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TEST RIG FOR EXPERIMENTAL INVESTIGATION OF THE DYNAMIC CHARACTERISTICS OF FLEXIBLE PIPELINES

This work deals with experimental verification of the dynamic characteristics of high-pressure sleeves. The paper contains design circuit of the test installation based on 3D model and description of the test procedure. Also, relationships are presented, which make it possible to calculate the value of the main dynamic indicator – the compliance coefficient.

Keywords: *dynamic characteristics, high-pressure sleeves, dynamic indicator, compliance coefficient.*

Introduction

Under current conditions, when various kinds of technological equipment are used, hydraulic drives received wide application because they have no alternatives regarding their specific power and control range. Practically all of them contain, along with metal pipelines, also flexible conduits, especially in the movable actuators. Therefore, dynamic characteristics of flexible pipelines affect dynamic behavior of the hydraulic drive as a whole. At present there is no single effective procedure for determining dynamic characteristics of flexible pipelines, primarily due to their complex structure, which is a composite consisting from a number of rubber, woven and metal layers.

For connection lines in the hydraulic drives of different-purpose machines high-pressure sleeves (HPS) are widely used [1, 2, 3]. HPS differ by their design parameters. This difference is not only in the number of metal or rubber braidings (Fig. 1) but also in the shape of their packaging, particularly that of the metal braiding. Direction of the sleeve deformation depends just on this parameter. E. g., if the packaging is made in the form of a spiral, deformation in the radial direction will be insignificant while its value will be considerable in the axial direction. If packaging is made in the form of a grid, the opposite situation will be observed. That is why sensors of two-direction displacement were used in the test rig design.

During HPS application energy accumulation process is determined by the effects of working fluid compression and deformation of the internal chambers of the sleeve lines, which are convenient to be estimated using the compliance coefficient K(p) that characterizes total change in the unit volume of the sleeve chamber and of the working fluid, which corresponds to the unit change of the volume.

In order to study dynamics of hydraulic mechanisms with HPS lines, it is necessary to know the dynamic compliance coefficient KD(p), the value of which could be determined experimentally.

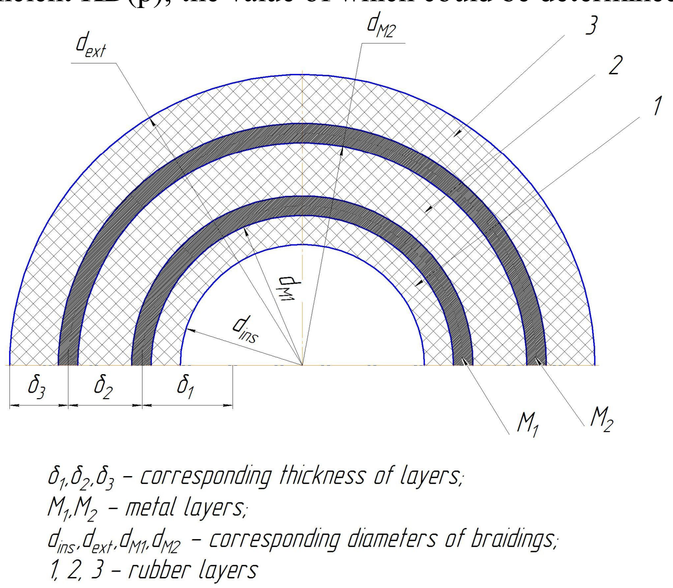

Fig. 1. Physical model of the high-pressure sleeve with two metal braidings

3D model of the experimental installation is presented in fig. 2. Flexible sleeve 1 to be investigated is mounted into a special housing 2 by means of a threaded connection.

In the housing plunger pair 3 is located. Its plunger is kinematically connected with excentric 4 that is rotated by axial-piston hydraulic motor 5 [4].

The hydraulic motor is mounted to plate 6 by means of a screw joint. Plate 6, in its turn, is connected with angle piece 7. Rotation speed of the hydraulic motor shaft together with the excentric mechanism is regulated by the flow rate of the variable pump НП-34 [5]. Test specimen of HPS is supported by columns 8 that, together with the angle piece, are based on the table with T-slots 9.

Housing 2 has a special channel that is connected with hydraulic lines of the pump station. Through this channel HPS chamber is filled with the working fluid after air plug is removed from the pipeline by means of a special cock 10.

In dynamics pressure in HPS is measured by means of a special pressure sensor 11.

External diameter of HPS (displacement in radial direction) is measured by a tensoresistive sensor 12 mounted on the traverse 13 while displacement of the plunger and HPS in axial direction is measured by inductive displacement sensors 14 that are mounted on special columns 15.

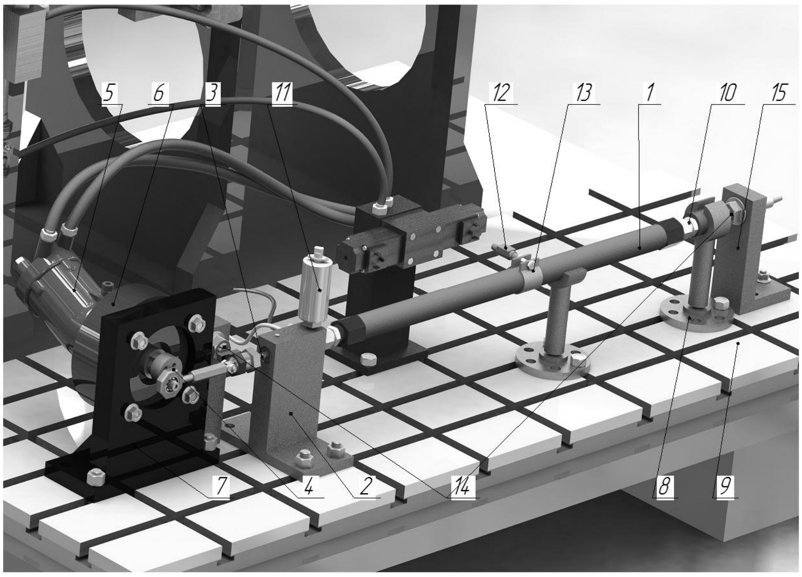

Fig. 2. 3D model of the test rig for experimental investigation of HPS dynamic characteristics

For determining frequency characteristics, static and dynamic compliance coefficient of HPS with working fluid the following procedure is used [6, 7, 8, 9]:

1. The fluid is supplied to the hydraulic motor 5 (mineral oil АМГ – 10 [10] is used as a working fluid), rotation speed of the hydraulic motor shaft is regulated by the flow rate of variable pump НП-34 in the range of 5-6000 rpm; the oscillation amplitude of pressure and HPS external diameter are determined.

2. HPS static compliance coefficient is found by the formula

$$K(p) \approx \frac{\Delta W}{W_0 \Delta p},$$

where ΔW is HPS volume change, calculated according to the plunger displacement; W_0 – initial volume known from HPS design parameters; Δp – pressure change in the external chamber of the sleeve (determined by means of the pressure sensor).

3. While changing fluid supply to the hydraulic motor 5, the amplitude of pressure and HPS external diameter oscillations are sequentially measured with different plunger oscillation frequency values and corresponding pressure oscillations in HPS. To compensate the possible change in the

pressure oscillation amplitude with the change of input signal frequency f, the possibility to regulate the excentricity of cam 9 is provided.

The amplitude-frequency characteristics of HPS is determined by the formula

$$A_{\Delta L}(f) = \frac{A_{\Delta p}(f) A_{\Delta d_{ext}}(f) K_{Д}(p)(f)}{2}, \tag{1}$$

where $A_{\Delta L}(f)$, $A_{\Delta p}(f)$, $A_{\Delta d}(f)$ – the amplitudes of oscillations of the external diameter, pressure in HPS and plunger displacement with the input signal frequency f; *K (p)(f)* – HPS dynamic compliance coefficient.

If f→0, then

$$A_{\Delta L_c} = \frac{A_{\Delta p_c} A_{\Delta d_{ext}} K(p)}{2}, \tag{2}$$

where $A\Delta Lc$, $A\Delta pc$, $A\Delta d_{ext}$ – the amplitude of oscillations of the external diameter, the pressure in HPS and displacement of the plunger in statics.

Taking into account relationships AΔp(f)=AΔpc (kept by changing the excentricity) and dividing (1) by (2), we obtain

$$\frac{A_{\Delta L}(f)}{A_{\Delta L_c}} = \frac{A_{\Delta d_{ext}}(f) K_{Д}(p)(f)}{A_{\Delta d_{ext}}(f) K(p)}. \tag{3}$$

Expression (3) makes it possible to determine the value of dynamic compliance coefficient in the process of dynamic loading provided that sensor readings and the values of static compliance coefficient are known.

AFC of HPS is presented in Fig. 3.

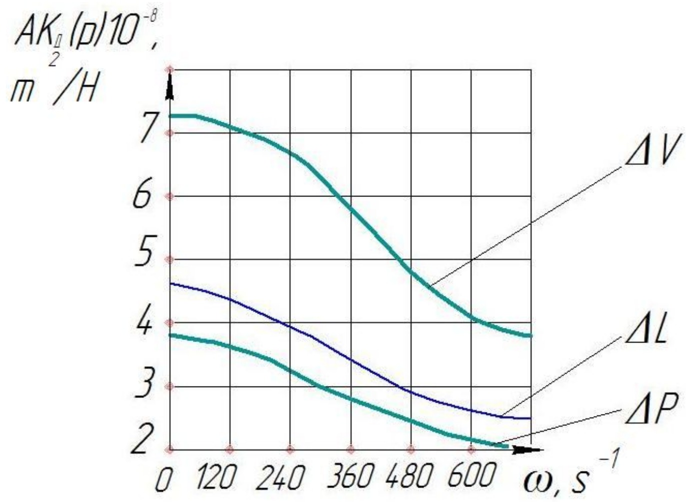

Fig. 3. Amplitude-frequency characteristic of HPS

An example of transient processes in HPS chamber is presented in fig. 4, 5.

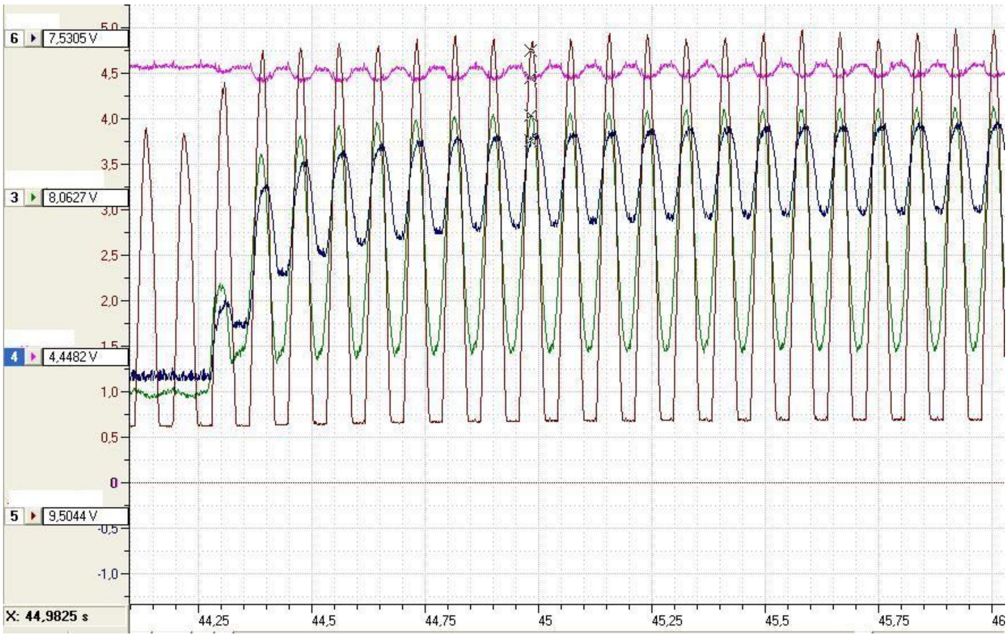

Fig. 4. Transient process in HPS chamber (input signal frequency is 8 Hz)

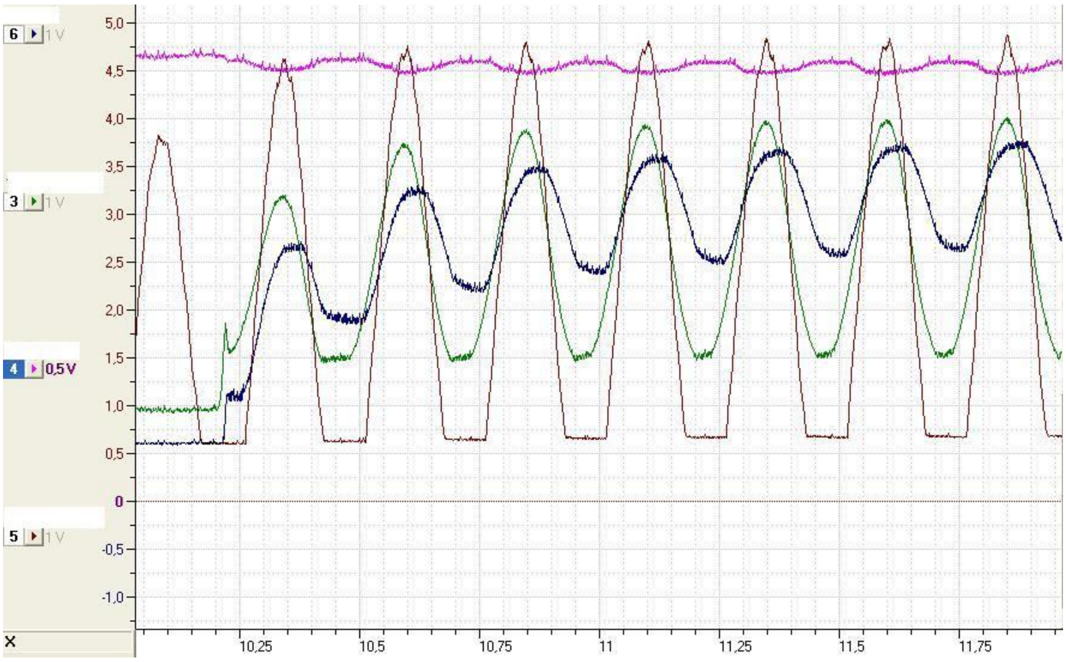

Fig. 5. Transient process in HPS chamber (input signal frequency is 2 Hz)

Conclusions

As a result of the conducted experiment amplitude-frequency and transient characteristics of HPS, presented in the paper, were qualitatively determined.

The presented relationships make it possible to obtain the required dynamic characteristics of HPS, which enables the obtained data application while designing hydraulic drives of different-purpose machines.

The proposed experimental investigation procedure based on the created 3D model makes it possible to determine the value of static compliance coefficient $K(p)$ of HPS, the dynamic compliance coefficient $K_D(p)(f)$ and to find the dependence of this coefficient variations on the input signal frequency.

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