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THE TEMPERATURE INFLUENCE ON OPERATING IN HYDRAULIC SYSTEMS

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ABSTRACT

The work is devoted to the influence of temperature on the operation of hydraulic systems. An important part of the hydraulic system, which largely determines its characteristics, is the pump. The gear pump with external involute gearing, which is widely used in the hydraulic drive of mobile machines, has the property of forming a trapped volume during operation, in which various hydrodynamic phenomena occur. It has been experimentally established that the intensity of cavitation that appears in trapped volume increases with increasing temperature of the working fluid, which may lead to an increase in the pressure pulsations in the hydraulic system. In the article, the proposed calculation method for mobile drives gives an opportunity to predict the time of operation of the source system elements.

INTRODUCTION

Hydraulic systems are widely used in modern machine building. They can perform various functions: energy transfer (hydraulic drive of machine tools, mobile machines, aircraft), lubrication of equipment elements, heat exchange, and others. In accordance with this, it can be concluded that the hydraulic systems operate over a wide temperature range and are exposed to various factors.

Especially interested are hydraulic systems of mobile machines operating under conditions of variable temperatures, polluted environments, etc.

Many parameters of the system depend on the type and characteristics of the pump, which it applies. In a number of equipment gear pumps are used, which can be explained by a number of advantages: relative simplicity of design and manufacturing, high reliability, low sensitivity to the cleanliness of working fluid, good mass-dimensional characteristics and the possibility of creating high pressures.

However, depending on the geometrical features of the gears, their mutual arrangement, the number of teeth, in pumps of this type there is a so-called trapped volume formed by the involute surfaces of the teeth and bushings (covers). Locking the liquid in the trapped can lead to unstable flow rate, reduced service life, noise and vibration during operation, which ultimately affects the efficiency of the pump and system.

EXPOSITION

As is known [1], hydrodynamic cavitation occurs in zones where the fluid pressure sharply decreases and the conditions for vapour formation appear. As a result, a cavern arises and the process of formation and collapse of the bubble occurs.

These phenomena can be observed in the trapped volume of a gear pump, where for certain values of the pressure at the inlet (underpressure and overpressure) and outlet of the pump, the bubbles form, that is, a cavitation zone appears.

The cavitation bubble, moving with the flow of liquid into the area with a higher pressure, collapses, creating a shock wave. This leads to cavitation corrosion - the destruction of the metal surface caused by the simultaneous action of shock pressures in the liquid (collapse of bubbles, caverns) and corrosion or cavitation wear as a form of mechanical wear.

Cavitation also causes additional vibration of the equipment, an increase in the noise level, a decrease in efficiency, and thus a reduction in the efficiency of hydraulic equipment, in particular pumps.

The pressure pulsations that accompany the collapse of the cavitation bubbles can be superimposed on the pulsations created by the operation of the pump and lead to a deterioration in the flow characteristics behind the pump, pressure pulsations lead to a change in the velocity diagram in the pipeline, create additional hydraulic energy losses in the system.

As a result of researching operation of a gear pump [2, 3] and visualizing its working process, the appearance of cavitation zones and the formation of caverns in the closed volume of the pump and their propagation into the suction chamber was confirmed. It was found that the intensity of this process is affected by the temperature of the working fluid, the pressure in the suction line and the speed of the pump gears.

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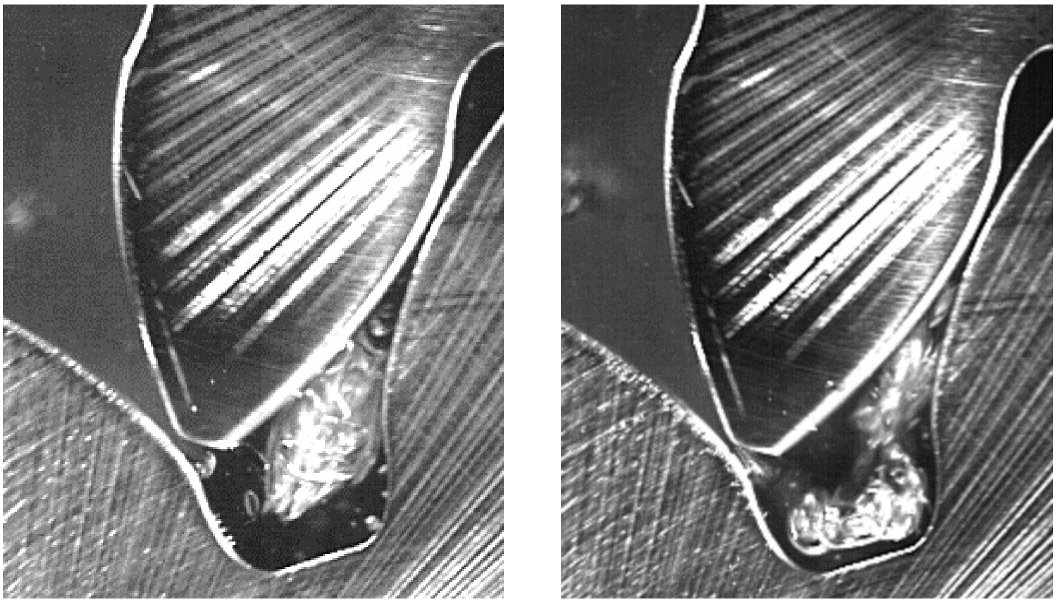
Studies were carried out using a high-speed camera Phantom v7.3 with a frequency of 10,000 fps. The distance between the camera and the object under study, as well as the lighting conditions, remained unchanged, which makes it possible to compare the images obtained.

The effect of temperature can be illustrated by comparing the spot of the cavitation zone observed in the pump at temperatures of 27°C and 60°C (Fig. 1). As can be seen, the area of the cavitation zone has grown almost 1,3 times.



a) b)

Fig. 1. Comparison of the intensity of cavitation in a closed volume with a change in the temperature of the working fluid: a) 27 ° C: b) 60 ° C

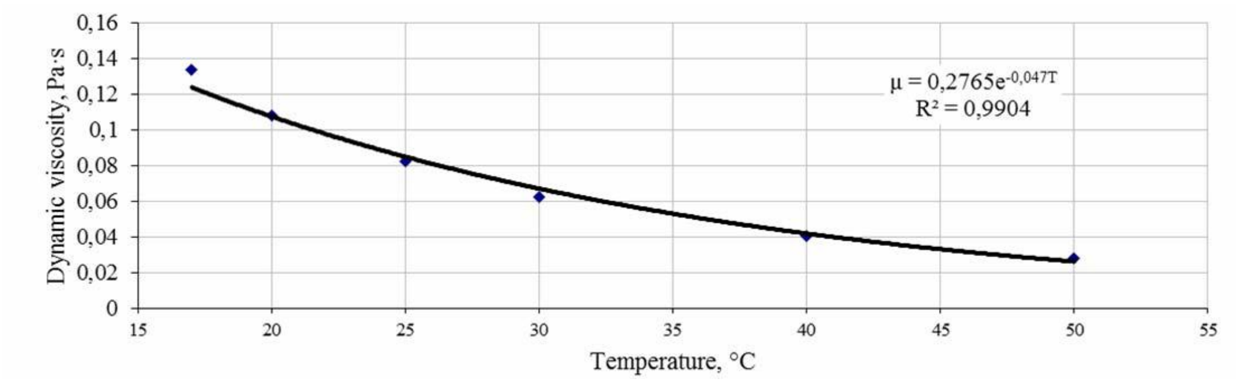


Fig. 2. - Viscous temperature characteristic of oil type HDZ

The effect of the temperature of the working fluid on the intensity of cavitation arises from the change in the pressure of saturated vapour, as well as the decrease in the viscosity of the liquid.

Studies carried out for oil type HDZ-46 have shown that with an increase in temperature from 20°C to 50°C, the dynamic viscosity of the liquid has changed almost 4 times (Fig. 2).

The measurement of the instantaneous pressure in the suction and discharge chambers simultaneously with the visualization of the pump operation made it possible to reveal that the rising edge of the pressure in the discharge line is observed at the time of formation of the closed volume (Fig. 3, position 1), then the value is practically unchanged. The next front arises at the moment when the closed volume reaches its minimum value (Fig. 3, position 2). The pressure drop occurs when the closed volume is opened (Fig. 3, position 3). The next pressure drop occurs when the second closed volume is opened (Fig. 3, position 4).

In the suction line, a doubled frequency of pressure pulsations was observed, and the rising pressure front corresponds to the instant of opening of the closed volume.

Thus, the effect of temperature on the operation of a gear pump is manifested in the growth of the intensity of cavitation, which can lead to the appearance of additional pulsations.

The influence of temperature affects not only the characteristics of pumps in the drives of mobile machines. The change in temperature also affects the performance indicators such as operating temperature range, preparation time for operation, efficiency, functional efficiency. For example, the use of gear-type pumps in cars in the lubrication system. The hydraulic lubrication system ensures the supply of lubricant to the friction elements of the units and mechanisms. To one element, the lubricating fluid is forced, and the other elements are lubricated when the liquid flows along their surfaces. Typically, the lubrication system consists of a small number of elements -

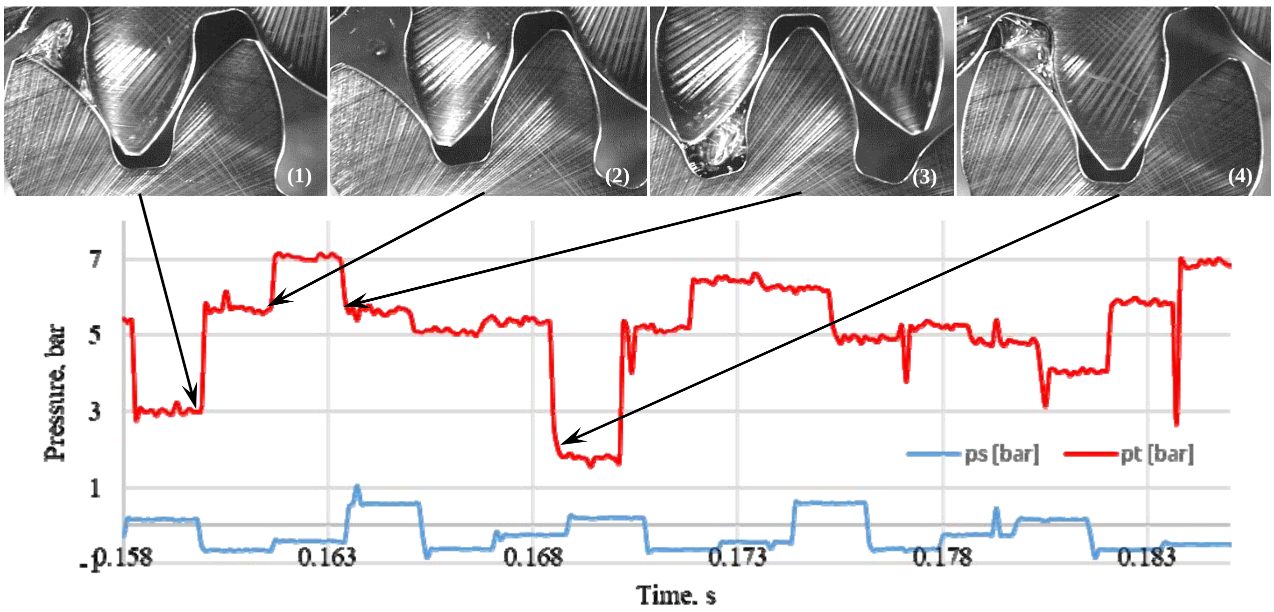


Fig. 3. Pulsation of pressure in the discharge (pt) and suction (ps) lines of the gear pump at the different mutual position of the gears and appearance of cavitation

a tank in which there is a lubricant, oil intake, pump, filter, channels for supplying oil to the elements and valves [4, 7].

Failure of any element of such a system can lead to the destruction of engine parts of the car. The lubrication system pump supplies fluid to the channels, which direct it to the filters, valves and system components. Lubrication must be performed for any initial fluid temperature. Lubrication to some elements is forced by pressure [4, 7]. Lubrication of other elements is carried out by splashing. The oil supply to the nozzles is carried out through narrow channels. The viscosity of the liquid in the channels at low temperatures increases. This, along with the breakdown of the elements of the system, also leads to the termination of the system due to increased pressure losses.

The performance of the lubrication system in different temperature conditions is especially important for mobile machines, such as a car. One of the modes of the system is to start the car at very low temperatures. The liquid will be completely warmed up when the motor and all its parts warm up to a stabilized temperature. The details of the upper part of the engine (pistons, cylinders, head) are warming up rapidly - the rate is practically the same [4, 7]. Especially slowly the oil in the tank warms up. For example, mineral oils - already at minus 20 … 25 °C, the best synthetics - at minus 45 … 55 °C can lead to failure of the lubrication system. As a result, the friction nodes work "dry", the wear of the parts increases sharply.

Of particular importance is the question of calculating the time of heating the liquid in the system. During this time, the lubrication system works little efficiently and the load on the engine must be kept to a minimum. An aviation hydraulic drive was considered in [5, 6], for which the operation is characterized in an unsteady temperature regime. The proposed method allows calculating the time of stabilization of the liquid temperature, which can be used as a warm-up time for the lubrication system of an automobile engine. The essence of the technique consists in considering the refined hydraulic model of the channels for the given values of the liquid temperature at the inlet and outlet of the channel and the known temperature of the channel walls.

Using the refined channel model, it is necessary to start calculating the flow in the channel according to the initial conditions (pressure, channel geometry, temperature, viscosity, density

$$U_{channel} = 0,\ \upsilon_{0(channel)} = \upsilon(T_{Environment}),$$

$$\rho_{0(\kappa channel)} = \rho(T_{Environment.}),$$

$$U_{input},\ \upsilon_{(input)} = \upsilon_{fluids.},\ \rho_{(input)} = \rho_{fluids.}).$$

Thus, the temperature $T_i = f(\nu_i, \rho_i, \lambda_i)$ between sections in the channel ΔTi= ±Tn-1 ±Tn, where Tn it was suggested that:

$$T_i = \frac{\lambda^3 \cdot t^3 \cdot 2\pi \cdot (l_i + r) \cdot (T_{fluid.channal} - T_{fluid.input})}{r^2 \cdot l_i^2 \cdot c \cdot \rho \cdot \sqrt{\dfrac{\lambda}{c \cdot \rho} \cdot \pi}} \cdot$$

$$\cdot (T_{fluid.channal} - T_{fluid.input}) + T_{fluid.input}$$

Calculating the value of the temperature in the sections, we proceed to calculate the pressure losses in the channel during the transient temperature processes during the start-up:

$$\Delta p = \xi 4 \cdot \frac{\sum_0^i \rho_{1i}(l_1 - l_{1i}) \cdot \sum_0^i U_{1i}^2 (l_1 - l_{1i})}{2} +$$

$$+ 32 \cdot \sum_0^i \rho_{1i}(l_1 - l_{1i}) \cdot \sum_0^i U_{1i}(l_1 - l_{1i}) \cdot \left(\frac{\nu_1 \cdot l_1 + \sum_0^i (l_1 - l_{1i}) \cdot \nu_{1i}}{d_2^{\,2}}\right) + \cdot$$

$$= 32 \cdot \sum_0^i \rho_{1i}(l_1 - l_{1i}) \cdot \sum_0^i U_{1i}(l_1 - l_{1i}) \cdot \left(\frac{\nu_2 \cdot l_2 + \sum_0^i (l_2 - l_{2i}) \cdot \nu_{2i}}{d^1{}_2}\right)$$

In conformity with the received pressure in the system, it is possible to determine the velocity of the liquid in the channel (along the length):

$$U_i = \frac{\Delta p \cdot d_2^{\,2}}{32 \cdot (\sum_{i}^{i+1}(\rho_i \cdot l_i) + \rho_0 \cdot l_0)) \cdot (\sum_{i}^{i+1}(\nu_i \cdot l_i) + \nu_0 \cdot l_0))},$$

where li and l0 – this value from the beginning to the end of the length of the calculation section l1.

In addition, for a site with local resistance « l1 → ξ4 → l2»):

$$U_{i(1,2)} = \frac{-32 \cdot (\sum_{i}^{i+1}(\rho_i \cdot l_i) + \rho_0 \cdot l_0) \cdot (A) \pm \Delta p \sqrt{\left(32 \cdot (\sum_{i}^{i+1}(\rho_i \cdot l_i) + \rho_0 \cdot l_0) \cdot (A)\right)^2 + 2 \cdot \xi 4 \cdot (\sum_{i}^{i+1}(\rho_i \cdot l_i) + \rho_0 \cdot l_0)}}{\xi 4 \cdot (\sum_{i}^{i+1}(\rho_i \cdot l_i) + \rho_0 \cdot l_0)},$$

where $A = \left(\frac{\nu_1 \cdot l_1 + \sum_0^i (l_1 - l_{1i}) \cdot \nu_{1i}}{d_1^{\,2}}) + (\frac{\nu_2 \cdot l_2 + \sum_0^i (l_2 - l_{2i}) \cdot \nu_{2i}}{d^1{}_1} \right)$.

We determine the time of stabilization of the velocity of the fluid in accordance with the proposed expressions for finding the speed in the drive channels in transient work processes. For example, in Fig. 4 shows the obtained graph of speed stabilization, followed by the time tstb (when the velocity of fluid in the system reaches a steady value).

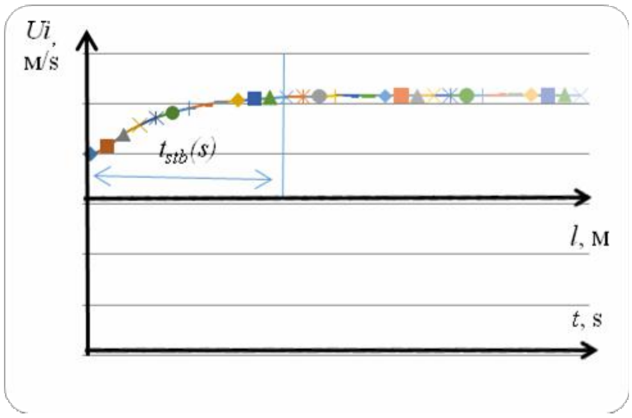


Fig.4. The graph of stabilization of the fluid velocity during the transient process

In carrying out a number of experiments with the drive and investigating the time of stabilization of the velocity for various initial temperatures, a graph of the dependence of u with the calculation of the calculated values on it was obtained (Fig. 5).

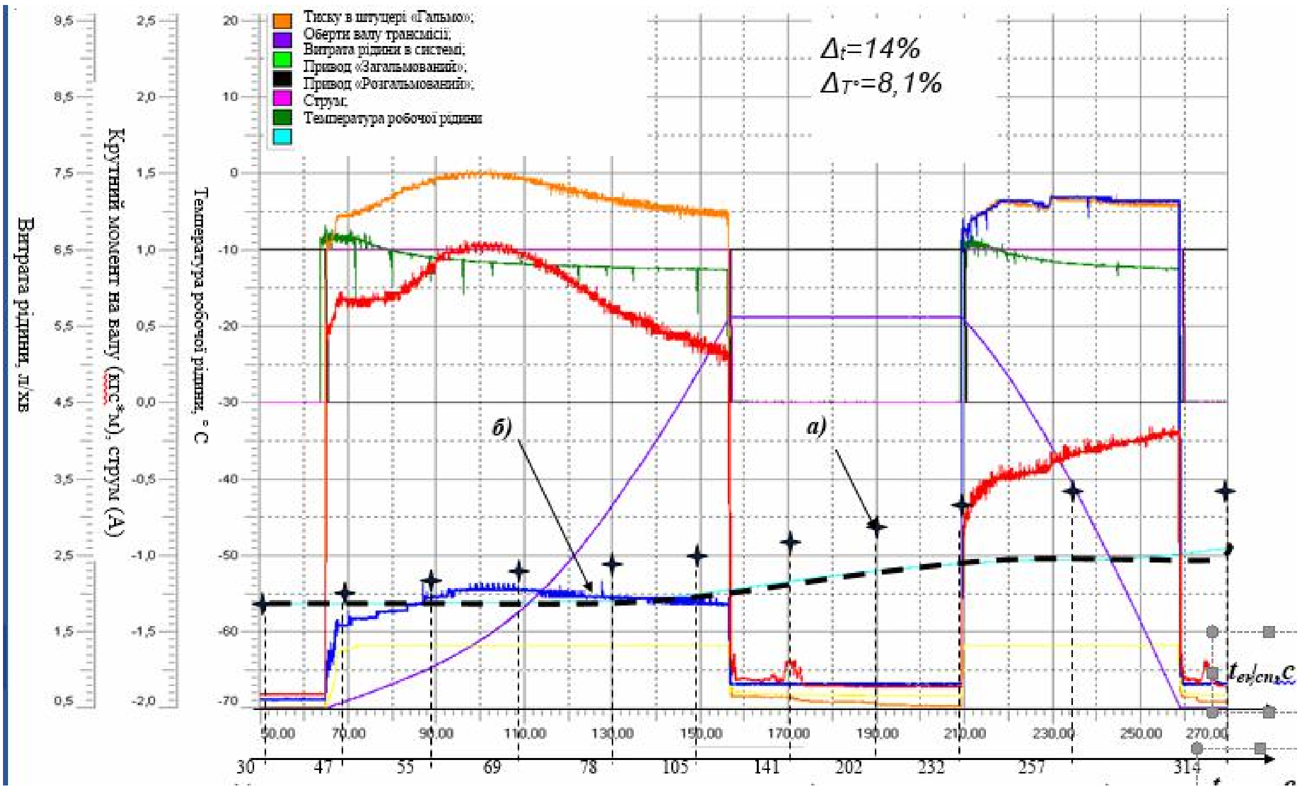


Fig. 5. The graph of stabilization of different drive parameters for a transient process with different initial temperatures: a) the results of theoretical calculations, b) the experimental value

CONCLUSION

This is especially important when the hydraulic equipment and pump are close to each other, while a sufficient distance between the elements and the use of flexible pipelines shows a pulsation attenuation.

The proposed calculation method for mobile drives gives an opportunity to predict the time of operation of the source system elements.

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