INVESTIGATION OF PARAMETERS OF ACCUMULATOR TRANSMISSION OF SELF-MOVING MACHINE

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Abstract. Under the influence of various factors the moment of resistance of the self–moving machine changes. The presence of hydrostatic transmission in the machine allows to get the desired transmission ration between the engine and the leading wheels and provide nominal load of the engine with the changeable moment of resistance. Since the operating liquid practically does not compress the transmission ratio changes by regulating the working volume of the hydraulic machines. In view of inertia of the components to change the working volume is possible only with definite frequency which practically is always less than the frequency of changing the moment of resistance. The fluctuations of the resistance moment within the zone of the insensitiveness of the regulator cause fluctuations of the angular speed of the machine engine as the consequence of which the usage of it might decrease. For reduction of fluctuations of loading of the engine in a zone of tolerance of a regulator the hydraulic accumulator connected in a delivery cavity of hydrostatic transmission is used. Theoretical researches are lead and dependences of key parameters of the hydraulic accumulator on the change of the moment of resistance of the self-moving machine are established.

Key words: accumulator, hydraulic system, self–moving machine, hydrostatic transmission, resistance moment, hydraulic motor, pump, operating liquid.

Introduction

The accumulator is a special container of certain capacity capable of accumulating the return to the hydraulic system of the operating liquid. It can perform different functions: to accumulate energy, to reduce the pulsation of pressure, to compensate the leakages of the operating liquid in the hydraulic system and so on. The construction of the accumulator is simple, it consists of the body divided into two cavities: liquid and aerial. The inner cavity is divided by the piston or the membrane. The aerial cavity is usually filled by nitrogen. The energy is accumulated when pressing nitrogen and returns to the system with its widening.

Under the influence of various factors the moment of resistance of the self–moving machine changes. The presence of hydrostatic transmission in the machine allows getting the desired transmission ration between the engine and the leading wheels and providing nominal load of the engine with the changeable moment of resistance. Since the operating liquid practically does not compress the transmission ratio changes by regulating the working volume of the hydraulic machines. In view of inertia of the components to change the working volume is possible only with definite frequency which practically is always less than the frequency of changing the moment of resistance. The fluctuations of the resistance moment within the zone of the insensitiveness of the regulator cause fluctuations of the angular speed of the machine engine as the consequence of which the usage of it might decrease.

The aims and tasks of the investigation

For reduction of the fluctuations of the engine load within the zone of the insensitiveness of the regulator there can be used the accumulator connected to the force cavity of the hydrostatic transmission (Fig. 1).

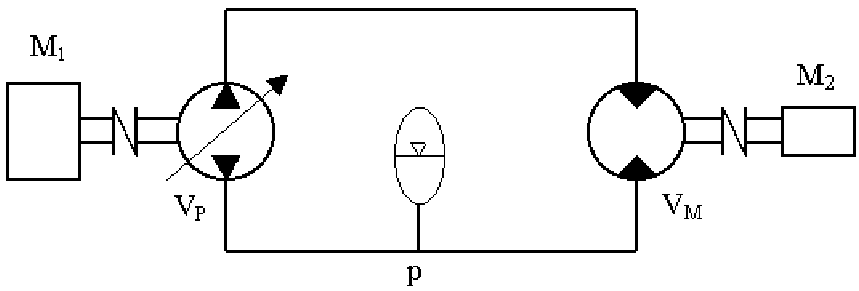

Fig. 1. **Hydrostatic transmission scheme of self-moving machines**

The aim of the investigation is determination of the main parameters of the accumulator in dependency on the desired damping moment of the resistance moment of the self–moving machine.

Methods and results of the investigation

For the analytical investigation and determination of the dependencies of the main parameters of the accumulator on the moment of the change of resistance of the self–moving machine the following assumptions were taken.

1. The efficiency factor of the hydraulic machine and accumulator is equal to 1.
2. The change of the moment of resistance goes on according to the sinusoidal law.
3. The operating liquid does not compress.
4. The leakages of the operating liquid and hydrostatic transmission are absent.

Considering the above indicated assumptions we can think that the torque of the hydraulic motor is directly proportional to the pressure:

$$M_M = \frac{1}{2\pi} V_M p \tag{1}$$

The increase of the moment of resistance of the self–moving machine with the constant working volume of the hydraulic motor causes an increase of pressure in hydrostatic transmission and by this increase of the torque on the shaft of the pump:

$$M_P = \frac{1}{2\pi} V_P p \tag{2}$$

Irregularity of the moment of resistance is determined by the coefficient of irregularity and the period of its change:

$$\delta_R = \frac{M_{R\max} - M_{R\min}}{M_{Ra}} \tag{3}$$

where $M_{R\,max}$ – maximal meaning of the moment of resistance;
$M_{R\,min}$ – minimal meaning of the moment of resistance;
M_{Ra} – average meaning of the moment of resistance.

According to (1) the equation the pressure of the operating liquid in the hydrostatic transmission will change from p_{max} (with M_{Rmax}) to p_{min} (with M_{Rmin}). That is why the coefficient of pressure irregularity δ_p will be equal:

$$\delta_p = \frac{p_{\max} - p_{\min}}{p_a} \tag{4}$$

where p_{max} – maximal pressure;
p_{min} – minimal pressure;
p_a – average pressure.

With sinusoidal law changes of the moment of resistance, the current meaning of the moment of resistance will be:

$$M_R = M_{Ra}\left(1 + \frac{\delta_M}{2}\sin kt\right) \tag{5}$$

where k – frequency of the change of the moment of resistance;
t – time.

The amplitude of the fluctuations of the shaft torque of the hydraulic motor according to (1) and (4) equations will be equal:

$$\Delta M_M = \frac{1}{4\pi} V_M \delta_p p_a \tag{6}$$

Irregularity of the resistance moment is determined by the coefficient irregularity and the period of its change will be equal:

$$\delta_M = \frac{2\Delta M_M}{M_{Ma}} \tag{7}$$

Taking into account (1) the equations of the average meaning of the shaft torque of the hydraulic motor will be equal:

$$M_{Ma} = \frac{1}{2\pi} V_M p_a \tag{8}$$

Taking into account (7) and (8) equation:

$$\Delta M_M = \frac{\delta_M V_M p_a}{4\pi} \tag{9}$$

Since δ_p=δ_M=δ_R, (5) the equation can be rewritten:

$$M_M = M_{Ma}\left(1 + \frac{\delta_p}{2}\sin kt\right) \tag{10}$$

The angular acceleration of the hydraulic motor shaft will be:

$$a_M = \frac{M_M - M_R}{I} \tag{11}$$

where I – attached to the hydraulic motor shaft the moment of inertia of the self–moving machine.

Taking into account that M_{Ma}=M_{Ra}, we get:

$$a_M = \frac{M_{Ma}}{2I}\left(\delta_p - \delta_R\right)\sin kt \tag{12}$$

Having integrated them in the obtained expression we determine the law of the change of the angular speed of the hydraulic motor shaft:

$$\omega_M = \omega_{Ma} - \frac{M_{Ma}}{2Ik}\left(\delta_p - \delta_R\right)\cos kt \tag{13}$$

where ω_{Ma} – the average angular speed of the shaft rotation of the hydraulic motor within the period T.

With the constant working volume of the hydraulic motor for getting the speed of rotation ω_M it is necessary to have the following consumption of the operating liquid:

$$\theta_M = \frac{1}{2\pi} V_M \omega_M \tag{14}$$

Under the condition when $M_M = M_{Ma}$, the feeding of the pump will be equal to the consumption of the hydraulic motor. With the change of the moment of resistance the angular speed of the shaft rotation of the hydraulic motor will change according to the equation (13). The difference of the pump feeding and the consumption of the hydraulic motor will inflow to the accumulator or from it:

$$\theta_A = \theta_P - \theta_M \tag{15}$$

Taking into account that the feeding of the pump and the consumption of the hydraulic motor are proportional to the working volume and the frequency of rotation we can write:

$$\theta_A = \frac{1}{2\pi}\left(V_P \omega_P - V_M \omega_M\right) \tag{16}$$

In case when in the hydrostatic transmission there are hydraulic machines of the same working volume used, the equation (16) takes shape:

$$\theta_A = \frac{V_M}{2\pi}\left(\omega_P - \omega_M\right) \tag{17}$$

Taking into account that $\omega_P - \omega_M = \Delta\omega$, with the account of the equations (17) and (13) we will get:

$$\theta_A = \frac{M_{Ma} V_M}{4\pi I k}\left(\delta_p - \delta_R\right)\cos kt \tag{18}$$

Having integrated the current expression in time we get the law of change of the volume of the operating liquid in the accumulator within the period T:

$$V_A = \frac{M_{Ma} V_M}{4\pi I k^2}\left(\delta_p - \delta_R\right)\sin kt + V_{\min} \tag{19}$$

where V_{min} – the minimal volume of the operating liquid in the accumulator.

Change of volume of the accumulator occurs in a range from V_{max} (at $sinkt$ = 1) up to V_{min} (at $sinkt$ = -1).

Therefore we may write:

$$\Delta V = \frac{M_{Ma} V_M}{2\pi I k^2}\left(\delta_p - \delta_R\right) \tag{20}$$

According to (1) and (20) equations, we receive:

$$\Delta V = \frac{p_a V_M^2}{4\pi^2 I k^2}\left(\delta_p - \delta_R\right) \tag{21}$$

Compression and expansion of gas inside the accumulator takes place according to the Boyle-Mariotte law regarding the status change in perfect gases:

$$p_0 V_0^n = p_{\min} V_{\max}^n = p_{\max} V_{\min}^n \tag{22}$$

In the remaining applications, such as energy accumulator, pulsation damper, emergency power source, dynamic pressure compensator, hydraulic spring, etc., it is possible to state, with reasonable accuracy, that the condition is adiabatic:

$$\frac{\Delta V}{V_{\max}} = 1 - \left(\frac{p_{\min}}{p_{\max}}\right)^{\frac{1}{n}} \tag{23}$$

where n – polytrophic exponent.

From the equation (23) we receive dependence on which it is possible to define the useful volume of the accumulator:

$$\Delta V = \frac{V_{\max}}{1 - \left(\frac{p_{\min}}{p_{\max}}\right)^{\frac{1}{n}}} \tag{24}$$

Conclusions

1. The given equations allow defining in the analytical way the working volume of the accumulator for desirable size damper the moment of resistance of the self-moving machine.
2. Dependence of the change of the twisting moment of the engine of the machine on the change of the moment of resistance of the self-moving machine is shown at the connected accumulator.
3. Dependences of the change of speed and acceleration of the hydraulic motor and the change of volume of the operating liquid in the accumulator also are shown.

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