International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

# Adaptive Control of Electrohydraulic Servo System

**Anju Susan Sam[1], Nasar A[2]**

[1]Department of Electrical and Electronics Engineering, TKM College of Engineering,Kollam, India

[2]Professor, Department of Electrical and Electronics Engineering, TKM College of Engineering, Kollam, India

**Abstract:** ***Electro hydraulic servo system, one of the important drive systems in industrial sector as it possess some merits such as high power to weight ratio, precise and fine control, small size, good load matching, high environmental stiffness, fast dynamic performances and wide adjustable speed range. It can be angular displacement, velocity or force control system depending on variable to be controlled. The objective of Adaptive Control is to achieve and to maintain acceptable level of performance when plant model parameters are unknown or vary. The system considered for the study consists of a hydraulic motor as actuator with a load attached to its shaft. The dynamics of hydraulic systems are highly nonlinear and make control design for precise output tracking very challenging. Also the hydraulic parameters may vary due to temperature changes and external load, friction, and noise effects result in unacceptable tracking errors. In this paper, A Model reference adaptive control with feed forward configuration is implemented in the system. Simulation results are presented to show the performance of Model Reference Adaptive Control (MRAC) with feedforward configuration***

**Keywords:** Model Reference Adaptive Control (MRAC), MIT rule, Lyapunov theory, Hydraulic motors

## 1. Introduction

Electro hydraulic Servo System (EHSS), a closed loop control system, which consists of an actuator unit to drive an object or load. Electro hydraulic servo systems have the advantages of, precise and fine control, high power to weight ratio, small size, good load matching, high environmental stiffness, fast dynamic performances and wide adjustable speed range. Large inertia and torque loads can be handled with high accuracy and very rapid response.

Many mobile, airborne and stationary applications employ hydraulic control components and servo systems. Hydraulic servo systems can generate very high forces, exhibit rapid responses, and have a high power-to -Weight ratio compared to other technologies. On the other hand, they exhibit a significant nonlinear behavior due to the nonlinear flow/pressure characteristics, oil compressibility, time varying behavior, nonlinear transmission effects, flow forces acting on spool and friction, which is not only largely uncertain but is greatly influenced by external load disturbances.

Much research has been conducted on the control of EHSS. Fuzzy logic control of EHSS is done in [1]. Feedback Linearization technique is applied in [2]. PID controllers were first used to track the position of EHSS [3]. Sliding mode control is used for EHSS in [5], but it causes chattering which affects the system performance. Nonlinear back stepping is applied for another system model of EHSS in [6].

In this paper, Model Reference adaptive control (MRAC) has been applied to the system. The Paper has been organized as follows. Section II deals with the modelling of electrohydraulic servo system. Section III deals with the design of model reference adaptive controller for the system. In Section IV the Simulation results are shown with some discussions on it. Section V is the Conclusion part.

## 2. Modelling of Electrohydraulic Servo System

The flow rate through the hydraulic motor can be controlled by changing the control input to the servo valve. Fig.1 shows the block diagram of electro hydraulic servo system. A controller has been designed in this paper.

The control input in the form of input current and overlapping area of control valve is related by equation (1),

$$\tau_v A^{\cdot}(t) + A(t) = K_x K_v I(t) \quad (1)$$

Where I(t), A(t), $K_x, K_v$ are the control current input, the servovalve opening area, servo valve area constant and servo valve torque motor constant respectively

The fluid dynamic equation of the motor, considering internal and external leakages and flow compressibility is given as

$$\frac{V_m}{4\beta} \dot{P}_L(t) = C_d A(t) \sqrt{\frac{P_s - sign(A(t)) P_L(t)}{\rho}} - D_m \dot{\theta}(t) - C_L P_L(t) \quad (2)$$

where $V_m$, *β*, $D_m$, $C_L$, *θ(t)* are the total oil volume in the two chambers of the actuator, the fluid bulk modulus, the volumetric displacement of the motor, the leakage coefficient and the angular displacement respectively. $P_L(t)$ is the motor pressure difference due to the load, $P_s$ is the supply pressure source, and ρ is the fluid mass density. For modeling purposes, the servo valve opening area *A(t)* may have a positive or negative sign depending on flow direction across the hydraulic motor. The sign function in Eq. 2 accounts for the change in the direction of fluid flow through the servo valve.

By Newton's second law for rotational motion and neglecting friction, the torque-acceleration equation of the load is given by

$$J\ddot{\theta}(t) = D_m(P_1(t) - P_2(t)) - B\dot{\theta}(t) - T_L \quad (3)$$

The parameters *J*, *B*, $T_L$ are the total inertia of the motor and the load, the viscous damping coefficient, and the load torque respectively. The variables $\theta(t)$, $P_L$ (t), *A (t)* are normalized by dividing them by their maximum values denoted by $\omega_{max}, P_S$ and $A_{max} = K_x.K_v.I_{max}$. The discontinuous sign function is approximated by the continuously differentiable sigmoid function defined as

$$sign(x) \approx sigm(x) = \frac{1-e^{-ax}}{1+e^{ax}}; a > 0 \tag{4}$$

EHSS can be described by the following state-space model

$$x'_1(t) = w_{max} x_2(t) \tag{5}$$

$$x'_2(t) = -\gamma \frac{w_h}{\alpha} x_2(t) + \frac{w_h}{\alpha} x_3(t) - \frac{w_h}{\alpha} t_L \tag{6}$$

$$x'_3(t) = -\alpha w_h x_2(t) - w_h C_L x_3(t) + \alpha w_h x_4(t)\sqrt{1 - x_3(t) sigm(x_4(t)} \tag{7}$$

$$x'_4(t) = -\frac{1}{\tau_v} x_4(t) + \frac{i(t)}{\tau_v} \tag{8}$$

Where $x_1(t) = \theta(t)$, $x_2(t) = \frac{\theta(t)}{w_{max}}$

$$x_3(t) = \frac{P_{L(t)}}{P_S}, \quad x_4(t) = \frac{A(t)}{A^{max}}$$

$$u_1(t) = i(t) = \frac{I(t)}{I_{max}}, \quad u_2(t) = t_L$$

$$\gamma = \frac{Bw_{max}}{P_s D_m}, \quad w_h = \sqrt{\frac{2\beta D_m{}^2}{JV}},$$

$$c_L = \frac{JC_L w_h}{D_m^2}, \quad \alpha = \frac{C_d A^{max}\sqrt{\frac{P_S}{\rho}} J w_h}{P_S D_m^2}$$

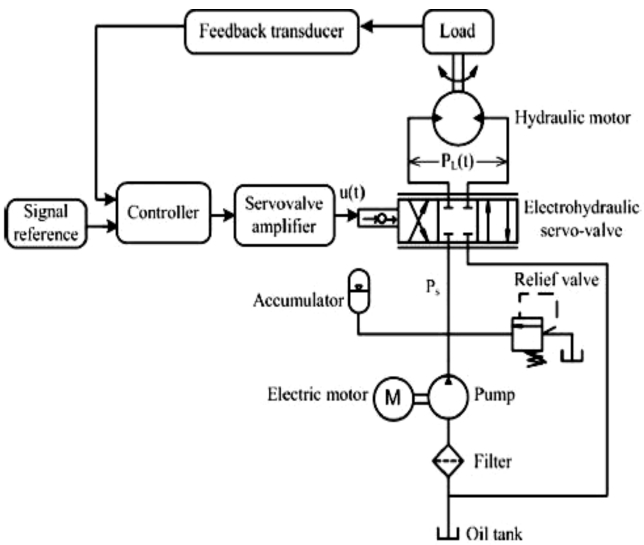


**Figure 1:** Block Diagram for Control for Electrohydraulic servo system

Hydraulic servo system consists of a tank, to hold the hydraulic oil, a pump to force the hydraulic liquid, an electric motor to drive the pump, flow control servo valve, hydraulic actuator, displacement transducer and a servo controller. The working of the system is as follows: The high pressurized liquid, when passed through the actuator convert the fluid energy into linear or rotary motion. When it converts the energy into reciprocating motion they are termed as cylinders/ linear actuators and when they rotate and produce torque they are named as motors/ rotary actuators.

## 3. Model Reference Adaptive Control

This section deals with the design of an adaptive control system for electrohydraulic servo system. An adaptive control adjusts the controller parameters so that the output of the actual plant tracks the output of a reference model having the same reference input. Model Reference Adaptive control (MRAC) is an adaptive control strategy which has some adaptive control parameters $\theta_i$ and an adjusting mechanism to adjust these controller parameters. In MRAC, desired behavior of system is specified by a model as shown in fig.2. The difference between model output and plant output is termed as error. Parameters of controller are adjusted based on the error with same reference input given to both controller and model.

The basic block diagram of MRAC system is shown in the fig.2. As shown in Fig. 2, $y_m$(t) is the output of the reference model and $y$(t) is the output of the actual plant and difference between them is denoted by e(t).

$$e(t) = y(t) - y_m(t) \tag{9}$$

Mathematical techniques like MIT rule, Lyapunov theory and theory of augmented error can be used to develop the adjusting mechanism. Lyapunov rule can be applied to both linear and nonlinear systems. While MIT rule is apt for linear systems.

### 3.1 Feedforward Model Reference Adaptive Control

In feedforward control, the control variable adjustment is not error-based. Instead it is based on knowledge about the process in the form of a mathematical model of the process and knowledge about or measurements of the process disturbances.

#### 3.1.1 Using MIT rule

The cost function is defined as

$$J(\theta) = {e^2}/{2} \tag{24}$$

Where $\theta$ is the adjustable parameter

A feedforward control law is defined as

$$u = \theta . U_c \tag{25}$$

$$\frac{d\theta}{dt} = -\gamma y_m e \tag{26}$$

Where $U_c$ is the input command signal, γ is the adaptation gain of the controller and $y_m$ is the output of the reference model.

#### 3.1.2 Using Lyapunov rule

A feedforward control law is defined as

$$u = \theta . U_c \tag{27}$$

$$\frac{d\theta}{dt} = -\gamma U_c e \tag{28}$$

## 4. Simulation Results

MATLAB software package is used to determine the response of the system. A simulation based study is used to evaluate the performance of a Model Reference adaptive controller (MRAC) on the nonlinear model of the EHSS. The reference signal used in simulation is unit step signal. Simulation results are shown in Fig. 2-4.

Fig.2-3 indicates feedforward angular displacement control of EHSS by MIT rule and Lyapunov rule respectively. The responses have no overshoots.

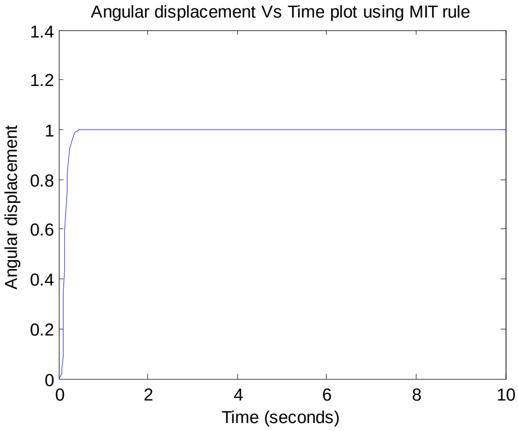


**Figure 2:** Feedforward MRAC control by MIT rule

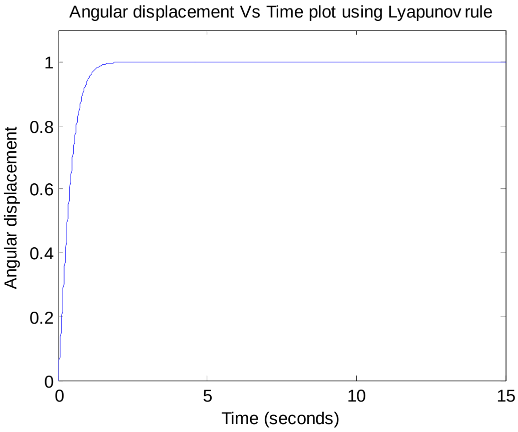


**Figure 3:** Feedforward MRAC control by Lyapunov rule

## 5. Conclusion

A detailed discussion on MRAC scheme using MIT rule and Lyapunov theory is done in this paper and the performance evaluation is carried out by means of simulations on SIMULINK. Here, MIT rule is applied to linearized system and Lyapunov rule is applied to the nonlinear system itself. For feedforward MIT rule, $\gamma$ takes a value of -180. For feedforward Lyapunov rule, $\gamma$ takes a value of 0.66861. Feed forward MRAC rule give better results than feedback MRAC rule.

## References

[1] Lekshmi Anand, Laila Beebi M, "Angular Displacement and Velocity Control of an Electrohydraulic Servo System Using Fuzzy Logic Controller" Int. Conf. on Emerging Trends in Electrial Engineering pp.133–137,2014

[2] J. Seo, R. Venugopal, and J.P. Kenne, "Feedback Linearization based control of a rotational hydraulic drive," Control Eng. Pract. , vol. 15(12), pp. 1495–1507, 2007

[3] A.Alleyne and R. Liu, "On the limitation of force tracking control for hydraulic servo systems", ASME Journal of Dynamic Systems, Measurement and Control, vol. 121(2), pp. 184–190, 1999.

[4] Honorine Angue-Mintsa, Ravinder Venugopal, "Adaptive Position Control of an Electrohydraulic Servo System with Load Disturbance Rejection and Friction Compensation", ASME Journal of Dynamic Systems, Measurement and Control, vol. 121(2), pp. 184–190, 1999.

[5] A. G. Loukianov, J. Rivera, Y. V. Orlov and E. Y. Morales Teraoka, "Robust trajectory tracking for an electrohydraulic actuator," IEEE Trans. Ind. Electron., vol. 56(9), pp. 3523– 3531, 2009

[6] C. Kaddissi, J.P. Kenne and M. Saad, "Identification and Real- Time Control of an electrohydraulic servo system based on Nonlinear Back-stepping," IEEE ASME Trans. Mechatronics, vol. 12(1), pp. 12–22, 2007

[7] K. J. Astrom and B. Wittenmark (2001), Adaptive control, 2nd ed., Dover Publications, New York.

## Author Profile

**Anju Susan Sam** was born in Kerala, India in 10/12/1991. She received B.Tech degree in Electronics and Instrumentation Engineering from TKM Institute of Technology, Kollam, Kerala in 2013. Currently, she is pursuing her M Tech degree in Industrial Instrumentation & Control from TKM College of Engineering, Karicode, Kollam. Her research interests include Control Systems. (anjususansamkunnathu@gmail.com).