The Simulation Analysis on Pressure Characteristics of Internal Leakage in Hydraulic System of Heavy Vehicles

Hongzhuang Zhang, Suli Feng* and Yang Li

Army Acadermy of Armored Forces Sergeant School, Huayuan ROAD, Changchun City, Jilin Province 130117 China
Email: 416946128@qq.com

Abstract. The internal leakage of hydraulic cylinder severely effects the normal operation running of hydraulic system. At present, the diagnosis approaches of internal leakage of hydraulic cylinder still have some problems. It is to make test slow when leaking or it is difficult to diagnosis when leaking weakly. A method to determine internal leakage using pressure change characteristics is proposed. Based on hydraulic system simulation software Automation Studio 6.1, this paper makes simulation analysis on normal status and fault status of hydraulic system operation, aiming to achieve time domain and frequency domain features. Accompanying with experimental test, the results of simulation are consistent with experiment results, which provides a new way for the detection for internal leakage of hydraulic cylinder.

1. Introduction

Hydraulic cylinders are widely applied in industrial production and daily life. The leakage of Hydraulic cylinder is one of the most common mechanical failures. Many causes lead to this situation and the causes varies from one another according to the differences in working condition or operating modes. The leakage are classified into internal leakage and outernal leakage. Comparatively speaking, the outernal leakage is much more easily identified by the outflowed hydraulic oil. While the common Hydraulic cylinder faults caused by internal leakage are hard to recognize for there is no oil leakage outside the cylinder blocks. But this fault will affect the technical spectations of the hydraulic cylinder, such as low motivation, decreased output power and unstable operating condition. Based on hydraulic system simulation software Automation Studio 6.1, a simulating model of one heavy vehicles hydraulic system is produced. This paper compared the nomal status and the fault status, analyse the differences and record the test. The results from the model is consistent with practical test, therefore provides a theoretical basis to the test of internal leakage of hydraulic cylinders.

2. The Mathematical Model of the Internal Leakage of Hydraulcylinder [1-5]

According to the basic theorem in physics and engineering hydraudynamics, structural mechanics and loop systematic, the static and dynamic relationships among kinds of parameters in physical model system is described quantificationally in the form of math, which is systemic model. In hydraulic servo system, mathematical model is mainly set up from aspects of load pressure flow equation of hydraulic valve, load flow equation of hydraulic cylinder and force equation of hydraulic cylinder [2]. The sketch of systemic model is shown in figure 1.
As shown in chart 1, p1 and p2 represent oil absorption and pressure oil of hydraulic cylinder respectively; A1 and A2 represent effective area of piston left and right chamber respectively; Q1 and Q2 represents the flux of oil absorption and pressure oil of hydraulic cylinder respectively; Ps and P0 represents oil source pressure and oil withdrawer pressure respectively; xv is hydraulic servo spool displacement; y is displacement [6-9].

Load flow is

\[ Q_L = \frac{Q_1 + Q_2}{2} \]  

(1)

Load pressure is

\[ P_L = P_1 - P_2 \]  

(2)

Pressure-flow equation of hydraulic cylinder

\[ Q_L = K_x x_v - K_p P_L \]  

(3)

where, \( K_x \) — flow plus
\( K_p \) — pressure-flow coefficient

Load flow equation of hydraulic cylinder

\[ Q_L = C_t P_L + \frac{V_e}{4\beta_e} P_L + A_{me} y \]  

(4)

where, \( C_t \) — leakage coefficient
\( A_{me} \) — average piston area
\( V_e \) — hydraulic cylinder equivalent volume
\( \beta_e \) — hydraulic oil cubage modulus

Force balance equation of hydraulic cylinder

\[ p_L A_x = m \ddot{y} + B_p \dot{y} + K_s y + F - F_{ad} \]  

(5)

where, m is quality; \( B_p \) is glutinosity damp coefficient; \( K_s \) is flexibility coefficient; F is outer load; \( F_{ad} \) is extra load.

\[ A_x = \frac{(1+\eta^2)A_1}{1+\eta^2}, \eta = \frac{A_2}{A_1} \]  

(6)

Take equation (3) into equation (5), we obtain
In equation (7), \( K_i \) is flow pressure coefficient, \( K_i = K_p + C_i \).

Leakage volume is proportional to the \( \delta^3 \) and pressure difference \( \Delta p \), and it is inversely proportional to the dynamic viscosity \([4]\).

\[
q \propto \frac{\Delta p \delta^3}{\mu}
\]

(8)

Based on the flow equation of continuity, the changing rate of pressure in the cubage cavity could be described as:

\[
P(t) = \left( E_p(t)/V \right) \sum \Delta q \cdot dt
\]

(9)

Increment expression:

\[
\Delta p = E_p \Delta V / V
\]

(10)

In (10), “\( V \)” is the volume of pressure area. “\( q \)” is the total oil variation of the pressure area. “\( \Delta V \)” is the cubic volume of hydraulic oil when the pressure of hydraulic oil in the pressure area change to \( \Delta p \). “\( E_p \)” is modulus of elasticity. The leakage flow effects \( \sum \Delta V \) and \( \Delta V \) When the hydraulic oil in the cubage cavity leaks, which will change the pressure rise and decrease during operation. Following with the increasing of leakage, the value of “\( \sum \Delta V \)” increases.

3. Simulation Analysis Of Pressure Characteristics in The Internal Leakage of Hydraulic Cylinder

3.1. Simulation Model Pressure Characteristics in The Internal Leakage of Hydraulic Cylinder

Simulation system model in the internal leakage of hydraulic cylinder is as shown in figure 2; Simulation parameters is shown in figure 3.

![Figure 2](image)

Figure 2. Simulation system model in the internal leakage of hydraulic cylinder.
3.2. Simulation Results Analysis of Pressure Characteristics in the Internal Leakage

It can be concluded that from the simulation results in figure 4, when the internal leakage in hydraulic cylinder is in different degrees, the pressure amplitude will change on one hand, the overshoot will also change on the other hand, and the image slope will change obviously.

Figure 3. Simulation parameters setting.

Figure 4. Pressure characteristics of internal leakage.
4. Experiment verification

Through the detection of the hydraulic cylinder pressure (figure 5), the characteristics of pressure waveform are obtained. The results are consistent with the results of theoretical analysis and simulation analysis (figure 6) [10].

![Figure 5. The detection of hydraulic cylinder pressure.](image)

![Figure 6. The results of the pressure testing.](image)

5. Conclusion

The method of determining the internal leakage by using the characteristics of pressure changes has been proved to be effective by experiments, which provides a new way for the detection of the internal leakage of hydraulic pump.

References

[1] Löffler M, Weiß M, Wiesgickl T and Rupitsch S J 2017 Study on analytical and numerical models for application-specific dimensioning of a amplified piezo actuator Tech. Messen. 84(11) 706–718.

[2] Chen X H, Cheng G, Shan X L, et al. 2015 Research of weak fault feature information extraction of planetary gear based on ensemble empirical mode decomposition and adaptive stochastic resonance Measurement 73 55-67.

[3] Singh D S and Zhao Q 2016 Pseudo-fault signal assisted EMD for fault detection and isolation in rotating machines Mechanical Systems & Signal Processing 81 202-218.

[4] Kedadouche M, Thomas M and Tahan A 2016 A comparative study between Empirical Wavelet Transforms and Empirical Mode Decomposition Methods: Application to bearing defect diagnosis Mechanical Systems & Signal Processing 81 88-107.

[5] Rupitsch S J, L Sensorik, Universität F A and Nürnberg E 2018 Sensors and Actuators Fundamentals and Applications 87-89.

[6] Yang Z X and Zhong J H 2016 A Hybrid EEMD-Based SampEn and SVD for Acoustic Signal Processing and Fault Diagnosis Entropy 18(4) 112.

[7] Chen X H, Cheng G, Shan X L, et al. 2015 Research of weak fault feature information extraction of planetary gear based on ensemble empirical mode decomposition and adaptive stochastic resonance Measurement 73 55-67.

[8] Singh D S and Zhao Q 2016 Pseudo-fault signal assisted EMD for fault detection and isolation in rotating machines Mechanical Systems & Signal Processing 81 202-218.

[9] Kedadouche M, Thomas M and Tahan A 2016 A comparative study between Empirical Wavelet Transforms and Empirical Mode Decomposition Methods: Application to bearing defect diagnosis Mechanical Systems & Signal Processing 81 88-107.

[10] Zhang C, Li Y, Lin H, et al. 2015 Signal preserving and seismic random noise attenuation by Hurst exponent based time–frequency peak filtering Geophysical Journal International 203(2) 901-909.