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A PID for Needle Valve Output Pressure Control Based on Servo Motor & LabVIEW

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***Abstract*—In this paper, a PID controller is designed and constructed to control the output pressure of needle valve in the hydraulic circuit. The valve is controlled by the servo motor which has connected to it. The pressure sensor at the inlet and outlet of the valve is used to measure the pressure. Input sensor for safety and output sensor for feedback has been used. The servo motor command is sent by the LabVIEW and DAQ card. In this paper, a new formulation for PID controller is presented in LabVIEW software too.**

Keywords—PID; Pressure Sensor; Servo Motor; Feedback; LabVIEW; DAQ Card

I. INTRODUCTION

Pressure control in hydraulic lines is very important for testing hydraulic sets. The speed and accuracy of the pressure setting to test the hydraulic set will increase the quality of the hydraulic product in the test.

Therefore, the PID controller is used to adjust the pressure. Here "P" represents proportional control action, "I" represents integral control and "D" represents derivative control action. It has tuning constants which brings the process value as close to the the desired operating point i.e. set point. Setting the parameters of PID is called as tuning of PID controller, which controls the respective control actions. In most conditions, the requirement is that the controller should act in such a manner that the process value is as close to the set point as possible [1].

Proportional action: It simply amplifies the error based upon the gain. P mode generates offset. Integral action: The integral term magnifies the effect of long-term steady state errors, applying ever increasing effort until they reduce to zero. Derivative action: The derivative part is concerned with the rate of change of the error with time: If the measured variable takes longer duration to approach the setpoint then the derivative action would speed up the controller action so that the process variable will rapidly reach the set point. Derivative action makes a control system behave much more intelligently. High value of Derivative constant would make controller action oscillatory [1].

The performance of the controller in the actual system design are usually defined by overshoot, rise time, settling time and steady state error of the final system output for reference tracking and disturbance rejection [2].

When the system has external disturbances, such as the variations of output pressure, changing process dynamics, then the transient response may go down. For this reason, intelligent control schemes have proposed [3].

This article contains 5 sections. The block diagram and general structure of the design will be presented in the part II. Section III reviews the principles and relationships of the PID controller in this system. The definition of the software and the programming method are described in the IV section. In Section V the practical results of the tests are presented. Finally, the debate will conclude.

II. DESCRIPTION OF PRESSURE CONTROL SYSTEM

The pressure control system consists of the entire hardware setup communicating with software programs written in LabVIEW, which is described under the heads of hardware and software of the system.

The block diagram of the pressure control system is shown in Fig. 1.

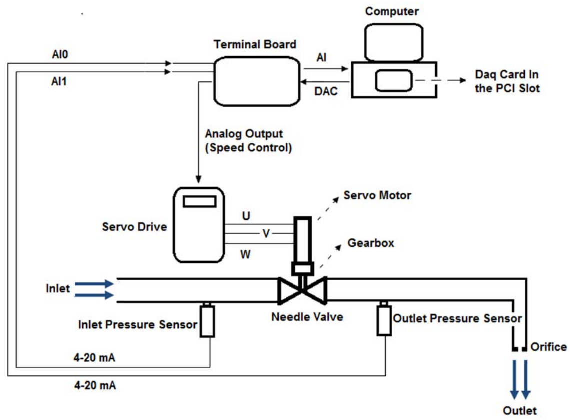

Fig. 1. block diagram of the pressure control system

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The servo motor of the Teco Electro Devices Company are connected to the needle valve by the 1:25 gearbox that is shown inFig. 2 .

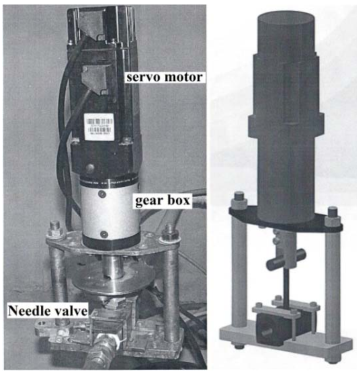

Fig. 2. Install the servo motor on the needle valve and model it with solidwork software

The reason for using a gearbox is to slow down the servo motor and increase the torque of the valve at high pressures. The servo drive controls the speed and direction of the servo motor in speed control mode. In the zero voltage, servo motor is stoped. The positive voltage will turn the servomotor clockwise and the negative voltage turns it counterclockwise. A higher voltage will make the spin faster. The applied voltage is between -10 to 10 volts.

The first and the end of the needle movement path is controlled by adjusting the clockwise and counterclockwise torque on the servo drive. This prevents the breakdown of the valve at the beginning and end of the movement.

In the hydraulic circuit, the orifice plays the role of hydraulic resistance whose it's inlet pressure must be adjusted.

The inlet and outlet pressure of the valve is measured by two pressure sensors with 4 to 20 mA output. Fig. 3 shows the outlet pressure sensor that has been installed on the pipe.

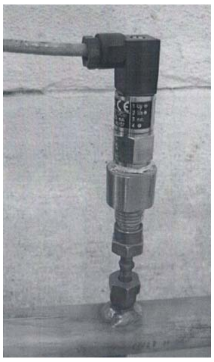

Fig. 3. Outlet pressure sensor installed on the pipe

4 to 20 mA current is converted to a voltage of 1 to 5 volts passing through a 250 ohm resistor. This voltage is applied to the National Instrument company data acquisition Card and processed on a computer.

Inlet pressure sensor is considered for safety. For example, if the output pressure should be set to 50 kgf/cm^2, the input pressure should be larger than 50 kgf/cm^2. Otherwise, depending on the type of test, the servo motor should be closed or not responding.

The outlet pressure sensor has the role of feedback. This sensor measures the output pressure and sends it to the computer to compare the pressure with the value of the set point and give a final decision for send a command to servo drive and control the servo motor.

The output signals of the pressure sensors enter the computer through the terminal board (Fig. 4). In this way, the analogue control signal is applied to the servo drive too.

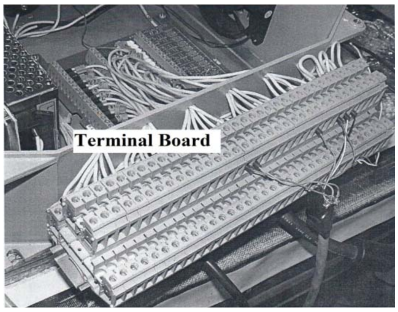

Fig. 4. The output signals of pressure sensors and the analog output are connected to terminal board. The terminal board is connected to the computer with an interface.

The computer controls the magnitude of the analog output voltage through the LabVIEW and PID controller. So that the output pressure is set accurately and quickly on the set point.

III. PID Controller in This System

A proportional–integral–derivative controller (PID controller) is a control loop feedback mechanism (controller) commonly used in industrial control systems. A PID controller continuously calculates an error value e(t) as the difference between a desired setpoint and a measured process variable and applies a correction based on proportional, integral, and derivative terms (sometimes denoted P, I, and D respectively) which give their name to the controller type[4].

A PID controller continuously calculates an error value as the difference between a desired setpoint and a measured process variable and applies a correction based on proportional, integral, and derivative terms. The controller attempts to minimize the error over time by adjustment of a control variable , such as the position of a control valve, a damper, or the power supplied to a heating element, to a new value determined by a weighted sum is determined in Fig. 5 [4].

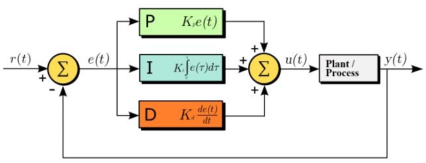

Fig. 5. PID Controller Determination

The output equation of PID is:

$$u(t) = k_p * e(t) + k_i * \int_0^t e(\tau)d\tau + k_d * \frac{de(t)}{dt} \quad (1)$$

In this model:

P accounts for present values of the error. For example, if the error is large and positive, the control output will also be large and positive [4].

I accounts for past values of the error. For example, if the current output is not sufficiently strong, the integral of the error will accumulate over time, and the controller will respond by applying a stronger action [4].

D accounts for possible future trends of the error, based on it's current rate of change. For example, continuing the P example above, when the large positive control output succeeds in bringing the error closer to zero, it also puts the process on a path to large negative error in the near future; in this case, the derivative turns negative and the D module reduces the strength of the action to prevent this overshot [4].

In this work, the following relationships are used to implement the PID controller.

$$Last\_error = 0 \tag{2}$$

$$Last\_iterm = 0 \tag{3}$$

loop:

$$error{=}SP{-}MV \tag{4}$$

$$pterm{=}k_p{\times}error \tag{5}$$

$$iterm{=}k_i{\times}error + Last\_iterm \tag{6}$$

$$dterm{=}k_d{\times}(error - Last\_error) \tag{7}$$

$$PID\_output{=}k{\times}(pterm{+}iterm{+}dterm) \tag{8}$$

$$Analog\_output{=}PID\_output \tag{9}$$

$$Last\_error{=}error \tag{10}$$

$$Last\_iterm{=}iterm \tag{11}$$

Goto loop

In these equations, SP and MV Specify setpoint and measured value respectively. k_p, k_i, k_d are the coefficients of proportional, integral and derivative terms. The k is the value that puts the PID_output in the range of -10 to 10 volts. Pterm, iterm and dterm are the terms of proportional, integral and derivative. PID_output is the sum of these terms and to be placed in analog_output of data acquisition card to control the direction and speed of the servo motor and output pressure of the needle valve. The last values of error and iterm are placed in the Last_error and Last_iterm to update the dterm and iterm. These relationships continue in the program loop to adjust the output of the PID.

IV. SOFTWARE AND PROGRAMING

To implement the PID controller, the LabVIEW software and the National Instrument data acquisition card have been used. Fig. 6 shows a program designed to control the output pressure of the needle valve.

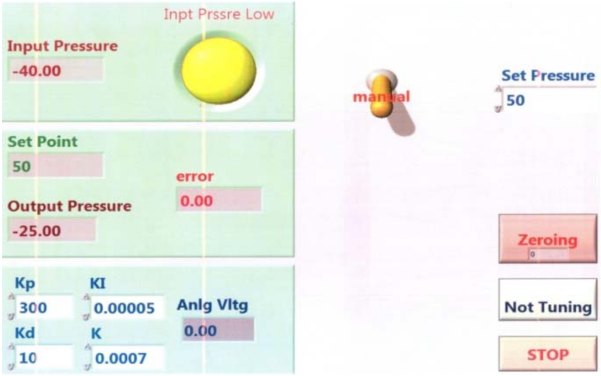

Fig. 6. program designed to control the output pressure of the needle valve

In this program, the output signals from pressure sensors are converted to voltage by resistance and are read by the card. In the program, these voltages are converted to pressure by the arrays of interpolation points 3 and 4, which are the conversion tables. Fig. 7 Shows this topic.

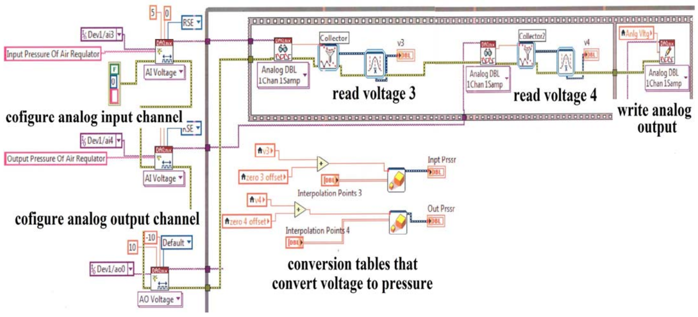

Fig. 7. Configure channels, read analog inputs, write analog output and conversion tables that convert voltages to pressurs

The zeroing button is used to zero off offsets in pressure sensors. As the value of the sensor voltage is read at zero pressure. And the difference is derived from the initial voltage. This difference is the same as the offset value added to the reading voltage. Fig. 8 Shows the zeroing action.

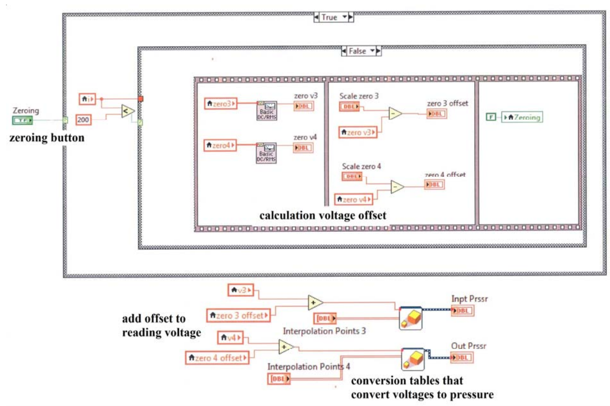

Fig. 8. LabVIEW program for zeroing the voltage offset

Setting the pressure of the needle valve starts when the input pressure is greater than the setting pressure. Also, the tuning button has been pressed. it has been shown in Fig. 9.

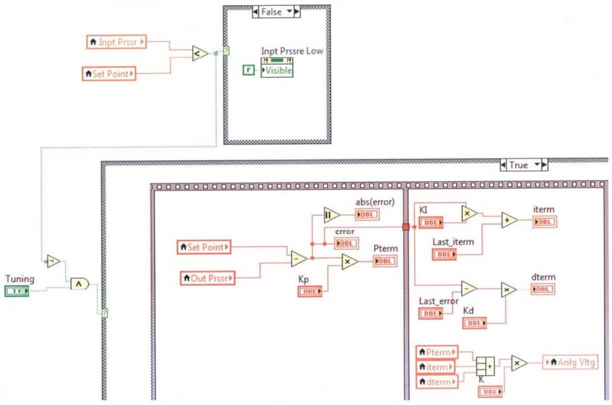

Fig. 9. Start of pressure tuning after the input pressure greater than set point and the tuning button is pressed

In section III, the PID controller relations of this system were expressed. These relationships have been implemented with the LabVIEW software (Fig. 10).

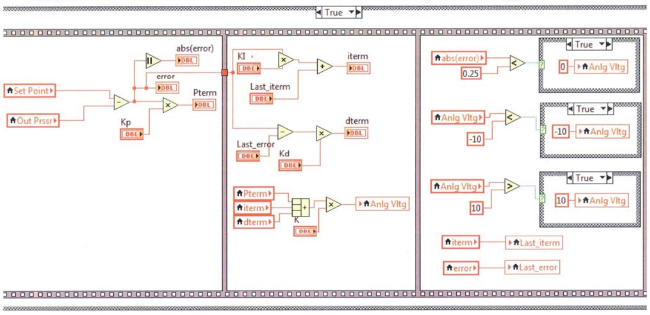

Fig. 10. PID controller relations have implemented with LabVIEW software

V. THE TEST RESULTS

The PID controller parameters are initialized with the manual tuning method [4]. The performed tests in this system are 3 different modes. In one mode, a step pressure is applied to the setting point. Fig. 11 shows the setting point 30 and Fig. 12 shows the setting point 60. In these Figures, the outlet pressure of the needle valve is also shown.

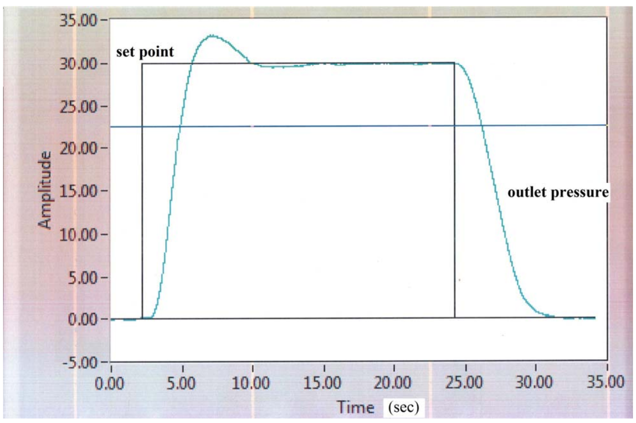

Fig. 11. Setpoint 30 and outlet pressure response

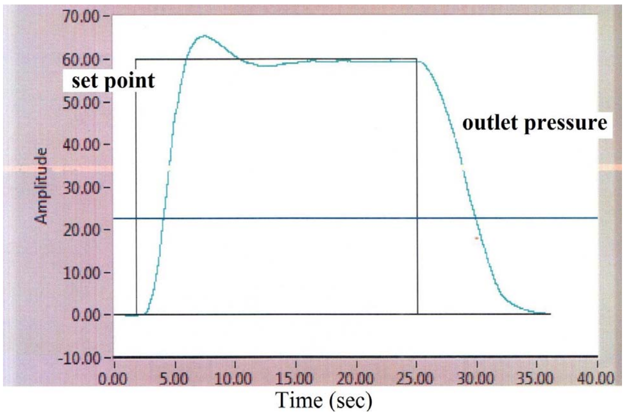

Fig. 12. Setpoint 60 and outlet pressure response

The second mode is a continuous steps of 10,20 and 30 pressures have been applied to the setpoint. Fig. 13 shows the outlet pressure response.

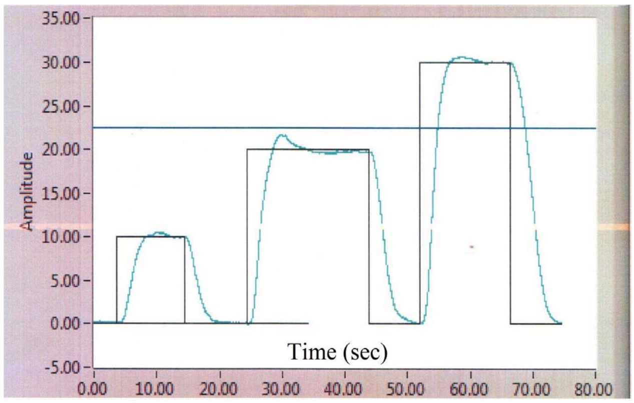

Fig. 13. continuous steps of 10,20 and 30 pressures and the outlet pressure response

in the last mode a Sinusoid pressure with 20 amplitude and 0.1 Hz frequency is applied to setpoint. The outlet pressure response is shown in Fig. 14.

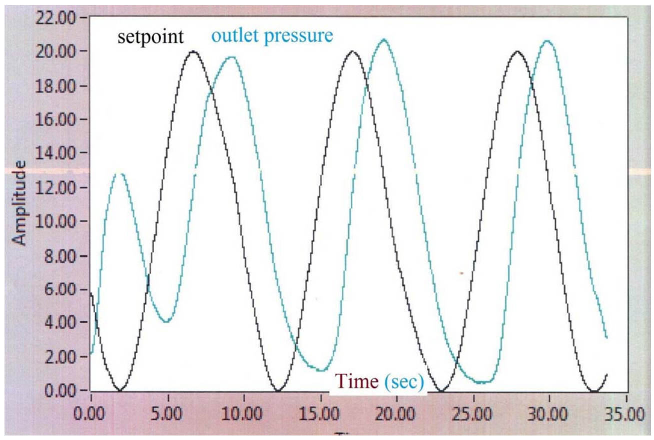

Fig. 14. A Sinusoid pressure with 20 amplitude and 0.1 Hz frequency and the outlet pressure response

VI. CONCLUSION

In this paper, a PID controller was designed and constructed to control the outlet pressure of the needle valve using LabVIEW software and a servo motor that has been installed on the needle valve. Using the pressure sensors, the DAQ card and the LabVIEW software, the inlet and outlet pressure of the needle valve is measured. And the necessary decisions are made to control the output pressure through the analog output to the servodrive and consequently to the servomotor. Also, the results of various tests have been analyzed for controlling the output pressure.

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