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INVESTIGATION OF THERMAL INTENSITY OF HYDROPNEUMATIC SPRING OF VEHICLE

Elena Cherkashina, Michail Liashenko
Victor Shekhovtsov, Mikhail Valentsev

Volgograd State Technical University, Faculty of Auto-tractor
Lenin Avenue 28, 4000131 Volgograd, Russia
tel.:+7 8442 236948 fax: +7 8442 248116
e-mail: vilena400065@inbox.ru, ts@vstu.ru, mixasik@voidi.info

Abstract

During the moving of vehicle is a change in temperature mode, which arises due to fluid friction in the dissipative element (throttle bores) hydropneumatic spring. In this case, hydropneumatic spring can be warm to significant temperatures. Due to lower viscosity of the fluid below the warning level, the increased heat causes a sharp increase in various types of leakage, increased friction parts, and as a consequence, the intensive wear and seizure of the surfaces. This leads to partial or complete loss of efficiency hydropneumatic springs. To changes in temperature mode in the hydropneumatic spring is influenced not only the external surface of the hydropneumatic spring, temperature and speed of blowing air flow, but also the conditions and the duration of the moving of vehicle. In this paper we investigate the heat intensity of the hydropneumatic springs of vehicle in weight 5.5 tons during the moving at different speeds for different types of roads. Investigations were carried out on the basis of mathematical models realized in a package of Matlab Simulink. In this case, was fixed the time average power released in the hydropneumatic spring in the form of heat. According to the research conclusions were drawn about the most heavy-duty vehicle and the amount of heat generated by the length of relative motion in this mode. To prevent overheating, an algorithm diagnosis of the condition and management of heat intensity of the hydropneumatic springs Also made recommendations to reduce the heat intensity hydropneumatic springs.

Keywords: *vehicle, hydropneumatic spring, average capacity, temperature, thermal intensity, the area of an external surface*

The movement of the vehicle according to a sinusoidal profile with a height of bearing surface roughness close to total displacement of suspension is the heaviest in terms of heat intensity of hydropneumatic springs (springs) [1].

In this mode, due to friction in the throttle bores, liquid, and then all the details of spring as a whole are heated to a significant temperature. Due to lower viscosity of the fluid below the warning level, the increased heat causes a sharp increase in various types of leakage, increased friction parts, and as a consequence, the intensive wear and seizure of the surfaces. Such heating may result in loss of efficiency [2]. For exception of damage because of overheat it is necessary to supervise temperature of spring constantly.

We propose the following algorithm of diagnostics and management of thermal intensity in spring.

1. If the temperature in one of springs has reached the limit, while in other springs temperature differs from the limit by less than δ (in advance set size of temperature in % from critical), then, in this case take place a mode of motion with intense movements supports of a vehicle. To prevent consequences the onboard information-operating system gives out a command on transition in a mode with less damping and a decrease in vehicle speed.
2. If the temperature in one of springs has reached the limit, while in other springs temperature differs from the limit by more than δ, then, in this case is probably a mechanical damage of spring, and onboard-information system gives out a command about necessity of check of the specified spring.

3. If temperatures of springs of one board differ more than δ, then analyzed analyzes the scope moves of a spring. If the colder spring moves more than hot, the message on damage of this spring stands out.

Since all the heat generated by the fluid is dissipated through the surface of a spring to the environment, in mathematical model of vehicle traffic, system Matlab realized in package Simulink, made the assumption that heat is released uniformly in the volume of oil so that the output volume of the source is constant and equal to the average power damping forces for the given mode of movement [3, 4].

At movement of a vehicle the external surface of a spring with temperature T_1 is washed by a stream of air with temperature T_f and the coefficient of heat transfer α_f. Then the temperature T_1 can be defined, knowing a thermal stream through external surfaces of a spring [5].

$$T_1 - T_f = \frac{N_{\text{cp}}}{\alpha_f \cdot S}, \tag{1}$$

where:
T_1 – temperature of external surface of spring,
T_f – temperature of a blowing air flow,
N_{cp} – the average power released as heat,
α_f – the coefficient of heat transfer from external surface of spring to a blowing air flow [6],
S – the area of an external surface of spring.

The average power dissipated in the form of heat when throttles ion of the working fluid is determined by the formula:

$$N_{\text{cp}} = \frac{1}{T}\int_0^T \left|Q(t) \cdot \Delta p(t)\right| dt, \tag{2}$$

where:
$Q(t)$ – flow through throttle system as a function of time, m^3/s,
$\Delta p(t)$ – pressure drop across the throttle system as a function of time, Pa,
T – time interval, s.

The estimation of thermal intensity of a spring in mathematical model of vehicle traffic was conducted for the following types of roads: dynamometric road, cobble-stone road and soil road of a satisfactory condition. Thus average power released as heat in a spring was fixed on time.

Tab. 1. The average power released as heat by a spring at movement of the vehicle in weight 5,5 tones on different types of roads

Type of road	Speed [km/h]	Average power [kW]
Dynamometric road	70	0,47
	90	0,6
	110	0,73
Cobble-stone road	30	0,29
	45	0,43
	60	0,56
Soil road of a satisfactory condition	30	2,1
	40	2,7
	50	3,1

Definition of own frequency of fluctuations of a considered vehicle also was carried out using the developed mathematical model at the enclosing the vertical force in the centre of elasticity of a vehicle. The centre of elasticity was defined by selection of a point of application of force, under condition of minimization of change of a longitudinal roll of the car at action of vertical force. The magnitude of own frequency of vertical fluctuations of a frame of a vehicle was 1 Hz.

For definition of dependence between the average power released as heat and type of road, we consider the spectra of displacement of rods of springs at movement of a vehicle on different types of roads. For an example the displacement of rod of the forward left spring are considered. Character and values of displacement of rods of other springs are similar to movements of a forward left spring.

At movement of a vehicle on dynamometric road (Fig. 1) at speed of 110 km/h maximum amplitude of the displacement of rod of spring occurs at a frequency of 0,5 and 1 Hz and is 0,004 m.

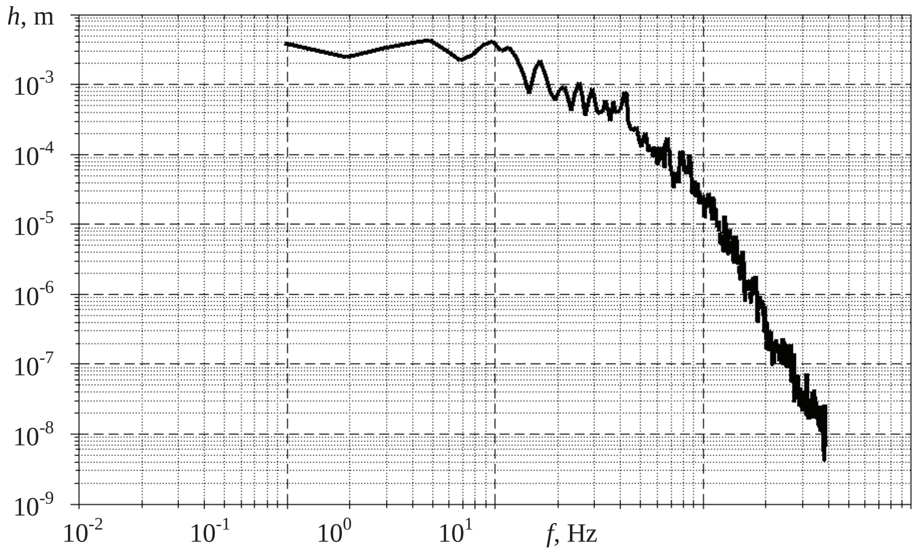

Fig. 1. Spectrum of the displacement of rod of spring at movement of a vehicle on dynamometric road at speed 110 km/h

At movement of a vehicle on cobble-stone road (Fig. 2) at speed of 60 km/h maximum amplitude of the displacement of rod of spring occurs at a frequency of about 0,8 Hz and is 0,02 m.

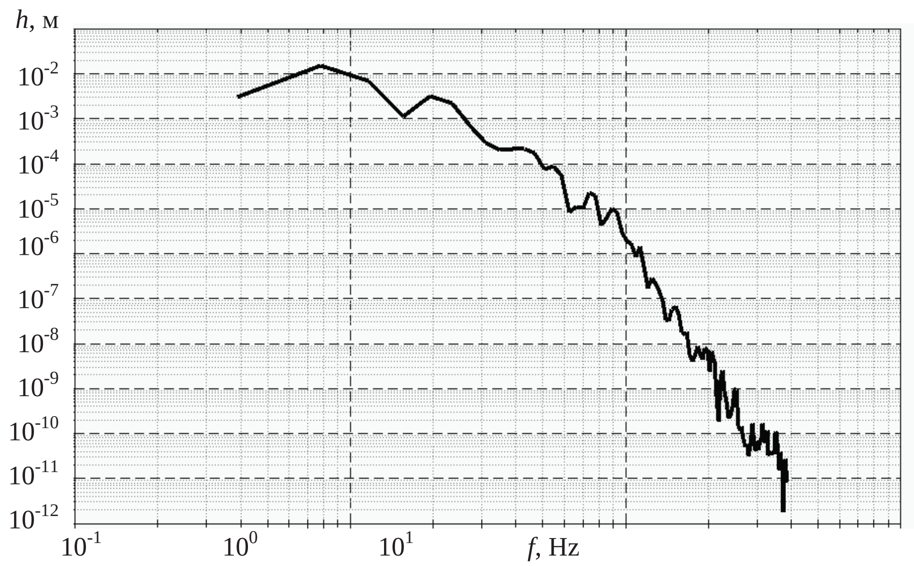

Fig. 2. Spectrum of the displacement of rod of spring at movement of a vehicle on cobble-stone road at speed 60 km/h

At movement of a vehicle on soil road (Fig. 3) at speed of 50 km/h maximum amplitude of the displacement of rod of spring occurs at a frequency of about 0,9 Hz and is 0.08 m.

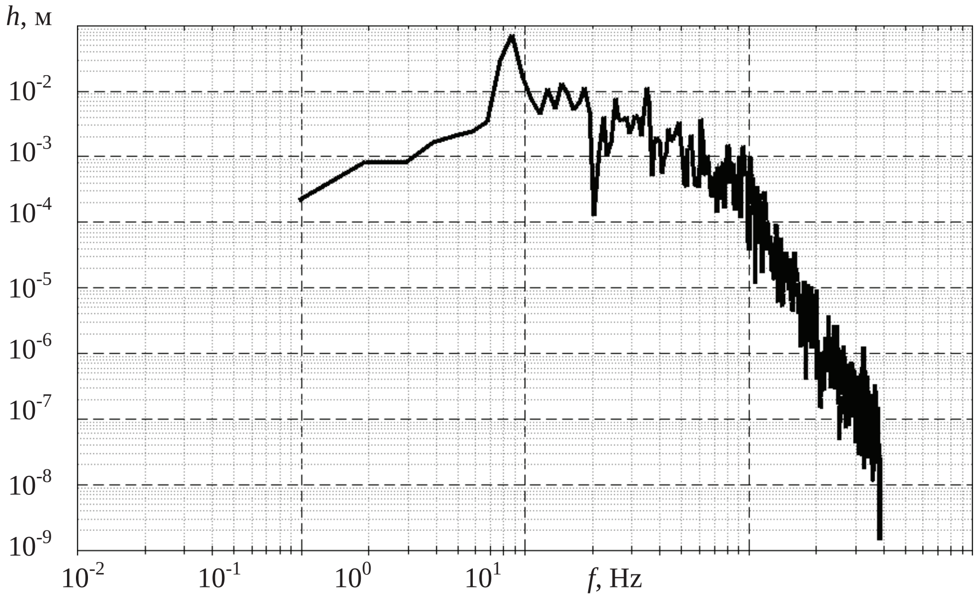

Fig. 3. Spectrum of the displacement of rod of spring at movement of a vehicle on soil road at speed 50 km/h

Conclusion

Thus, the maximum power released as heat by a spring when the displacements of rod of spring occur to the maximum amplitudes and frequency close to the own frequency of the vehicle. As seen from the graphs (Figs. 1, 2, 3), the most heavy-duty traffic, in terms of thermal intensity, is the movement of vehicle on a soil road at a speed of 110 km/h. The maximum amplitude of the displacement of rod of spring occurs at a frequency of about 0,9 Hz and is 0,08 m. In this case, the power released in spring is 3,1 kW, and the temperature difference between the external surface of spring and the surrounding flow is 177ºC. Moreover if the temperature of the blowing air flow is 40ºC, then set the temperature at the external surface of spring is 217ºC. This heat flow can not be dispelled from the external surface of spring without additional measures, and continued movement in this mode can lead to total or particular loss of efficiency of spring. Therefore, to prevent loss of efficiency of spring recommended:

– to reduce the degree of damping in a spring;
– to install an additional cooling in a spring;
– to limit the time and (or) the vehicle speed in these conditions.

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