RESEARCH ARTICLE OPEN ACCESS

Experimental investigation for improvement of the supply pressure decay by using different hydraulic system designs

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ABSTRACT: This paper reports an experimental study of the supply pressure decay within many different hydraulic system designs. The experimental pressures are compared to a supply pressure with changing the number of valves different design. The hydraulic control system contains mainly hydraulic power unit (Oil Tank; 110 L, Pressure Filter, Pilot Operated Pressure Relief Valve, Non-Return Valve, Manometer, Return Filter, Thermostat and Heating Unit, Cooling Unit and many types of control valves). These investigations provide a study for decay of supply pressure under different operating conditions. The investigations have been carried out for different system designs. The analysis of the results introduces the effect of system designs on supply pressure. Also, the investigations provide experimental studies to solve pressure decay problem.

Keywords:fluid power control system, hydraulic cylinder, proportional flow control valve, directional control valve, throttle control valve.

Date Of Submission:06-09-2018 Date Of Acceptance: 22-09-2018

I. NOMENCLATURE

p_s	Supply pressure, [bar]
p_{sa}	Actual value of supply pressure, [bar]
Δp	Pressure drop; (p_s - p_1), [bar]
θ	Throttle valve opening, [%]
ϕ	Flow control valve opening, [%]
ϕ_1	Opening of Directional flow control valve
Φ	Opening of proportional flow control valve. [%]
Φ_I	Opening of Servo control valve. [%]

ABBREVIATIONS

A, B	Working lines.
DFCV	Directional flow control valve
EHSV	Electro hydraulic servo valve
FCV	Flow control valve.
P	Supply pressure line.
PFCV	Proportional flow control valve.
PDFCV	Proportional directional flow control valve
ThV	Throttle valve
T	Return (Tank) line.

II. INTRODUCTION

Control components in Hydraulic system one of the most important functions in any fluid power system is control. If control components are not properly selected, the entire system will fail to deliver the required output.

Elements for the control of energy and other control in fluid power system are generally called "Valves". It is important to know the primary function and operation of the various types of control components. This type of knowledge is not only required for a good functioning system, but it also leads to the discovery of innovative ways to improve a fluid power system for a given application. The selection of these control components not only involves the type, but also the size, the actuating method and remote control capability. Pressure is an across type variable, which means that it is always measured one can talk about the pressure across a fluid power element such as a pump or a valve, which is the pressure differential from one side to the other, but when describing the pressure at a point, for example the pressure of fluid at one point in a hose, it is always with respect to a reference pressure.

Performance of fluid power control systems was, firstly, well documented in the 60's, such as by Blackburn [1], 1962, Merritt [2], 1967, and Guillon [3], 1968. All researchers mostly considered a constant value for supply pressures. Some researchers studied the general information and performance of hydraulic control systems as Taplin [4], 1971, Jacobs and Shräder [5], 1971, Federlein [6 & 7], 1976, Nikiforuk [8], 1963, Laika [9], 1974, and Williams [10], 1965. They studied, mainly the flow - pressure relationship, load and supply pressure requirements, advantages of closed-loop systems. Kalange and Alcott [11], 1970, Baumgartner [12], 1975, and Laika [13], 1975 & [14], 1979, studied the effect of dynamic damping in position control systems through external friction, leakage or under-lap in spool valve. Akers and Lin [15], 1990, investigated the performance of control systems theoretically and experimentally considering different operation conditions, however with constant values for supply pressure.

III. EXPERIMENTAL PROCEEDINGS AND OPERATING CONDITIONS

Supply pressure has been controlled using the frequency inverter which provides the DC motor by an electric signal with specific frequency. Different setting values for supply pressure has been adjusted in the all cases, then specify the decay

The experiments have been carried out as follows:

Firstly, connecting the Throttle Valve and Directional Control Valve

The throttle/check valve serves to set an exact oil flow in one direction, and to allow free return flow in the opposite direction. Fig. 1 shows hydraulic circuit, symbol and schematic drawing of the throttle/check valve [16].

- The supply pressure (p_s) has been changed as the values 20, 30, 40 and 50 bar.
- At each value of the supply pressure, the throttle valve opening (ThV); (θ) has been changed as a percentage of full-opening; 50, 75, and 100%.
- The decaying variation of supply pressure for setting values 20, 30, 40, 50 bar at each condition of throttle valve opening (ThV) (θ); 0, 12.5, 25, 37.5, 50, 62.5, 75, 87.5, and 100% have been noticed from the Digibar transducer [17]. Results are presented in Fig. 2.

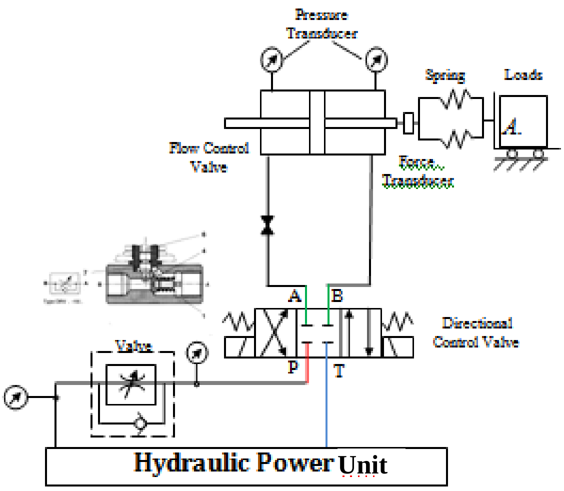

Figure 1. Hydraulic circuit with connecting the Throttle Valve and Directional Control [18]

Secondly, connecting the throttle valve, directional control valve and flow control valve[19] in flow control system, the flow rate could be affected by altering the area of an orifice inside the valve. Figure 3 shows a sectional drawing of flow control valve, and schematic drawing for hydraulic circuit .

The flow control valve has been connected to the circuit. Then the same experiments as the before-mentioned conditions have been carried out for different values of flow control valve - opening (FCV) as a percentage of its maximum-opening value (ϕ); 100, 50, and 16.66%.

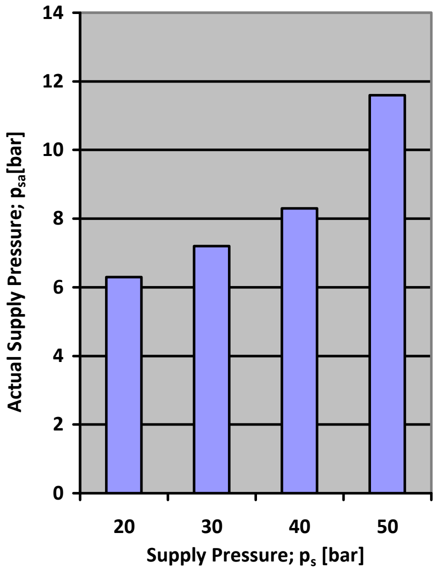

Figure 2. Relationship of Actual supply Pressure; p_{as} at full ThV-Opening; θ for Different Values of Supply Pressure; P_s Under No- Load; F = 0.0 N.

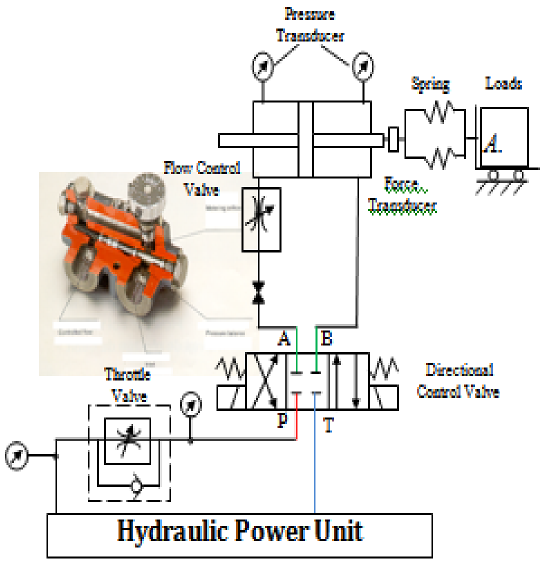

Figure 3. Hydraulic circuit with connecting the Throttle Valve, Directional Control Valve and Flow Control Valve

Values of decayed pressure supply (p_s) verses throttle valve (ThV) opening (θ) and flow control valve opening (FCV) (ϕ) for setting values of 20, 30, 40, and 50 bar. Results are presented in Fig. 4.

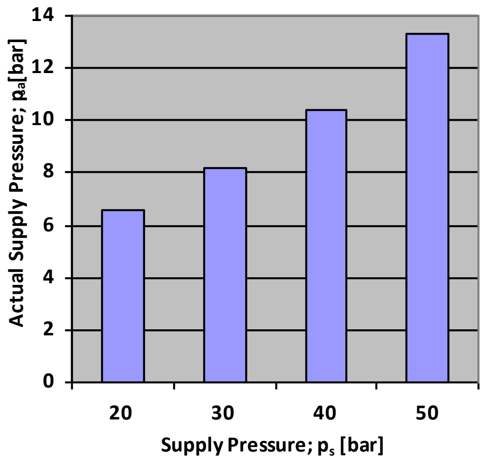

Figure 4. Relationship of Actual supply Pressure; p_{as} at full FCV-Opening; ϕ for Different Values of Supply Pressure; Ps Under No- Load; F = 0.0 N.

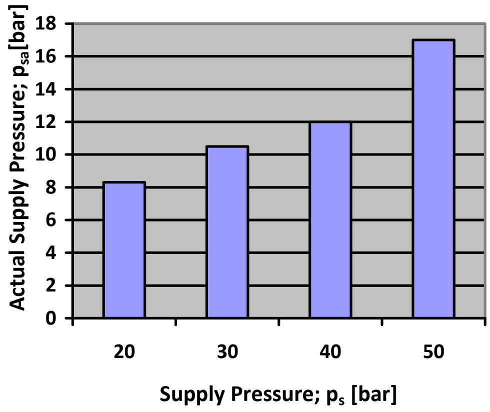

Figure 6. Relationship of Actual supply Pressure; p_{as} at full PFCV-Opening; Φ for Different Values of Supply Pressure; P_s Under No- Load; F = 0.0 N.

Thirdly, connecting the throttle valve, directional control valve and proportional flow control valve; (DFCV) Φ under the same conditions. Fig. 5 shows the Hydraulic circuit

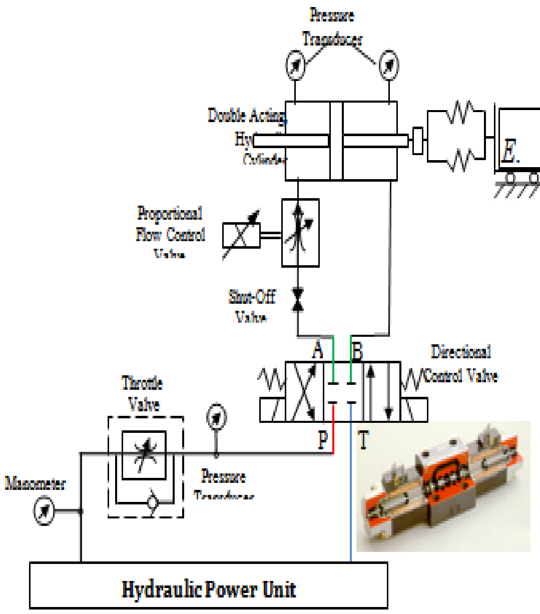

Figure 5. Hydraulic circuit with connecting the Throttle Valve, Directional Control Valve and Proportional Flow Control Valve [20]

Fourthly, connecting the proportional directional flow control valve instead throttle valve, directional control valve and flow control valve as shown in Fig. 7. Proportional directional flow control valve the flow control valve is chosen as 4/3 proportional pilot operated. This type is a 4-way valve operated by means of proportional solenoids [21]. Results are presented in Fig. 8.

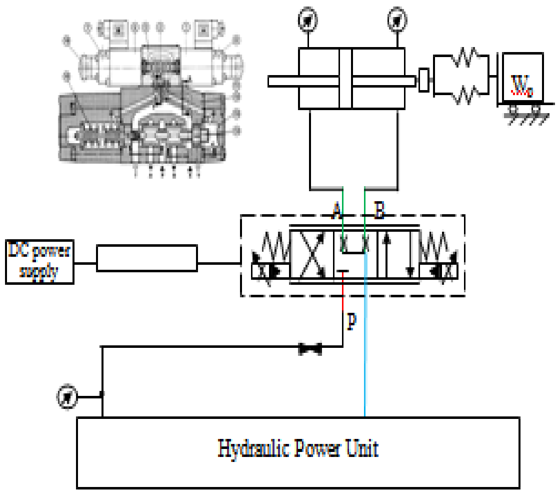

Figure 7. Hydraulic circuit with connecting the Proportional Directional Flow Control Valve

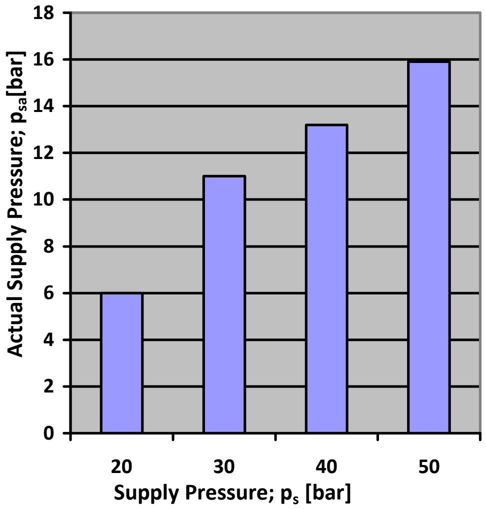

Figure 8. Relationship of Actual supply Pressure; p_{as} at full PDFCV-Opening; ϕ1 for Different Values of Supply Pressure; P_s Under No- Load; F = 0.0 N.

Fifthly, connecting the Servo valve an electro-hydraulic servo control valve is used in the present investigation. A schematic drawing for the valve and Hydraulic circuit are shown in Fig. 9. Results are presented in Fig. 10.

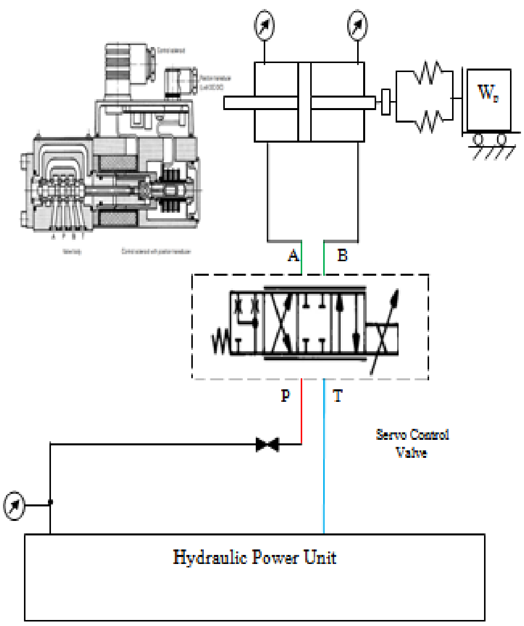

Figure 9. Hydraulic circuit with connecting the Servo Control Valve [22]

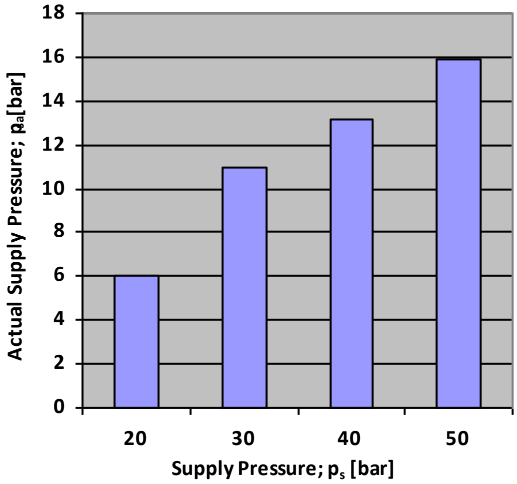

Figure 10. Relationship of Actual supply Pressure; p_{as} at full EHSV-Opening; Φ1 for Different Values of Supply Pressure; P_s Under No- Load; F = 0.0 N.

IV. COMPARISON OF SUPPLY PRESSURE FOR DIFFERENT SYSTEM DESIGN

System supply pressure is studied experimentally considering the actual supply pressure is specified, accordingly supply pressure values. Results are interpreted in the above Figs. for all case of free-load and with connecting the ThV, FCV, PFCV, DPFCV and EHSV. Results are recorded in Table 1.

Table 1. Actual Supply Pressure; P_{sa}, Under Free-Load According To Different System Designs At Full-Opening; [θ, ϕ ,Φ, ϕ1 and Φ1]

Different system designs	**p_s [bar]**			
	Actual **supply pressure; p_{sa}[bar]**			
	20	30	40	50
ThV [θ]	6.3	7.2	8.3	11.6
FCV [ϕ]	6.6	8.2	10.4	13.3
PFCV [Φ]	8.3	10.5	12	15.7
PDFCV [ϕ1]	8.3	11	13.2	15.9
EHSV [Φ1]	10.55	15.1	16.42	19.83

V. RESULTS AND DISCUSSION

The results are extracted and interpreted in the following graph. Fig. 11 shows the decay of supply pressure with supply pressure at full-opening valves for each minimum and maximum value of supply pressure; (p_s) for different system designs.

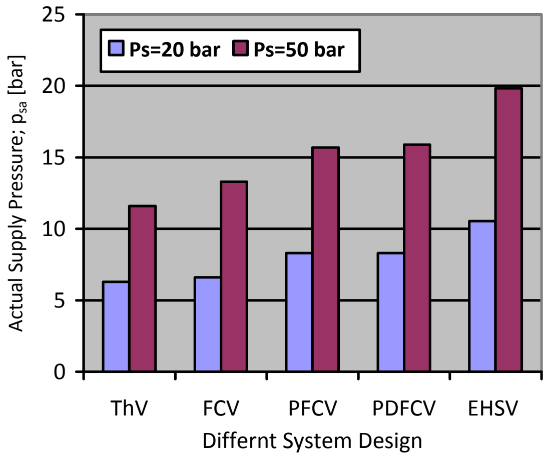

Figure 11. Supply Pressure Decay According to Different System Designs.

Table 2 shows the comparison between different system designs. At case of supply pressure; (p_s) = 50 bar at full- opening valves. In case of connecting the ThV the supply pressure decays to 23% from initial value, considering this valve a reference. The comparison indicates that the actual supply pressure (p_{sa}) decays, in the case of connecting the flow control valve with the throttle valve (FCV & ThV) it decays to 26% of the initial value. That means, there is 3.5 % modification. In the case of connecting the proportional flow control valve with the throttle valve (PFCV & ThV) it decays to 31.4 % of the initial value. That means, there is 8.4 % modification. But in the case of connecting the proportional directional flow control valve (PDFCV) alone, the supply pressure decays to 31.8 % of the initial value. That means, there is 9 % modification. While it was connecting the Electro hydraulic servo valve (EHSV) the supply pressure decays to 40 % of the initial value. Therefore, there is 17 % modification in this case better than that in all before cases.
Table 2 illustrates this improvement.

Table2 Improvement Of Supply Pressure Decay According To Different System Designs At P_s = 50 Bar.

Different system designs	**EHSV**	**PDFCV**	**PFCV& ThV**	**FCV & ThV**	**ThV**
Improvement of supply pressure decay	17 %	9 %	8.4 %	3.5 %	0.0 %

VI. CONCLUSIONS

- This investigation provides that the supply pressure decays during system operation. This occurs whatever the system is loaded or even under no load.
- The experimental results indicate the improvement of the supply pressure decay by using different hydraulic system designs.
- Reducing decay in supply pressure has great value in the economy and industry

REFERENCES

[1]. Blackburn J. F., Reethof G., Shearer S. L. "Fluid Power Control" Band 2, Krausskopf Verlag Wiesbaden, 1962.
[2]. Merritt H. E., "Hydraulic Control Systems" John Wiley & Sons, Inc., New York, 1967.
[3]. Guillon M. "Hydraulische Regelkreise und Servosteuerungen" Carl Hanser Verlag, Munchen, 1968.
[4]. Taplin, L.B. "Philosophy of Analysis In Fluid Control Systems", 1st Symposium on Flow, Its Measurement and Control in Science and Industry, 9 - 14 May 1971, Pittsburgh, Pennsylvania, pp. 1183 - 1189.
[5]. Jacobs, A., Schräder, W., "What you should know about open and closed loop hydraulic systems", Hydraulics & Pneumatics, July, 1971, pp. 71 - 73.
[6]. Federlein, H.G., "How to analyze steady-state flow in a hydraulic system, Hydraulics & Pneumatics, June, 1976, pp. 61 - 62.
[7]. Federlein, H.G., "How to analyze steady-state pressures in a hydraulic system, Hydraulics & Pneumatics, July, 1976, pp. 70 - 72.
[8]. Nikiforuk, P.N. "Very High Pressure Hydraulic Control Systems", Trans. Engng. Inst. of Canada, 1963, Series B, paper No. 17, pp. 3 - 15.
[9]. Laika, A., "Einflu⇓ der Eingangsgrö⇓en auf die dynamischen Kenngrö⇓en elektrohydraulischer Servovemtile" ölhydraulik und pneumatik, 18, 1974, Nr. 10.
[10]. Williams L.J., "High Performance Single-Stage Servovalve", paper presented at SAE Aerospace Fluid Power Systems and Euipment Conference, May 18 – 20, 1965 (Moog Technical Bulletin 106).
[11]. Kalange, M.A., Alcott, R.J., "Dynamic Damping Helps Servo Overcome Resonance in Positioning High Inertia Loads", Hydraulics & Pneumatics, December, 1970, pp. 75 - 77.
[12]. Baumgartner Von H., "Die Dämpfung hydraulischer Vorschubantriebe", Fertigung 6/75, pp. 171 - 175.
[13]. Laika, A., "Messung der Hysterese hydraulischer Steuerkolben und Maßnahmen zu ihrer Verminderung", ölhydraulik und pneumatik, 1975, Nr. 12, pp. 873 - 877.
[14]. Laika, A., "Untersuchung von Dämpfungsmaßnahmen für hydraulische Zylinderantriebe", ölhydraulik und pneumatik 23, 1979, Nr. 6, pp. 437 - 441.

[15]. Akers, A., Lin, S. J., "The Effect of Some Operating conditions on the Performance of a Two-Stage Controller-Pump Combination", Transactions of the ASME, Journal of Dynamic Systems, Measurement, and Control, Vol. 112, December, 1990, pp. 755 - 761.
[16]. REXROTH Throttle/Isolating and Throttle/Check Valves, RE 32 502/08.92, Mannesmann Rexroth GmbH, P.O. Box 340, D-8770 Lohr a. Main.
[17]. HBM Electrical Measurement of Mechanical Quantities, Digibar pressure transducers, HOTTINGER BALDWIN MESSTECCHNIK GmbH, Postfach 4235. Im Tiefen See 45, D-6100 Darmstadt 1.
[18]. Tahany. W. Sadak, Mahassen Rizk, , ― Hydraulic Cylinders-Response in Fluid Power Control Systems ‖ Proceedings of the 2012 20th International Conference on Nuclear Engineering collocated with the ASME 2012 Power Conference ICONE20-POWER2012, Anaheim, California, USA, July 30 - August 3.
[19]. BOSCH Flow Control Valve Catalogue, Robert Bosch GmbH, Geschaftsbereich Hydraulik, Pneumatik, Postfach 300240, 7000 Stuttgart 30, Germany.
[20]. Tahany W. Sadak and Mkawee, T. E. ″Analysis and Modification of the Design of ASME Power 2013 Int. Conf. on Powering the Future, a Balancing Act "In Harmony with the Environment", Boston, Massachusetts, USA, July 29- August 1, 2013.
[21]. REXROTH, 4WRZ Proportional Directional Control Valve Catalogue, Mannesmann Rexroth GmbH, P.O. Box 340, D-8770 Lohr am Main, Germany.
[22]. Tahany W. Sadak and Fouly, A. Anwer" The Effect of Different Designs on Performance of a Fluid Power Control System", ASME Power 2013 Int. Conf. Power2014, Baltimore, Maryland, USA, 28- 31 July, 2014.

Tahany W. Sadak
"Experimental investigation for improvement of the supply pressure decay by using different hydraulic system designs
"International Journal of Engineering Research and Applications (IJERA) , vol. 8, no.9, 2018, pp 01-05

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