강건제어기와 전기-유압 액추에이터를 이용한 압연롤의 중심위치제어
Improvement of Center Position Control in Steel Rolling Machine based on Electro-Hydraulic Actuator and Robust Control Technique

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1. Introduction

Hydraulic systems have been considered as the potential choices for modern industries ranging from heavy-duty manipulators to precision machine tools because of their advantages. Previous servo hydraulic actuators mostly contain hydraulic control valves, thus lots of energy was transferred into heat due to throttle losses at the valves. In order to overcome these weak points in the conventional hydraulic systems and satisfy new demands, hybrid actuator – electro-hydraulic actuator, known as the compact energy-saving and low-noise hydraulic device which shifts from high-speed electric to high-force hydraulic [1-4]. Due to its efficiency, EHAs have a wide range of applications for which high accuracy and fast response of force/pressure or position control are exceedingly necessary, especially in heavy industry, etc.

In steel rolling machines, the quality of steel rolls is affected by the roller center position which is currently controlled by human through a SHA. Consequently, the worker skills and concentration are very important. In order to improve the SRM working performance as well as to save human power, automation in the CPC process is necessary. This research is a proposition to use the EHA with automatic feedback control as an advanced solution for the CPC in SRMs. A steel rolling machine in POSCO Corp. is then investigated to improve with center position control. The EHA hardware structure is based on the used SHA parameters and working conditions to satisfy all the desired CPC requirements. A test rig is setup in order to evaluate the EHA with position control performance.

2. EHA design and verification for the steel rolling machine (SRM) with center position control (CPC)

2.1 Specifications of EHA for CPC of the SRM and test rig setup

Based on the previous research [2], an EHA type, intelligent hydraulic (IH) servo driver pack, made by YUKEN company is chosen as a feasible solution. The suitable IH pack specifications are then selected and shown in Table 1.

Table 1 EHA – IH servo driver pack – setting parameters

IH servo drive pack	Parameters	Values
YSD2-B-44	Pump displacement[cc/rev] Max. shaft speed[rpm]	16 2000
A-16-B B-11	AC servo motor power[kW] Rated Torque[Nm]	4.4 28.4

Consequently, the schematic diagram of the test rig is shown in Fig. 1. The system hardware consists of the EHA, which is named motion generator, a load and a linear sensor to feedback position signal. In addition, a computer included PCI-bus multifunction cards are used built the overall control system to perform position control performance of the EHA.

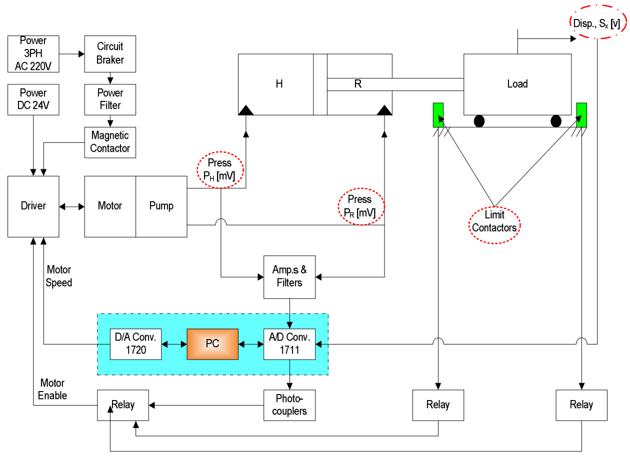

Fig. 1 Schematic diagram of the EAH test rig

2.2 Position control using quantitative feedback theory (QFT)

2.2.1 QFT control overview

Quantitative Feedback Theory (QFT) is a unified theory that designs and implements robust control for a system with structure parametric uncertainty to satisfy the desired performance specifications, even when faced with the presence of disturbance, noise amplification or resonance [2-4]. The QFT method proposes as a general control strategy the two of freedom structure presented in Fig. 2.

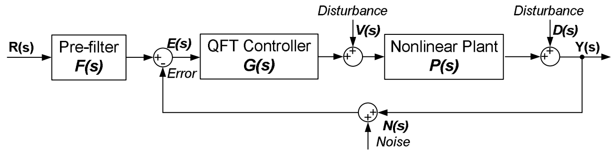

Fig. 2 Structure of the QFT control system

2.2.2 System identification

The first step in designing a robust QFT controller is thus to derive a family of uncertainties of the plant transfer function. By using the identification process as shown in [REF], the EHA can be presented by a family of second-order transfer functions as follow

$$P(s)=\frac{k}{(1+p_1 s)(1+p_2 s)},\ [mm/V] \tag{1}$$

here

$$k\in[64.58,81.31][N/mV];\ p_1\in[0.11,1.79];\ p_2\in[0.11,1.71]$$

2.2.3 QFT controller synthesis

The objective of this section is to design a robust force controller for the EHA that is represented by the uncertainty transfer function (1). In QFT, for tracking performance requirement, the strictly proper controller, G(s), and a strictly proper pre-filter, F(s), (Fig. 2) are to be designed base upon the stability and system performance's specifications in the time domain [2-4]. In this case, the system should fulfil the following control criterions for the unit step response:

Settling time less than 1.5 [s].

Maximum percentage of overshoot $\le 2[\%]$

Based on the design requirements and from [2-4], the robust QFT controller is determined:

$$G(s)=\frac{6.13\times10^{5}s-6.851\times10^{5}}{s^{2}+3399s+1.035\times10^{6}} \quad (2)$$

$$F(s)=\frac{14.04}{s+14.45} \quad (3)$$

2.3 Experimental results

The QFT control algorithm used to control the EHA are built by the combination of Simulink and Real-time Windows Target Toolbox of Matlab and connected to Advantech cards. In order to check the working performance of EHA for position control, a sinusoidal excitation signal is given as the reference. As the result, the position response of the system using the designed QFT controller is depicted in Fig. 3. From this figure, it is clearly that the EHA using the proposed controller is able to apply to the CPC of the SRM.

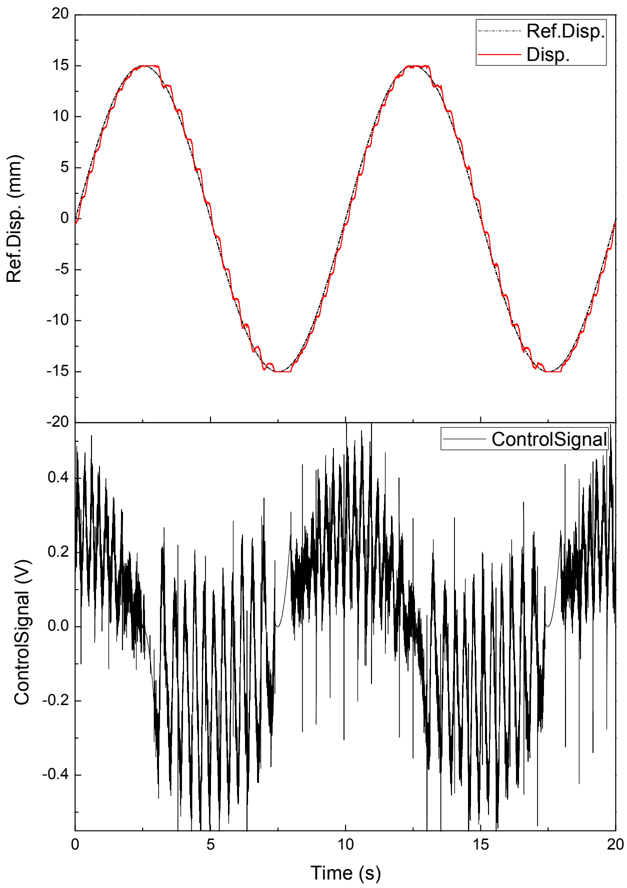

Fig. 3 Position response of the EHA using QFT Controller

3. Conclusions

In this research, an advanced solution for the CPC process in the SRMs is proposed as a closed-loop feedback control using the EHA. The EHA specifications are selected based on the setting parameters of the traditional actuator controlling the CPC and the control requirements. In addition, the QFT controller is also suggested to use for the closed-loop feedback CPC with high stability.

후기

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참고문헌

1. Rahmfeld R., Ivantysynova M., “Displacement Controlled Linear Actuator with Differential Cylinder - A Way to Save Primary Energy in Mobile Machines.,” In Proc. of the 5th Int. Conf. on Fluid Power Transmission and Control (ICFP), Hangzhou, China, 316-322, 2001.
2. 안경관, 윤종일, 딩광졍, 윤장원, “전기-유압 액추에이터를 이용한 압연롤의 중심위치제어,” 유공압시스템학회 추계학술대회 논문집, 121-129, 2009
3. Ahn K.K., Chau N.H.T., Truong D.Q., “Robust force control of a hybrid actuator using quantitative feedback theory.,” Journal of Mechanical Science and Technology, 21(12), 2048-2058, 2007.
4. J. H. Yoon., K. K. Ahn., D. Q. Truong., and W. G. Jo., “Active Force Control of Electro-Hydraulic Hybrid Loadsimulator using Quantitative Feedback Theory,” Journal of the Korean Society for Precision Engineering, 26(2), 45-53, 2009.
5. Ahn K.K., Truong D.Q., Thanh T.Q., Lee B.R., “Online Self Tuning Fuzzy PID Control for Hydraulic Load Simulator.,” Journal of System and Control Engineering, Proceedings of the IMechE, Part I, 222(2), 81-95, 2008.
6. Rober S.J, Shin Y.C, Nwokah O.D.I., “A digital robust controller for cutting force control in the end milling process.,” ASME Journal of Dynamic System, Measurement and Control, 119(2), 146-152, 1997.