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Design of a Tuned PID Controller for a Hydraulic System

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Abstract: ***In the matter of fact this paper aims to design a numerical PID controller for hydraulic system. The estimated model has been used to numerically tune the PID parameter to control the industrial hydraulic system and the step response of the system has been checked. Indeed for a hydraulic system designing an optimal control technique is required. Hydraulic system often uncertain parameters and contain components exhibiting strong friction, saturation, variable inertia mechanical loads, etc. Actually the characteristics of these non-linear components some time cannot known exactly as structure or parameters. So that, tuning of the traditional PID controller parameters to control this system for the required performance faces struggles and drawbacks. In congestion to that, in this paper design PID controller that has the capability to solve the control problem of highly uncertain systems like the hydraulic system.***

Keywords: PID controller, Hydraulic system, Stepresponse

1. Introduction

“Hydraulics” is a drive system uses to control machinery and equipment, actually comparable with pneumatics and electricity. Indeed the practical hydraulic application eventually seen in the marketplace in 1900’s. Before that for a long time, “water hydraulics,” the origin of the fluid power systems, the development history of some typical water and oil hydraulics. Nowadays, production machinery and their drive systems needed to be environmentally friendly; “water hydraulics” is in the spot light again in view of its cleanliness and safety [1]. Electrohydraulic drives are commonly used in industrial applications, for example in rolling and paper mills, as actuators in aircraft, as well in many different automation and mechanization systems. The essentially reason for industrial applications is it’s exert a great power capacity when it compared with AC or DC counterparts, without effecting on the dynamic response and system resolution, [2]. To control the hydraulic system, basically model of the existing hydraulic system must create and then must find an acceptable parameter settings for the PID in view of control the system [3]. Over willing majority of the controllers are still PID controller because of applicability and robust performance in wide range of operating systems [4]. Actually PID controller is designed, and the method is easy to be realized, but the control effect is not good when the load changes [5].

2. Electro-Hydraulic Actuator System

Electro-hydraulic actuator which working to converts electrical signal into hydraulic power. Indeed it is used in orderto delivering high actuation forces and high power. It is commonly usedin view of it has simple construction, low cost small size-to-power ratios and also be able to apply very large torques and forces with fast response time. In addition to that, it is highly non-linear system with uncertain dynamics which provide a satisfied performance closed-loop controllers. Actually, the mathematical representation of the system cannot sufficiently represent the practical system. Basically, single-rod and double-rod actuator with either proportional valve or servo valve are used. Since electro-hydraulic actuator can provide precise movement, high power capability, fast response characteristics and good positioning capability, its applications are important in the field of robotics, suspension systems and industrial process. Actuation time, hydraulic fluid supply pressure range, acting type, over torque protection, local position indicationand integral pushbuttons and controls are among the important specifications for electro-hydraulic valve actuators [6]. However, hydraulic actuators with single rod cylinder have inherently severe nonlinearities that significantly affect to the command following performance of end-effect. PID control system widely used in industries is not proper to compensate the nonlinearities and it is difficult to cancel the unexpected disturbance. In this work, the robust control scheme to compensate a nonlinearity of hydraulic actuator and cancel an unexpected disturbance is proposed [7].

3. Methodology

The methodology of this paper can be simply state as flowing:at the beginning , representing the modeling of the hydraulic system including: setting of the hydraulic system of the transfer function, after that stating the setting of the requirements and make sure of the results by testing the controller with different gains and eventually analyzing the results in order to obtain the final desired controller.

4. Transfer Function of a Typical Hydraulic System

The stability of Dynamical analysis is performed in the following part using Matlab software for examining the roots of the characteristic equation. Transfer function in matlab as in the following manner: H=TF(system). As following there an examples for transfer function of hydraulic system:

$$1\backslash \quad TF = \frac{1}{s^2+0.4s+1} \tag{1}$$

The step response of hydraulic system for the transfer above using Matlab is shown in Figure 1.

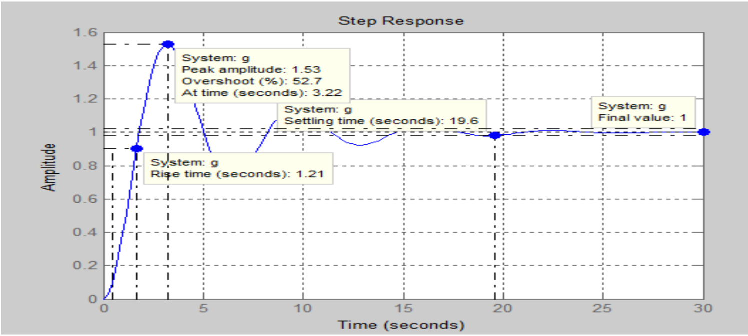

Figure 1: Step response of transfer function1

4.1 PID Controller

PID (proportional integral derivative) control is one of well-known control strategies. In view of it is simple control structure which can be understand and apply clearly by the operators, also it have wide range of applications in industrial control. When the value of K_p,Ki and K_d of the PID controller has been tuned, the response of the system such as rise time, overshoot, settling time and steady state error can be improved. Ki or integral controller will have the effect of eliminating the steady state error, but may make the transient response worse. Derivative controller or K_d will have the effect of increasing the stability of the system, reducing the over shoot and improving the transient response. Proportional controller or K_p will have the effect of reducing the rise time , but never eliminate the steady state error. The synthesis of PID can be described by

$$u(t) = K_p\, e(t) + K_i \int_0^t e(t)\, d(t) + K_D \frac{d_e(t)}{dt} \qquad (2)$$

Where e (t) is the error, u (t) the controller output, and KP, KI, and KD are the proportional, Integral and derivative gains [9].

The tuning value of Kp, Ki and Kd are determined by using the self-Tuning tool in Matlab /Simulink.

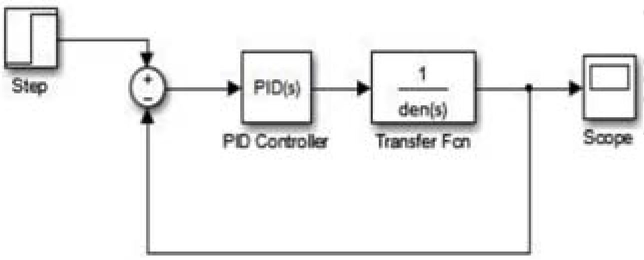

Figure 2: PID Controller in Matlab/Simulink [8]

5. Results and Discussions

When the system should be remain online, firstly set KI and KD values to zero. And then increase the value of KP till the output of the loop oscillates, after that the KP should be set to approximately half of that value for a "quarter amplitude decay" type response. Also the value of KI must increase until any offset is corrected in sufficient time for the process. Taking into account that, a too much increasing in the value of KI will make the system unstable. Lastly, the value of KD increase, if needed, till the loop is acceptably quick to reach its reference after a load disturbance. Actually, higher values of KD will make bad response and overshoot. A fast PID loop tuning usually overshoots slightly to reach the set point faster in fact,a lot of systems cannot accept overshoot, this case, in imperative need to an over-damped closed-loop system, which will require a KP setting significantly less than half that of the KP setting that was made oscillation. In proportional and integrative controller mode, the transfer function below was produced and added to system, reminding that adding P or I or D may improve some required response and but still cause an undesired response.

The simulations after adding PID controller are approved in MATLAB environment and the results obtained are shown in Fig.6, Fig.7 andFig.8.

- **At KP=1.2728 and KI= 0.03252**

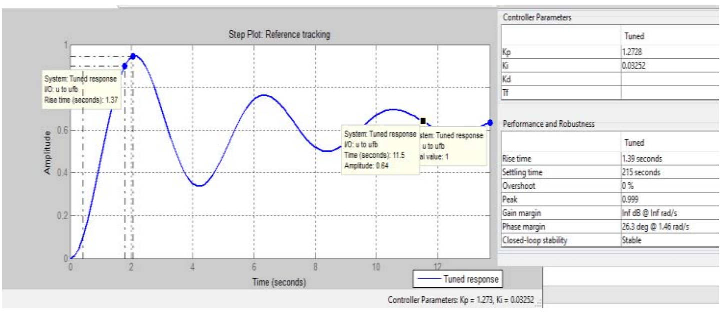

Figure 3: Step response of transfer function after adding PI controller

- **At KP=4.8447and KD=3.8234**

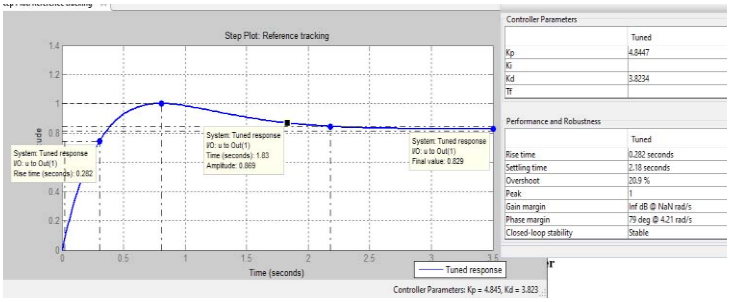

Figure 4: Step response of transfer function after adding PD controller

- **At KP=4.9407, KI=1.2002and KD=5.0847**

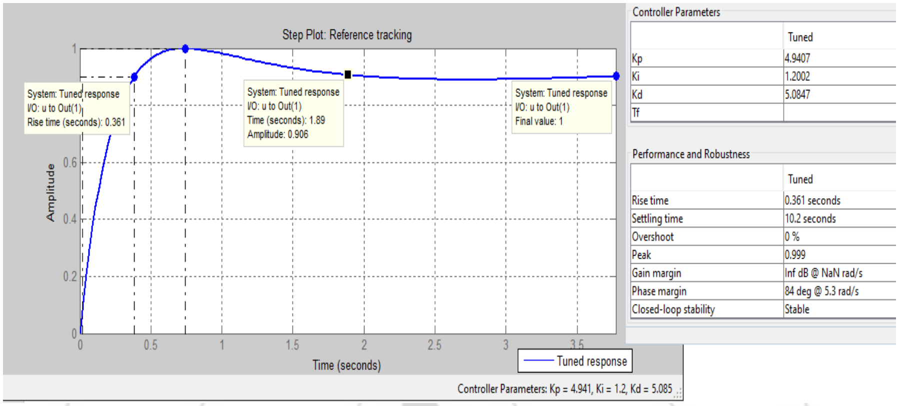

Figure 5: Step response of transfer function after adding PID controller

This transfer function is a PID controller with K_I, K_P and K_D. The resulting of step responses is shown inTable1.

Table 1: Effects of Adding PI, PD and PID control system

Controller	Rise Time	Overshoot	Setting Time	Steady State Gain
Pi	1.390	0.00%	215	1
Pd	0.282	20.9%	2.18	1
Pid	0.361	0.00%	10.2	1

6. Conclusions

Obviously in this paper, the PID controller of electro hydraulic system is Modeled and simulatedby MATLAB /SIMULINK. The PID control design toolbox written in MATLAB enables the designer to have flexibility in the off-line design of PID controllers for hydraulic systems. These techniques above have been successfully applied to the hydraulic system. The experimental results have shown that they can significantly improve system performance as shown in the table above.

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