Analysis of Self-priming Performance of Hydraulic Pump

Han Zhiyin, Li Yanfang, Wu Huijun
Weifang Engineering Vocational College Qingzhou China 262500

Abstract. This article analyzes the self-priming performance of hydraulic pumps in hydraulic systems and describes many factors affecting the poor self-priming performance of hydraulic pumps in hydraulic systems. All these factors are analyzed one by one and some effective solutions are proposed.

1. Introduction
In the hydraulic system, the hydraulic cylinder of the actuator often fails due to poor self-priming performance of the hydraulic pump, which causes the system to malfunction [1-4]. There are many factors that affect the poor self-priming performance of hydraulic pumps, such as: pressure, speed, installation height of the pump, length of the suction pipe, diameter of the pipe, energy loss and flow state, etc. This article mainly analyzes the installation height of the hydraulic pump, the absolute pressure at the suction port of the hydraulic pump, and the energy loss.

2. Normal Oil Suction Condition of Hydraulic Pump
First, one or more sealed working chambers must be formed in the hydraulic pump, which can be used to hold the working medium hydraulic oil. In addition, the related flow distribution device can be used to separate the oil suction chamber and the pressure oil chamber to prevent the oil from flowing backward.

Secondly, the oil is sucked normally. The hydraulic pump starts to rotate under the drive of the motor or other prime mover. During the rotation, the volume of the sealed working chamber increases, and the air is drawn off to form a vacuum. It communicates with the atmosphere (as shown in the figure below, the external conditions of the normal operation of the hydraulic pump). The vacuum is less than the atmospheric pressure so the oil is sucked into the working cavity under the interaction of the vacuum formed in the sealed working cavity and the atmospheric pressure in the oil tank. Finally, the oil absorption is completed.

3. Analysis of Factors Affecting the Normal Oil Absorption of Hydraulic Pumps
As shown in the Fig. 1, the hydraulic pump is installed above the liquid level of the fuel tank, with the fuel tank as the reference level, the liquid level of the fuel tank as the constant level. The Bernoulli’s equation from section 1-1 to section 2-2 is as follow:

\[ \frac{p_1}{\rho g} + \frac{\alpha_1 v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{\alpha_2 v_2^2}{2g} + h_2 + \Sigma \lambda \frac{v^2}{2} + \Sigma \xi \frac{v^2}{2} \]  \hspace{1cm} (1)

where \( p_1 \)-the pressure on the tank level;
\( \rho \)-the density of the working medium hydraulic oil;
\( g \)-gravitational acceleration;
\( \alpha_1 \) and \( \alpha_2 \)-Kinetic energy correction coefficient;
\( v_1 \)-the movement speed of the oil on the tank surface;
\( h_1 \)-assume the fuel tank liquid level as the reference level;
\( p_2 \)-absolute pressure at the suction port of the hydraulic pump;
\( v_2 \)-the average flow velocity of the working medium hydraulic oil in the pipeline;
\( h_2 \)-the height of the suction pipe;
\( \sum \lambda \rho \frac{l_{v_2}^2}{d_2^2} + \sum \xi \rho \frac{v_2^2}{2} \)-the energy lost per unit weight of the liquid due to overcoming internal friction when the liquid moves from the through-flow section 1-1 to the through-flow section 2-2.

In the above formula, the tank is an open one \( p_1 = p_a = 1.01 \times 10^5 p_a \), \( v_1 \approx 0 \), \( h_1 = 0 \). After organization, the formula is as follow:

\[
\frac{p_1}{\rho g} = \frac{p_2}{\rho g} + \frac{\alpha_2 v_2^2}{2g} + h_2 + \sum \lambda \rho \frac{l_{v_2}^2}{d_2^2} + \sum \xi \rho \frac{v_2^2}{2}
\]  
(2)

The vacuum degree \( p_1 - p_2 = \frac{\alpha_2 v_2^2}{2} \rho g h_2 + \sum \lambda \rho \frac{l_{v_2}^2}{d_2^2} + \sum \xi \rho \frac{v_2^2}{2} \) always positive, so that a vacuum must be formed at the pump inlet, which also meets one of the necessary conditions for the normal operation of the hydraulic pump.

If we want to create a vacuum to be reduced \( p_2 \), namely to improve \( v_2 \), \( h_2 \), \( \sum \lambda \rho \frac{l_{v_2}^2}{d_2^2} \sum \xi \rho \frac{v_2^2}{2} \), then it is impossible to improve \( \sum \lambda \rho \frac{l_{v_2}^2}{d_2^2} \) and because of the loss of energy. In addition, it is also not possible to improve \( v_2 \) because the energy loss is proportional to its square.

It is also not feasible to decrease \( [M] \), i.e., the absolute pressure at the suction port of the hydraulic pump because vacuum at the oil inlet cannot be too high in order to ensure the normal operation of the hydraulic pump of the power unit. If the vacuum is too high, when the absolute pressure at the suction port of the hydraulic pump is too small, and it is lower than the separation pressure of air. As a result, the air originally dissolved in the oil will be separated out and precipitated with the formation of air bubbles. The pump sucks in the air bubbles and the air bubbles are under great pressure in the device, which causes cavitation, which causes cavitation, vibration and noise. Therefore, to improve the self-priming performance of the pump, it is necessary to increase the installation height of the hydraulic pump, that is, to increase the self-priming performance of the pump \( h_2 = \frac{p_1 - p_2}{\rho g} - \frac{\alpha_2 v_2^2}{2g} - \sum \lambda \rho \frac{l_{v_2}^2}{d_2^2} - \sum \xi \rho \frac{v_2^2}{2} \).

The parameter \( \alpha \) is related to the flow of liquid, and there are two kinds of flow: one is laminar, and the other is turbulent. Laminar \( \alpha = 2 \), turbulent \( \alpha = 1 \), and flow regimes are related to the Reynolds number \( Re = \frac{v_2 d}{\gamma} \).

In the formula: \( \alpha \)-the average flow velocity of the liquid in the pipeline;
\( d \)-the diameter of the pipe;
\( \gamma \)-Kinematic viscosity of the liquid.

Therefore, to improve the self-priming performance of the hydraulic pump, that is, to increase the installation height \( h_2 \) of the hydraulic pump, it is necessary to reduce the absolute pressure at the suction port of the hydraulic pump \( p_2 \), the average flow velocity \( v_2 \) of the liquid in the pipeline, the pressure loss \( \sum \lambda \rho \frac{l_{v_2}^2}{d_2^2} \) and local pressure of the liquid in the pipeline \( \sum \xi \rho \frac{v_2^2}{2} \).

Improving the tightness of the connection between the hydraulic pump and the oil pipe also reduces the oil inlet speed \( v_2 \) and the energy loss in the oil pipe \( \sum \lambda \rho \frac{l_{v_2}^2}{d_2^2} \) and \( \sum \xi \rho \frac{v_2^2}{2} \), but the speed of the liquid in the pipeline \( v_2 \) cannot be too small. If it is too small, the working efficiency of its hydraulic system will be very low. The absolute pressure \( p_2 \) must not be too small. When it is lower than the air separation pressure, the air originally dissolved in the oil will be separated out, and the air will be
precipitated to form bubbles. Then the hydraulic pump will suck the bubbles and produce Cavitation causes cavitation, vibration and noise. For this reason, the best way to improve the self-priming performance of the hydraulic pump is to increase the installation height $h_2$ of the hydraulic pump. And the best measure to increase the installation height of the hydraulic pump $h_2$ is to reduce energy loss $\sum \lambda \rho \frac{v^2}{d}$ and $\sum \zeta \rho \frac{v^2}{2}$.

![Fig. 1 Illustration of hydraulic pump.](image)

4. Solutions to Poor Self-priming Performance of Hydraulic Pumps

In summary, to reduce energy loss, i.e., to reduce pressure loss along the process $\sum \lambda \rho \frac{t v^2}{d}$ and local pressure loss $\sum \zeta \rho \frac{v^2}{2}$, the self-priming performance of the hydraulic pump can be improved.

The first measure is to keep the inner wall of the pipeline smooth. It is best not to use a curved pipe on this oil suction pipe. Try to ensure the straightness of the pipe and the smoothness of the inner wall of the pipe, that is, to reduce the along-path resistance coefficient $\lambda$ and local resistance coefficient $\zeta$.

The coefficient of resistance along the journey is $\lambda$ related to the Reynolds number $R_e$, so to reduce the coefficient of resistance along the journey $\lambda$, the kinematic viscosity $\gamma$ needs to be reduced. The kinematic viscosity is related to the temperature of the oil. Do not increase it excessively, because excessively increasing the oil temperature will cause the oil to become very thin, the leakage will increase, and the high oil temperature will also destroy the oil film strength in the hydraulic oil and increase the friction of the system. Keep the oil temperature between 30 and 60°C.

The local resistance coefficient $\zeta$ is related to the structure of the pipeline, and the pipeline is also straight. The smaller the resistance coefficient, so in order to improve the self-priming performance of the hydraulic pump, make the suction pipe as straight as possible to reduce bending and friction inside the pipeline.

The second measure is to increase the diameter $d$ of the self-suction pipe and reduce the length of the self-suction pipe.

The third measure is to reduce the movement speed of the oil in the pipeline $v_2$ (but $v_2$ the minimum movement speed in the suction pipe is generally 0.15-1.5 mm/s, which can not be lower), because the
pressure loss along the way and the local pressure loss are proportional to its square. Under normal working pressure, the speed of the hydraulic pump should not be too large.

The fourth measure is to increase the pressure $p_1$. This measure aims to improve the absorption properties under a normal pressure from the hydraulic pump moves from the root. As long as the tank is adjusted to open a closed reservoir, the pressure increase in the tank can be set at 0.5MPa-3MPa, because the open tank uses the relationship between atmospheric pressure 0.101MPa and vacuum to suck oil. So, increasing the pressure here can obviously improve the self-priming performance of the hydraulic pump.

5. Conclusion
The self-priming performance of the hydraulic pump of the power unit will directly affect the good performance of the hydraulic system. If the self-priming performance of the hydraulic pump is not good, it will cause the action of the hydraulic cylinder or hydraulic motor of the actuator to fail and affect the system work. It can be seen from the above analysis that many factors affect the self-priming performance of the hydraulic pump. Therefore, when designing and installing the suction pipe, it is necessary to ensure the self-priming performance of the hydraulic pump. The temperature of the oil and the speed of the oil in the pipeline is also important to pay attention to other influencing factors in actual work, and it is best to adjust the fuel tank in the hydraulic system to a closed fuel tank, because this is a measure to fundamentally improve the self-priming performance of the hydraulic pump under normal pressure.

References
[1] Zhang Fengshan. Fault diagnosis and maintenance of hydraulic and hydraulic systems for construction machinery. Chemical Industry Press. 2009 (3): 3.
[2] Yuan Chengxun. Hydraulic and Pneumatic Transmission. Excellent Teaching Materials of Mechanical Industry Press. 2007 (7): 111.
[3] Jiang Jihai. Hydraulic pump performance experiment in hydraulic transmission teaching experiment. Machine Tool and Hydraulics, 2010, (19): 61-63.
[4] Zheng Minghui. Design of hydraulic pump performance test bench. Machine Tool and Hydraulics, 2011, (20): 76-78.