Influence of temperature fluctuation on friction inside hydraulic cylinder

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Abstract. This paper considers variety of hydraulic actuators. Also it shows analysis of hydraulic equipment. The contribution is important due to the fact that it determines influence of temperature on friction in hydraulic equipment. The paper examines the factors of reducing the performance of hydrofected machines during operation at low temperatures. The importance of the work is due to the fact that the effects of temperature on friction in hydraulic equipment are considered. An experiment was also conducted, due to which the influence of temperature on the wear resistance of the hydraulic cylinder was revealed.

1. Introduction
Hydraulic actuator is an ensemble of elements designed to actuate mechanisms and machines by force of power fluid under pressure.

Hydraulic actuators are popular present machine-tool manufacture. It brings a vast improvement to kinematics of machine tools, reduces its steel intensity, improves accuracy and performance reliability, also it fines level of automation.

2. Hydraulic equipment review
Hydraulic equipment is a complex of facilities allowing to actuate operating mechanisms and machines using energy of power fluid - hydraulic oil under pressure. In order to run mechanisms using hydraulics it is necessary to use various tools, some of them transfer energy from engine body to fluid, other change characteristics of fluid flow and thirds convert fluid energy into movement of machine actuating devices.

Different hydraulic equipment is used in operation of current technology, list of essential facilities might be quite long. It is convenient to separate all those facilities into several groups to maintain and design hydraulic equipment [1-3].

Pumps – facilities enabling to convert mechanical energy of actuating motor into the energy of fluid flow.

Hydraulic engine discharge an opposite function to pumps - convert hydraulic energy into mechanical.

Hydraulic actuator - hydraulic engine, using which energy of fluid flow is converted into a linear displacement.

Hydraulic oil motor - hydraulic engine that gives an opportunity to get a rotational movement.

Hydraulic equipment lets to achieve desired parameters of power fluid flow.

Directional control hydraulic equipment – makes possible to revert flow of fluid.

Regulating equipment is needed to change fluid flow characteristics: flow-rate and pressure.
Fluid conditioner are used to provide required quality of liquid - cleanliness, temperature. Filters clean oil from contaminants. Lubricating oil coolers and heat exchangers arrange appropriate fluid temperature. Hydraulic accumulators provide accumulating energy and using it if needed.

3. Analysis of influence of temperature on friction in hydraulic equipment

The problem of increasing the efficiency of a Hydraulic gear is solved at the stage of its design, manufacture and operation.

The use of high-strength materials for the manufacture of critical parts of hydraulic equipment. As an example of this direction of improving efficiency, we can note the use of more resistant metals in pumps, regulating and guiding hydraulic equipment for the manufacture of parts subject to cavitation erosion. The use of cold-resistant steels for the manufacture of rods and eyelets of hydraulic cylinders, pump shafts and hydraulic motors, the use of durable and frost-resistant polyurethane and rubber-fabric seals of hydraulic equipment, which have high strength, retain sufficient elasticity in a wide temperature range and are not subject to intensive aging and vulcanization.

Friction in hydraulic equipment have a great impact on efficiency hydraulic actuator effect.

When temperature drops lower than -40°C, friction force increases by a factor of 1.7-1.8, of circular cross-section rings by a factor of 1.4-1.6, and of iron rings by a factor of 1.1. Friction force also increases with rising temperature.

Let's consider reasons of friction force of cup packing increase under temperature above and below zero. Friction force increase under temperature below 0°C firstly occurs due to viscosity increase of lubricating mineral oil, i.e. increase of viscous forces, which are defined by critical shear stress of a single fluid layer towards another [4].

Friction force increase under temperature above +20°C is based on simultaneous raise of hysteresic and adhesion friction force components. When temperature rises rubber springing develops, therefore actual contact area and adhesion friction force component scale up. Rubber seal springing develop leads to growth of depth of strained uppermost layer as penetration resistance to roughness of hard surface reduces. Growth of depth of strained uppermost layer forces up hysteresis loss in seal element. Overall magnification of two components reasons friction force increase under positive temperatures. Moreover, oil viscosity exerts a great influence over friction force increase. Fluid unctuosity gets worse when viscosity decreases, also breakdown of oil film occurs at point of contact between sealant and metal surface, areas of solid friction appear, molecular interaction between sensing surfaces on it increases, i.e. adhesion friction force component scales up.

Bearable force of static and sliding friction of control valve spool also depends on temperature.

Owing to high sliding velocities (in axial-piston pump in contact surface of piston and internal cylinder block) temperature increases quickly and it is impossible to quantify dependence between friction force and temperature.

Analyze of dependence between friction force and temperature for hydraulic cylinder sealants, control valve spools, axial-piston pumps let us note that such a temperature (viscosity) range exists when power waste for friction forces in hydraulic equipment is minimal.

Under low temperatures usable forces on actuating devices of hydroficated machines dip down, it bears upon machine load-lifting capacity. Main reason of such sthing is pressure loss in hydraulic equipment, pipings and pump intake lines. Pressure loss is caused by several factors: fluid friction in piping and channels of hydraulic equipment; fluid flow strain caused by eddies in local resistances, change of speed and direction of flow; thick liquid time lag.

Energy determining pressure loss in hydraulic system goes on passing friction forces, fluid inertia, flow strain. This loss increases when viscosity scales up and might bring decrease of usable forces on output elements of hydraulic engine or to total loss of function of machine, when pumped pressure is not enough even for free runoff working equipment. Such a situation practically occurs in a time of barring under temperatures below -25°C [5-6].
It should be noted that the mechanism of pressure losses in the suction and pressure hydraulic lines has some differences. If pressure losses in the suction pipeline are associated with friction and inertia of a viscous liquid, then in the pressure and drain pipelines - with friction and deformation of the liquid flow. These differences are explained by the nature of the fluid movement: in the suction pipeline, the flow direction is constant, there are no branches, there are fewer bends, and the flow rate is also limited. In the pressure pipeline, the flow branches into several streams and a large number of bends and local resistances are encountered on its way. When switching the guide and regulating hydraulic equipment, changes in the direction and reversal of the flow occur due to increased speeds (5 m/s or more), vortices are observed.

After conducting the experiment, the influence of temperature on the wear resistance of the hydraulic cylinder, shown in figure 1, was revealed.

![Figure 1](image-url)

Figure 1. The influence of temperature on the wear resistance of the cylinder.
1 - stem seal, 2 - piston seal, 3 - cylinder surface, 4 - stem surface

Although the pressure loss in the pressure lines is significantly higher than in the suction lines, the latter have a more significant impact on the performance of the hydraulic drive.

It is possible to eliminate or significantly reduce hydraulic losses in the suction pipeline by using the following design measures [7-8]:

- reducing the diameter with a decrease in the length of the pipeline;
- reducing the number and magnitude of local resistances;
- reducing the roughness of the inner surface of the pipeline;
- the use of conoidal suction pipes;
- the location of the hydraulic tank above the suction line of the pump;
- the use of hydraulic tanks with an internal pressure higher than atmospheric;
- installation of an additional make-up pump;
- optimization of the temperature (viscosity) of the working fluid.
When the temperature decreases, intense foaming occurs, the beginning of which corresponds to the viscosity of the liquid 500 m²/s. The foam in the oil contributes to the manifestation of cavitation and worsens the dynamic characteristics of the hydraulic drive.

The use of hydrofected self-propelled vehicles in the northern regions is hindered by their low efficiency in winter.

The performance of hydrofected machines at low temperatures is reduced due to three factors [9-10]:

- reduction of the volumetric efficiency of pumps;
- increase of pressure losses in the hydraulic system;
- increase the response time of the equip

4. Conclusion

Having considered various types of hydraulic equipment, it was found that when the temperature changes, friction in hydraulic equipment has a significant impact on the efficiency of the hydraulic drive.

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