Climatic effect on characteristics of a hydraulic drive of a self-propelled vehicle

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Abstract. This paper considers the dependences of performance parameters of the hydraulic drive of self-propelled vehicles used in road-building, logging, oil-producing, and other fields. Performance parameters of the hydraulic drive depend on numerous factors. The most important of them is the ambient temperature. The hydraulic drive has a wide temperature range from -60 °C to +100 °C.

1. Introduction

The area of the largest amount of forest harvesting operations determines the climatic zone of hydraulic logger operation. Eastern Siberia and the Far East with unfavorable climate conditions for logger operation have the largest amount of forest concession in Russia. Low environment temperatures in these areas last for six to seven months per year. Therefore, it is necessary to create a special well-designed hydraulic machine used at low temperatures.

Experimental studies undertaken by domestic and foreign scientists have found that a decrease of the temperature of the hydraulic fluid below 0 °C and its increase above +40 °C affect negatively on the hydraulic drive. The next characteristics show this impact:

- pump power ascension because of increasing pressure when the liquid flows through the discharge pipe and return line;
- reduction of the stem force of the hydraulic cylinder and the shaft torque of hydraulic motor;
- discontinuance of the liquid flow in the suction tube, which leads to cavitation in pumps;
- increase of liquid friction in pipelines, hydraulics, and increase of restriction losses;
- increase of mechanical friction in pumps, distributor units, valved hydraulics;
- loss in hydraulic fluid filtering conditions to increasing surface abrasion of friction and reduction of hydraulic equipment life;
- changes of clearances of the spool-type valve, valved equipment, axial piston pumps;
- deficiency of seal elements, which causes internal and external leakages of the hydraulic fluid;
- reduction of volume, mechanical and hydro-mechanical efficiency of pumps and hydraulic drive in general;
- hydraulics parts breakdown (pump shaft assemblies, bodies, pistons, separators APN) that occur at run-up of the engine at low temperatures;
- relaxation of fixed joints of the suction tube, which leads to the airing into the suction line of the pump;
- loss in dynamic characteristics of the hydraulic drive.

2. Analysis of the working ability of the hydraulic drive

Experience has proven that the main sources of failures and slowdowns of hydraulic machines operated with a wide environment temperature are:

- physical change and change of characteristics of the technical condition of hydraulic fluid;
- thermal distortion of hydraulic drive parts (spools, pistons, bodies, connecting threads);
- change of mechanical-and-physical properties of materials of the hydraulic equipment.

Figure 1 shows the dependences of characteristics of a hydraulic drive containing gear-type pumps on the temperature (viscosity) of the hydraulic fluid. This graph generalizes the research results of many domestic and foreign scientists. It confirms the above conclusions. The figure also shows the numerical values of the parameters using in solving mathematical models of hydraulic drive.

![Figure 1. The dependence of characteristics of a hydraulic drive containing gear-type pumps on the temperature (viscosity) of the hydraulic fluid: $t_{opt}$ - hydraulic fluid temperature at which all values are optimal; $\xi$ - local loss coefficient; $G$ - fuel consumption per hour; $P$ - flow line pressure; $\Delta P$ - 1 m pipe-line pressure loss; $C$ - capacity of a machine; $\tau_{c}$ - hydraulic cycle time; $\eta_{vol}$ - pump volumetric efficiency; $F_v$ - frictional force of directional control valve spool; $F_s$ - frictional force of piston seals; $Q_f$ - filtering element flow; $J_w$ - weight wear of rubber seal; $N$ - pump drive power; $k_i$ - relative leakage factor; $t$ – hydraulic fluid temperature; $\nu$ - hydraulic fluid viscosity.](image)

One of the main properties of the hydraulic fluid is the viscosity, that is, the resistance of the relative movement of parallel layers due to molecular bonds. The liquid viscosity-temperature
characteristic reflecting changes in viscosity at its temperature ranges has a practical bearing. According to the literature sources, the temperature of motor lubricating mineral oils ranging from -40 °C to +80 °C, the viscosity arises a thousandfold. It affects the working ability and efficiency of the hydraulic drive. Therefore, all characteristics of the hydraulic drive gotten worse, the capacity of the hydraulic machine reduces too.

Lubricating mineral oils crystallize, and paraffin falls out at a negative temperature. There are filter loading and siltation of orifice hole and path gaps of plunger and barrel assemblies because of that. It leads to an increase in the switching forces in the valve and spool hydraulics. The viscosity increased early in the run-up of the pump, cavitation occurs in the hydraulic drive, especially in the pump suction tube. Cavitation conditions during operation can destroy pumps, hydraulic motors, valve hydraulics in a few hours.

Mechanical-and-physical properties affect on the working ability and efficiency of the hydraulic drive due to internal structural changes. These changes associate with austenite-to-martensite transformation made secondary stresses leading to brittle fracture initiation. Strength loss causes the breakup of shaft of pumps and hydraulic motors, separators of axial-piston pumps, bodies of hydraulic equipment.

Besides, a significant change in mechanical-and-physical properties of rubber seals causes degradation of the hydraulic drive. Each hydraulic machine has a few dozen moving and fixed seals. For example, from 50 to 60 seals of different designs use in hydraulic cylinders, pumps, distributors, swivel unions. Functional loss of one seal leads to lingering downtime of equipment. Seals work in very difficult conditions. There is significant specific pressure on the locking surface caused by the pressure of the seals in the winter when the rubber hardness increases and abrasive particles circulate in large quantities in the pipelines. Research of the logger work during operation shows that the seal life is 600 hours, and the renewal of worn seals leads to significant downtime of the equipment. Observation over the operation of the hydraulic machine finds that from 40% to 60% of failures of the hydraulic drive is associated with sealing technology. It is worth pointing out that the cost of rubber seals is very small. Worn seals replacing, machine downtime and the amount of assembling and dismantling reduce the mechanical efficiency and lead to higher production costs. Also, assembling and disassembling works in hydraulic equipment filled with lubricating mineral oil in the open air, and even in the winter at a low temperature, is not only time-taking but also extremely inadvertent process. One of the factors is a change of joint clearance and thermal distortion of parts of hydraulic equipment. It also affects the productivity of the equipment. This factor can cause emergency consequences due to the fixing of moving elements in the directional control and regulating hydraulic equipment. Displacement of working bodies, destruction of pipelines, pump bodies, liner distortion and displacement of shaft of hydraulic cylinders accompany such failures. These failures lead to long downtime. Hydraulic equipment cannot be maintained, but only complete replacement of hydraulic equipment and arm can be. It is almost impossible in Siberian conditions. Also, the stresses in the threaded connections of the pipelines changing, air comes into the pump suction tube and liquid leaks flow in the discharge pipe.

The presence of air in the hydraulic fluid causes degradation of the dynamics of the hydraulic drive and metal structure, the destruction of hydraulics, intensive corrosion, and reduce of life of the hydraulic fluid. It also leads to reducing of protective properties, increasing wear of a friction couple of hydraulic equipment.

It is worth pointing out that the increase in the temperature of the hydraulic fluid also adversly affects the characteristics of the hydraulic drive. The temperature rising above +50 °C, its viscosity decreases to 70·10^{-6} m²/s or less. Thereat, the protective properties of oils get worse, and the friction force increases. There is an increase in the intensity of wear of the surfaces of hydraulic equipment parts, internal and external leaks of the working fluid. The volumetric efficiency of pumps, hydraulic motors, directional control and regulating hydraulic equipment, decrease.

Figure 1 shows that the turnaround time of equipment arises, and process capacity reduces when the value of temperature increases. Internal leaks in the pump, distributor, and other directional control
and regulating hydraulic equipment are the main cause of the reduced capacity. Leaks reduce the volumetric efficiency of hydraulic equipment affecting the supply of pumps, the speed of movement of the piston of hydraulic cylinders. After all, the turnaround time rises. The main factor of this interaction circuit is the efficiency of pumps.

Besides, as the temperature rises, the oxidation and chemical decomposition of the liquid increases. Moreover, oxidation increases exponentially (curve $k_1$), that is, an increase in temperature for every 10 degrees increases the oxidability twice. Ultimately the life of the liquid increases.

3. **Conclusion**

The lack of control over the state of the hydraulic fluid during equipment operation reduces the life of hydraulic equipment and the productivity of hydraulic machines.

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