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INTERRELATIONSHIP BETWEEN THE CLEARANCE IN THE "BUSHING-PLUNGER BLOCK" COMBINATION AND WORKING FLUID LEAKS

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Problem Statement. The work is part of a series of articles devoted to increasing the durability of plunger pairs of axial piston pumps. Studies conducted earlier have shown that the parameters of the technical condition that cause volume losses and affect the operability of the hydraulic drive of the transmission drive include wear of the connection "block sleeve - plunger". In this case, we will be interested in the volume of working fluid leaks caused by wear of the connection parts.

*Primary Research Materials***.** The issue of the relationship between the gap in the plunger and piston pairs and the leakage of the working fluid has been considered in sufficient depth in a number of works [1, 2].

Therefore, to consider our relationship, we will use the already known dependencies, while it is necessary to take into account that the wear of the sleeve and the plunger occurs unevenly [6 – 8]. The unevenness of wear is explained by the presence of a tipping moment at the heel of the plunger, which causes its skew in the sleeve [9].

Obviously, in this regard, the value of the leakage of the working fluid must be determined taking into account the real position of the plunger in the sleeve (Fig. 1) [2]:

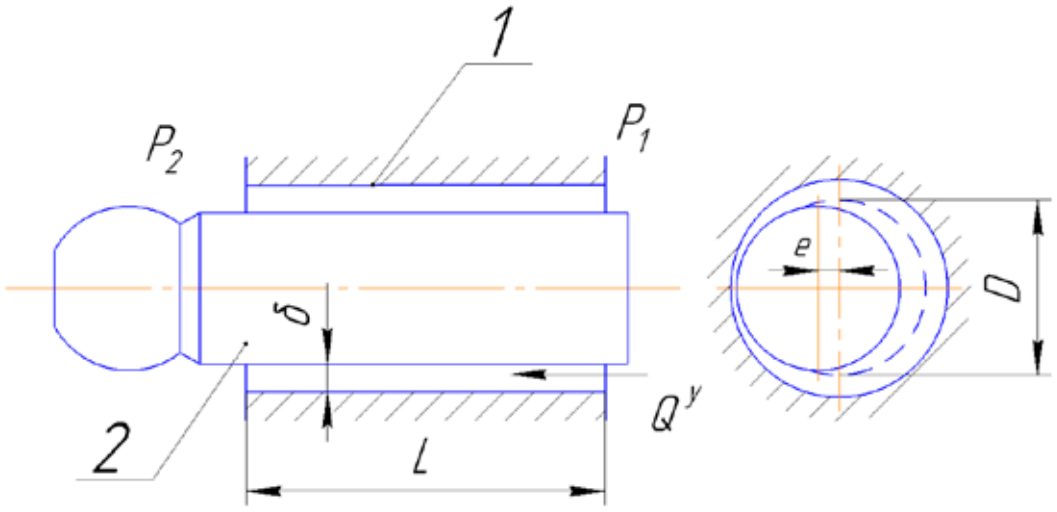

Fig. 1. Diagram illustrating an eccentric gap that occurs due to the skew of the plunger (2) in the sleeve (1).

$$Q^y = Q_к^y \left(1 + \frac{3}{2} e^2\right), \quad (1)$$

where $Q_к^y$ – losses of working fluid through the radial clearance with a concentric arrangement of the plunger, which are determined by the expression:

$$Q_к^y = \frac{p \times D \times \Delta R \times d^3}{12 \times l \times \eta \times r}. \quad (2)$$

where D – average gap diameter;

ΔR – pressure drop of the working fluid at the design site;

d – nominal clearance in the coupling;

l – length of the section where the working fluid flow rate is determined;

e – relative eccentricity, which is equal to:

$$e = \frac{e}{d}, \quad (3)$$

where e – the displacement of the plunger axis relative to the sleeve axis.

Taking into account the above, at maximum eccentricity, the leakage value is determined by the following expression:

$$Q^y = 2,5 \times Q_k^y, \quad (4)$$

Substituting into the expression (4) value $Q_к^y$ from (2) we obtain an expression for determining the leakage of the working fluid in the connection “block sleeve – plunger”:

$$Q^y = \frac{2,5p \times D \times \Delta P \times d^3}{12 \times l \times \eta \times r}, \quad (5)$$

In expression (5), the working fluid leakage is determined for one coupling. When the pumping unit of an axial piston hydraulic pump contains nine plungers, with five plungers operating in the high-pressure line $\Delta P_1 = 21,0$ MPa, and four in the low pressure line $\Delta P_2 = 1,45$ MPa. Thus, the total leakage of the working fluid will be determined by the gap in the friction pair "block sleeve - plunger", as well as the number of these pairs. Then the total leakage of the working fluid in the combination "block sleeve - plunger" can be determined from the expression:

$$Q^y = \frac{2,5p \times D \times \Delta P \times d^3}{12 \times l \times \eta \times r} \times (\Delta P_1 \times z_1 + \Delta P_2 \times z_2), \quad (6)$$

where ΔP_1 – working fluid pressure in the high-pressure line;

ΔP_2 – working fluid pressure in the low pressure line;

z_1, z_2 – respectively, the number of plungers in the high and low pressure lines.

The calculation of the working fluid consumption depending on the gap in the "block sleeve-plunger" coupling was carried out using the following data: coupling diameter $D = 0,02$ m; gap in the coupling $\delta = 0¼60 \times 10^{-6}$ m; length of the section where the working fluid flow rate is determined $l = 4 \times 10^{-2}$ m; pressure drop of the working fluid between the high-pressure line and the low-pressure line $\Delta P_1 = 3,5;\ 15,0;\ 21,0 \times 10^{-7}$ H/m; pressure drop of the working fluid between the low pressure line and the drainage line $\Delta P_2 = 0,14 \times 10^{-7}$ H/m; number of plungers in the high-pressure line $z_1 = 5$, number of plungers in the low pressure line $z_2 = 4$; working fluid density $\rho = 900$ kg/m^3; coefficient of kinematic viscosity $\nu = 12 \times 10^{-6}$ m^2/s.

The calculation results are summarized in a table. 1.

Table 1 – Values of estimated total working fluid consumption due to the gap in the "block sleeve-plunger" coupling

Gap value δ, microns	Working fluid consumption Q^y, cm^3/s for the following values $\Delta P_1, \Delta P_2$		
	ΔP_1=3,5 MPa ΔP_2=1,4 MPa	ΔP_1=15,0 MPa ΔP_2=1,40 MPa	ΔP_1=21,0 MPa ΔP_2=1,40 MPa
10	0,59	2,47	3,45
20	4,72	19,80	27,60
30	15,93	66,70	93,20
40	37,80	158,10	221,00
50	73,80	308,00	431,20
60	127,40	533,50	745,20

Analysis of the obtained results shows that at the values of the gap in the friction pair "block sleeve - plunger", equal to 40 microns, working fluid leaks are approaching limit values (225 cm^3/s) and constitute 221 cm^3/s. However, to obtain an accurate estimate of the limit value of the gap, as well as to determine the proportion of working fluid leaks caused by wear of the parts of the "block sleeve – plunger" coupling, it is necessary to conduct an experimental study of the relationship between the gap and working fluid leaks, as well as to determine the dynamics of the gap.

Conclusions. Theoretical studies of the relationship between the gap of the "block sleeve – plunger" coupling and working fluid leaks allow us to draw the following conclusions:

1. The average value of the gap should be considered as a structural parameter of the technical condition of the "block sleeve – plunger" coupling parts (δ) since the plunger is located in the sleeve with a skew and causes uneven wear of the sleeve.

2. To obtain an accurate estimate of the limit value of the gap and the proportion of working fluid leaks caused by wear of the mating parts of the "block sleeve - plunger", it is necessary to conduct an experimental study of the relationship between the gap and working fluid leaks, as well as to determine the dynamics of the gap.

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