RESEARCH ON AIRBORNE INTELLIGENT HYDRAULIC PUMP SYSTEM

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Abstract

Development and adoption of so called Intelligent Hydraulic Power System (IHPS) whose pressure or flow rate output is adjusted based on real time load of hydraulic system provides a radical and effective solution to decrease heat power consumption and difficult heat dispersion. Aiming at the object, here studies are performed on intelligent hydraulic pump mechanical structure, realization of real time load sensing and control strategies for IHPS on the base of current study level. In addition to theoretical analyses and simulation involved in IHPS pressure or flow rate control, experimental research is practiced on the system. the experimental results are compared with that of simulation and theoretical study as well as control strategies are validated.

1 General Introduction

High pressure and high power level is one of the main trends of the hydraulic system for current military aircraft in order to enhance the performance. Consequently increased heat power consumption and difficult heat dispersion, however, is a headache due to the wide adoption of constant pressure hydraulic power on board. Development and adoption of so called Intelligent Hydraulic Power System (IHPS) whose pressure or flow rate output is adjusted based on real time load of hydraulic system provides a radical and effective solution to the problem. Aiming at the object, here studies are performed on intelligent hydraulic pump mechanical structure, realization of real time load sensing and control strategies for IHPS on the base of current study level.

2 The Configuration and Mechanism of Intelligent Hydraulic Pump

The configuration and mechanism of intelligent hydraulic pump comes out based on specific requirement of air born hydraulic power system on safety and reliability, after comparison among other configurations and mechanisms achieved domestically or abroad. This pump configuration (Fig.1), which is adopted here in experiments, makes pump feature quick displacement variation and high reliability due to the direct drive of displacement variation mechanism by servo valve and reset of maximum displacement by balance spring.

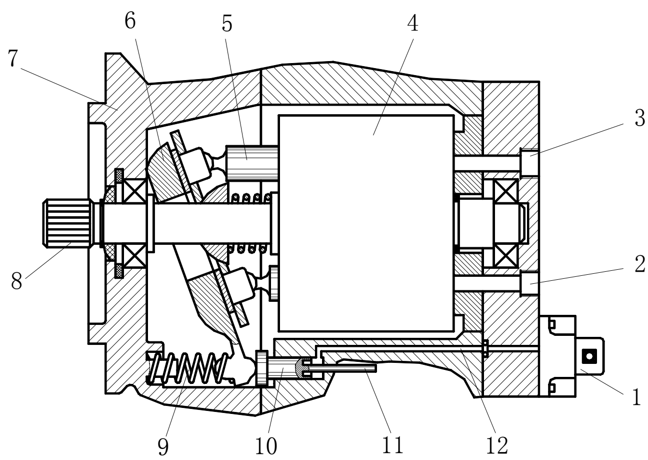


Fig.1 The pump configuration

1-Servo Valve 2-Oil Outlet 3-Oil Inlet 4-Jar 5-Piston 6-Swashplate 7-Shell 8-Spline Shaft 9- Restoration Spring 10-Variable Piston 11-Displacement Pole 12-Control Oil Path

3 Variable Mechanism Performance Analysis

3.1 Mathematics Model

The pump configuration is showed in Fig.1; Its principle can be predigested to Fig.2.

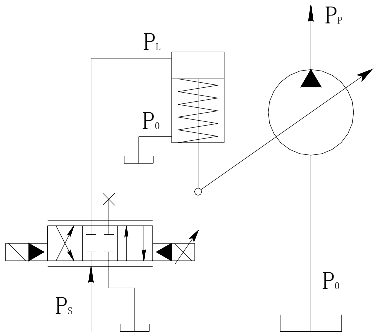


Fig.2 The principle of variable machine

Based on Fig.1 and Fig.2, The mathematics model of variable machine can be constructed.

1) Flow rate-relative pressure equation

$$Q_L = C_d A \sqrt{\frac{2}{\rho}\Delta p} \tag{1}$$

Here, Q_L -Load flow rate, m^3/s;

C_d - Flow-pressure coefficient;

A - Opening area, m^2;

ρ - The density of a fluid in it's per unit volume, kg/ m^3;

ΔP - Pressure drop of valve port Pa.

2) Fluid continuity equation

$$Q_L = A_p \frac{dx}{dt} + \frac{V}{\beta_e}\frac{dP_L}{dt} + C_L P_L \tag{2}$$

Here, A_p - Area of cylinder with variable piston, m^2;

x - Displacement of cylinder with variable piston, m;

V - Cylinder control cavity effective volume, m^3;

β_e - The fluid bulk modulus of elasticity, Pa;

C_L - Cylinder leakage coefficient, $m^3/(Pa \cdot s)$.

3) Variable cylinder piston and force balance equation

$$P_L A_p = m_p \frac{d^2 x}{dt^2} + B_p \frac{dx}{dt} + F \tag{3}$$

Here, m_p - The quality of piston, kg;

B_p - The movement of the piston to the viscous damping coefficient, N·s/m;

F - Swash plate piston reaction, N.

According to the above equation to establish the swash plate variable displacement mechanism nonlinear mathematical model, using the MatLab Simulink toolbox , establish the Fig. 3 intelligent pump control system simulation model.

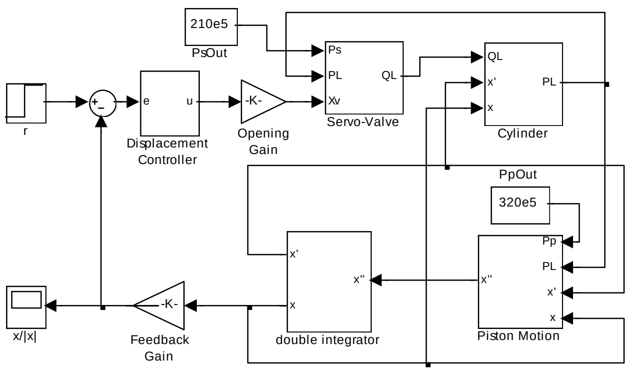


Fig.3 Intelligent pump control system simulation model

3.2 Variable Mechanism Characteristic Analysis

The actual parameters into the model simulation, the simulation results are shown in Fig.4.

Fig.4 fine lines as the reference input signals to the output of the system, solid lines. The results show that the system output rose from 0.1 to 0.9 and from 0.9 to 0.1 required for the rise time of 22ms, overshoot and static precision is less than 8%, less than 0.7%.Speed of response, maximum overshoot and static precision can meet the requirements.

Because the variable cylinder controlled chamber has the advantages of small volume, small piston assembly quality, so the position of the slanting plate system response speed. According to the simulation calculation of parameters, dynamic hydraulic natural frequency of 1.662×103Hz.Even when considering oil clamped in the air will keep the bulk modulus of elasticity decreases, and the oil outlet to the oil cylinder servo valve between the oil will increase the control cavity volume and other factors, calculates actual hydraulic natural frequency should be more than 300Hz.

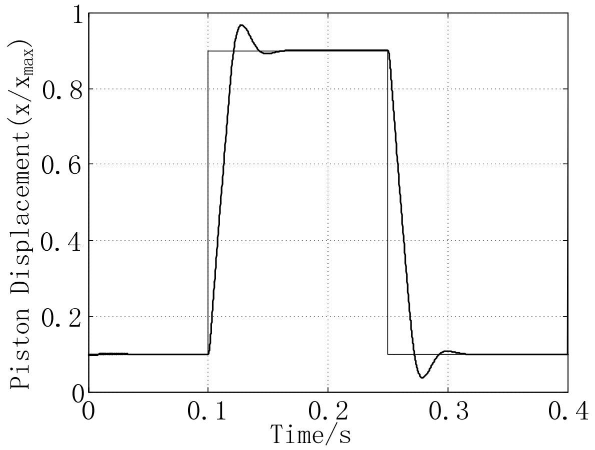
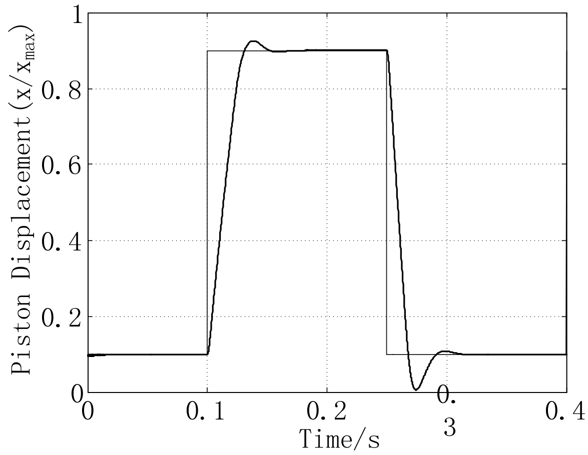


Fig.4 The simulation results

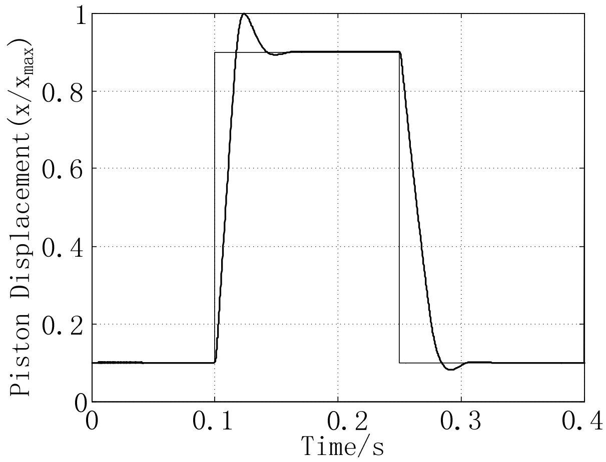
3.2.1 *Spring Pre-compression Effect*

The above simulation, reset spring pre-compression force pressure =100bar, similar to the servo valve oil pressure =210bar 1/2.In order to measure the reset spring pre-compression on system performance impact, there is increasing and decreasing of the reset spring pre-compression numerical simulation, get the results shown in Fig.5. (a) for spring pre-compression is equal to 1.2 times the original value of the simulation results, rise time of 24ms, fall time of 20ms, drop increased the overshoot; (b) for spring pre-compression to original 1/2 simulation results, rise time of 19ms, fall time of 25ms, on the or when increased the overshoot.

The comparison of the simulation results, the optimal reset spring pre-compression is equivalent to the servo valve oil pressure 1/2.Increase and decrease of the reset spring precompression quantity, will affect the response variable speed in positive and negative direction ymmetry.



(a)



(b)

Fig.5 Spring pre-compression effect

3.2.2 *Oil Volume Elastic Modulus Effect*

When the oil liquid with 1% air, oil bulk modulus is reduced to the original 1/4.The hydraulic oil bulk modulus value artificially reduced to the original value of the 1/4 (=3.75 × 108Pa) after simulation, the simulation results as shown in Fig.6.

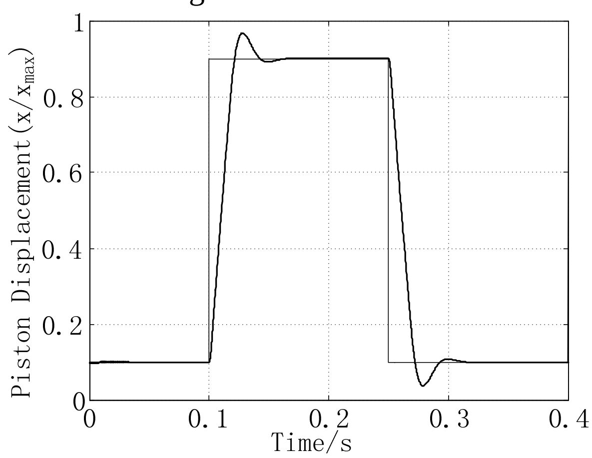


Fig.6 Spring pre-compression effect

Comparing Fig.6 and Fig.4 results in no fundamental difference, it shows that the geometric size smaller variable cylinder, hydraulic oil bulk modulus decrease (such as air inclusions), the basic will not affect the hydraulic pump variable speed of response.

3.2.3 Hydraulic Pump Discharge Oil Pressure Effect

The original simulation of hydraulic pump discharge of oil pressure is 0 bar, now for the hydraulic pump output pressure is changed to 50 bar, obtained simulation results as shown in Fig.7.Graph representation, rise time prolongation of 2ms, up to 24ms; down time reduced 2ms, up to 20ms.

This shows that, due to hydraulic plunger pump of swash plate hydraulic torque always face the swash plate angle decreasing direction, so the output pressure changes will affect the response variable speed in forward and backward on the symmetry.

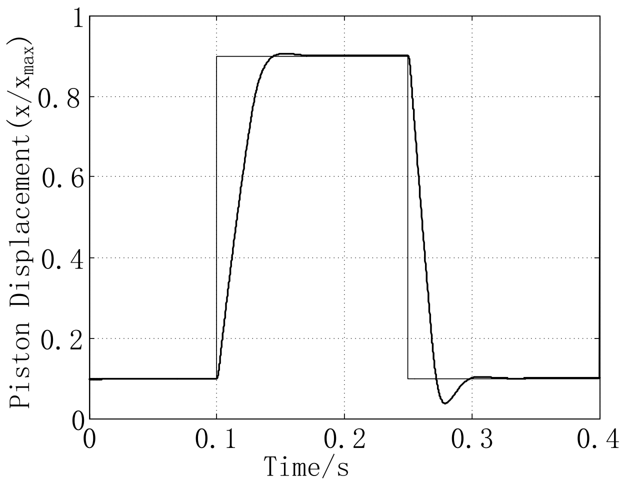


Fig.7 Hydraulic pump discharge oil pressure effect

3.2.4 Hydraulic Pump Inlet Oil Pressure Effect

Reduce the servo valve oil pressure will decrease the pump displacement direction decreasing response speed. For example, the servo valve oil source when the pressure is 150bar, the simulation results as shown in Fig.8.Graph response rise time is 35ms, much longer than the original 22ms.Because the oil pressure is reduced to directly reduce the gain of the system, so the servo valve is to ensure oil supply pressure.

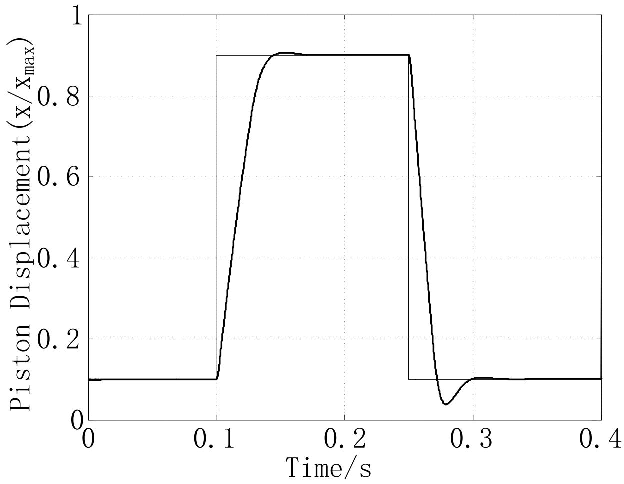


Fig.8 Hydraulic pump inlet oil pressure effect

4 Intelligent Pump System Simulation

4.1 Pressure Control

Intelligent pump system through the control system can be stable, accurate, rapid response to pressure, flow or power of the reference input. Intelligent pump system in most cases through the pressure regulator to achieve and load matching, so called "intelligent pump controlled variable pressure pump”. Only in the small load and the need for constant speed control to flow control mode, for example on the retractable undercarriage, retractable flaps, and the gear plate, when the load pressure is less requirements of cylinder for constant speed operation, when the pump source with constant current control mode, maximum system pressure by overflow valve limited. Intelligent pump can realize power control power control, but the actual application conditions remains to be further studied.

Fig.9 shows the intelligent pump pressure control system the structure principle; system comprises a position control inner loop and outer loop pressure control. The whole system reference input; for the whole system to output pump system pressure, pressure sensor test; variable displacement of the piston displacement sensor detection, a detection signal as an output position control. Displacement sensor gain is V/m. Hydraulic pump speed detection by speed meter.

And respectively output error and position error, for the control of swash plate position servo valve input signal. Influence of system disturbance: hydraulic force interference, maximum inclination angle of the swash plate (constant) disturbance and load flow interference.

The computer is the controller of the system, it through the data acquisition card detection signal according to the control algorithm, calculates and output the control signal.

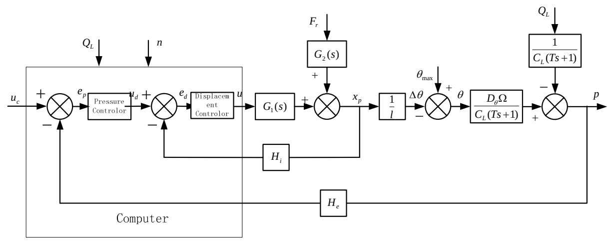


Fig.9 Pressure control system the structure principle

Fig.10 shows the reference input command to a square wave signal; picture shows the output of the reference model and the output of the object. From the chart to see objects and models between the outputs of a minor error. The error is due to hydraulic pump hydraulic pressure caused by the moment, namely the Figure 5.1 in the resulting hydraulic pump output pressure error. If the removal of the interference to the simulation, the simulation results shows that the object output can track the output of the reference model. The effect of such errors is to adjust the time increase, while the overshoot decreases, but eventually causes no static error.

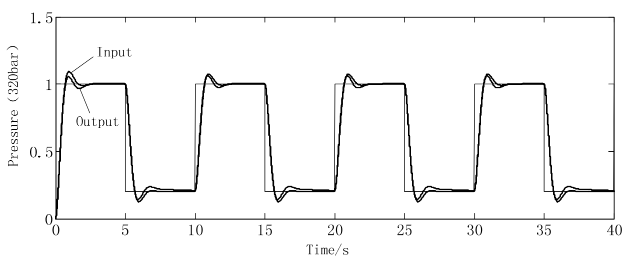


Fig.10 The output of the object in pressure system

4.2 Flow Control

As shown in Fig.11, a flow control system includes a position control loop and flow control outer loop, and respectively the position sensor and the flow sensor. Pump output pressure for flow control forming external disturbance.

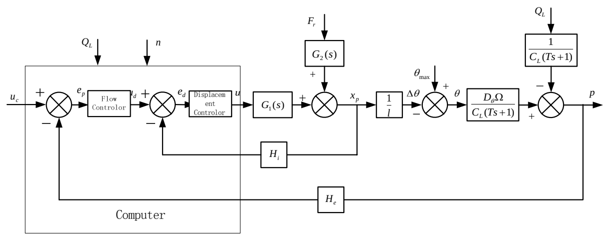


Fig.11 Flow control system the structure principle

Fig.12 shows the second half as the pressure disturbance condition: the appearance at the pressure interference, interference in pressure to increase, in the pressure disturbance to.

According to the simulation results, the pressure disturbance in 0 cases, the pump source tracking step signal (load) rise time (0 - 100%) for 0.7s, in the pressure disturbance after 0.3s within the output flow back to stable amplitude (98%).Similarly in the pressure interference into after the 0.4s output flow can return to stable amplitude (98%).

For the slowly varying pressure interference in the system, when the system reaches a constant flow state to join the 1bar/s ramp signal, the simulation results show that the system output keeps constant basically.

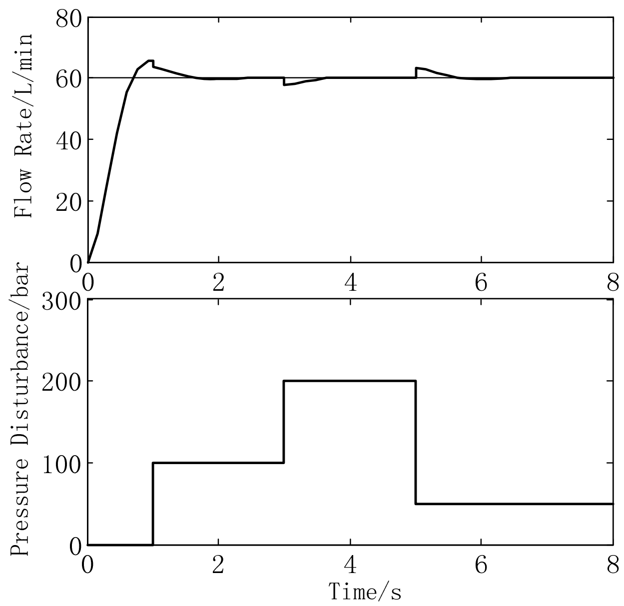


Fig.12 The output of the object in flow system

5 Intelligent Pump System Experiment

As shown in Fig.13, experimental measurement and control system according to the classification of equipment including hydraulic experimental platform, control cabinet and a computer measurement and control system.

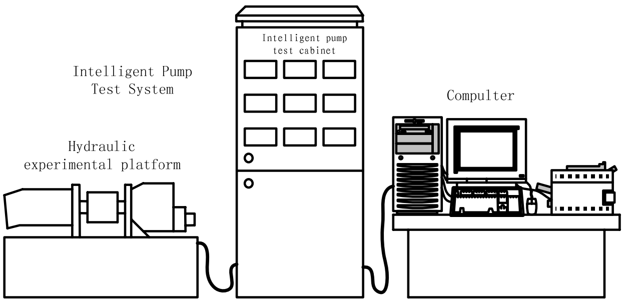


Fig.13 Intelligent pump test system

5.1 Experimental Study on The Variable Pressure Control

Variable pressure control application is designed to control law makes the work load in the system allows any set value. The purpose of this experiment is to test whether meet the requirements of control law. The reference input is cycle for 10s square wave signal, square wave signal high amplitude were 200bar and 100bar, the ratio is 50%.During the experiment the load throttle opening remains unchanged. The experimental results as shown in Fig.14..

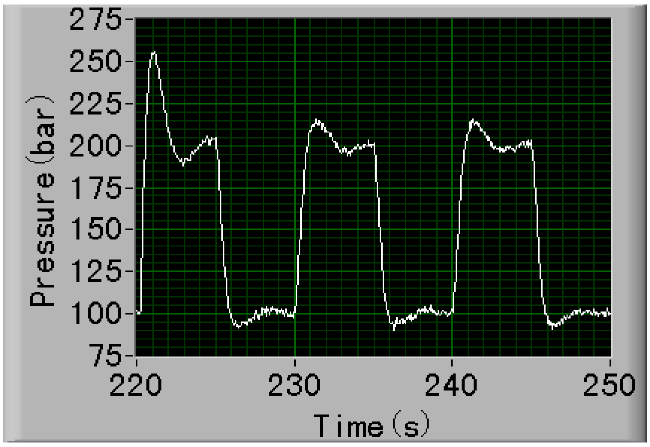


Fig.14 Experimental result on the variable pressure control

From the experimental results that, in the first square wave cycle, the pressure overshoot is relatively large, stable pressure for longer periods of time.But in the subsequent square wave cycle in the pressure overshoot is reduced gradually, pressure stabilizing time gradually shortened, to the third cycle pressure overshoot and stability time has been basically with each cycle of the same.This result reflects the control law of adaptive function: because the control law with adaptive function, so it can be in the control process, through the measure of system output and the model output error between the gradual adjustment of the parameters of the controller, the system output gradually approaching the model output.

5.2 Experimental Study of Variable Flow Control

Variable flow control reference input is cycle for 10s square wave signal, square wave signal high amplitude were 30L/min and 20L/min, the ratio is 50%.During the experiment the load throttle opening remains unchanged. Results the pump output flow is shown in Fig.15.

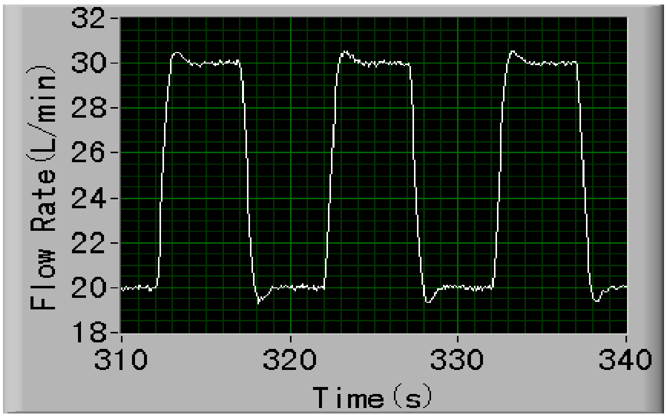


Fig.15 Experimental result on the variable flow control

The experimental results show that, intelligent pump flow control system under varying load conditions, the realization of output of step type reference input the zero-steady-state-error tracking, the slowly varying load output flow can be maintained constant, the mutation load output flow only in the moment fluctuation of steady state dynamic mutation, is back on the reference input tracking. The experimental result and the simulation result are the main differences between flow adjustment rise time: experimental results (Fig.15) flow rate increased from 20L/min to 30L/min rise time is about 1s, the simulation results (Fig.12) flow rate increased from 0 to 60L/min rise time less than 1s.

5 Conclusion

In addition to theoretical analyses and simulation involved in IHPS pressure or flow rate control, experimental research is practiced on the system. Specific experimental system is build up, in which a personal computer is centered and VI (Virtual Instrument) technology is adopted. Here basic performance parameters of hydraulic pump are measured, and pressure, flow rate and output working power control for IHPS experimentally investigated using corresponding control laws, the experimental results are compared with that of simulation and theoretical study as well as control strategies are validated.

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