An Elevator Hydraulic System Using Cabin Speed Feedback

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Abstract

The effects of load variation, oil temperature variation, and friction on the performance of proportional valves using flowrate feedback affect the operating stability and riding comfort of hydraulic elevators. In this paper, an elevator hydraulic system using a new proportional valve is introduced. In the new system developed, the new proportional valve is controlled in accordance with the speed feedback from the elevator cabin. The new system, therefore, is more robust so that it can offer more stable operation and more comfortable ride.

Introduction

Over the years, the industry of hydraulic elevator has been developing very rapidly all around the world. On-off control and proportional control are two types of elevator hydraulic control systems that have been widely applied. On-off control systems are usually open looped, so it's output speed curve is not as good as that of proportional systems in many aspects.

By now, there are types of proportional products available and used widely. But these systems still have some problems that needed to be improved. Firstly, these proportional systems use flowrate feedback to construct the closed loop, but the accuracy of flowrate feedback is seriously affected by the temperature variation of oil. Secondly, these systems' pilot loop always use oil from the main circuit as pressure source, so the pressure source of the pilot loop is affected by the always varying load of the elevator. Thirdly, these systems use the analog PID controller, the parameters of the controller can not be adjusted automatically to optimize the system operation during elevator operating process.

In the system introduced in this paper, measures are adopted to resolve the three main problems of the proportional elevator hydraulic systems.

Structure of The System

As shown in Fig. 1, the control system mainly consists of a pump unit, a valve block, a 8098 single chip microprocessor board and an encoder that fastened on the elevator cabin. The pump unit have two pumps, the big one supplies oil for the main circuit and the small one for the pilot loop. The encoder on the elevator cabin transmits the displacement of the cabin into electronic pulses and sends the pulses to the chip [illegible] environment and computer board. The microprocessor board communicates with the main controller of the elevator, (the main controller may be PC or PLC), and output control value to the proportional solenoid in accordance with the speed feedback and proper control strategy. The valve block is the key component of the system, which is used to adjust the flowrate to and from the cylinder. As the system use speed feedback instead of flowrate feedback, the valve block has to be specially designed to keep the system stable and work well.

Working Principles of The System

In the valve block, cartridge valve 3 and relief valve 4 work together as a safety valve to prevent the system pressure to be too high. When the elevator stops at station, the solenoid of valve 13 is not energized, so the valve 13 is closed and causes the cartridge valve 7 to be closed. At this time, the cone shape of spools of cartridge valve 7 and valve 13 prevents internal oil leakage through the valves.

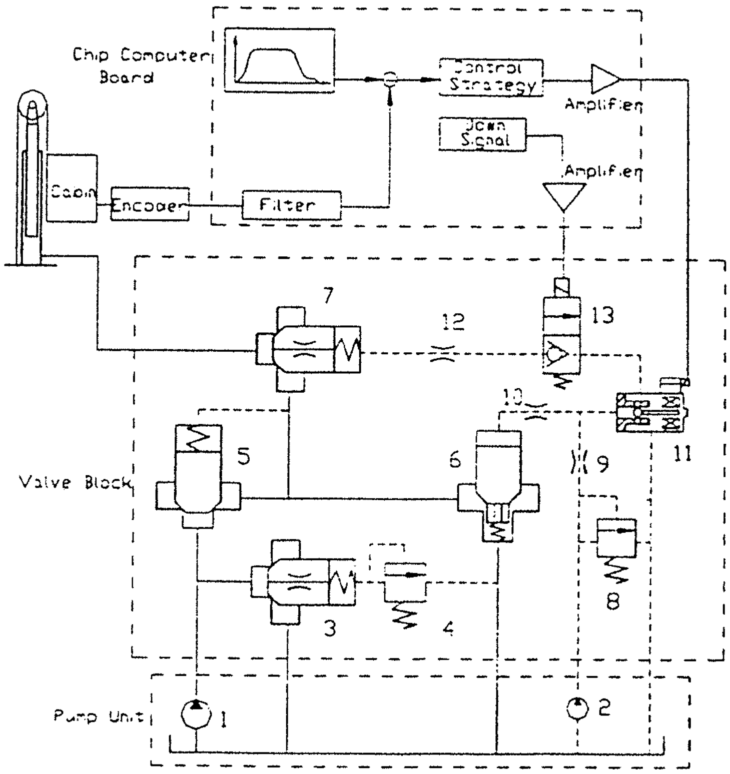


Fig. 1 Structure of The System

When the microprocessor receives up signal from the main controller of the elevator and both pumps ae started, the microprocessor outputs control value to cause the proportional throttle valve 11 to close gradually. As the valve gradually closes, the pressure on the back side of the spool of the cartridge valve 6 increases and causes the valve to close gradually. Then the pressure of the main circuit increase and causes the valve 7 to open, oil from the main pump 1 flows through valve 7 into the cylinder and pushes the rod to accelerate and move upward.

When the microprocessor receives down signal from the elevator's main controller and the small pump is started, it firstly gives out a largest control value to the proportional throttle valve 11 to close the cartridge valve 6; then it sends out signal to make the solenoid of the valve 13 energized to open the valve 7; afterwards, it reduces control value to the proportional throttle valve 11 to open the cartridge valve 6 gradually, oil in the cylinder gradually flows back to the reservoir and the elevator moves downward.

In the elevator's upward and downward operation, the control value from the microprocessor to the proportional solenoid is optimized by a properly selected control strategy in accordance with the bias between the speed feedback and the ideal speed curve previously stored in the microprocessor system.

Analysis of Speed Feedback

As introduced before, an encoder is fastened on the elevator cabin as a feedback component. The encoder transmits the displacement of the cabin into electrical pulses, then the pulses are counted and calculated in the microprocessor system to acquire the cabin speed. In the experimental system, the number of the pulses in a time base is counted to calculate the speed. But as shown in Fig. 2, because the resolution of the encoder is limited, the accuracy of the speed calculated is limited. For example, in the experimental system, the resolution of the encoder is about 0.052 mm/pulse, and 18.87 ms is used as time base to calculate the speed. As the pulses counted in each time base has an maximum error of ± 1, the corresponding error of the speed calculated are 0.556% and 5.56% respectively at the actual speed of 0.5m/s and 0.05m/s. This means that the error of measured speed increases with the decrease of the actual speed. Especially when the elevator is starting to move, the cabin speed is very slow and the measurement error of the speed is very large and this may affect the stability of the system. Different numerical filters, therefore, have to be applied in different speed phase of the elevator operation to ensure the accuracy of the speed acquired.

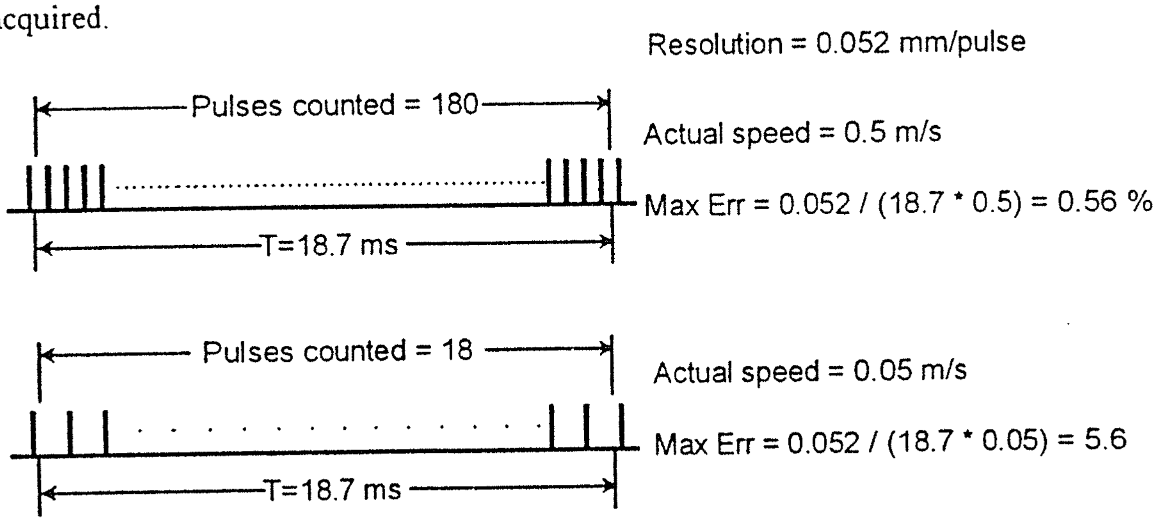
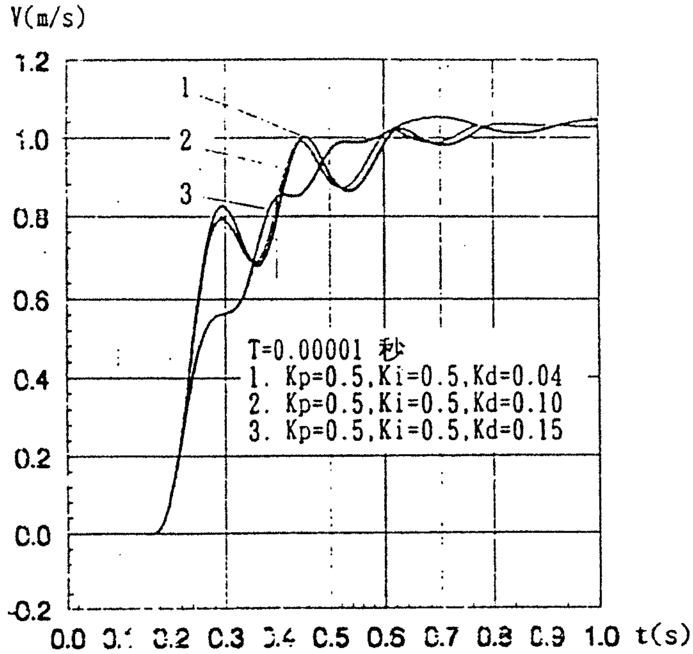


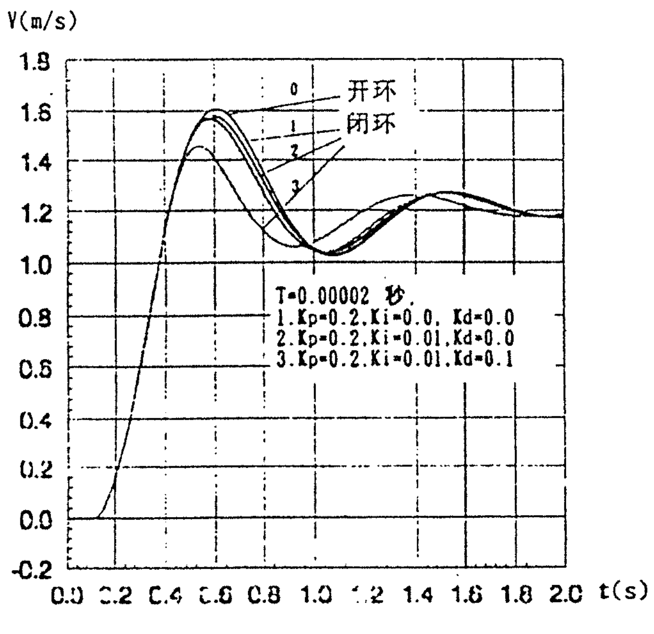
Fig. 2 Error of Measured Speed

Dynamics of The Closed Loop

The closed loop of the system with a numerical PID controller is shown in Fig. 3. The system's dynamic response to step input is simulated to determine the effects of PID parameters. The simulation results of up operation and down operation are shown in Fig 4.

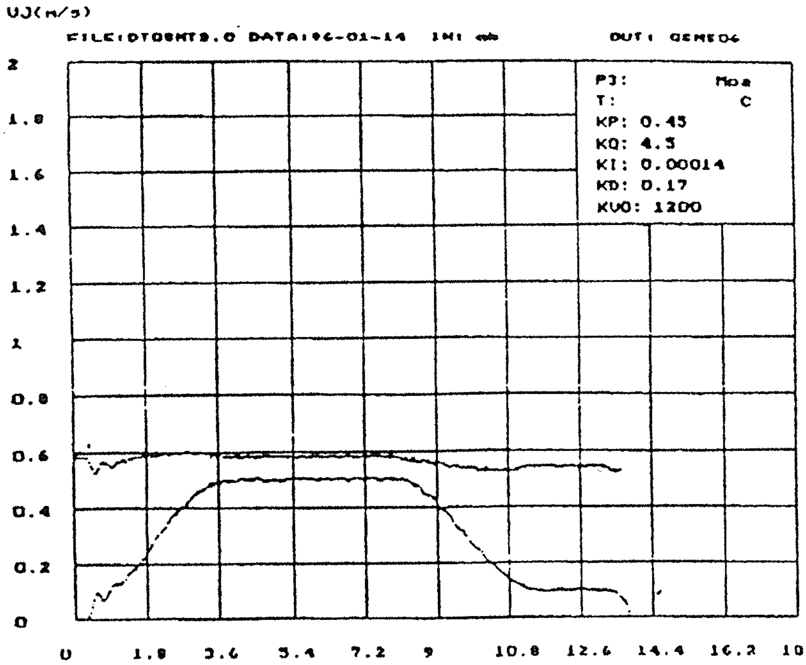


a). Up

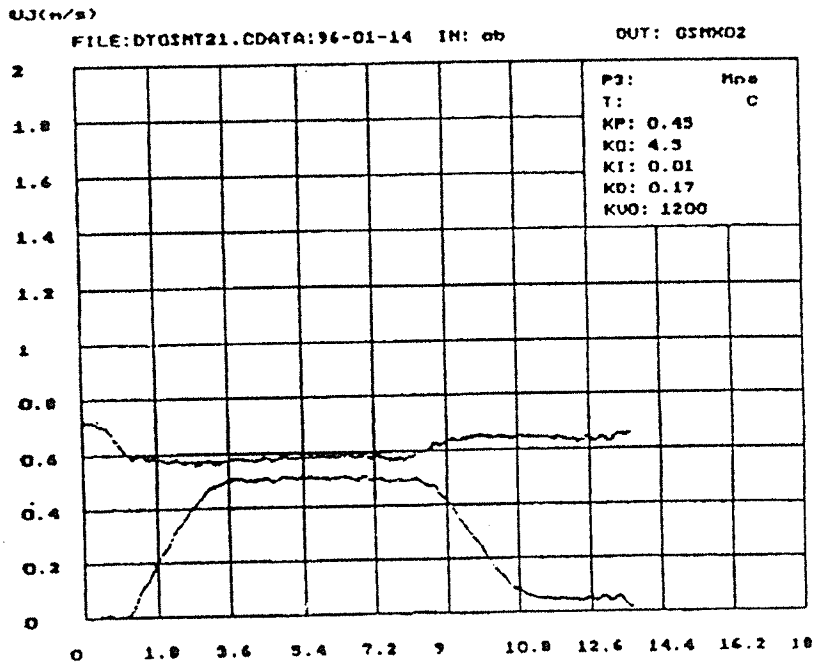


b). Down

Fig.4 Simulated Result to Step Input



a). Up



b). Down

Fig. 5 Speed Curve of Experimental Elevator

It can be seen from Fig 4 that the system is stable in both up and down operation, but the dynamic properties of the system are quite different in up and down operation. Therefore, the PID parameters in different stages of elevator operation have to be set respectively. This is very easy for the system because the numerical controller is flexible to be modified.

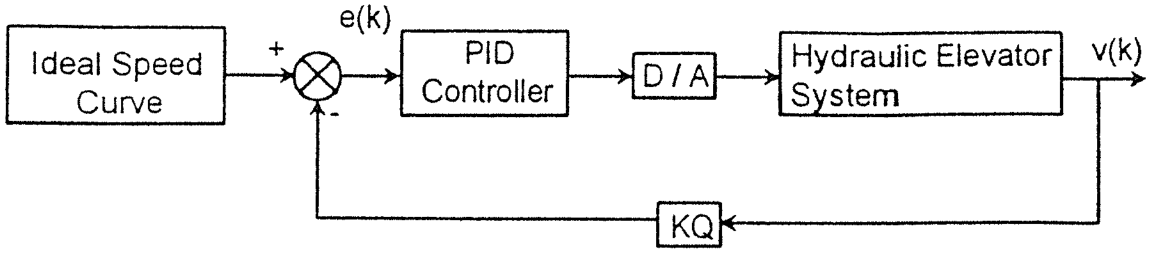


Fig. 3 Closed Loop of The System

Experiment of The System

The experiments of the system are carried out on an test elevator. The elevator has a structure of 2:1 roping. The travel height is 8.08 m and the load capacity is 1000 kg.

In the experiment, the PID controller is realized as follows:

$$u(k) = u(k-1) + K_p[e(k) - e(k-1)] + K_I e(k) + K_D[e(k) - 2e(k-1) + e(k-2)] + KVO$$

where K_P is the proportional coefficient, K_I is the integral coefficient, K_D is the differential coefficient, KVO is a constant used to compensate for deadband caused by the hydraulic system.

Fig. 5 shows the typical speed curve of the elevator in up and down operation. It can be seen from the figure that the starting of down operation is smoother than that of up operation. The oscillation of the starting of the up operation is caused by static friction. In down operation, before opening of the proportional valve, there is oil flow from cylinder through valve 13 (as shown in in Fig. 1) back to the reservoir in a flowrate of about 2 l/min. This causes the elevator cabin starting to move downward in a very slow speed before the control process begins and the effect of static friction is avoided.

Another remarkable point of the experiment is that except K_P, K_I and K_D, the constant KVO also has great effect on the behavior of the closed loop system and it's value needs to be carefully selected.

Conclusion

It can be seen that the new design of proportional valve block using stable pressure pilot oil source is successful working with speed feedback and numerical controller.

The cabin speed feedback makes the system more robust to the temperature and load variation. The use of numerical controller make the system more flexible to adjust the control parameters.

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