SIMULATION OF A HYDRAULIC CONTROL SYSTEM FOR POWERSHIFT TRANSMISSION OF TRACTORS

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ABSTRACT

Performance of a hydraulic system is influenced by its working temperature. Therefore, it is very important to make the system perform uniformly in an entire range of the working temperature. In this study a simulation of a hydraulic control system for the powershift transmission of tractors was conducted and the effect of the temperature was investigated in terms of design conditions of the system. Results of the simulation are as follows. The hydraulic control system with a spring accumulator was found to be more convenient to control the shifting time than that with a gas accumulator. By returning the oil from the clutches to the system through a path between the filter and pump, the time delay due to the pressure difference between the low and high temperatures could be reduced. Therefore, it was recommended that the hydraulic control system for the powershift transmission of tractors must be equipped with a spring accumulator and a circuit to return oil from the clutches to the system through a path between the filter and pump.

Key Word : Tractor, Powershift, Transmission, Hydraulic control system

INTRODUCTION

Agricultural tractors are used for many kinds of farm works under various soil and field conditions. In most of tractor operations, the torque load exerted on the tractor fluctuates severely and accordingly, frequent shifting of gears is required, resulting in inconvenient operation of tractors. Transmission of tractors should be power-efficient and operationally convenient. Powershift is a type of transmission that can satisfy both requirements. Powershift exhibits the characteristics of both the manual and hydraulic shifting transmissions. The hydraulic control system is most important component of the powershift transmission. Performance of the hydraulic control system is affected by its working temperature. Therefore, it is very important to make the system achieve its best performance in an entire range of the working temperature.

Development of a hydraulic control system is usually done by a trial and error type of performance testing method which takes a long period of time. Therefore, in order to shorten the development period a simulation method may be used as an alternative. The objectives of this study was to conduct a simulation of a hydraulic control system for powershift transmission of tractors and investigate the effect of temperature on the system performance. More detailed objectives are as follows:

1. To design two types of hydraulic control systems with different types of accumulator; one with a spring type and another with a gas type.

2. To design two types of hydraulic circuits for each hydraulic control systems; one with a return path of oil and another without it.

3. To perform the simulations of all the designed systems at low and high working temperatures of 10℃ and 100℃, respectively.

4. To compare the pressure characteristic curves of each hydraulic control systems.

HYDRAULIC CONTROL SYSTEM

A hydraulic control system shown in Fig. 1 is used for a basis of this study. The direction valve controls the clutches on and off. The accumulators and orifices with a by-pass check valve were used for shifting the clutches smoothly.

As shown in Fig. 2, a return path to transfer the oil from the T-port to the hydraulic circuit between the filter and pump was added so that the oil from the clutches does not flow out directly to the oil tank but return to the system again.

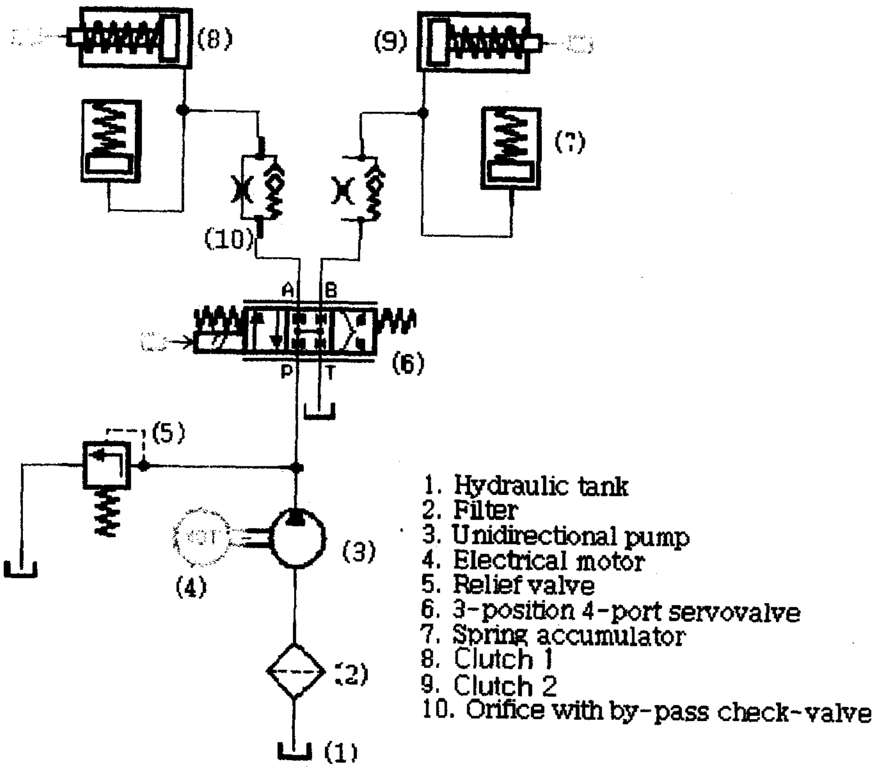

Fig. 1. Hydraulic control system.

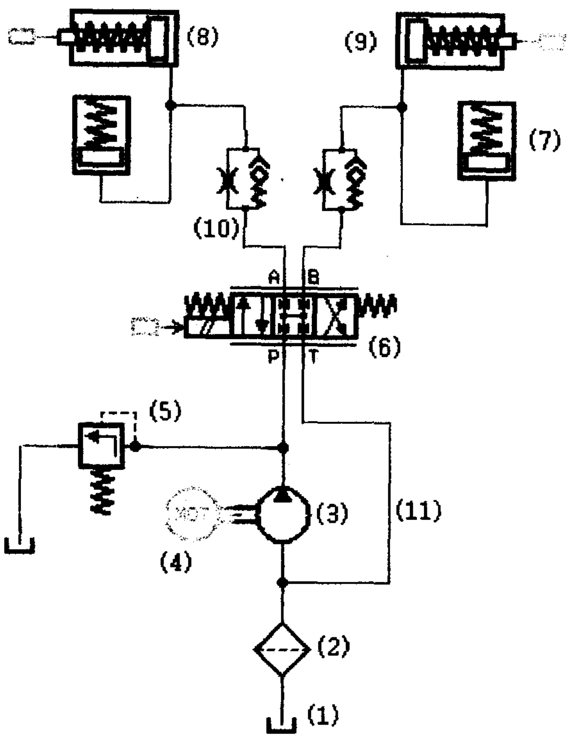

Fig. 2. Hydraulic control system with a return path.[(11) : return path]

MODELING

The pressure characteristics of the lower and upper shift clutches were analyzed so that the pressure changes at the clutches 1 and 2 could be monitored respectively. Fig. 3 shows the model of a hydraulic control system made by commercial simulation program. Using the models, the simulations were conducted by varying the values of design parameters of the hydraulic control systems at different temperatures.

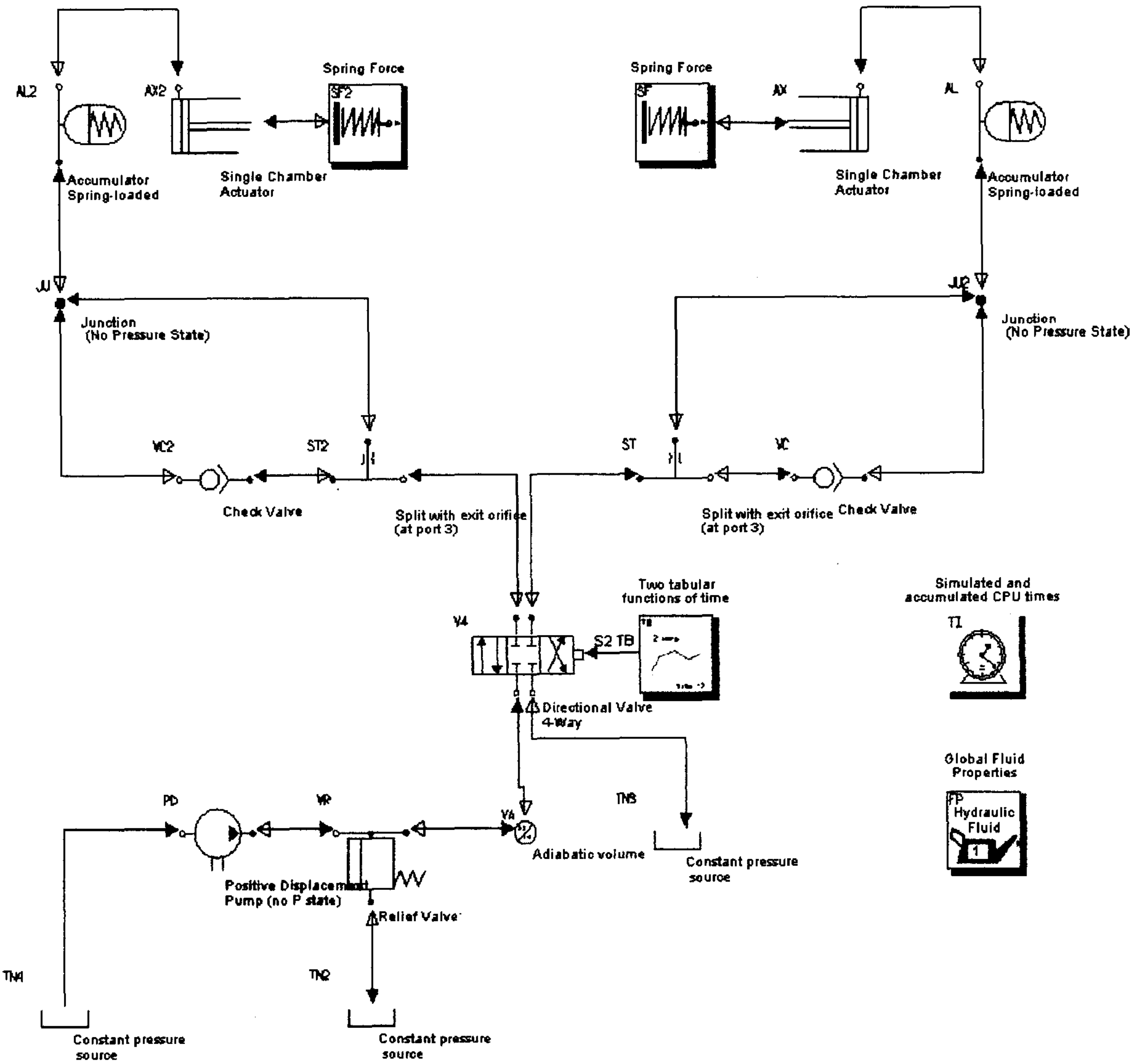

Fig. 3. Model of hydraulic control system.

Properties of oil are most important parameters in the simulation of the hydraulic control systems. Table 1 shows the properties of the oil.

Table 1. Properties of hydraulic oil

Density	850 kg/m^3
Bulk modules	17000 bar
Fractional air content	0.1%
Kinematic viscosity(10℃)	300 cSt
Kinematic viscosity(100℃)	10 cSt

RESULTS AND DISCUSSIONS

Fig. 4 show the results of simulation of the hydraulic control system with a spring accumulator and without a return path. The time for pressure rise at high temperature was 0.7 seconds and 1.7 seconds at low temperature. The difference was 1.0 seconds.

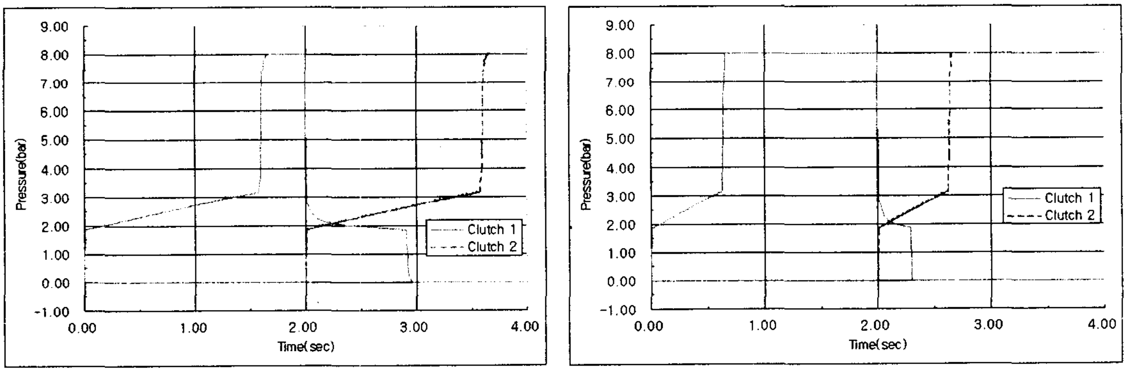

Fig. 4. Pressure characteristic of hydraulic clutch with a spring accumulator and without a return path at 10℃ and 100℃.

Fig. 5 show the results of simulation of the hydraulic control system with a spring accumulator and a return path. The time for pressure rise at high temperature was 0.5 seconds and 1.1 seconds at low temperature, resulting in a difference of 0.6 seconds which is less than the time difference obtained without the return path. However this is about 0.3 seconds more than that 今井 幹夫[1] has obtained.

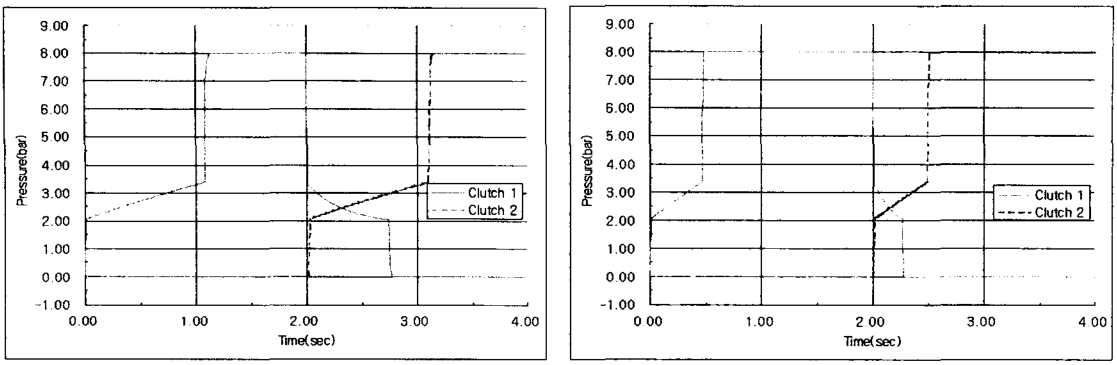

Fig. 5. Pressure characteristic of hydraulic clutch with a spring accumulator and a return path at 10℃ and 100℃.

Fig. 6 show the results of simulation of the hydraulic control system with a gas accumulator and without a return path. The pressure changes very slowly but rate of the change was fast due to the characteristics of the compressible gas. In order to shift smoothly, the pressures at the clutches must be increased until they reach a constant level. However, the system with a gas accumulator was not able to make it. To stop the functioning of the gas accumulator, the components like release and modulating valves were installed additionally. Consequently, the system with the gas accumulator became more complicated. In addition, the effects of the orifice size and the accumulator capacity were more significant on the system with a gas accumulator than the system with a spring accumulator.

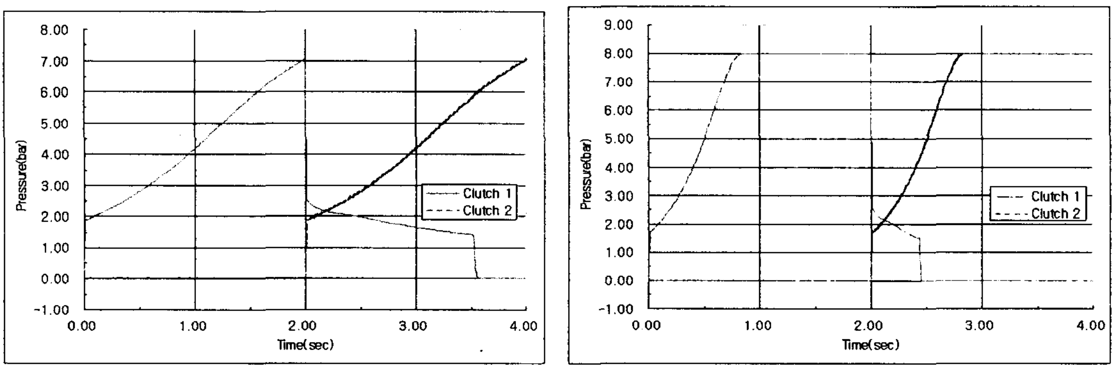

Fig. 6. Pressure characteristic of hydraulic clutch with a gas accumulator and without a return path at 10℃ and 100℃.

Fig. 7 show the results of simulation of the hydraulic control system with a gas accumulator and a return path. It was noticed that the difference in time for raising pressure at low and high temperatures was reduced by adding the return path to the system.

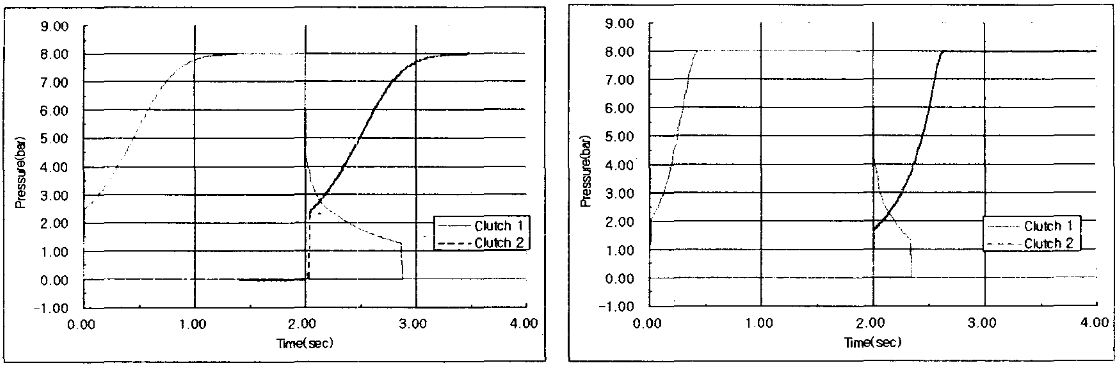

Fig. 7. Pressure characteristic of hydraulic clutch with a gas accumulator and a return path at 10℃ and 100℃.

SUMMARY AND CONCLUSIONS

Simulations of the hydraulic control systems with different types of accumulator and oil return path were conducted and the effect of working temperature on the time for raising pressure at the clutches were investigated. Results of the simulations are as follows:

1. The accumulator capacity and orifice size were important parameters to control the smoothness of shifting.

2. The hydraulic control system with a spring accumulator is less sensitive to the orifice size and more convenient to control the time for shifting than the system with a gas accumulator.

3. By adding an oil return path to the hydraulic circuit between the filter and pump, the difference in time for raising pressure at the clutches at low and high temperatures could be reduced.

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