Modeling and Implementation of a Proportional-Derivative Controller for Electroviscous Damper.

OMORODION
Department of Materials and Production Engineering
Ambrose Alli University, Ekpoma, Edo State, Nigeria
S.O. AMIEBENOMO
Department of Mechanical Engineering
Ambrose Alli University, Ekpoma, Edo State, Nigeria
C.I. OVIAWE
Department of Mechanical Engineering
Edo State Institute of Technology and Management Usen, Edo State, Nigeria

ABSTRACT
This paper is focus on the design, modeling and implementation of a proportional-derivative controller in the control of the performance characteristics of an electroviscous damper.The implementation shows that proportional derivative (P-D) controller reduce both the system overshoot and the settling time and had small effect on the rise time and steady state error.
Keywords: proportional. Integral, controller, transfer function, electroviscousity.

As early as 19^{th} century (DUFF 1896, Quinke 1897), scientist began studying electroviscous fluid response to input electric field. The fluid gained prominent when winslow (1947, 1949) published results of his research work. Electro viscous fluids consist of fine polarizable particles dispersed in a nonconductive, low viscositiy fluid. Electro viscous fluids exhibit a rapid, yet reversible induced shear resistance when exposed to an applied electric field. Engineers and scientists have identified possible applications including vehicle suspensions, hydraulic values and soft clutches that would utilize the special properties of electro viscous fluid. Development of commercial applications of devices using electro viscous fluids has been hampered by inability to quickly and precisely control the electro viscous fluid state Clark, et.al., 1996). previous studies have focused on varying aspect as to the composition of fluid and particulate sizes varying the electric fluid strength and shearing rate has been investigated Strangroom (1978, 1980).The application of the fluid in mechanical devices also have been investigated Block and Kelly (1986). A simulation method was developed to describe structure formation in electro viscous suspensions (Klingen berg et al., 1989). Current devices such as electro viscous fluid bused valves, clutches or hydraulic mounts typically do not react quickly or precisely enough to meet needs of the applications (Duclos ,1987; Ushijima et al., 1988, Arguelles et al, 1973). The objective of this paper is to investigate the response of a typical electro viscous application in shock absorber to a step input signal using the proportional – derivative P-D controller.

The proportional – derivative controller model

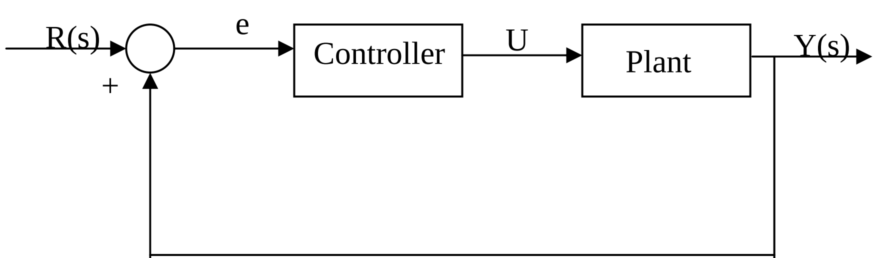

Figure 1:P- D control model

Plant is the system to be controlled. The controller provides the excitation for the plant designed to control the overall system behaviour. This controller is two – terms controller ;

P-D controller and the system transfer function is given as;

$$K_p + K_{ds} = \frac{K_{ds} + K_{ps}}{S}$$

K_P = proportional gain

K_{dS} = Derivative gain

The tracking error is the difference between the desired input value (R) and actual output (Y). The error signal is sent to the P-D controller, and the controller compute the integral of this error signal. The signal (U) just past the controller is now equal to K_P times the magnitude of the error plus the integral gain K_d times derivative gain error.

$$U = K_{pe} + K_d \frac{de}{dt} \quad \ldots\ldots(2)$$

This signal (U) will be sent to the plant, and the new output Y will be obtained.

Table:Characteristics of P -D controller.

System parameters	Rise time	overshoot	settling	Steady state error
K_p	Decrease	Increase	Small change	Decrease
K_d	Small change	Decrease	Decrease	Small change

The focus of this paper is to show how each of K_p and K_d contributes to obtaining.

Fast rise time , Minimum overshoot ,reduce steady – state error and Open – loop step response.

THE MATHEMATICAL MODEL

$$M\ddot{Y}(t) + b\dot{Y}(t) + kY(t) = u(t) \quad \ldots\ldots(3)$$

Assume all initial conditions are zero using laplace transform

$$MS^2 Y_s + bSY_S + KY_s \quad \ldots\ldots(4)$$

$$\frac{Y(s)}{U(s)} = \frac{1}{MS^2 + bs + k} \quad \ldots\ldots(5)$$

Parameters used
Stiffness K = 20N/m
Mass M = 1kg
Damping coefficient b = 15Ns/m

Substituting the parameters in eqn. (5). The system transfer function is

$$\frac{Y(s)}{U(s)} = \frac{1}{S^2 + 15s + 20} \quad \ldots\ldots(6)$$

Open loop step response employing matlab software is given as shown in the plot below;

PROPORTIONAL CONTROL IMPLEMENTATION

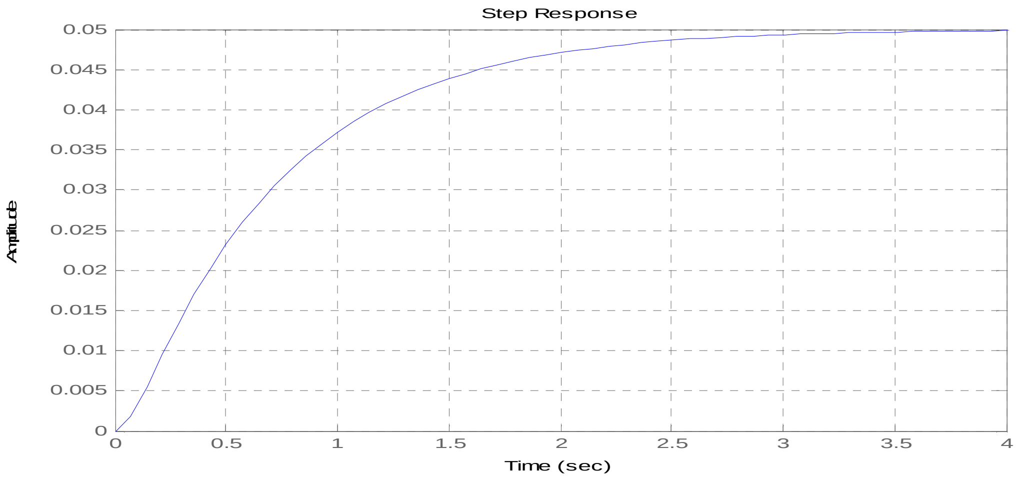

Figure 2: Open step response graph

From the Table 1 above , the proportional controller kp reduces the rise time, increases the overshoot, and reduces the steady state error. The closed loop transfer function of the proportional controller is given as;

$$\frac{Y(s)}{U(s)} = \frac{K_p}{s^2+15s+(20+K_p)} \quad \text{..(7)}$$

using matlab software, and taking proportional gain kp = 300 we have the plot below

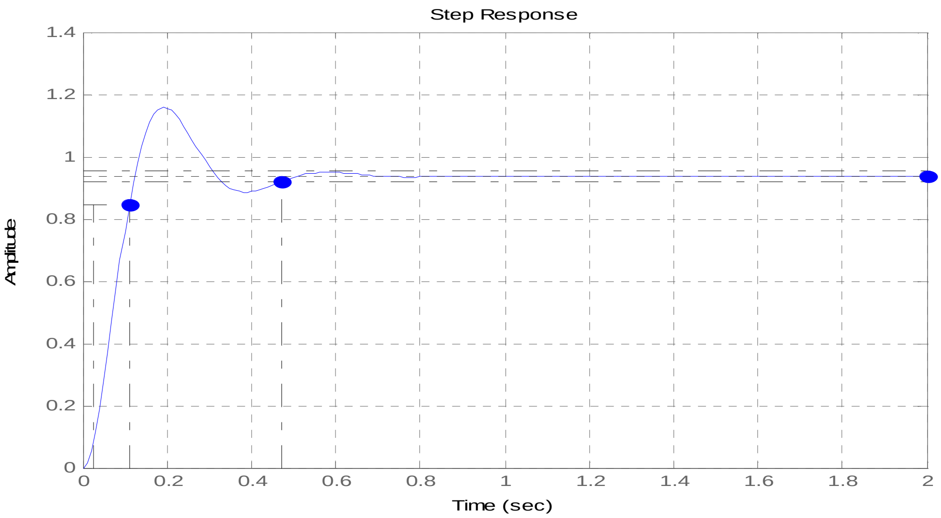

Figure 3: Proportional controller graph

This plot shows that the proportional controller reduced both the rise time and the steady-state error, increased the overshoot, and decreased the settling time.

Proportional-integral control

The transfer function is given as

$$\frac{Y(s)}{U(s)} = \frac{K_{ps}+K_{d(s)}}{s^2+(15+K_d)s+(20+K_p)} \quad \text{...(8)}$$

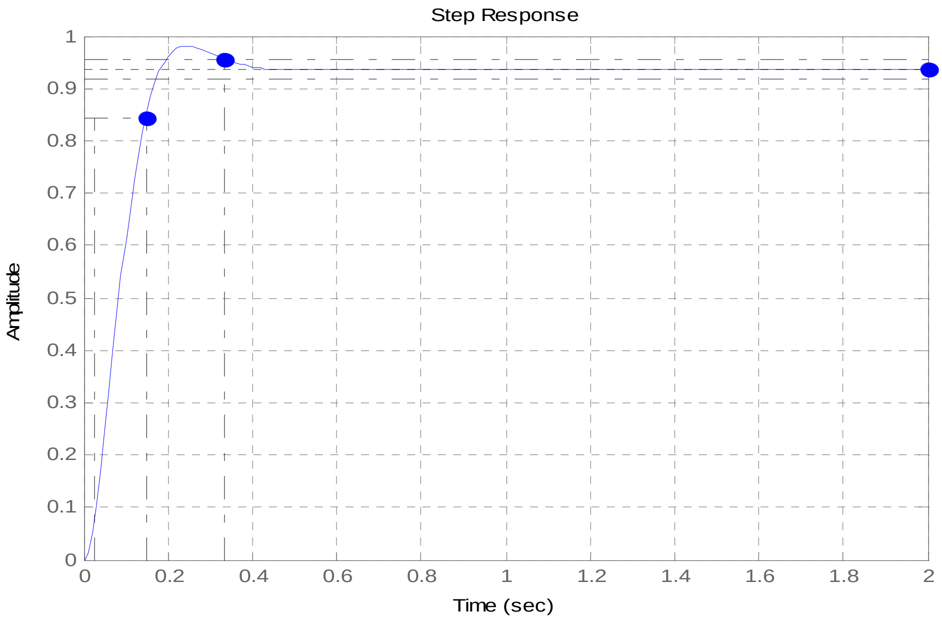

Figure 4:P-D step response graph

Conclusion

The proportional-derivative controller has been successfully implemented in the control of electro viscous damper performance characteristics. Rise time, overshoot and the steady state error to step input responses has been implemented using the Mathlab software.

REFERENCES

Argulles, J., Martin, H. R., and Pick. J., 1973, “Some Experiments with Electrosensitive Fluids,” 3rd International Fluid Power Symposium, Paper F-pp. 25-35, May 9-11.

Block, Hermann, and Kelly, Jeffrey Philip, 1986, “Electrorheological Fluids, “Eur. Pat. 0,191,585, Aug. 20.

Contrad, H., Sprecher, A.F., Choi, Y., and Chen, Y., 1991, “The Temperature Dependence of the Electrical Properties and Strength of electrorheological Fluids, “The Society of Rheology, Inc., May, 1991, pp. 1393-1410.

Duclos, Theodore G., 1987, “An Exponentially Tunable Hydraulic Mount which Uses Electro-Rheological Fluid,” proceedings of the 1987 Noise and vibration conference, pp. 131-137, April 28-30.

Duclos, Theodore G., Acker, Debra N., and Carlson, J. David, 1988, “Fluids that Thicken Electrically,” Machine Design, Jan. 21, pp. 42-45.

Klingenberg, D.J., van Awol, Frank, and Zukoski, C.F., 1989, “Dynamic Simulation of Electrorheological Suspensions,” Proceedings of the ACS Division of polymeric Materials Science and Engineering, Sept. 11-18, Vol. 61, pp. 154-155.

Stangroom, James Edward, July 5, 1977, “Electric Field Responsive Fluids” U.S. Patent 4,033,892.

Stangroom, James E., Devcember 12, 1978, “Electric Field Responsive Fluids,” U.S. Patent 4,129,513

Ushijima, T., Takano, K., and Noguchi, T., 1988, “Rheological Characteristics of ER Fluids and Their Application to Antivibration Devices with Control Mechanism for Automobiles,” Passenger Car Meeting & Exposition, Oct.31-Nov.3, 1988, Society of Automotive Engineers, Paper 881787, pp. 1-9.