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Optimizing PID controller for an electro-hydraulic servo system via gradient descent technique

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ABSTRACT – This paper presents the basic knowledge in optimizing parameters of PID controller for an electro-hydraulic servo (EHS) system. Based on the Ziegler-Nichols tuning method, the obtained PID controller parameters were implemented in the physical model of EHS system. Then, an optimization technique which known as Gradient Descent is utilized using the MATLAB Simulink library. The findings show significant improvement in EHS tracking performance for both step and sinusoidal reference signal by applying the presented optimization technique.

1. INTRODUCTION

Many studies related to the **e**lectro-hydraulic **s**ervo (EHS) system problems have been conducted to figure out right direction to surmount these problems. The problems such as nonlinearities, uncertainties and disturbances that could degrade the EHS system performance must be solved. One of the ways is by optimizing the system controller performance. As the optimization technique has becoming popular nowadays, it can be utilized to optimize various types of controller such as PID controller that employed in this paper.

In order to optimize the PID controller, the PID parameter is first obtained by using Ziegler-Nichols tuning methods. Ziegler and Nichols published a paper that suggested a rule for tuning PID controller through the experimental step response or by adjusting the value of K_p that results in marginal stability. Ziegler-Nichols rules are helpful when the mathematical models of plant are not known [1]. After the obtained parameter was inserted into the controller, the improvement was caused by using optimization technique to the controller.

Optimization was described as the cognitive operation of researching for the solution that is more useful than several others. Qualitatively, this assertion implicitly recognizes the requirement of selecting among alternatives. This condition implies that an outcome of using optimization technique to the problem or design must yield numbers that will define our solution; in other words, numbers or values that will qualify the particular invention or overhaul. Quantitative description of the solution conducts a quantitative description of the problem itself. This description is called a mathematical model. The application of the optimization methods must be expressed mathematically according to the design and characteristic.

In this paper, the performance of position tracking control for EHS system is investigated using a PID controller with optimization technique. The servo valve and hydraulic actuator integrating with nonlinear dynamics model is derived. Subsequently, the performance of position tracking controller is compared with the optimized controller performance to demonstrate the significant enhancement of the controller through the proposed technique.

2. MODELING EHS SYSTEM

The block diagram of the EHS system is described in Figure 1 below.

By producing mechanical motion of the spool valve, the electrical current is supplied to the coil that connected to the servo valve. The torque motor that received the power source will drive the servo spool valve to the desired position. An electrical signal of the torque motor is given as in equation (1) [2].

$$V = \frac{dI}{dt} L_c + R_c I \quad (1)$$

where *Rc* and *Lc* are the coil resistance and inductance respectively.

The dynamics of the servo valve are represented by a second order differential equation that relates to electric current drive from the torque motor as expressed in (2).

$$\frac{d^2 x_v}{dt^2} + 2\xi\omega_n \frac{dx_v}{dt} + {\omega_n}^2 = I{\omega_n}^2 \quad (2)$$

where ξ is the damping ratio while ω is the natural frequency of servo valve.

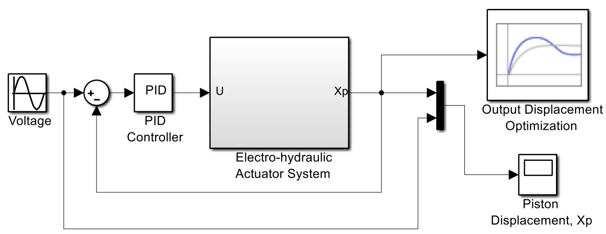

Figure 1 EHS system block diagram.

The flow relation that neglecting the internal leakages in servo valve for each chambers are given in (4) and (5).

$$Q_1 = \begin{cases} K_1 x_v \sqrt{P_s - P_1} & ; x_v \geq 0, \\ K_1 x_v \sqrt{P_1 - P_r} & ; x_v < 0, \end{cases} \quad (4)$$

$$Q_2 = \begin{cases} -K_2 x_v \sqrt{P_2 - P_r} & ; x_v \geq 0, \\ -K_2 x_v \sqrt{P_s - P_2} & ; x_v < 0, \end{cases} \quad (5)$$

The hydraulic actuator volume for each chambers are modelled in (6) and (7).

$$V_1 = V_{line} + A_p(x_s + x_p) \quad (6)$$

$$V_2 = V_{line} + A_p(x_s - x_p) \quad (7)$$

where V_{line} is the volume between hydraulic cylinder and pipeline. Pressure for each chambers can be obtained by defining the relation between bulk modulus, volume, and flow rate as expressed in (8) and (9).

$$P_1 = \frac{\beta}{V_{line} + A_p(x_s + x_p)} \int \left(Q_1 - q_{12} - q_1 - \frac{dV_1}{dt} \right) dt \quad (8)$$

$$P_2 = \frac{\beta}{V_{line} + A_p(x_s - x_p)} \int \left(\frac{dV_2}{dt} - Q_2 - q_{21} - q_2 \right) dt \quad (9)$$

Through the overall dynamics equation of moving mass, damper, and spring, the total force produced from hydraulic actuator can be evinced in (10).

$$F_p = A_p (P_1 - P_2) = M_p \frac{d^2 x_p}{dt^2} + B_s \frac{dx_p}{dt} + K_s x_p + F_f \quad (10)$$

3. RESULTS AND DISCUSSION

The comparison result for the PID controller and optimized PID controller for position tracking performance is shown in Figure 2 and 3. In both figures, step input and sinusoidal input have been fed to the system. The simulation result illustrates better performance through optimized parameter that is fed into the PID controller. Figure 2 depicted that the optimized controller produced a much stable response and eliminated the overshoot effect of the response. Figure 3 shows the position tracking performance which has been enhanced through the optimized parameters that is fed into PID controller. The parameters value was tabulated in Table 1.

Table 1 Parameters value for PID controller and Optimized PID Controller.

PID	Parameters Value		
	Ziegler-Nichols	Optimization	
		Step Input	Sine Input
K_p	1020	289.6602	1487.6219
K_i	0.0150	2.4999	0.0037
K_d	0.0038	0.1015	0.0003

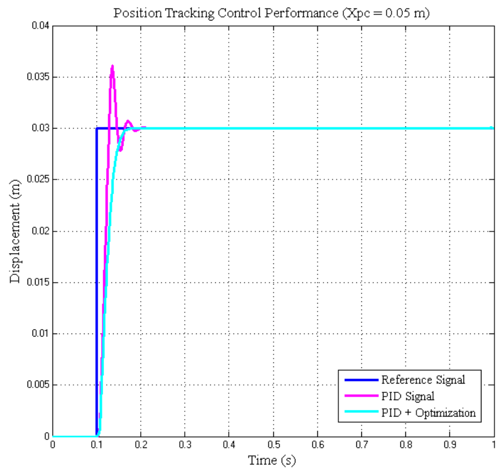

Figure 2 The comparison result for step input.

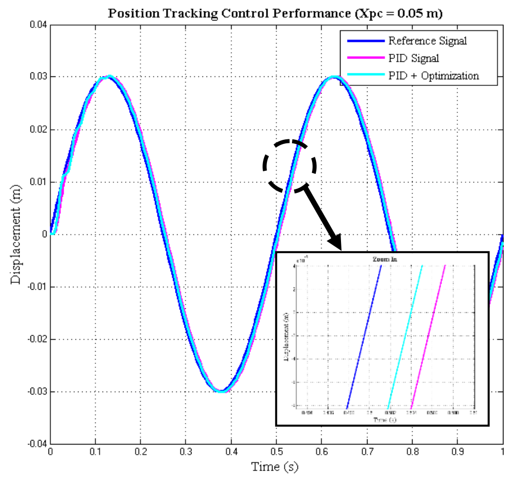

Figure 3 The comparison result for sinusoidal input.

4. CONCLUSIONS

In this paper, mathematical modelling of electro-hydraulic servo system has been derived and impended in the simulation study. The performance of the PID controller is evaluated by considering the Gradient Descent technique that applied to the controller. The numerical simulations show that the optimization technique provides significant improvement to the controller and produced much precise position trajectory tracking.

5. REFERENCES

[1] H. Angue-Mintsa, R. Venugopal, J.-P. Kenné, and C. Belleau, "Adaptive Position Control of an Electrohydraulic Servo System With Load Disturbance Rejection and Friction Compensation," *J. Dyn. Syst. Meas. Control*, vol. 133, no. November, p. 064506, 2011.

[2] R. Ghazali, Y. M. Sam, M. F. Rahmat, A. W. I. M. Hashim, and Z. Zulfatman, "Position tracking control of an electro-hydraulic servo system using sliding mode control," *Res. Dev. (SCOReD), 2010 IEEE Student Conf.*, vol. 4, no. 10, pp. 4749–4759, 2010.