Study on Vibration and Noise of CY Type Plunger Pump Starting Process

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Abstract

In view of the plunger pump, the influence of the starting operation of the plunger pump (including outlet pressure, cylinder speed and inclined angle) on the source flow pulsation of the plunger pump is analyzed, and the influence of the parameters on the cobbbm pulsation is given, which provides the basis for the optimization of the noise reduction structure. In view of the huge finite element model of the flow pulsation of the plunger pump, the solution time is too long and is not suitable for the analysis of the variable parameters. The simulation results are obtained by the parallel solver, and the flow fluctuation of the plunger pump is introduced under the dynamic boundary simulation, and the plunger pump is further deepened.

Keywords

Axial piston pump; flow noise; finite element model; start-up condition.

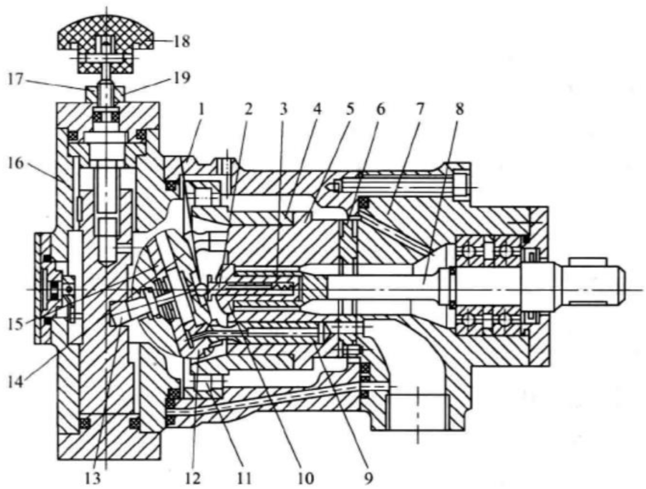
1. Introduction

With the progress of industry and the development of science and technology, people's demands for low noise living and working environment are increasing. In the industrial environment, the noise produced by vibration is very serious to the human body. Strong noise can lead to low work efficiency, ear discomfort, cardiovascular damage, nervous system dysfunction, and even visual. As one of the main noise sources, the noise control of hydraulic pump is particularly important. In addition, the noise level of plunger pump is the highest among different types of hydraulic pumps. Therefore, it is of great significance to study the noise cause of piston pump.

The progress of low noise plunger pump technology can also promote the development of technology in relevant industries, in line with the state's policy guidance for hydraulic components. The foundation of hydraulic foundation in China is poor, and the initial research investment is insufficient, resulting in the current technology level lingering in the lower grade. To overcome this problem, the state has increased investment in the hydraulic infrastructure industry. Speeding up the development of the basic parts of the machinery industry is the top priority for the development of the equipment industry during the "fifteen" period. The national "12th Five-Year" plan proposed to adjust the structure of the construction machinery industry to support the development of key supporting parts and components, so as to achieve the goal of improving the domestic level of the whole machine. During the 13th Five-Year plan, we still stressed the need to improve the manufacturing industry, improve basic technology, basic materials, research and development of basic components and system integration level, and realize the technology autonomy of key components. Therefore, the national current policy is conducive to the deep research and development of low noise plunger pumps.

2. The an Overview of the Noise of CY Axial Piston Pump

The noise of axial piston pump is divided into mechanical noise and fluid noise. The mechanical noise is mainly caused by the vibration of the key parts of the plunger pump. The periodic load and torque acting on the inclined disk, the flow disc and the spindle are the exciting source, and the noise transfer path of the plunger pump is shown in Figure 1.



1- pump body; 2- inner sleeve; 3- centering spring; 4- cylinder sleeve; 5- cylinder body; 6- flow disc; 7- front pump body; 8- input shaft; 9- plunger; 10- sleeve; 11- bearing; 12- slide;

Fig 1. Working principle diagram of plunger pump

The fluid noise of the plunger pump is the main noise source of the hydraulic system, which is mainly excited by the flow pulsation of the pump source. The periodic flow pulsation of the pump outlet drives the valve and tank by connecting the pump to the pump, causing the whole hydraulic system to increase the aerodynamic noise. The source flow of the plunger pump is mainly influenced by the flow of plunger plug at the outlet of the flow tray, the flow rate of plunger inversion in the low pressure to high pressure transition zone and the leakage flow rate. The characteristic parameters of the outlet piping of the piston pump are another important factor affecting the aerodynamic noise in the system.

1. The geometric structure of pump outlet pipe is the main factor.

2. fluid performance, including oil density, elastic modulus, viscosity and so on, the elastic modulus of fluid is the most important factor.

3 the gas precipitation and cavitation phenomenon in the oil fluid affect the pump source impedance by changing the elastic modulus of the oil.

The influence of the 4. pump shell's compliance and mechanical impedance on the pump source impedance is small.

3. Theoretical Analysis of Transient Conditions

During the operation of the plunger pump, the operating conditions of the pump, the outlet pressure, the cylinder speed and the inclined angle may be constant, and may also be due to the change of the control signal of the throttle valve and the plunger pump, the pressure of the plunger pump, the outlet pressure, the cylinder speed and so on, so the plunger pump is transported in two different operating conditions in the steady state and the transient state. It needs to be analyzed separately.

(1) Periodic changes of pressure

Because of the flow pulsation of plunger pump, the inlet and outlet pressure of piston pump are fluctuating periodically. When the outlet pressure of the plunger pump is periodically changed, the mean value of the pump outlet pressure is, the amplitude of the pulsation is for the period, and the outlet pressure of the plunger pump can be expressed in the following formula.

$$P(t) = P_o \sin(\omega_p t + \varphi_p)$$

(2) Sudden change of pressure

The sudden opening and closing of the valve port and the pressure of the pump outlet change rapidly during the load adjustment process. When the pressure of the plunger pump is suddenly changed, the initial value of the pressure is set, the highest value is the initial value generation time and the highest value generation time, and the outlet pressure of the plunger pump can be expressed in the following formula:

$$P(t) = \frac{(P_{in} - P_\beta)}{(t_{in} - t_\beta)}(t - t_{in}) + P_{in}$$

The outlet pressure of the pump first rises quickly and then drops rapidly. When the time is, the highest value is, when the time is and the pressure of the plunger pump is, the relationship between the pressure changes in different time periods is derived.

When running time, the outlet pressure of the plunger pump can be expressed as follows:

$$P(t) = \frac{(P_{in} - P_\beta)}{(t_{in} - t_c)}(t - t_{in}) + P_{in}$$

When running time, the outlet pressure of the plunger pump can be expressed as follows:

$$P(t) = \frac{(P_{fi} - P_\beta)}{(t_\beta - t_c)}(t - t_\beta) + P_\beta$$

The rest of the time: $P(t) = p_{in}$

(3) Periodic changes of rotational speed

The cyclical variation of the rotational frequency of the main engine will also directly affect the swashplate axial piston pump, which will drive the periodical change speed. When the speed changes, the speed of the plunger changes, so it is necessary to simulate the cyclical speed by dynamic mesh. When the speed average, speed amplitude, speed, frequency, initial speed and cylinder speed can be expressed as follows:

$$\omega(t) = \omega_0 + \omega_{am} \sin(\omega_\omega t + \varphi_\omega)$$

The velocity of the plunger along the axis is shown as follows:

$$v_p = R(\omega_0 + \omega_{am} \sin(\omega_\omega t + \varphi_\omega)) \sin(\omega_0 t - (\omega_{am} / \omega_\omega)(\cos(\omega_\omega t + \varphi_\omega) - 1) + C_1$$

(4) Sudden change of speed

When the plunger pump starts or closes, the speed of cylinder body is gradual change, so linear speed drive is formed. When the initial speed of the speed is changed, the speed of the cylinder is changed.

$$\omega(t) = k_0 + k_\omega t$$

The velocity of the plunger along the axis is shown as follows:

$$v_p = R \tan\beta (k_0 + k_\omega t) \sin(0.5 k_\omega t^2 + k_0 t + C_2)$$

4. Analysis of Influence of Transient Condition

4.1 Periodic Change of Pressure

Due to the inherent pulsation characteristics of the pump outlet flow, the periodic pulsation of the oil pressure of the connected pipeline is caused, and the vibration of the connected pipes and valves can be excited, and the aerodynamic noise is finally produced. When the pressure is 15MPa, the amplitude of outlet pressure pulsation is 0.3MPa, 0.6MPa, 0.9MPa, and the piston pump outlet flow and piston chamber pressure are shown in the figure.

It is known from the diagram that when the mean of the outlet is 15MPa and the amplitude of the pulsation increases from 0.3MPa to 0.9MPa, the pump outlet flow pulsation and the plunger chamber pressure basically do not change. Thus, it is concluded that the pump outlet flow pulsation is unchanged when the pressure fluctuation amplitude of the pipe pressure fluctuation is less than 6% of the mean pressure.

When the outlet pressure is 10MPa, 15MPa and 22 MPa, the amplitude of outlet pressure pulsation is 0.3MPa, and the outlet pressure of plunger pump and piston chamber pressure are shown in Figure 2.

As shown in Figure 3, with the increase of the mean of the outlet pressure of the plunger pump, the amplitude and the pulsation rate of the pump source flow increase. Therefore, the mean of the pressure fluctuation at the outlet has an important influence on the flow rate of the plunger pump.

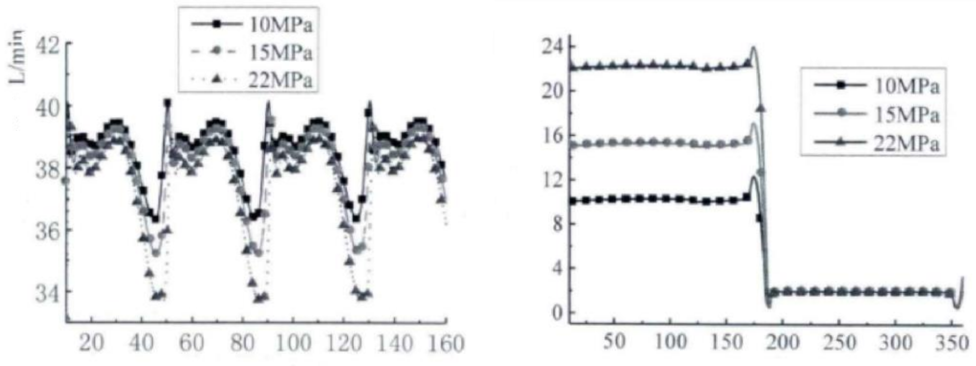


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Fig 2. Sudden change curve of piston pump outlet pressure

In summary, the influence of the pressure fluctuation mean is greater than the magnitude of the amplitude. Therefore, it is necessary to ensure the constant export pressure during the test.

4.2 Sudden Change of Pressure

The opening and closing of the valve and the change of the valve port will result in the instantaneous increase or decrease of the outlet pressure of the plunger pump. In this paper, the flow fluctuation of the plunger pump at the same change amplitude, different mutation time and different change amplitude and the same mutation time will be given in this paper.

First, in the same time period, when the maximum change of the piston pump outlet pressure is 18MPa and the mutation time is 0.0033s, 0.00467s and 0.006s, the flow pulsation of the plunger pump and the pressure of the plunger cavity are shown as shown in Figure 3.

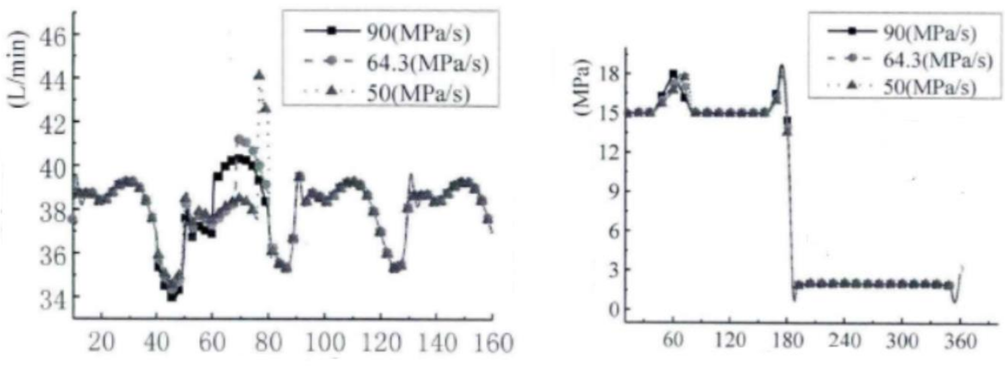

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Fig 3. Flow pulsation curve at different time of mutation

As shown in Figure 5, with the change of the mutation time, the pressure time variation rates of the plunger pump are 90./90 (MPa/s), 64.3/150 (MPa/s) and 50/450 (MPa/s), respectively. With the delay of the mutation time, the maximum value of the outlet flow pulsation of the piston pump increases. In the stage of pressure rise, the outlet flow of the plunger pump is smaller with the delay of the sudden change of time. In the stage of pressure drop, the outlet flow of the plunger pump is larger with the delay of the sudden change of time; the main reason is that with the delay of the sudden change, the amplitude of the pressure change rate in the rising stage decreases and the pressure change rate in the falling stage increases, and the sudden change rate increases. The time rate of change increases, so it is deduced that the higher the pressure change rate, the greater the flow volume of the piston pump outlet.

When the plunger pump outlet pressure mutation is the highest value of 18MPa, 22MPa and 25MPa, the change time is 0.00467s, the flow pulsation of the plunger pump and the pressure of the plunger cavity are shown as shown in Figure 4.

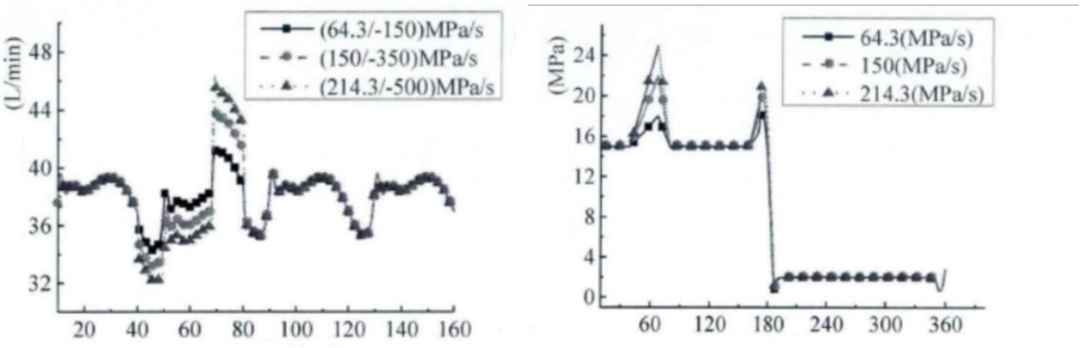

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Fig 4. Flow pulsation curve under different maximum amplitude

As shown in Figure 4, with the change of the highest mutation value, the pressure change rate is 64.3/150 (MPa/s), 150/350 (MPa/s) and 214.3/500 (MPa/s). With the increase of the maximum mutation value, the maximum value of the flow pulsation increases; in the stage of rise and decline, the greater the increase of the sudden change, the greater the flow rate of the plunger pump; mainly Because with the increase of the maximum value, the pressure and time change rate of the plunger pump increases during the rise and fall stage, and the outlet flow of the piston pump increases.

To sum up, the pressure time variation rate of piston pump outlet is an important factor affecting the flow pulsation of plunger pump. And its influence degree is greater than that of piston pump outlet static pressure.

5. Conclusion

The influence of the transient condition of the plunger pump on the pump source flow pulsation and the main factors of the source flow pulsation in the piston pump under different operating conditions are given. The influence of the outlet pressure on the plunger pump and the cylinder speed on the pump source flow pulsation is analyzed, and the periodic pressure fluctuating amplitude is lower than 6% of the pulsating mean. The flow pulsation of the source flow is basically the same. The influence of the change rate of the sudden change pressure on the flow pulsation of the plunger pump is greater than that of the static pressure; the periodic and abrupt rotational speeds have an important influence on the source flow pulsation of the pump pump, and the influence of the compressibility, viscosity, cavitation and flow state of the oil fluid on the flow pulsation of the pump pump is obtained. The compressibility of the effluent has the greatest influence on the flow pulsation of the pump source, followed by the oil viscosity

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