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Modeling and Simulation Analysis of Pre-Valve Compensation of Flow-saturated Resistant System

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Abstract. The load-sensing pre-valve compensation technology is widely used in the single-pump multi-acting mechanism composite motion circuit. Due to the use of multi-valve inlet valve front compensation, its structure is simple, only need to set a two-way fixed-rate valve, but the flow saturation conditions cannot be automatically adjusted. Through an in-depth theoretical analysis of the anti-saturation mechanism, composition and control strategy principle based on automatic flow reduction (AVR), the AMESim model of the system is established, and the anti-flow-saturation output characteristics of the system are obtained under different operating conditions by numerical simulation means, and the results show that the system can solve the problem of flow-saturation. It provides some technical reference for the design of the load-sensing pre-valve compensation system.

1. Introduction

Load-sensing technology is now widely used in construction machinery such as drilling, cranes and some other machines. [1] The technology improves the energy utilization efficiency of mechanical system. Efficiency is much higher than that traditional hydraulic system. High efficiency, low power loss means fuel savings and low heat generation in hydraulic system. [2-3]. However, when high-power occurred, load-sensing system can cause the pump's flow-saturation.

To solve this problem, based on Bucher’s AVR, the principle of the hydraulic system for the pre-valve compensation anti-flow-saturation circuit is shown in Fig 1.

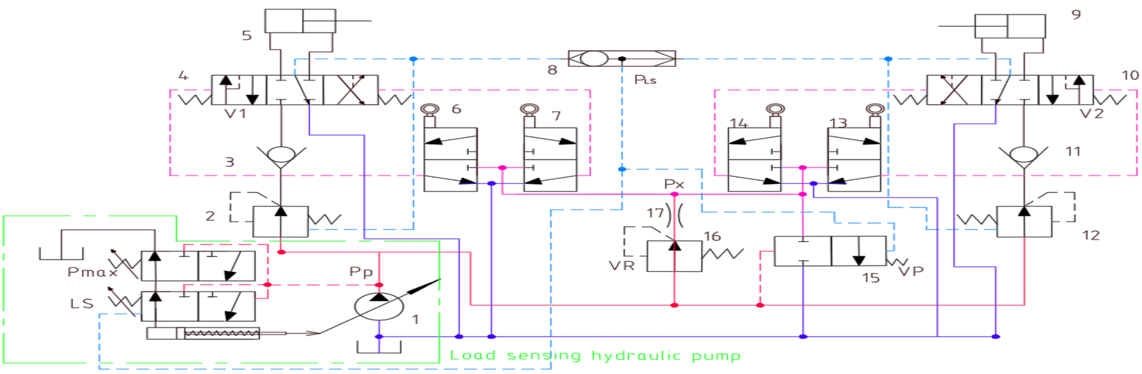

Figure 1. Hydraulic System Schematics

As shown in Figure 1, the system circuit schematic is made up of 1 load sensing pump; 2, 12 pressure compensation valve; 3, 11 check valve; 4 liquid-controlled proportional change valve (V1, V2 valve); 5, 9 hydraulic cylinder; 8 Shuttle valve; 6, 7, 13, 14 manual, liquid or solenoid pilot change valve; 15 liquid-controlled two-way valve (VP valve); 16 relief valve (VR valves), and 17 throttle valve.

The VR valve use for controlling the pilot pressure p_X, which is use for controlling the opening of the V valve. The initial spring compression of the VP valve is x_0 the force analysis of the VP valve is:

$$\left(p_p - p_{LS}\right) * A_{\mathrm{VP}} = k_{\mathrm{VP}} x_0 \tag{1}$$

In the equation: A_{VP}—VP valve core force area, m^2,k_{VP}—VP valve spring stiffness, N/mm

When the system is saturated with flow, the force of the VP valve changes as follows:

$$\left(p_p - p_{LS}\right) < \frac{k_{\mathrm{VP}} x_0}{A_{PV}}, \tag{2}$$

Under the action of the spring force, the valve core will move to the left and the opening of the valve opening will increase, at which point the flow through the VP valve is:

$$Q_{VP} = C_{VP} A_{VP} \sqrt{\frac{2p_X}{\rho}} \tag{3}$$

At this time the VP valve will be in the case of partial overflow. If the $p_p - p_{Ls}$ continues to decrease to zero, then the VP valve opening will open completely, at which point the p_X will be switched on to the tank resulting in a pressure of 0, resulting in the V valve in the middle under the action of spring force. Because the reverse locking of check valves will automatically cut off the sudden special high pressure on the system to protect them.

2. System Modeling

2.1. Modeling of AVR Modules

Modeling 15, 16, 17 modules according to Hydrogram 2 of the hydraulic system, the model is shown in Figure 2.

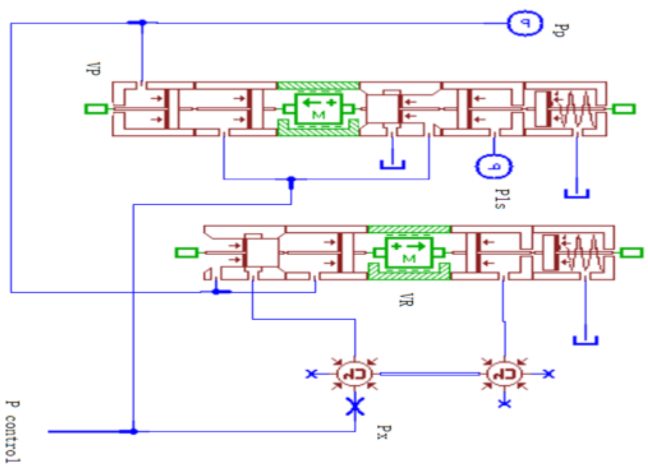

Figure 2. AVR Modules

The system VR valve core quality is set to 0.03kg, the pump does not open the VP valve under normal operation, the spring control initial force of the VP valve is set to 40N, the maximum opening of the valve port is 2mm, the valve core pressure difference is set at unsaturated time p_X is 2.5Mpa,

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Under the above two conditions, the valve core diameter of 0.4mm.VR valve is a pressure relief valve, because the initial set of the control oil route into the control oil flow of 0.65L/min, normal operation when the normal decompression than p_X is higher than 0.5Mpa, that is, according to 3MPa pressure design, Set the quality of the VR valve core to 0.05kg, set the initial conditions of the above v. VP, VR design calculation, the module simulation to obtain the design results as shown in Figure 3, Figure 4.

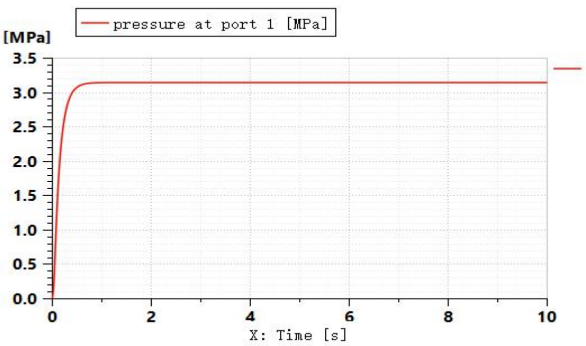

Figure3.VR Pressure Relief Valve Outlet Pressure

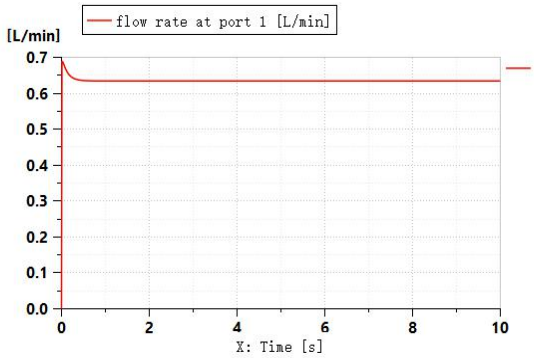

Figure 4. VR Valve Outlet Flow

2.2. Modeling of the Principle of V Valve

The model is shown in Figure 5 according to the principle of V valve operation.

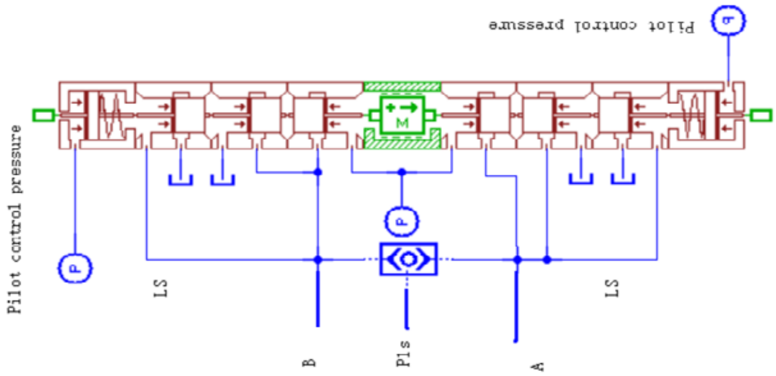

Figure 5. V Valve Model

As shown in Figure 5, the initial median when the two ends of the LS port connection tank to unload the load, when the pilot control pressure at the upper end is greater than the lower end, the action of the spring force will make the valve core down at this time, B port and upper LS port and the tank connected, hydraulic path is P→A, B→T. Conversely, if the lower pilot control pressure is greater than the upper pilot control pressure, then A→T, P→B.

In order to allow the pump in the flow saturation time, the two V valve will fall proportionally, now set the size load of two V valve spring stiffness of 2:1, under the same liquid pressure, the elastic pressure so that the valve core displacement is 1:2, at this time the two-way flow area is 1:2. Place the above two modules in the hydraulic system schematic as shown the overall hydraulic system schematic in figure 6.

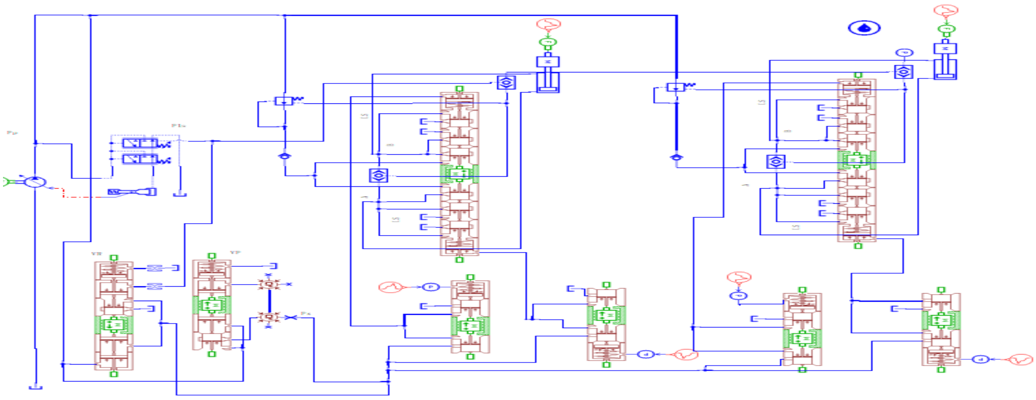

Figure 6. AMEsim Hydraulic System

3. AMEsim Model Simulation Analysis

3.1. Analysis of Normal System Movements and Partial Saturation Simulation

For a constant load, the load sensitivity of the system when normal operation corresponds to a pressure of 15Mpa (0-5s) outside the load corresponding to 120kN,, which is larger than this pressure when the pump will appear partially saturated, when the load pressure reaches 8MPa (5-10s), with an external load corresponding to 148kN, the pump will be completely saturated.

Due to the increased pressure of the large load, it will result in a decrease in $(p_p - p_{LS})$. For large loads, a decrease in pressure differential will cause the throttle in the pressure compensation valve to open gradually to full open, making it difficult to play the initial pressure compensation effect. From gradual to full open process. The proceeding of the large load compensation valve throttle full open, the system will give priority to the small load oil supply. Because the inlet pressure is large enough, the pressure compensator of the small load can work properly, in this process of change, the system's coordinated action will be affected. The pump will be partially saturated. The results of the operating simulation analysis are shown in Figures 7, 8 and 9.

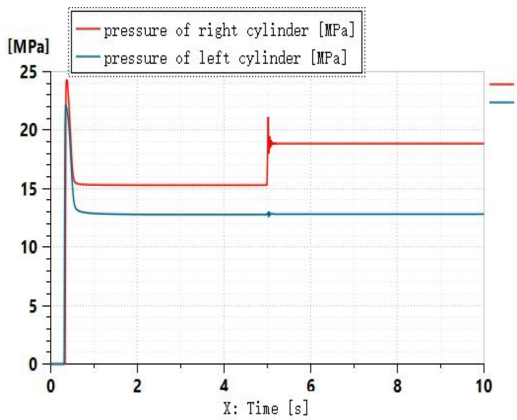

Figure 7. Pressure of the System

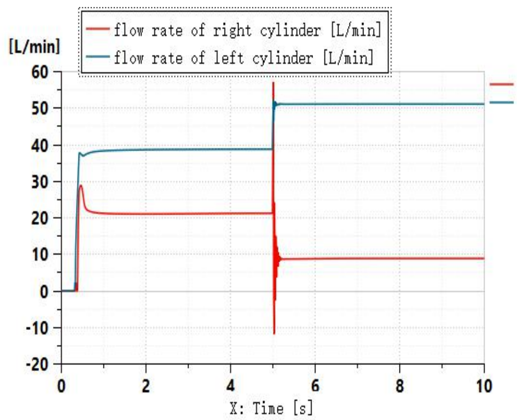

Figure 8. Flow of the System

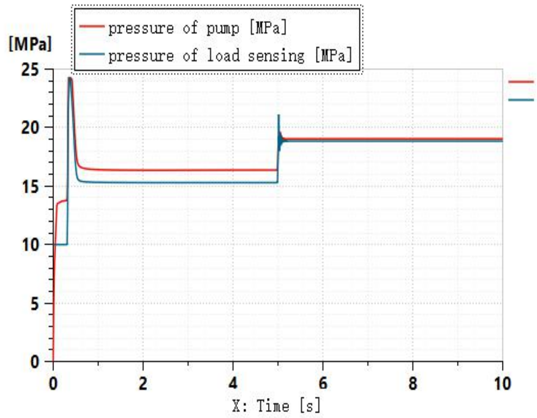

Figure 9. System Sressure and Load Sensing Pressure

Figure 7 shows that the system in 5s pressure mutation, the system's self-adjustment time is very short, and performance is very good. At the same time in the 0-5s, system working normally. When the pressure increases. The flow of the small load will be given priority because the inlet pressure is large enough to provide oil first. The results of simulation analysis are consistent with the results of theoretical analysis.

3.2. Simulation of Pump Fully Saturated

Continuing to increase the pressure, the outside load force is set to 120kN (0-2s), 125kN (2-4s), 148kN (4-7s), 185kN (7-10s) when the load increases enough to fully saturate the pump, the simulation results are as shown as Figure10, 11, 12.

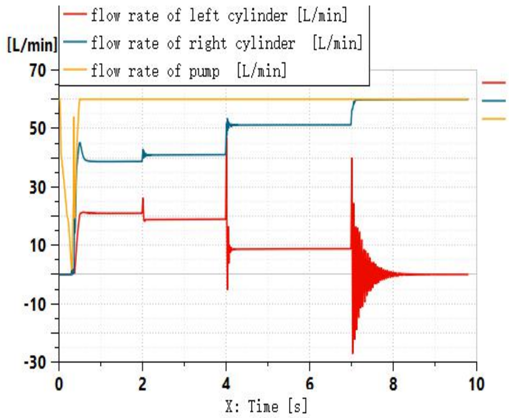

Figure 10. To Fullsaturation System Flow Diagram

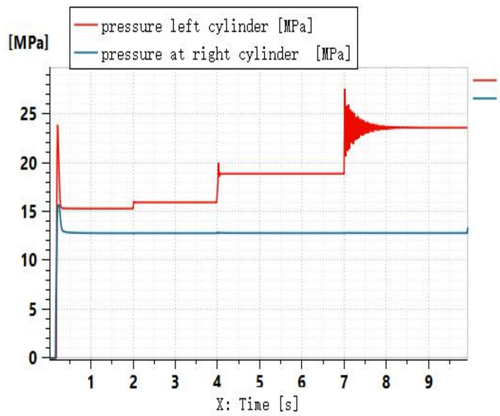

Figure 11. Pressure Diagram

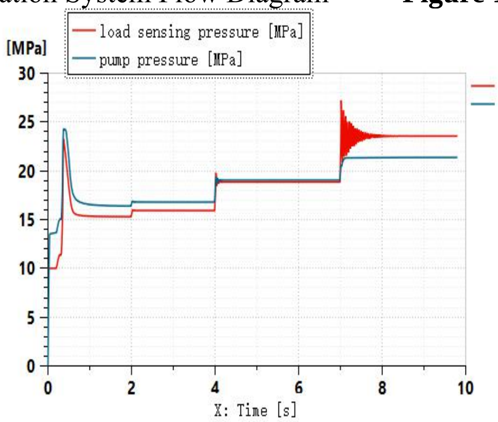

Figure 12. System Pressure and Load Sensing Pressure

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As shown in Figure10, when the large load pressure changes sufficient to make the pump fully saturated. At that time, the large load has stopped the action.

When the load changes in the system as shown in Figure 11, the pressure changes presented by the system are determined by the load.

Figure 12, when the load pressure is too high, the full flow saturation, the VP valve adjusted pressure p_X, has been difficult to start the V1 valve. At this time The V1 valve moves to the middle, the LS port of the V1 valve connects the tank; the load sensing port is unloaded. Due to the role of the check valve, the large load has been automatically cut off, the system is protected. The pump supplies oil to small load.

3.3. Anti-flow-saturation Simulation Analysis

In order to solve the problem of flow saturation under constant power conditions of the pump in the heavy load, the large load cylinder is set the same as the former, and the VP valve is enabled, in this case the simulation analysis is carried out. The simulation results are shown in Figures 13, 14, and 15.

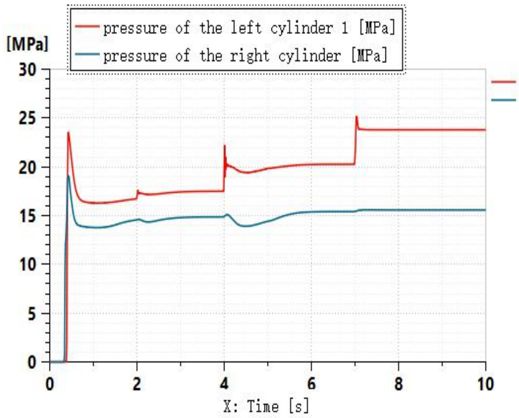

Figure 13. Enable VP Valve Hydraulic Cylinder Pressure Diagram

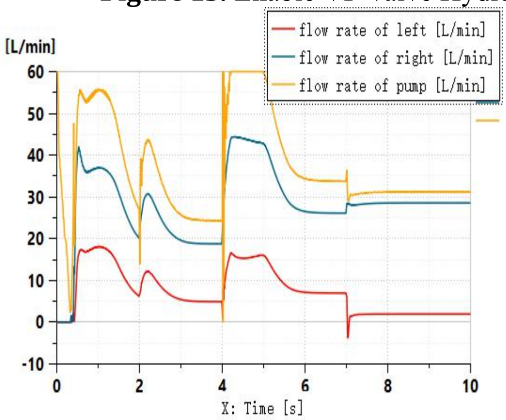

Figure 14. Flow Rate Chart

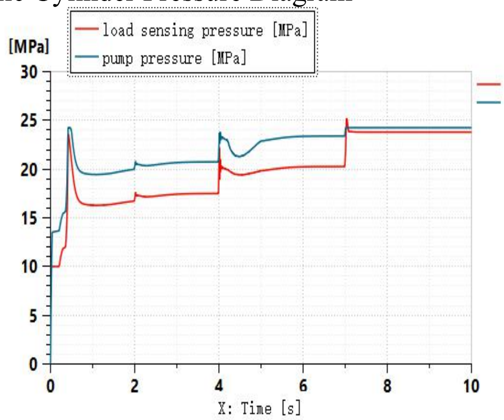

Figure 15. Pump Pressure and Load Sensing Pressure

The pressure control curve shown in Figure 12 is similar to that of the VP valve not enabled.

As shown in Figure 13, when the large pressure increases, VP valve partly open to overflow, the pilot pressure will be reduced. The control pressure of proportional valve will be reduced, the V valve core will move to the median, the valve opening will be reduced, the flow demand of the flow rate will decrease proportionally. The action synergy of system has greatly improved when pump partial flow-saturation.

In Fig13, the pressure in 15-20MPa, the system can automatically adjust the V valve, the coordination of the action is independent of the external load, when the system pressure beyond

22MPa, the large almost stops move.

Figure 14 shows the load becomes larger, the pump will continue to supply oil to the large load, the pump's outlet pressure will be closely consistent with the load-sensing pressure when entering constant power conditions.

4. Conclusion

Based on the theoretical analysis of the working process and principle of a VR module, this paper makes depth study on the system's anti-flow-saturation mechanism, theoretical analysis of the response principle and working process of key components such as liquid-controlled two-way valve (VP valve) and pressure relief valve (VR valve), puts forward the operating conditions and influencing factors of flow saturation in the system, and puts forward anti-flow-saturation measures. Through mathematical modeling, the action process and principle of anti-saturation system are analyzed, and the theoretical analysis results of the operation simulation technology are verified. The results of the study provide some reference for the problem of anti-flow saturation of the valve front pressure compensation system.

5. Acknowledgements

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