퍼지 PI를 이용한 배수갑문용 유압실린더의 위치 및 동기 제어기 설계

최병재*

Synchronous Position Controller Design of Hydraulic Cylinders for a Sluice Gate Using Fuzzy PI

Byung-Jae Choi*

요 약 수문 제어의 주요기술은 두 개의 실린더가 하나의 수문을 동시에 10[m] 이상 들어 올리는 행정 동안 정밀하게 제어되도록 하여 동기 작동 시키는 것이다. 실린더에 공급되는 유량 및 압력이 일정하지 않으며, 실린더 피스톤의 비선형적인 마찰력에 의해 두 개의 실린더 위치 오차가 발생하게 되면 수문의 개폐 시 비틀림 현상을 야기 시켜서 수문의 마모를 발생시키고, 수문의 개폐작동 불능 현상을 마들기도 한다. 배수갑문용 유압실린더의 위치 및 동기 제어기를 설계하기 위하여 fuzzy PI 제어기를 이용하여 두 개의 실린더의 위치 및 동기 제어기를 설계하고, 시뮬레이션을 통해 효용성을 제시한다.

Abstract In general a main technology of control a sluice gate is accurate synchronous position control for the two cylinders when they are moving with the sluice gate together over 10[m]. Because the nonlinear friction and the unconstant supply flow. Cylinders' displacement will be different. In this case the sluice gate may be deformed and abraded, and even the sluice gate may unable to work. In order to design the controller for this system, we designed two kinds of Fuzzy PI controllers. Fuzzy PI position controller and Fuzzy PI synchronous controller have been designed. We show some simulation results for its availability,

Key Word : Hydraulic Cylinders, Fuzzy PI controller, Position Controller, Synchronous Controller Sluice Gate, Position Controller

Ⅰ. Introduction

The hydraulic cylinder system has been discussed in many places. In order to control the position of cylinder servo valve can be used. Servo-hydraulic system can be used to provide large processing force and has a good positioning capability, and this system always complex and highly nonlinear.

In this paper the object of study is a sluice gate which has two cylinders, each cylinder's traction force is 250[ton], and the weight of sluice gate is 300[ton]. While sluice gate and cylinders are moving together at the same time, since the supply flow and supply pressure for cylinders are not constant and a nonlinear friction force of piston in cylinders

* Corresponding Author: Electronic Engineering Professor of Chungwoon University (huiwuyin@gmail.com)
Received : August 07, 2014 Revised : August 21. 2014 Accepted : September 11. 2014

exists, the displacement of these two cylinders will be different. Because of this difference the sluice gate may be deformed and abraded, and even the sluice gate may unable to work.

In this study synchronous and position control of a sluice gate with two cylinders are considered. In order to push the cylinders to an exact position with an exact speed and in order to remove the difference between displacement of two cylinders, a fuzzy PI system which has two kinds of fuzzy PI controller has been designed.[5]

II. System Description

Servo valves are often used to control the cylinders in hydraulic system. The servo valves can control the supply flow by changing the area of orifice base on its input current.

In this system the supply pressure Ps is constant, and the return pressure Pt is 0. The area of servo valve orifice and displacement of valve spool is in proportional. The pressure in each cylinder distributes equally, and no cavity exists. The critical center valve of servo valves is matched and symmetrical. The oil density and temperature is constant.

The equation of servo valves is:

$$x_{sv} = K_{sv} i \qquad (1)$$

Where x_{sv} is the servo valve position, K_{sv} is the gain of servo valve, and i is the input current.

The orifice function is:

$$Q_L = K_q x_{sv} \qquad (2)$$

$$Q_L = Q_1 - Q_2 \qquad (3)$$

Where x_{sv} is the position of servo valve, K_q is the gain of servo valve flow, and Q_1 is the flow rate of cylinder head-side chamber, Q_2 is the flow rate of cylinder rod-side chamber.

The continuity equation is:

$$P_L = \frac{K_q}{C_{tp}} x_{sv} - \frac{A_p}{C_{tp}} \dot{x}_p \qquad (4)$$

Where A_1 is the cylinder head-side area, A_2 is the cylinder rod-side area, x_p is the displacement of the each single rod cylinder piston, C_{tp} is the total leakage coefficient, and $A_p = \frac{A_1 + A_2}{2}$ is the average area of piston.

The motion equation is:

$$M\ddot{x}_p = P_1 A_1 - P_2 A_2 - B_p \dot{x}_p - F_f(v) \qquad (5)$$

Where P_1 and P_2 is the intensity of pressure of left and right side of cylinder, A_1 is the cylinder head-side area, A_2 is the cylinder rod-side area, B_p is the viscous damping coefficient, and $F_{f(v)}$ is the nonlinear friction force.[5]

III. Design of Fuzzy PI controller

3.1. Structure of controllers

In this study we consider two control objectives of this hydraulic system. The first objective is to push or pull the sluice gate with an exact speed to an exact position. The second objective is to remove the displacement difference between two cylinders when they are moving together.

Two kinds of fuzzy PI controller are considered, one of them is fuzzy PI position controller, and the other one is fuzzy PI synchronous controller.

3.2. Fuzzy PI position controller

First one is fuzzy PI position controller. The inputs are the gap between reference signal and the displacement of each cylinder and its differential coefficient. The controller rules are shown in table 1.

Table.1 Fuzzy control rules for fuzzy position controller.

		$\dot{e}$						
e		NL	NM	NS	ZO	PS	PM	PL
	NL	NL	NL	NL	NL	NM	NS	ZO
	NM	NL	NL	NM	NM	NS	ZO	ZO
	NS	NL	NM	NM	NS	ZO	ZO	PS
	ZO	NM	NS	NS	ZO	PS	PS	PM
	PS	NS	ZO	ZO	PS	PM	PM	PL
	PM	ZO	ZO	PS	PM	PM	PL	PL
	PL	ZO	PS	PM	PL	PL	PL	PL

3.3. Fuzzy PI synchronous controller

Another fuzzy PI controller is used to remove the displacement difference between these two cylinders. The synchronous controller has been designed with three inputs, first and second one are difference between two cylinders and its differential coefficient, the last input is the difference between reference signal and displacement signal of each cylinders. The rules are showed in table 2.

Table.2 Fuzzy control rules for fuzzy synchronous controller.

		$\dot{e}$ $(Reference - x_p = N \text{ or } ZO)$						
e		NL	NM	NS	ZO	PS	PM	PL
	ZO	ZO	ZO	ZO	ZO	ZO	ZO	ZO
	PS	ZO	ZO	ZO	ZO	ZO	ZO	ZO
	PM	ZO	ZO	ZO	ZO	ZO	ZO	ZO
	PL	ZO	ZO	ZO	ZO	ZO	ZO	ZO
		$\dot{e}$ $(Reference - x_p = P)$						
		NL	NM	NS	ZO	PS	PM	PL
	ZO	NS	NS	NS	ZO	PS	PS	PM
	PS	NS	ZO	ZO	PS	PM	PM	PL
	PM	ZO	ZO	PS	PM	PM	PL	PL
	PL	ZO	PS	PM	PL	PL	PL	PL

IV. Simulation Results

We apply the fuzzy PI controller to the position and synchronous control of the hydraulic system. The objective speed is 2.3[mm/s] at the retracting stroke, and the objective displacement difference is under 10[mm]. The simulation results are shown in figure 1 and figure 2.

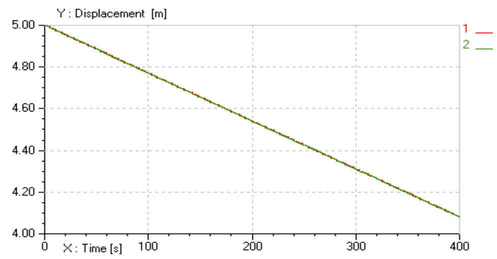

Fig.1 Ramp response of cylinders (at retracting stroke)

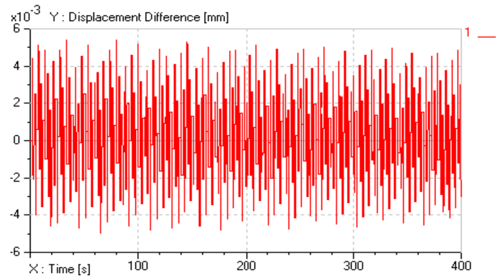

Fig.2 Displacement difference between cylinder rods

Figure 1 shows the position change with time for each cylinder. And figure 2 shows the displacement difference between two cylinders. As these pictures show The average speed of cylinders are 2.3[mm/s], the cylinders move with reference signal correctly. And the displacement difference between two cylinders is under 5.5[mm].

V. Conclusions

Two kinds of fuzzy PI controllers have been considered in this paper. These two kinds of controllers can work together well. Simulation result shows the average speed is 2.3[mm/s] and the difference of two cylinders is under 5.5[mm]. It also shows that by using fuzzy PI controller the cylinders can move with the reference signal correctly, and the difference of cylinders is bounded.

Reference

[1] Yi-Xiang Zhao,Xin-du Chen,Xin Chen, 2009, "Repeatability Analysis of a Vulcanizer Hydraulic Cylinder System Using Fuzzy Arithmetic", International Conference on Computational Intelligence for Measurement System and Applications.

[2] Jong Hwa Kim, "A suggestion of Nonlinear Fuzzy PID Controller to Improve Transient Responses of Nonlinear or Uncertain Systems," 한국퍼지및지능시스템 학회논문지 Vol.5,No.4 ,pp.87-100,1995.

[3] Chuen Chien Lee, "Fuzzy logic in Control system." IEEE Trans. On System, Man, and Cybernetics, Vol.20, No.2, March/April 1990.

[4] Ho Triet Hung, Ahn kyoung kwan,"A Study on the Position Control of Hydraulic Cylinder Driven by Hydraulic Transformer Using Disturbance Observer" International Conference on Control ,Automation and Systems 2008.

[5] Kyung Soo Kim, 2008 "Synchronous Position Controller Design of Hydraulic Cylinders for A Sluice Gate" Graduate School Chungnam National University.

[6] Jin-Kyu Kim, 2003, "A Position Control of Nonlinear Hydraulic System using Variable Design-Parameter Fuzzy PID Controller", Journal of the Korean Society of Marine Engineers.

저자약력

최병재 (Yeong-seok Lee) 평생회원

2009 - 미래경북전략위원회 기획위원
경북테크노파크 운여위원
한국지능전보시스템 편집위원
한국지능정보시스템 학괴 이사대구대학교 산학협력단 단장
현재- 대구대학교 전자공학부 교수

<관심분야> 지능제어및시스템/지능로봇, 영상인식