Pressure Characteristic Analysis of a Hydraulic System

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Abstract. EPPR (ElectroProportional Pressure Reducing) valve control the MCV (Main Control Valve) built on the mobile heavy machine. The EPPR valve was tested in the experimental setup and the performance of the valve was compared with that of the existing EPPR valve. On this study, electromagnetic properties analysis using AMESim program was performed to optimize the designing of EPPR Valve (Electric Proportional Pressure Reducing Valve) and by applying its results to the hydraulic system analytical model, performance of the valve could be predicted. Also by comparing the results of the actual experiment and the simulation, The results of this study is that the 3 factor (cone angle, tip width, clearance between sleeve and plunger) have much effectiveness than other components in the EPPR valve.

1. Introduction
EPPR valve (Electric Proportional Pressure Reducing Valve) has been used in controlling hydraulic system electrically. It is the valve controlling pressure proportional input-current and is using industrial department (fork lift, excavator, special motorcar, heavy machine) variously [1,2].

As shown in figure 1, the study of EPPR Valve has been very important because it must satisfied flow force, hysteresis, linear form, repeating precision. So, it was performed hydraulic characteristic of newdesigned model EPPR valve using of AMESim and compared with experimental method.

2. Modeling for AMESim analysis.
Modeling of EPPR valve was completed with assemble HCD component and library in AMESim program. The viscous friction value of spool was determined two kinds method [3,4].

First, the case of non- spring model, it was used viscous friction coefficient of the meaning of physical.

\[ C_v = \frac{\mu \pi D^2}{\text{clearance}} \left[ \frac{N}{m/s} \right] \]

\[ \mu = \rho v \]

D : diameter of mass
L : contact length of mass and chamber
clearance : distance within of mass and chamber

Second, the case of spring existing model, it was used viscous friction coefficient of the meaning of math ematical.

\[ C_v = 2\zeta \sqrt{km} \left[ \frac{N}{m/s} \right] \]

\[ \zeta = \text{damping ratio (0.4)} \]
On the above expression, the system was damped over and oscillation was not created if damping ratio was too big, the system was damped under and oscillation was created if damping ratio was too small. But the parameter value showing above expression was not just exacted and the various parameter operated to determine viscous friction coefficient. The exact value of viscous friction coefficient was determined only by experiment. But, on this paper, additional experiment was omitted and added next assumption.

- The temperature variation of system was assumed normal condition maintaining initial condition.
- The volume of load side was constant.

![Figure 1. structure of EPPR valve](image)

3. Results of AMESim analysis

The valve of supply pressure $P_s$ was 25bar and viscosity damping coefficient $B$ was 8000 [N/(m/sec)] and another parameter was displayed in table 1. The parameter of solenoid was shown in figure 2 [5], [6]. The parameter value of solenoid valve was displayed in table 2. AMESim model of EPPR Valve was shown in figure 3. Using of 3D table editor, as shown in figure 4, the magnetic analysis values of Maxwell program was inputted in AMESim program parameter and the output values of P-I diagram was generated according to spool stroke.

| parameter name       | parameter value | unit         |
|----------------------|-----------------|--------------|
| $M_s$ spool mass     | 0.97            | g            |
| $M_s$ amateur mass   | 27.75           | g            |
| $B$ viscosity damping coefficient | 8000 | N/(m/sec) |
| $K_s$ spool spring coefficient | 0.2353 | N/mm |
| $d_s$ spool diameter | 3.5             | mm           |
| $\beta$ volume elastic coefficient | 8000 | bar |
| $P_s$ supply pressure | 25              | bar          |
| $P_t$ tank pressure  | 0               | bar          |
| $C_d$ orifice coefficient | 0.61    | -            |
ρ oil density 880 kg/m³

Figure 2. Parameter of solenoid valve

Table 2. Changing value of solenoid valve shape

| cone angle | tip width | clearance | rear groove | front groove |
|------------|-----------|-----------|-------------|-------------|
| existent value | 27° | 0.3mm | 0.2mm | 13.8mm | 3.6mm |
| new value | 26° | 0.2mm | 0.1mm | 9.5mm | 2.0mm |

Figure 3. AMESim model of EPPR Valve
Resulting of AMESim program analysis, the pressure linear form of EPPR valve was in proportion from 100 mA to 700 mA and the range of pressure was controlled from 0 bar to 25 bar as shown in figure 5 [7].

4. Hydraulic characteristic experiment of EPPR valve

It was obtained the P-I diagram according to current value of EPPR valve by experiment connecting with PC type data acquisition system and then the supply pressure $P_s$ was 50 bar. The experimental system of EPPR valve was shown in figure 6.

[hydraulic power unit & test stand]
- Regular pressure: 210 bar
- Regular flow: 70 lpm
- 16 channel strain amplifier
5. Forklift application experiment of improved EPPR valve

Figure 6. experimental system of EPPR valve

Figure 7. experimental P-I diagram of existent value

Figure 8. experimental P-I diagram of new value

Figure 9. Forklift equipped improved EPPR valve
6. Results of experimental analysis

The linear pressure range was started from 300mA in existent model as shown in figure 7, but it was
started from 100mA in new manufactured model as shown in figure 8. So, The non-linear pressure
range of new manufactured model was improved about 30%. The improved linear pressure range is
meant that it is able to descend the useful pressure of EPPR valve and the controllable pressure range
is extended widely contrast to existent model. Also, the hysteresis was improved properly about the
first stage of EPPR operating system. It was shown Forklift equipped improved EPPR valve in figure 9.
Though Lift-up valve was operated at 4.3 sec and Lift-down valve was operated from 9 sec to 13.7 sec
in figure 10, it was able to know the system was operating very stable.

7. Conclusions

It was proved that the result of simulation using AMESim coincided with result of experiment nearly.
And then it was able to suggest the optimum model condition of AMESim program.
It was changed the dimension of EPPR valve parts by the results AMESim simulation and was proved
that the sleeve of cone angle, tip width, clearance of plunger and sleeve was very important parameter.
The performance of new manufactured model was improved about 30% and the controllable pressure
range is extended widely contrast to existent model.
We were able to know that the Forklift operating pressure and velocity was followed suitable and the
system was operated very stable in field experiment adapting improved EPPR valve.

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