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RESEARCH ON CHARACTERISTICS OF LOAD-SENSING SYNCHRONOUS CONTROL

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Abstract: To obtain high precision synchronous control in very poor working condition, such as coal mines, a load-sensing synchronous control (LSSC) is developed in this paper, which is made up of a load-sensing loop and a synchronous valve loop. In the LSSC system, the load-sensing loop supplies pressure and flow required by the system through pressure closed-loop control in load-sensing pump, and could improve the capability of anti-offset load by pressure compensation in load-sensing valve; the synchronous valve loop is between the load-sensing pump and valve, to achieve equal distribution of flow supplied by the pump. A test system with in LSSC is established, and then experiments under different partial loads are carried out. The experimental results show that, compared with the traditional synchronous valve control (SVC), LSSC has the advantages of higher synchronous precision, higher energy efficiency, and the ability of velocity regulation.
Keywords: Synchronous control system; Load-sensing control; Synchronous valve; anti-offset load

INTRODUCTION

Hydraulic synchronization control system is widely used in multi-actuator synchronous motion [1]. According to the control method, the synchronous control has two kinds of forms: closed loop control and open loop control. The closed loop synchronous control could achieve very high synchronous precision through the feedback of displacement or velocity [2-4], but is costly because of using expensive components, such as servo valves or proportional valves, controllers and various sensors, and is not suitable for severe environment due to low reliability. The open loop synchronous control mainly uses throttling valve, synchronous valve, and synchronous motor, and is adapt to very poor working condition because of high reliability [5-7]. For throttling valve control, the synchronous deviation is generally more than 5%, and it is hard to operate because the repeated debugging of throttling valve is required to achieve higher synchronous accuracy4. For synchronous valve control (SVC), the synchronous deviation is generally more than 3%, and the synchronous velocity also cannot be adjusted3. For synchronous motor control, the synchronous deviation is generally more than 1%, but it is very expensive. In addition, the above synchronous systems in open loop control use a constant pressure oil supply, which will lead to large heat and low efficiency due to the overflow loss. Overall, existing open loop synchronous control has some serious drawbacks, such as low synchronous accuracy, low efficiency, and the difficulty of velocity regulation.

In order to make up above shortcomings of open loop synchronous control, this paper propose a new synchronous control scheme, load-sensing synchronous control (LSSC), and explains its principle in detail, and experimental results show that, compared with the traditional open loop synchronous control, LSSC has the advantages of high synchronous precision, high energy efficiency, and the capacity of velocity regulation.

PRINCIPLE OF LSSC

Hydraulic principle diagram of LSSC system is shown in Figure1, and two cylinders as the actuators are driven synchronously by LSSC. The LSSC system is made up of a load-sensing loop and a synchronous valve loop. The load-sensing loop includes a load sensing (LS) pump and LS valves, and the pump could supply pressure and flow required by the system through pressure closed-loop control [8-9], which could improve the system efficiency; the LS valves is used to regulate synchronous velocity of actuators by adjusting the opening of valve, and its pressure compensation function [10-11] could enhance the capability of anti-offset load of actuators. The synchronous valve loop is between the LS pump and valves, to realize equal distribution of flow supplied by the pump, and has a certain anti-offset load capacity. It is important to emphasize that, the opening of the two valves should be the same to achieve higher synchronous accuracy.

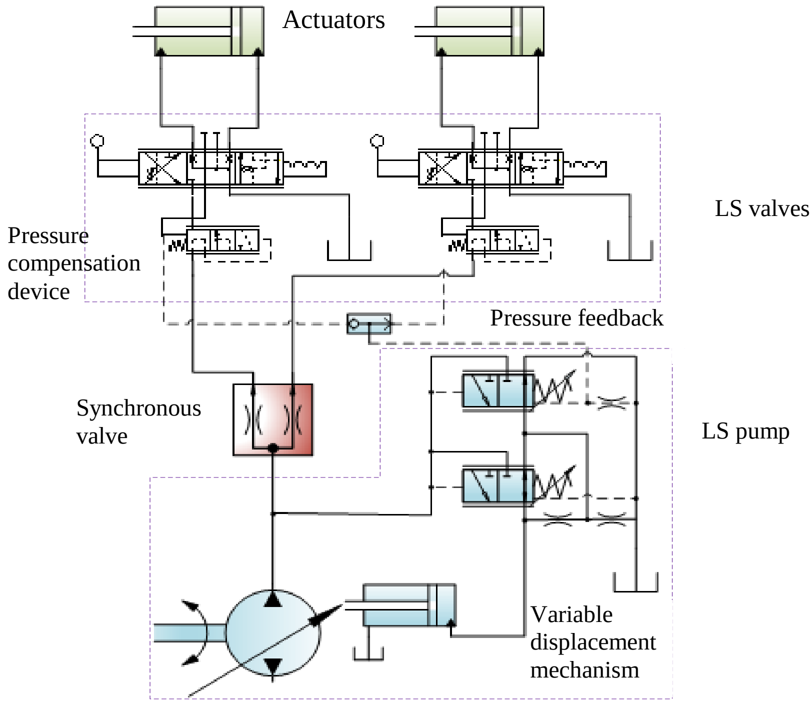


FIGURE 1. Hydraulic principle diagram of LSSC system

TEST SYSTEM

In order to verify the characteristics of LSSC, a test system is designed as Figure 2 and established as Figure 3, it's a two cylinders synchronous system. The two driving cylinders is in LSSC, and is loaded by two cylinders with the same size. The backpressure of loading cylinders is controlled by two proportional relief valves (PRV), and giving different control signals to PRV will adjust different overflow pressures and realize offset load. Synchronous error will be obtained by comparing the two displacements of driving cylinders, which are measured by two draw-wire encoders. The test system in LSSC could switch to SVC by retaining synchronous valve and the removing the LS valves and replacing the LS pump by a fixed pump. We make detail characteristics comparison between LSSC and SVC.

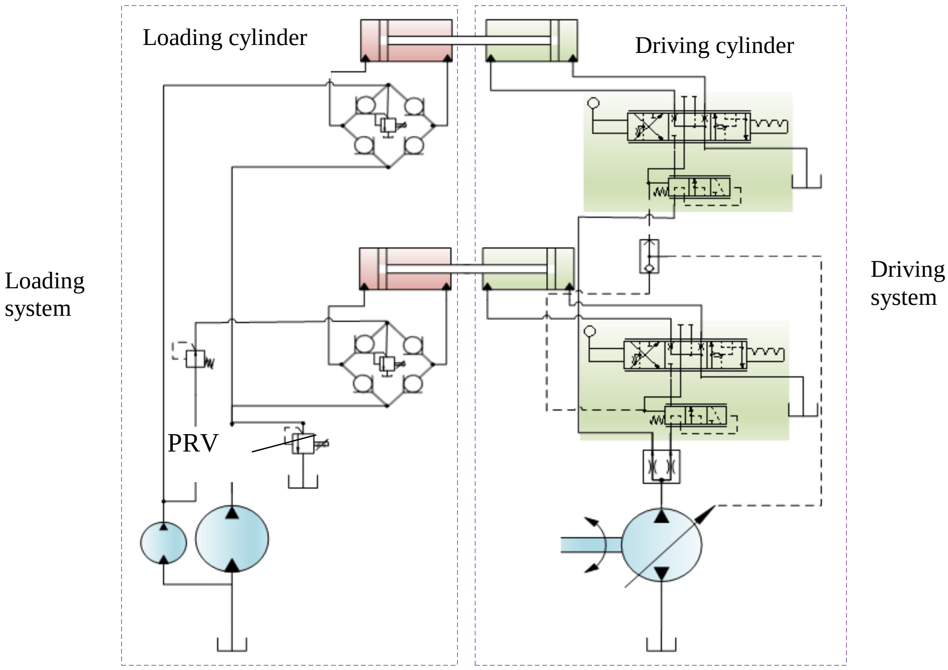


FIGURE 2. Hydraulic principle diagram of system in LSSC

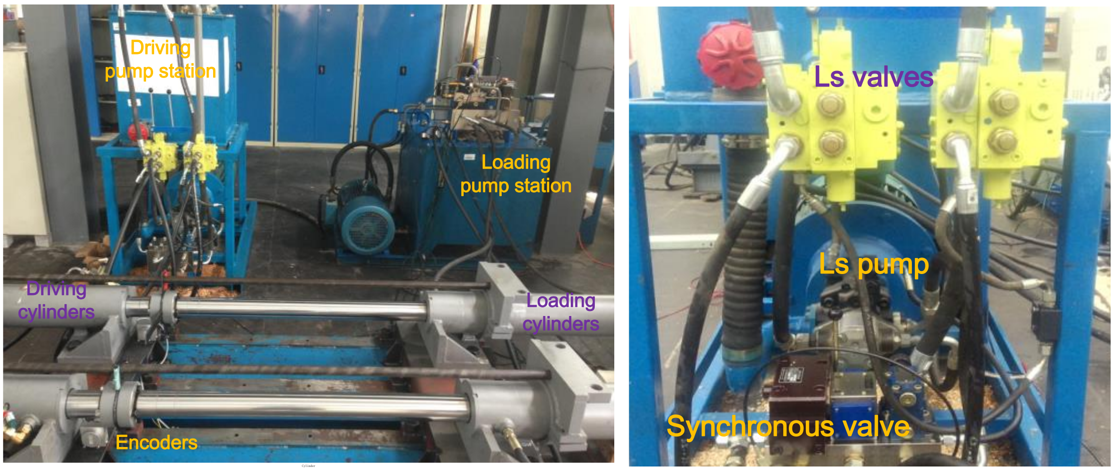
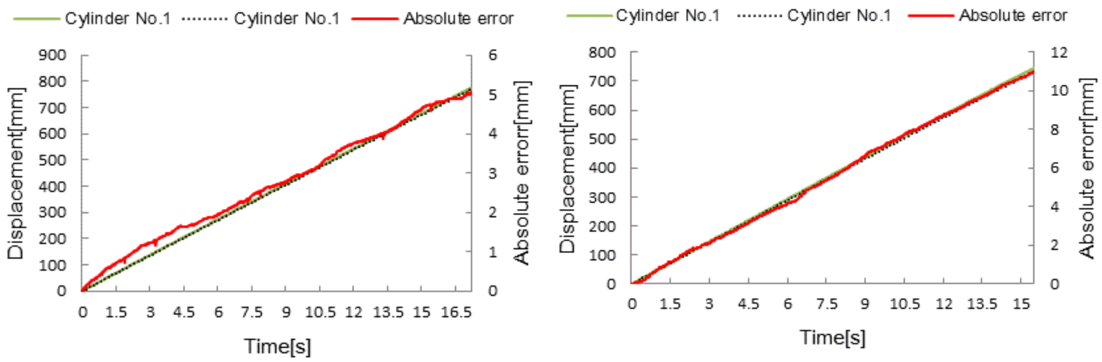


FIGURE 3. Experimental test bed

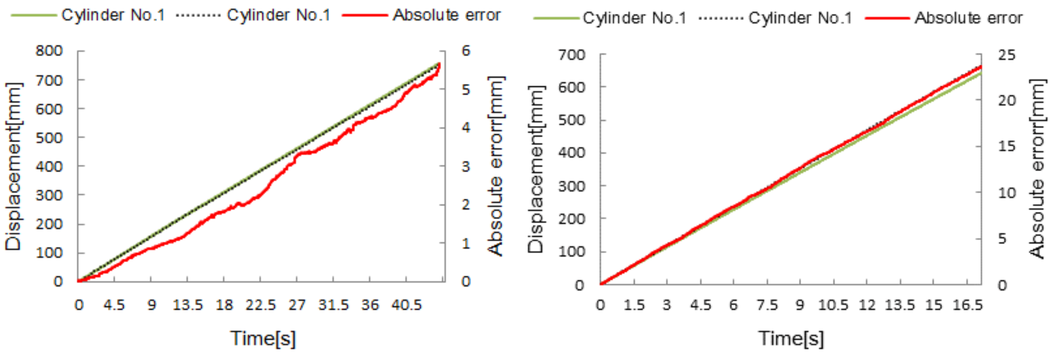
EXPERIMENTS AND ANALYSIS

First of all, synchronous driving in LSSC and SVC under different offset loads are respectively carried out. Experimental results under the offset loads of 2MPa and 4MPa are shown in Figure 4 and Figure 5, respectively, and the comparison of synchronous errors under LSSC and SVC is make in Table 1. Experimental results show that for both LSSC and SVC, larger offset load will lead larger synchronous error; compared with SVC, LSSC has stronger anti-bias capacity and has higher synchronous accuracy, and its synchronous error is less than 1%.



(a)LSSC (b) SVC

FIGURE 4. Synchronous displacement under the offset load of 2 MPa



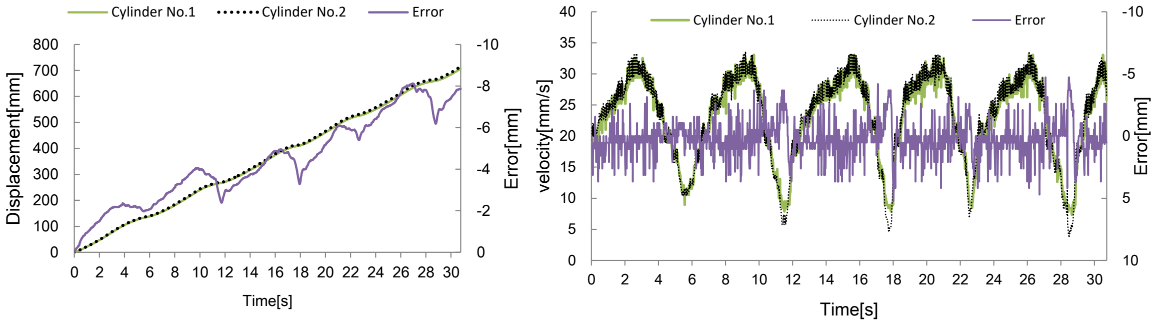
(a) LSSC (b) SVC

FIGURE 5. Synchronous displacement under the offset load of 4 MPa

TABLE1. Synchronous error in LSSC and SVC under different offset loads

Control scheme	**2MPa**			**4MPa**		
	Displacement /mm	Absolute error/mm	Relative error	Displacement /mm	Absolute error/mm	Relative error
LSSC	800	5	0.625%	780	5.8	0.743%
SVC	750	11	1.47%	680	23	3.38%

Next, variable velocity synchronous experiments under LSSC are carried out by adjusting opening of LS valves, as shown in Figure 6, which is under the offset load of 4MPa. Experimental results indicate that using LSSC can achieve variable velocity synchronization of multi-actuators; the synchronous accuracy are still high, but is lower than that in constant velocity situation, that is because synchronous valve can't adjust dynamically with the flow rate in time.



(a) Displacement and error (b) Velocity and error

FIGURE 6. Variable velocity synchronization under LSSC

Finally, Temperature rise of system experiments under LSSC and SVC are carried out, as shown in Figure 7. Within 35minutes, the system temperature under SVC rises 22ºC, but that under LSSC only rises 3ºC, which indicates that the synchronous system using LSSC has higher efficiency and less heating, that is because the control scheme of SVC usually uses a fixed pump to supply oil and there is a great deal of overflow loss, but the control scheme of LSSC can realize the pressure and flow of the system consistent with the load demand by load sensing technology, and there is very little overflow, so the system temperature would be kept at the lowest level.

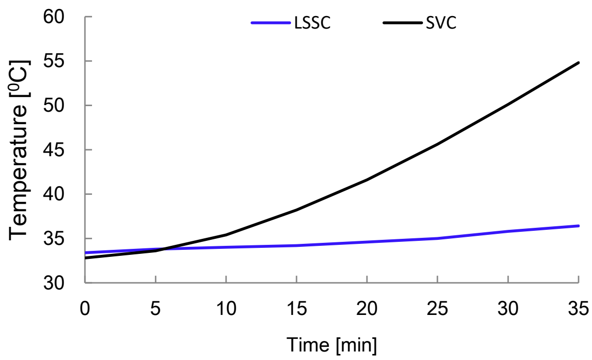


FIGURE 7. Temperature rise of system in LSSC and SVC

CONCLUSIONS

To obtain high precision synchronous control in very poor working condition, this paper proposes a new synchronous scheme in open loop control, a load-sensing synchronous control and studies its control performance by experiments. Experimental results indicates that compared with traditional synchronous valve control scheme, the new scheme has the following advantages:

(1) The pressure compensation function in LS valve can enhance the capability of anti-bias load, so LSSC has the advantage of higher synchronization accuracy.

(2) LSSC can realize the pressure and flow of pump meet the load demand by load sensing control in LS pump, which will reduce system heating, so LSSC has the advantage of higher efficiency.

(3) Velocity of actuators could be regulated by adjusting the opening of LS valve, so LSSC has the function of variable velocity synchronization

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