLAB and the PID controller of the cart follower is tuned by the "Control System Designer toolbox" in MATLAB. The PID tuning methods used in this paper are Ziegler-Nichols (ZN), Chien-Hrones-Reswick (CHR), Skogestad Internal Model Control (SIMC) and Approximate M - constrained Integral Gain Optimization (AMIGO) tuning methods. These PID tuning methods have been simulated and the rise time, overshoot, settling time and steady-state error are determined for performance comparison. Since the derivative term sensitives to noise in practical, the PID tuning methods are implemented into the cart follower and compared with the Proportional Integral (PI) tuning methods. For the overshoot performance accuracy, the percentage of error determined from the AMIGO and SIMC PID tuning methods are 108.5% and 265% respectively which are larger deviation compared to PI tuning methods.

KEYWORDS: *PID tuning methods, System identification method, Performance, Derivative term*

1.0 INTRODUCTION

PID controller is common for its simplicity and fulfilling performance.(Abdulameer, Sulaiman, Aras, & Saleem, 2016a) This controller has been used to improve the transient response and the steady state error of the system.(Abdulameer et al., 2016a) The cart follower system is designed for the wheelchair user that faced difficulties when carrying their luggage. DC motor which has been used widely in homes or industries and usually driven by direct current had been used to drive the cart follower. Thus, in term of the safety and performance purpose of the cart follower, the velocity control of the brushed DC motor has become a focused aspect of this paper.

The objective of this paper is to compare the performance of the cart follower after implementing different PID tuning methods. PID tuning methods involved are Ziegler-Nichols (ZN), Chien-Hrones-Reswick (CHR), Skogestad Internal Model Control (SIMC) and Approximate M - constrained Integral Gain Optimization (AMIGO). These PID tuning methods can be used to control the velocity of the brushed DC Motor.(Abdulameer, Sulaiman, Aras, & Saleem, 2016b)

The earliest ZN tuning method is known to introduce by Ziegler, Nichols and Rochester in 1942.(Nishikawa, Sannomiya, Ohta, & Tanaka, 1984) Figure 1 shows the PID control block diagram of the system. There are three parameters involved, which are K_P, K_I and K_D with feedback equal to 1 since the control sensor is not involved in this paper. The proportional term, K_P is usually contributing to the overall control factor of the system, the integral term, K_I is usually contributed to steady-state error improvement and the derivative term, K_D contributed to transient response improvement.(Kiam Heong, Chong, & Yun, 2005)

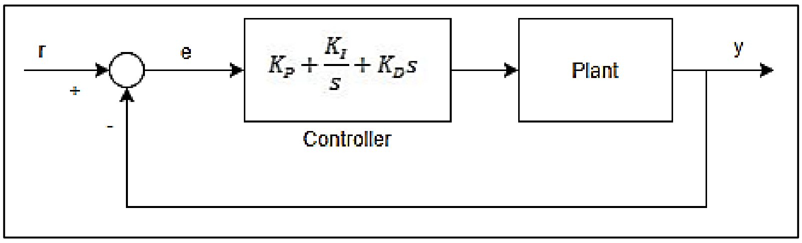

Figure 1: PID Controller Block Diagram

CHR tuning method is a modified from Ziegler-Nichols tuning method and proposed by Chien, Hrones and Reswick in 1952 to have better control to the overshoot criteria.(Abdulameer et al., 2016b) The other famous tuning methods which have been widely used are SIMC and AMIGO tuning methods. These tuning methods can be used for improving the disturbance rejection properties.(Khandelwal, Aldhandi, & Detroja, 2017; Wu, 2017)

The PID tuning methods are simulated in MATLAB. The performance criteria such as rise time, overshoot, settling time and steady-state error are determined from the closed-loop response. However, since the derivative term is usually very sensitive to noise in practical, the noisy factor has led the PI controller to be used.(John & Vijayan, 2017) The simplicity and easy to tune characteristics of PI control has made it famous to be used in motor speed control.(John & Vijayan, 2017) The performance of the implementation of different PI tuning methods shall be compared with the PID tuning methods.

2.0 METHODOLOGY

A. System Identification Method
The cart follower had used the brushed DC Motor as the motor to move and Arduino Mega 2560 had used to calculate the speed of the cart through the rotary encoder. The speed obtained from 0.25s sampling time is processed the plant transfer function is determined by the "System Identification Toolbox" in MATLAB.

B. Controller Tuning and Implementation
After the PID controller of the system is tuned by determining the three parameters for PID tuning as Figure 1 using "Control System Designer Toolbox", the three parameters determined from PID tuning methods are then implemented into the cart follower by using Arduino IDE software to compare the overshoot performance with PI tuning method. The accuracy of the overshoot performance is determined by using the formula as shown in Equation 1.

$$Percentage\ of\ error = \frac{Error}{Actual\ value}\ x\ 100\% \qquad (1)$$

3.0 RESULT AND DISCUSSION

The transfer function obtained for the plant modeled using System Identification Method is shown in Equation 2.

$$\frac{10.01}{s^2+2.553s+10.91} \qquad (2)$$

The three parameters, K_P, K_I and K_D determined from the ZN, CHR, SIMC and AMIGO PID tuning methods are tabulated in Table 1.

Table 1: Proportional, integral and derivative terms for different PID tuning methods.

Tuning Methods	K_P	K_I	K_D
ZN	3.4661	13.9752	0.2149
SIMC	1.7183	4.4184	0.0895
CHR	2.7447	9.3005	0.1429
AMIGO	1.5189	6.1682	0.0846

The plant with tuned PID controller is then feedback with H=1 as Figure 1 and the step responses of the cart follower system can be determined as Figure 2.

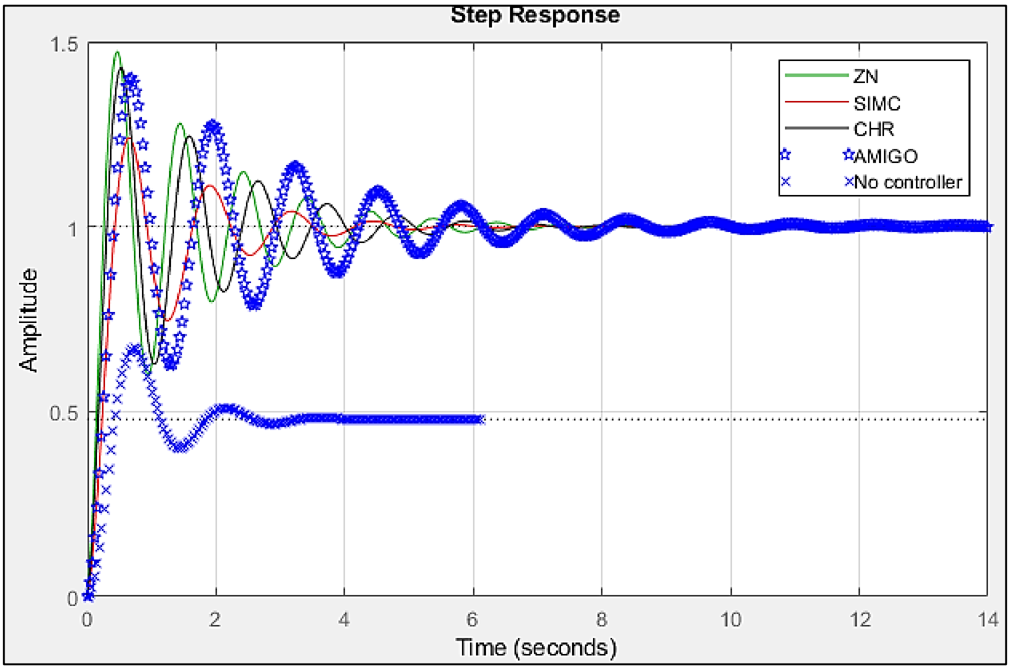

Figure 2: Step responses of different PID tuning methods

The performance of the simulation result done using MATLAB is then tabulated in Table 2 which shows that the steady-state error had been improved with the longer settling time needed by stimulating the PID tuning methods.

Table 2: Performance for the PID tuning methods.

Tuning Methods	Rise Time(s)	Overshoot (%)	Settling Time(s)	Steady-state error
ZN	0.192	47.5	5.43	0.0040
SIMC	0.309	24.0	3.94	0.0017
CHR	0.222	43.1	5.39	0.0030
AMIGO	0.292	40.1	7.87	0.0023
No controller	0.284	40.1	3.02	0.5207

From Table 2, the ZN and CHR PID tuning methods have slightly improved the rise time. The SIMC PID tuning method improved the overshoot while AMIGO remains. Since the derivative involved, the PID tuning method is implemented in the real-time application. From the experimental result, 83.6% of overshoot determined from the AMIGO PID tuning method shows the percentage of error to be 108.5% which is quite large. Thus, the PI tuning method is implemented in the real-time application to compare the performance with the PID tuning method done as shown in Figure 3.

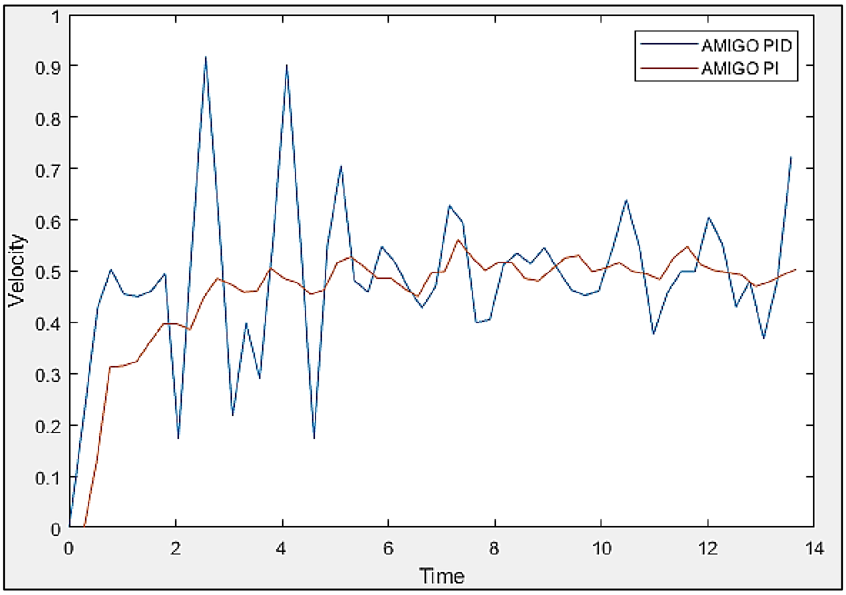

Figure 3: Experimental response of AMIGO PID and PI tuning methods

From Figure 3, the AMIGO PID tuning method implementation has created a large overshoot for 83.6% which is greater than 12.2% for AMIGO PI tuning method implementation. The overshoot can be caused by the derivative term since the derivative part is very sensitive to noise measurement when the sampling time is small.(Su Whan Sung, 2009) The SIMC PID tuning method is also implemented with overshoot of 87.6% making the percentage of error become 265%. Since the SIMC PID tuning methods implementation shows a large deviation compared to PI tuning methods, the PI tuning methods shall be considered for the velocity control of the cart follower in this paper.

4.0 CONCLUSION

In this paper, the plant of the system is modeled using "System Identification Toolbox" and the controller of the system is tuned by using different PID tuning methods. From the simulation of the PID tuning method result, the ZN and CHR have slightly improved the rise time, SIMC improved the overshoot while AMIGO remains. However, after the implementation of PID tuning methods into the cart follower, the response created large overshoot due to the derivative term in small sampling implementation. Thus, PI tuning methods are suggested to be used for the velocity control of the cart follower.

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