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Calculation of Geometrical Parameters of Geokhod Transmission With Hydraulic Cylinders

M Yu Blaschuk, A A Dronov, S S Ganovichev

Yurga Institute of Technology, TPU Affiliate, 26, Leningradskaya Str., 652050, Yurga, Russia

E-mail: mby.tpu@gmail.com

Abstract. Developed analytical expressions for determining parameters of transmission hydraulic cylinders' arrangement are considered, as well as the conditions for internal arrangement of a required number of hydraulic cylinders.

Introduction

Currently, creation of geokhods' prototypes has been actively conducted. The geokhod is a new kind of mining heading machines embodying innovative technical solutions and working modes [1,2]. A transmission (power drive) with hydraulic drive on the basis of hydraulic cylinders, placed chordwise inside the sections, is the most promising design for the geokhods'. In order to ensure the requirements for a new generation of geokhods' power drives [3], design solutions should be made on the basis of layout diagrams, representing hydraulic cylinders' operation in different phases [4,5].

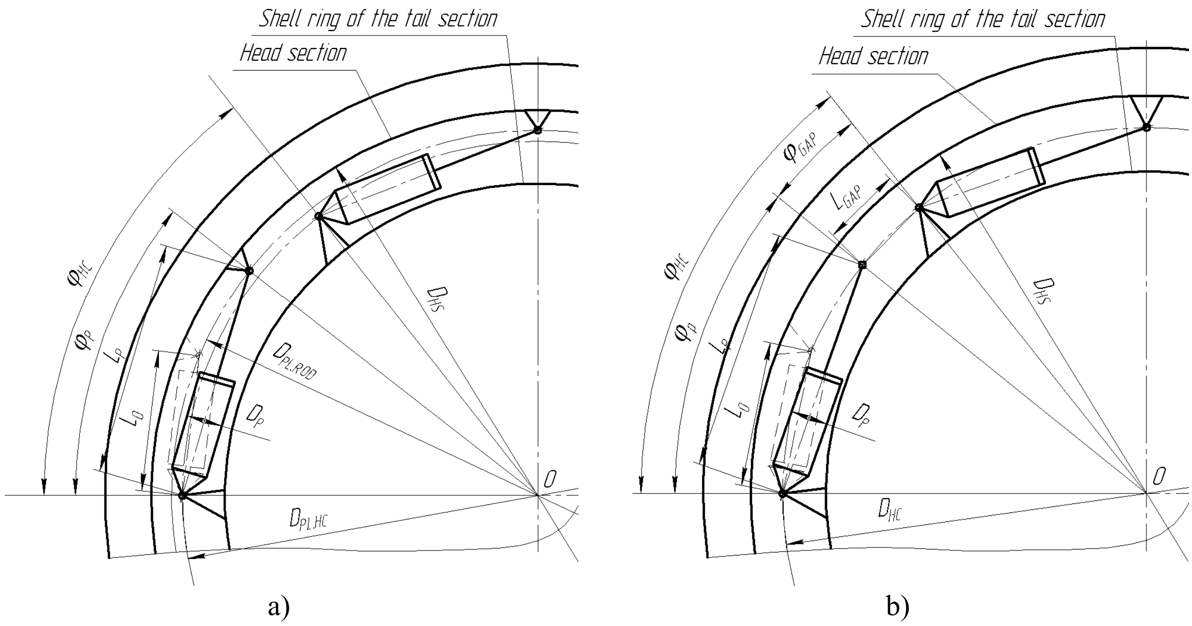

Figure 1. Schemes of hydraulic cylinders characterization

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Results and Discussion

The hydraulic cylinders are arranged in the space between two cylindrical shells (Figure 1). Hydraulic cylinder' body supports are fixed on the outer surface of the tail section shell, and rod supporting members periodically engage into mesh with the ratchet rack on the inner surface of the head section. While rod cylinders are advancing, sliding members engage the ratchet rack and drive it into revolving. Body and rod's spatial position changes while advance and return motions of the hydraulic cylinder rod; at that, head and tail shell should not impede changes in spatial positions of hydraulic cylinders' elements. Power drive layout schemes have shown that the most rational parameters of hydraulic cylinders arranged between the shells are obtained with the following proportions

$$D_{PL.HC} = D_{HS} - (3...4)D_P, \tag{1}$$

$$D_{PL.ROD} = D_{HS} - (2...3)D_P. \tag{2}$$

When arranging hydraulic cylinder supports at one circumference (Figure 1b), that is when $D_{PL.ROD} = D_{PL.HC} = D_{HC}$ it can be taken:

$$D_{HC} = D_{HS} - (3...4)D_P, \tag{3}$$

Most commercially available cylinders [6,7] has the following ratio of a piston stroke length L_x to a size along axes of mounting brackets L_0

$$L_X = (0.3 \div 0.8)L_0, \tag{4}$$

The maximum distance between the hydraulic cylinder supports L_p can be represented as the sum of

$$L_p = L_0 + L_X, \tag{5}$$

Stroke length value L_X can be obtained from the formulas (4) and (5)

$$L_X = \frac{L_p}{1 + \frac{1}{(0.3 \div 0.8)}}, \tag{6}$$

Approximate value of the maximum possible distance L_p between the hydraulic cylinder supports can be obtained from the scheme, taking into account the total number of cylinders – n_{HC} [8] (Figure 1b). To simplify the calculation, we assume that the hydraulic cylinder support will be arranged on one circumference [9], that is $D_{PL.ROD} = D_{PL.HC} = D_{HC}$. The angle φ_{HC} between bodies (rods) supports of adjacent cylinders will be determined by the number of cylinders n_{HC}

$$\varphi_{HC} = \frac{360^\circ}{n_{HC}}, \text{ degrees} \tag{7}$$

Cylinder with maximally advanced rod will cut the chord of L_p length on the circumference D_{HC} based upon the central angle φ_P.

Between these geometric parameters there is a relationship, described by the expression:

$$L_P = D_{HC} \cdot \sin\frac{\varphi_P}{2}, \tag{8}$$

The central angle φ_P will be taken for reasons of leaving a required angular gap φ_{3A3} between rod supports and bodies of adjacent cylinders. The angle φ_{GAP} will be based on a chord L_{GAP} on the circumference D_{HC}. For this scheme (Figure 1b) a gap magnitude can be set equal to the diameter of the piston D_P, that is $L_{GAP} = D_P$, while, similar to the expression (8), it can be written:

$$L_{GAP} = D_P = D_{HC} \cdot \sin\frac{\varphi_{GAP}}{2}, \tag{9}$$

Let us express φ_{GAP} from (9)

$$\frac{D_P}{D_{HC}} = \sin\frac{\varphi_{GAP}}{2}\text{, from which}\quad \arcsin\frac{D_P}{D_{HC}} = \arcsin(\sin\frac{\varphi_{GAP}}{2});$$

$$\varphi_{GAP} = 2\cdot\arcsin\frac{D_P}{D_{HC}}\text{, degrees} \tag{10}$$

The central angle φ_P will be equal to

$$\varphi_P = \varphi_{HC} - \varphi_{GAP}\text{, degrees} \tag{11}$$

Substituting in (11) the expressions (7) and (10) we find

$$\varphi_P = \frac{360^\circ}{n_{HC}} - 2\cdot\arcsin\frac{D_P}{D_{HC}}\text{, degrees} \tag{12}$$

Now, substituting the expression (12) in (8) we find the expression for L_p

$$L_P = D_{HC}\cdot\sin\left[0{,}5\left(\frac{360^\circ}{n_{HC}} - 2\cdot\arcsin\frac{D_P}{D_{HC}}\right)\right] = D_{HC}\cdot\sin\left(\frac{180^\circ}{n_{HC}} - \arcsin\frac{D_P}{D_{HC}}\right), \tag{13}$$

In view of the expression (3), the expression (13) takes the form

$$L_P = \left[D_{HC} - (3...4)D_P\right]\cdot\sin\left(\frac{180^\circ}{n_{HC}} - \arcsin\frac{D_P}{\left(D_{HC} - (3...4)D_P\right)}\right), \tag{14}$$

Another distance limitation L_p can be longitudinal stability of compressible rod. Maximum distance between the supports can be determined by the formula

$$L_{P\max} = \frac{356.8\cdot d_{ROD}^2}{D_P\cdot k_H\sqrt{p\cdot[n]}}, \tag{15}$$

where d_{ROD} – is cylinder rod diameter, m;

k_H – fixing coefficient for hinge mounts on both ends of the cylinder k_H =1;

[n] – safety margin (usually [n] = 3.5…4);

p – working pressure in the hydraulic cylinder, Pa.

The rod diameter is usually taken to be based on the ratio [10]

$$d_{ROD} = (0.3\div 0.7)\cdot D_P, \tag{16}$$

For a compressive load it is recommended to take larger values of the expression (15).

While the hydraulic cylinders operate in different stroke phases, it is necessary to ensure the reverse of the piston of one cylinder or group of cylinders while advancing of other pistons at a distance of amount of difference between adjacent phases' strokes. This occurs when the reverse speed υ_{REV} is above the stroke rate $\upsilon_{P.X}$ by n_{PH}, that is

$$\upsilon_{REV} \geq n_{REV}\cdot\upsilon_{P.X}, \tag{17}$$

Based on this condition, rod diameter d_{ROD} at a constant working fluid's flow rate Q_{Pi} will be determined by the formula

$$d_{ROD} = D_P\sqrt{1-\frac{1}{n_{PH}}}, \tag{18}$$

Substituting (18) into (15) we obtain

$$L_{P\max} = \frac{356.8\cdot\left(D_P\sqrt{1-\frac{1}{n_{PH}}}\right)^2}{D_P\cdot k_H\sqrt{p\cdot[n]}} = \frac{356.8\cdot D_P\cdot\left(1-\frac{1}{n_{PH}}\right)}{k_H\sqrt{p\cdot[n]}}, \tag{19}$$

When the number of reversing cylinders is n_{REV} = 1, number of intermediate positions (phases) will be

$$n_{PH} = n_{HC}, \tag{20}$$

Then the expression (19) takes the form:

$$L_{P\max} = \frac{356.8 \cdot D_P \cdot \left(1 - \frac{1}{n_{HC}}\right)}{k_H \sqrt{p \cdot [n]}}, \tag{21}$$

Figure 2 shows diagrams the maximum possible (safe) distances between hydraulic cylinder supports – L_p against the number of cylinders n_{HC} and the piston diameter D_P, plotted for a section with diameter D_{HC} = 3.7 m by design arrangement condition (Fig. 2) and stability condition (Fig. 3).

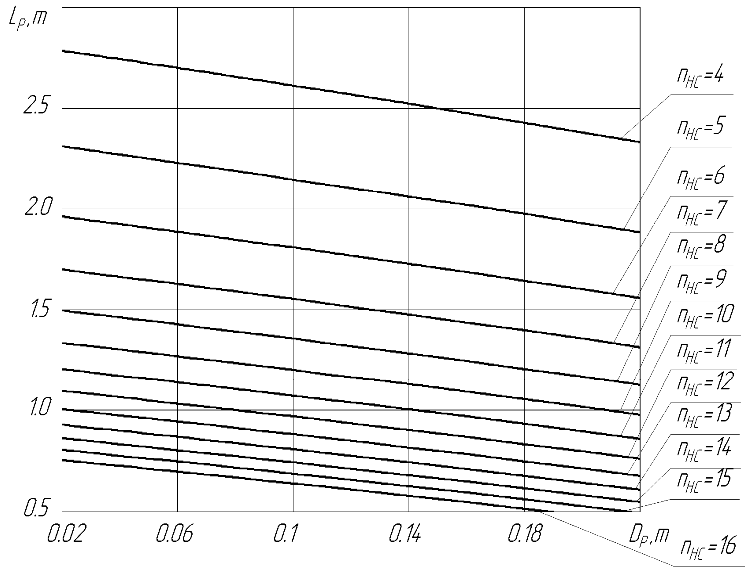

Figure 2. Dependence of the safe distance by stability condition

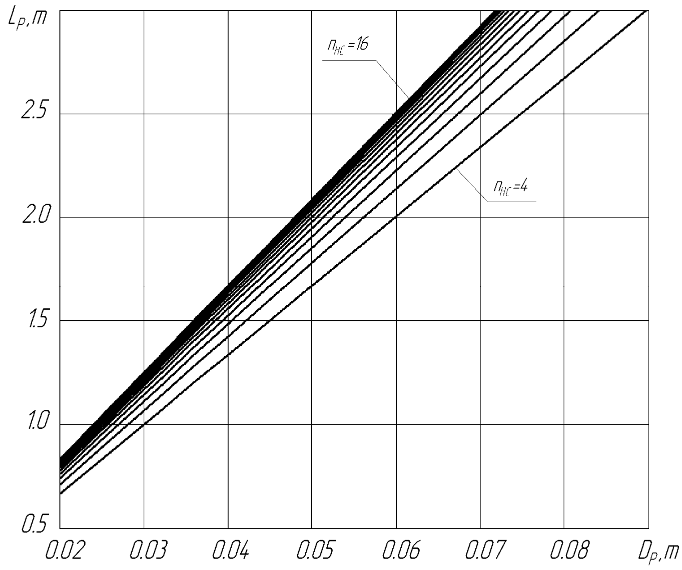

Figure 3. Dependence of the safe distance by design condition

Figure 4 shows a diagram plotted on both conditions for various numbers of cylinders.

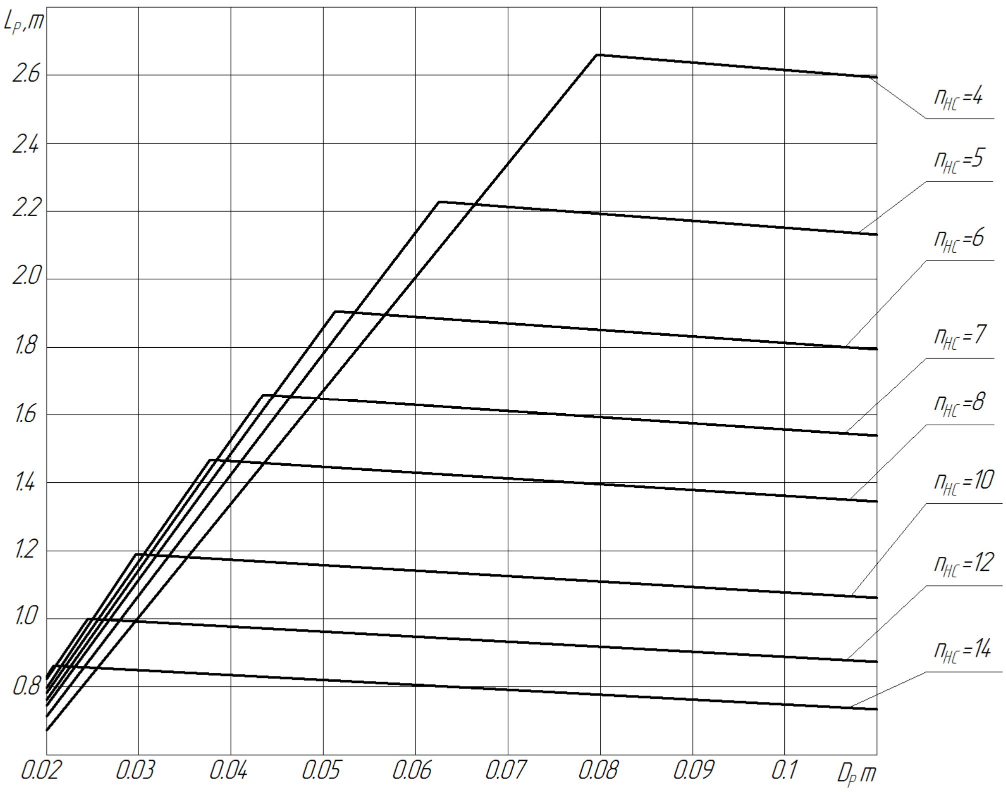

Figure 4. Dependence of safe distance by design arrangement condition and stability condition

Conclusion
Diagrams of dependences of the safe inscribable distance between the hydraulic cylinder supports by stability condition show that for small piston diameter safe distances between the hydraulic cylinder supports by stability condition are significantly less than the maximum safe distance by design arrangement condition; thus, as a number of cylinders increases, the stability condition is predominant.

In addition to the length limitations by design conditions and stability condition, the required inside structure gage may also limit geokhod size. For the purpose of increasing its size, it is necessary to diminish the distance between supports and, correspondingly, the stroke length.

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