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MODELING AND IMPLEMENTATION OF A PROPORTIONAL-INTEGRAL CONTROLLER FOR ELECTROVISCOUS DAMPER

OMORODION, I.I[1], AMIEBENOMO, S.O[2] AND B.O.A. Ozigi[3]

Department of materials and production engineering[1] and Department of mechanical engineering[2]

Ambrose Alli University, Ekpoma. Edo state. Nigeria.

Power Equipment and Electrical Machinery Development Institute[3] Okene,Kogi

State,Email:oabdulmaleeq@gmail.com

sebastianamiebenomo@gmail.com

ABSTRACT

This paper is a research undertaken on the design, modelling and implementation of a proportional-integral controller. It focuses on how the proportional-integral controller can be applied in controlling the performance characteristics of an electro viscous damper.

KEYWORDS: proportional-Integral controller, transfer function, electro viscosity, Damper.

INTRODUCTION

The study of how electro viscous fluid responds to the input electric field dates back to the 19th Century (Duff, 1896;Quinke, 1897),The study of fluid gained prominence with the publication of Winslow's research work in the late 1940s (Winslow.1947, 1949).

Electro viscous fluids consisted of fine, polarizable particles which are dispersed in a non-conductive, low-viscosity fluid. When Electro viscous fluids are exposed to an applied electric field, they display.a rapid, induced shear resistance which nonetheless remains reversible. Possible applications that would utilize the special properties of electro viscous fluid. Have been sought by Engineers and scientists. Some of the applications identified include: vehicle suspensions, hydraulic values and soft clutches. The development of commercially viable applications of devices which use electro viscous fluids has been hampered by the inability to quickly control the electro viscous fluid state with some precision (Clark, et.al., 1996).

Previous studies undertaken in this field focused on varying the composition of fluid and the sizes of the particulate. They also focused on varying the electric fluid strength, and shearing rate (Strangroom, 1978, 1980).The application of this electro viscous fluids in mechanical devices has also been investigated (Block and Kelly, 1986). Klingen berg et al.(1989) developed a simulation method that described the structure formation in electro viscous suspensions However other researchers observed that modern devices like the commonly used electro viscous fluid bused valves, clutches or hydraulic mounts did not react quickly or precisely enough to meet the needs of the applications (; Arguelles et al, 1973;Duclos ,1987;Ushijima et al., 1988;).

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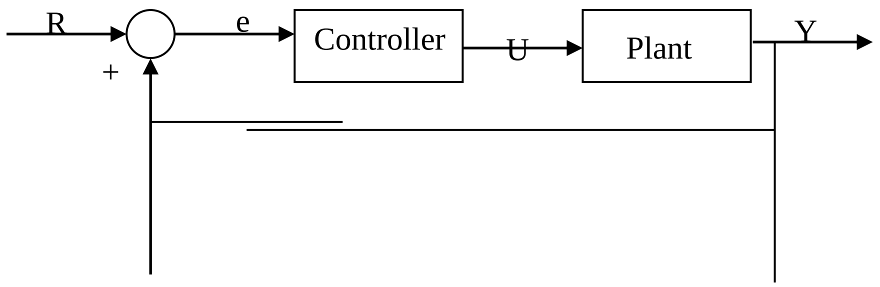
OBJECTIVE

This paper investigates how the electro viscous application in a typical shock absorber responds to a step input signal.

The proportional – integral controller model



In this case, the proportional - integral controller model plant is the system to be controlled. The controller provides the excitation required for the designed plant to control the overall system behaviour. This controller is a two- terms controller

PI controller and the system transfer function is given as;

$$K_P + \frac{K_i}{S} = \frac{K_P + K_i}{S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

K_P = proportional gain
K_i = Integral gain

The tracking error is the desired input value (R) minus the actual output (Y). The controller computes the integral of the error signal when the error signal is sent to the PI controller. Immediately after the signal (U) passes the controller, the signal (U), becomes equal to the added value of K_P multiplied by the magnitude of the error and K_i multiplied by the integral of the error.

This value is given by the function:

$$U = K_{pe} + K_i \int edt \qquad (2)$$

This value of the signal (U) is feed into the plant, for a new output (Y) to be obtained from the operation.

Table 1:Characteristics of P I controller.

System parameters	Rise time	Overshoot	setting	Steady state error
K_p	Decrease	Increase	Small change	Decrease
K_I	Decrease	Increase	Increase	Eliminate

This paper evaluates how the values of K_p and K_i contribute to the process of obtaining: Fast rise time ,Minimum overshoot ,reduce steady - state error and Open - loop step response.

The Mathematical Model

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

Assume all initial conditions are zero employing the Laplace transform

$$MS^2 Y_s + bSY_s + KY_s \qquad (4)$$

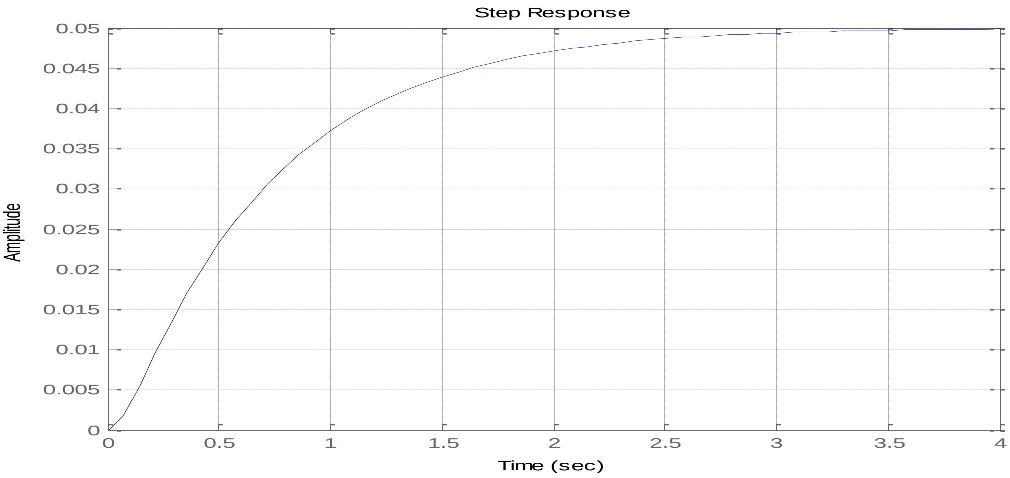
$$\frac{Y(s)}{U(s)} = \frac{1}{MS^2+bs+k} \qquad (5)$$

The parameters used were Stiffness K = 20N/m Mass M = 1kg Damping coefficient b = 15Ns/m Substituting the parameters in eqn. (5). The system transfer function is

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

By employing the tools available in the Mat Lab software, the Open loop step response which was produced with Mat Lab is shown in the plot below.

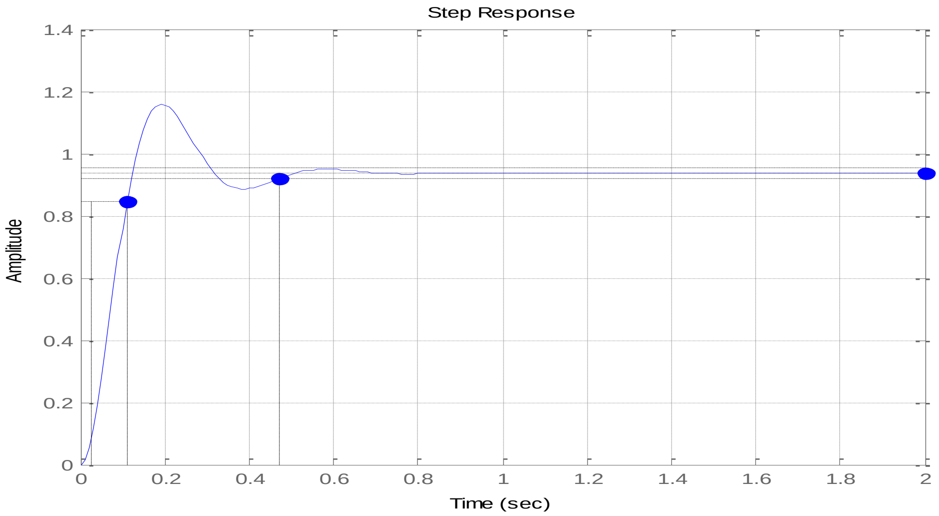
PROPORTIONAL CONTROL IMPLEMENTATION



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

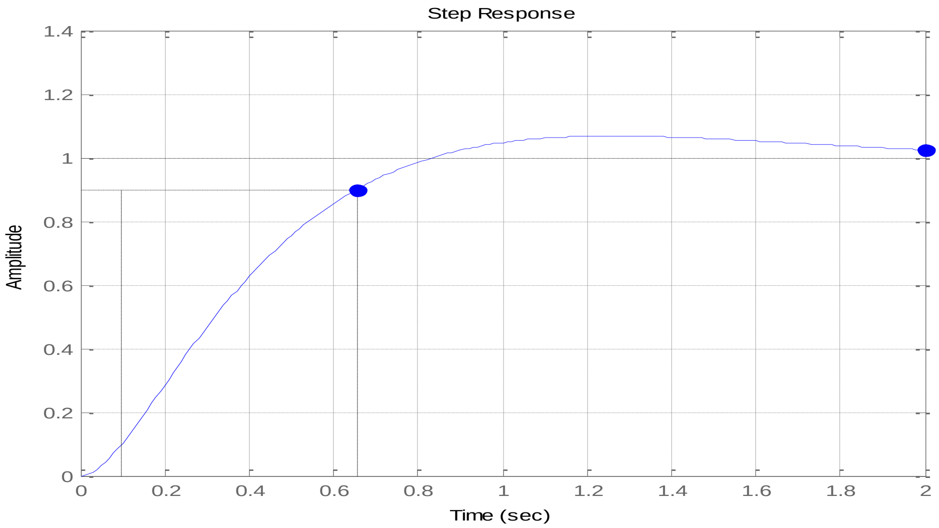
$$\frac{Y(s)}{U(s)} = \frac{K_p}{S^2+15s+(20+K_p)} \qquad (7)$$

With the use of MatLab software, and taking proportional gain kp = 300, the plot below is obtained.



This plot referenced shows that the proportional controller: not only reduced the rise time and the steady-state error, but also increased the overshoot, and decreased the settling time. As for the **Proportional-integral control**, the transfer function is presented as.

$$\frac{Y(s)}{U(s)} = \frac{K_{ps}+K_{i(s)}}{S^2+15s+(20+K_p)s+k_i} \qquad (8)$$



CONCLUSION

In this paper, the proportional-integral controller has been successfully implemented in the control of the performance characteristics of electro viscous damper. The Rise time, overshoot and the steady state error to step input responses has also been implemented. Implication of this study is that electro viscous damper can improve ride comfortably of vehicle suspension system arising from the reduce rise time, increase the overshoot, and reduce the steady state error of the unit step input response.

REFERENCES

1) 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.
2) Block, Hermann, Kelly, and Jeffrey .P, (1986). Electrorheological Fluids, Eur. Pat. 0,191,585, Aug. 20.
3) 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.
4) Duclos and 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.
5) Duclos, Theodore G., Acker, Debra N., and Carlson, J. David, (1988). Fluids that Thicken Electrically. Machine Design, 4(5), pp. 42-45.
6) 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, 61(2) ,pp154-155.
7) Stangroom and James Edward, (1977). Electric Field Responsive Fluids, U.S. Patent 4,033,892.
8) Stangroom, and James E., (1978) Electric Field Responsive Fluids, U.S. Patent 4,129,513
9) 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, Society of Automotive Engineers, Paper 881787, pp. 1-9.