Study of Hydraulic Directional Control Valve with Cylinder Performance using Matlab Simulink

Kishor. S. Joshi
Department of Mechanical Engineering
Maratha Mandal Engineering College, Belgaum,Karnataka, India

C.S.Rajshekar, Asst. Prof
Department of Mechanical Engineering
Maratha Mandal Engineering College, Belgaum,Karnataka, India

Abstract: - The present work is conducted to study the performance of hydraulic control system and the designed of electro-hydraulic control circuit contained hydraulic directional control valve size type [4WRE6981X/24Z4M]. The theoretical part includes essential branches. The analysis of the system is used to find the mathematical model to the electro-hydraulic system and a nonlinear analysis for the system for three position spool to proportional directional control valve. The theoretical results of the control system were developed using the Matlab/SIMULINK to simulate the system and drawing the results as a step responses. This shows a steady response of the system to step inputs at different case studies

Keywords: hydraulic directional control valve, mathematical model, Matlab/SIMULINK.

I.INTRODUCTION

The use of hydraulic systems for control and regulation has made possible important fields for automation. However, in spite of the specialized field has not yet been circulated to a high enough degree. As a result of this, the application of hydraulic systems has been restricted. Today, we understand under the term `hydraulic` the transmission and control of force and movement by means of fluid. The objective of a fluid power system is to do useful work. This is accomplished in three fundamental steps. First, a mechanical energy input is converted into fluid energy by a hydraulic pump. Next, this fluid energy is transmitted through fluid conduits and any necessary control devices. Last, the fluid energy is reconverted into mechanical energy by an output device – usually a hydraulic cylinder or a hydraulic motor [1].

II.MATHEMATICAL MODEL

The system describes detailed mathematical modeling of HSS for hydraulic mini press machine. The system consists of high-speed, electronic drives, hydraulic actuators, and position transducers. The mathematical model behaviour of servo valves can be developed from the relationship between the displacement and input voltage for the proportional valve. A third order model is sufficient for HSS, which is described by the equations given in following sections [3].

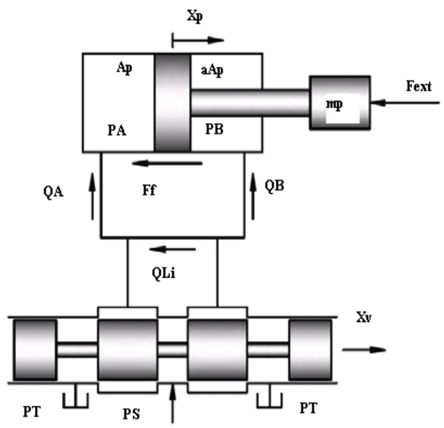

Figure. 1. A hydraulic actuator with four-way valve configuration

In pressing machine, the hydraulic actuator is typically a double-acting hydraulic cylinder. The cylinder Ports are connected to a proportional valve, and piston motion is obtained by modulating the oil flow into and out of the cylinder chambers. A servo valve provides this modulation as shown in Fig 1. The actuator can be precisely controlled by regulating the flow rates and . However, the relationship between the piston position, , and the flow rates depends on the dynamic properties of the load acting on the piston [5]. The mathematical model used in simulation is represented by the following system of equations:

$$M.\frac{d^2x}{dt^2} + Fv + Fs - Fp + Fco.\,sign\,\frac{dx}{dt} = 0 \tag{1}$$

Where

$Fv = \text{Viscous force} = C\frac{dx}{dt}$

$Fs = \text{Spring force} = K.X$

Fp is the net force acting on the piston which can be computed by multiplying the area of the piston annulus Ap by the differential pressure between two chambers 1 and 2.

$$Fp == (PA - PB)Ap \tag{2}$$

A.The hydraulic power supply

All hydraulic systems require a supply of pressurized fluid, usually a form of mineral oil. The behavior of the hydraulic power supply may be modeled by applying the flow continuity equation to the volume of trapped oil between the pump and control valve. In this case, the input flow is held constant by the steady speed of the pump motor, and the volume does not change. The equation of the model is

$$\frac{dPs}{dt} = \frac{B}{Vt} * (Qpump - QL) \tag{3}$$

This equation takes into account the load flow QL drawn from the supply by the control valve, and accurately models the case of a high actuator slew rate resulting in a load flow which exceeds the flow capacity of pump. The action of the pressure relief valve may be modeled using a limited integrator to clamp the system pressure to the nominal value.

B.Cylinder chamber pressure

The relationship between the valve control floe and actuator chamber is important because the compressibility of oil creates a spring effect in the cylinder chamber which interacts with the piston mass to give a low frequency resonance. The effect can be modeled using the net flow into a container to the internal fluid volume and pressure

$$\frac{dPA}{dt} = \frac{B}{Vt} * (Q1 - \frac{dv}{dt}) \tag{4}$$

The same equation can also be represent chamber 2.

$$\frac{dPB}{dt} = \frac{B}{Vt} * (Q2 - \frac{dy}{dt}) \tag{5}$$

C. Flow rate

The main function of directional control valve is to direct and distribute flow between onsumers ie between cylinder and pump and tank from the other side. The way of valve is modeled by well known relationship flow-pressure for turbulent flow.

$$QA = Cd * Aa * \sqrt{\frac{Ps - PA}{\rho}} \tag{6}$$

$$QB = Cd * Ab * \sqrt{\frac{Ps - PB}{\rho}} \tag{7}$$

III.SIMULINK MODEL

The equations (1) to (7)) are represented in SIMULINK ®MODEL to analyze the displacement of the poppet, Outlet flow rate and pressure rate with considering the effects of bulk modulus with the time rate. The MATLAB SIMULINK model is given below

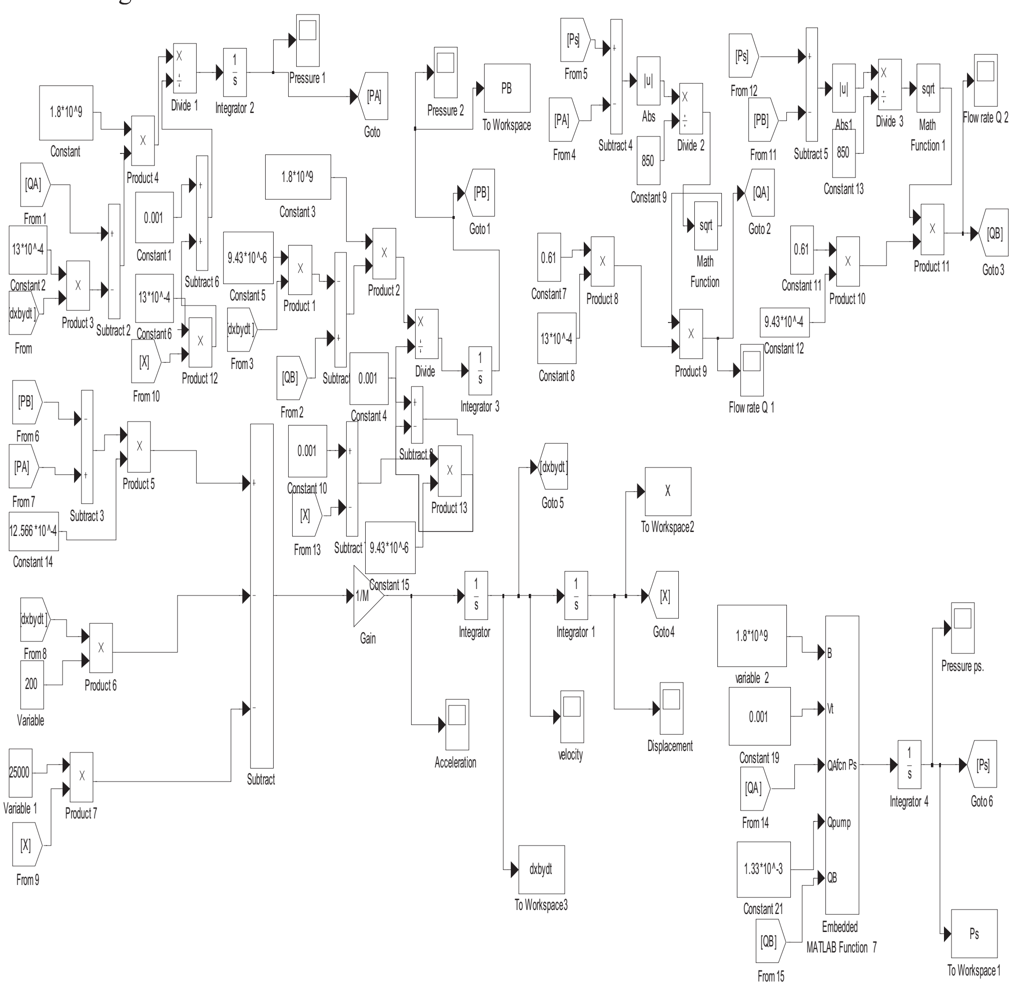

Figure.2. SIMULINK model

IV. ANALYSIS

The valve model was ready for analysis and simulations. Certain parameters like stiffness of spring, volume, inlet flow rate, bulk modulus and area were kept constant. The analysis was considered with time as given in Fig.

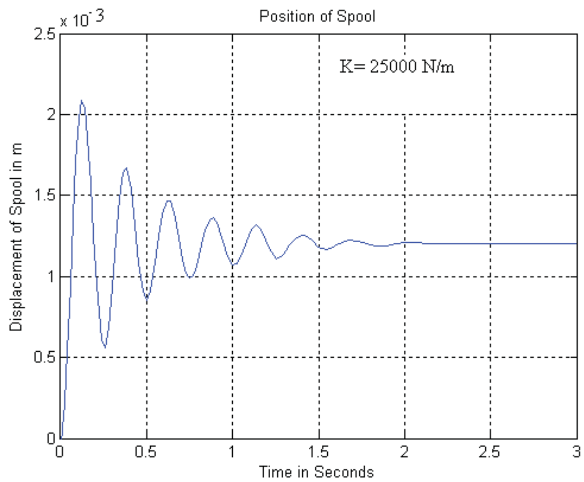

Figure. 3 Spool displacement for K=25000 N/m

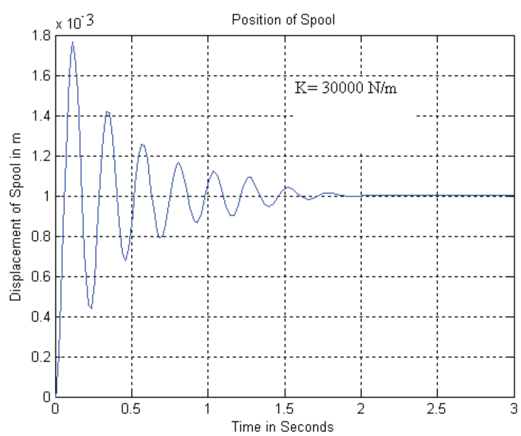

Figure.4 Spool displacement for K=30000 N/m

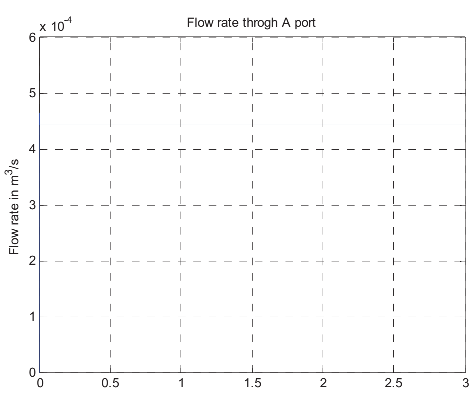

Figure 5. Flow rate in A port

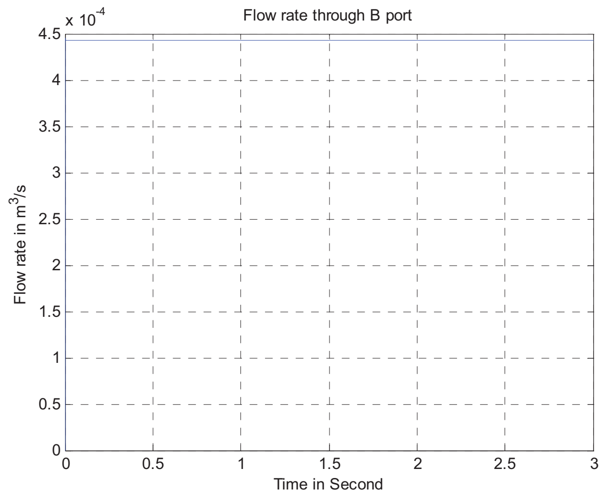

Figure. 6. Flow rate in B port

V. CONCLUSION

In this paper, developed a unified model for proportional control valves and analyzed the effect of spool lapping on open – loop hydraulic system properties. The nonlinear mathematical equations relate the flow rates through the valve ports to the valve parameters. The flow rates are expressed as a continuous but nonlinear function of lapping parameters, as well as other conventional parameters. These equations are readily applicable to various types of proportional valves, and they unify the cases of critical centre, overlapped, and under lapped valves. The spool lands geometry is individually controlled via model parameters. Also derived simplified flow rate equations under certain widely – used assumptions while keeping nonlinearities due to spool geometry. The variation of the flow gain and uncertainly bounds of the flow rates of an under lapped valve are also analyzed

REFERENCES

[1] Department of Labor, Occupational Safety and Health Administration, Process Safety Management of Highly Hazardous Chemicals, 29 CFR 1910.119, February 24, 1992.

[2] American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels, Division 1, ASME, New York, 2001 plus addenda.

[3] American Petroleum Institute, API Recommended Practice 520, Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries, Part I, Sizing and Selection, API, Washington D.C., 2000.

[4] Fisher, H.G., et al., Emergency Relief System Design Using DIERS Technology, AIChE’s Design Institute for Emergency Relief Systems, DIERS, AIChE, New York, 1992.

[5] Quoc-Khanh, Tran and Reynolds, Melissa, Sizing of Relief Valves for Two-Phase Flow in theBayer Process, Kaiser Engineers PTY Limited, Perth, Western Australia, 2002.

[6] Hauptmanns, Ulrich and Yllera, Javier, Fault-tree Evaluation by Monte Carlo Simulation,Chemical Engineering magazine, January 10, 1983.

[7] Crosby® Engineering Handbook Technical Publication No. TP-V300, Pressure Relief ValveEngineering Handbook, Crosby Valve Company, Somewhere, somedate.

[8] The Crane Company Technical Paper No. 410, Flow of Fluids through Valves, Fittings, and Pipe, 25th printing, 1991.9. Blackwell, Wayne W., Calculating Two-phase Pressure Drop, Chemical Engineering magazine, September 7, 1981, pp. 121-125.