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THE CHARACTER OF THE TRANSFER PHENOMENON IN THE WORK PROCESSES OF THE HYDRAULIC DAMPER

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ABSTRACT

The article considers the nature of the transport phenomenon, which is usually considered at three hierarchical levels: macroscopically, microscopic, and molecular. It is shown that the viscosity transfer coefficient significantly affects the resistance of the hydraulic damper and depends on the level of consideration of the medium, work processes and their rheological properties of the working fluid. Technical visualization of the working processes of the movement of the working fluid through the throttles and valves made it possible to study the hydrodynamic processes and establish the conditions for the formation of foaming and cavitation, which leads to the appearance of a two-phase flow of the working fluid.

INTRODUCTION

In thermodynamically nonequilibrium systems, special irreversible processes arise, which in physics are called transference phenomena, which result in the spatial transfer of energy, mass, momentum [1-2]. Currently, liquids and gases in hydrodynamics are called continuous media, which at the molecular level represent a collection of molecules and atoms [5]. These particles are in constant chaotic motion and interact with each other. But continuum mechanics usually do not consider the forces of internal particle interaction at the molecular level, but consider the dynamics of a continuous medium when exposed to external force and thermal fields at the macro-level [5] Fig. 1.

In processes at the macro level, a combination of various transport phenomena is considered [1, 3, 4]; in some cases, both macroscopic and microscopic relationships are presented in more depth, where transport is associated with molecular, as shown in the general case in physics by a whole series of transport coefficients.

Molecular transport of a substance is described under certain conditions associated with the orientation of the molecules in the volume.

For example, when critical stress is reached, the molecules are oriented or structured in a given direction, which ensures molecular transfer [9].

Significant examples where the microscopic transfer is usually considered are ferromagnetic dampers [9], predictions of lubricant dynamics, modelling of nano and microflows in filters, microreactors, tribology and wear in the field of lubrication contact mechanics, lubrication in miniaturized components, separation of liquid phases [3 5]. The transfer phenomenon is represented by three main transfer factors: friction coefficient, heat transfer coefficient, and mass transfer coefficient.

A liquid damper will appear as a classic example of dissipation of vibrational energy due to viscous friction in throttle elements [1-2].

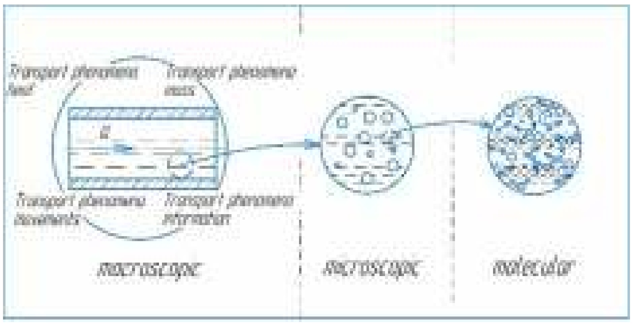

Fig. 1. Levels of the phenomenon of transfer andaccompanying processes

EXPOSITION

Let us consider in more detail the nature of the transfer phenomenon and analyze the influence of the transfer coefficient using the example of a hydraulic damper. The principle of operation of the hydraulic damper is to convert the energy of mechanical vibrations into thermal energy due to viscous friction in calibrated chokes, followed by dispersion into the environment (Fig. 2). Therefore, with a significant intensity of oscillations and prolonged operation of the damper, a change in temperature conditions will also occur.

The analysis found that changing the temperature of the working fluid affects its viscosity, density [6]. Given that the characteristics of the damper depend on the characteristics of the throttling process, for example, a

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decrease in viscosity leads to an increase in the flow rate of the working fluid.

This causes a decrease in the pressure drop across the piston and, accordingly, a decrease in the resistance force of the damper. To improve the operational properties of the damper, it is necessary that the planned characteristics do not change in a wide temperature range of -20 ... + 120°C[6].

Fig. 2. Scheme of physical processesdiagram of a hydraulic damper

The simplified design of a single-tube hydropneumatics damper is shown in Fig. 3.

Damping is achieved by passing the fluid through the calibrated channels and the openings of the valve-throttle assembly "compression" 1 and "return" 2. Both valves are located in the piston and the cylinder acts as a housing. When the rod moving downwards, it is the 'compression" mode (Fig. 3), the fluid flows from the lower cavity 5 to the upper 4 through the throttle assembly 1. The piston moves up it is "return" mode – the valve 1 closes and the fluid flows through the throttle assembly 2. The chamber 3 is filled with pressurized air, separated from the floating fluid. piston 3.

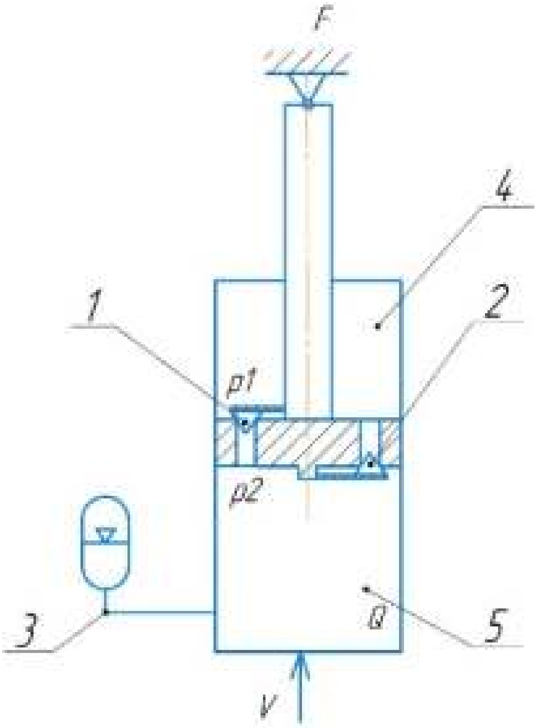

Fig. 3. Simplified schematic diagram of a hydraulic damper

Liquid dampers have a certain characteristic, the dependence of the resistance force on the speed of the piston. Particularly sensitive to the effects of temperature are dampers with linear characteristics, in which the flow of the working fluid in the control element is carried out during the laminar motion of the fluid. The resistance force for a damper with linear characteristics is determined by the following mathematical dependence [6]:

$$F = k \cdot v_p, \tag{1}$$

where v_p - piston speed, k - the damping factor.

A quantitative assessment of the effect of viscosity on the damper characteristic was carried out experimentally. A schematic diagram of an experimental bench is shown in Fig. 4. Moreover, the problem, which was the need to measure the characteristics of throttles moving together with the shock absorber piston during its operation, was solved by setting up the inverse experiment [6]. The valve-throttle assembly was fixed in the shock absorber sleeve and a differential pressure was created on it, which caused the working fluid to move through the throttles. The study was performed using «NDT (Naidite)»damper elements. Considering that the resistance of the shock absorber is determined by hydraulic chokes, the effect of temperature directly on the flow through the chokes was estimated.

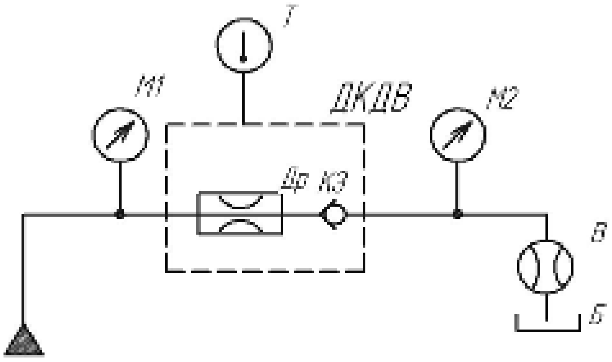

Fig. 4. The basic hydraulic diagram of the stand

The experimental procedure was as follows, set a differential pressureand measuring the flow rate and temperature of the working fluid. The differential pressure was set equal to 1 MPa. The discharge was measured in a volumetric manner.

The kinematic viscosity was calculated for the «MGP-12» shock-absorbing working fluid, for changing the temperature of the working fluid in the range of +20 ° C …+ 55 ° C, with a density of 917 kg / m3.

The results showed that with an increase in temperature from 20 to 55°C and a pressure drop of 1 MPa, the flow rate increased by 50% for the "compression" mode.

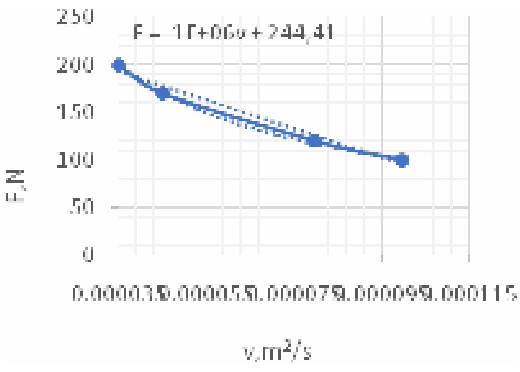

Fig. 5.Temperature characteristic of the damper (dependence of the resistance of the damper force when the kinematic viscosity of the working fluid changes in the range of 0,000035 ... 0,0001 m2/s (Δp-1MPa,Q-0,00001…0,00002 m3/s)

Analytical processing of the experimental results made it possible to determine and evaluate the effect of kinematic viscosity for fluid on the damper resistance force in the range 0.000035 ... 0.0001 m2/s (Fig. 5). At the same time, when the temperature changes from +20 °C…+ 55 °C, the damper resistance efforts changed almost 2 times, which is unacceptable and does not meet the standardization requirements. The results obtained allowed us to determine the mathematical function for determining the resistance force from the kinematic viscosity (Fig. 5).

In the general case, viscosity is non-linear in temperature and is described by the Frenkel-Andrade equation. The movement of fluid in the calibrated channels of the damper can be represented by the pulse flux density (the force of internal friction between two layers of gas (liquid), which is described by Newton's law into which we to express the Frenkel-Andrade law) [3,5]:

$$I_L = -\mu \frac{du}{dx} = -Ce^{\frac{W}{kt}} \frac{du}{dx} \tag{2}$$

where W -activation energy, kt -average energy of chaotic motion, C - coefficient depending on the intensity of oscillations, temperature, hopping, $\frac{du}{dx}$- the velocity gradient is the rate of change of velocity in the direction perpendicular to the direction of motion of the layers.

The Newtonian viscosity coefficient depends on temperature, pressure, and the type of substance:

$\mu = f(T, p, \rho)$.

Fig. 6. Visualization of hydrodynamic processes in the operating chamber of the damper

Fig. 7. The process of the origin of foaming and cavitation in the working chamber of the damper operating mode throttle: (t = 20°C)

Let us consider in more detail the characteristic features of the viscosity transfer coefficients of the liquid and analyze their dependence on various factors of foaming and cavitation.

At the next step, studies were carried out to visualize work processes in the damper chambers. To simulate work processes in a typical single-tube damper, a transparent damper (Fig. 6).

The damper allows simulating work at pressure drops of 0 ... 1 MPa and a flow rate of 0 ... 0,0002 m^3/s, a temperature of -20 ... + 80 ° C corresponding to the operating conditions of the chokes in hydraulic damper.

To be able to monitor the working processes, the damper sleeve is made of plexiglass, and the analysis of the processes was carried out using a high-speed camera using the technical visualization method. All structural elements except thebushingand the floating piston are used standard with «NDT (Naidite)» damper.

Hydrodynamic cavitation in dampers arises due to a local decrease in absolute pressure, to the pressure of saturated vapours, in one of its cavities (Fig. 7). For this damper, cavitation of two types occurs: volumetric - in the working cavity and jet - in the fluid flow. The occurrence of cavitation and foaming of the working fluid significantly affects the performance of the damper at frequencies from 0.1 ... 3 Hz and can under certain conditions be a greater degree of influence than a change in viscosity. The operation of the damper at low frequencies with a decrease in the viscosity and density of the liquid change of the working characteristic, a decrease in the resistance force.

Having analyzed the workflows in the damper, it is further was installed that the of transfer coefficients mainly have to should determine corrective action to form the damper characteristics. The coefficients form and directly influence the pressure ripples in the working cavities of the following and form the nature of the ripple and the law of oscillation damping.

As a result of in-depth analysis of work processes, it is established that the functional disadvantages of the damper include: foaming, cavitation of the working fluid, pressure pulsations, dependence of viscosity and density on temperature and inertia of the working fluid.

On the other hand, corrective actions of the working characteristic can be achieved by structuring the substance, changing the shape and concentration of molecules (particles) in a given direction, or using repulsive clathrates of heterogeneous nanoscale structures (clathrate compounds) [8], which can be the main tool in the design and the development of intelligent designs with adaptive properties.

CONCLUSION

In-Depth knowledge of the phenomenon of transfer and accounting for transient operating modes in changing operating conditions may be the main criterion in the design of dampers with a stable operating characteristic.

It was also found that in accordance with the above approach, the damping problem in a hydraulic damper with a variable viscosity transfer coefficient was considered when the temperature changed from +20 ° C… + 55 ° C, the resistance of the damper was halved. That requires the use of a compensation unit - a “compensator” and an in-depth study of rheological models and properties of working fluids on a synthetic basis.

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