Factors Determining the Size of Sealing Clearance in Hydraulic Legs of Powered Supports

Gennady Buyalich[1*], *Konstantin* Buyalich[1], *Maxim* Byakov[1]

[1]T.F. Gorbachev Kuzbass State Technical University, 650000, 28 Vesennyaya St., Kemerovo, Russia

Abstract. The factors that directly influence the formation of a sealing clearance between the piston and the working cylinder in hydraulic legs of powered supports are considered in this article, the size thereof has a direct effect on the tightness of the legs and, as a result, on the safety of work at the production face. A detailed description of these factors is given, which is supported by the dependencies obtained from the results of finite element modeling of various types of legs under various strength and geometric parameters, external load types and locations in the support section. The problems of formation of radial deformations of a working cylinder loaded with working fluid pressure are considered, and their dependence on the level of this pressure and extension. Based on the simulation results, the mechanisms for the formation of additional clearances due to rod and cylinder misalignments are described, and the conditions and causes of the resonant phenomena development are given. The classification of these factors according to the degree of generalization and the functional interaction between each other is proposed.

1 Introduction

The main trend in underground coal mining in recent decades is reduction of the total number of integrated mechanized faces with a simultaneous sharp increase in their efficiency. At the same time, this situation is accompanied by deterioration of the geological and mining conditions for functioning of such sets of equipment. Thus, in July 2017 the mine named after V. D. Yalevsky of the coal mining company SUEK-Kuzbass mined 1.5 million tons from one face setting a record of monthly production. It all poses higher requirements to the reliability of operation of integrated mechanized faces.

The main elements of the powered support, directly taking up rock pressure and ensuring reliable and safe working conditions for labour and mechanisms at the production face, are hydraulic legs, their functioning determines the operation of the set of mining equipment as a whole [1-5].

2 Materials and methods

* Corresponding author: gdb@kuzstu.ru

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Radial deformations of the wall (dR) of the working cylinder are determined by the design and geometric dimensions of the hydraulic legs, the main of which are wall thickness, length, and extension [6-7].

As shown by numerous studies carried out by the authors using finite element methods on hydraulic legs of various designs [8,9] installed in powered supports of different manufacturers, the shape of a typical curve of radial deformations of the working cylinder wall is shown in Fig. 1. This curve has 5 characteristic key points. Points 1 and 5 (p.1 and p.5 in Figure 1) are located in the places of the largest deformations of the cylinder, from the piston and the bottom sides of the cylinder, respectively.

Key point 2 (p.2) corresponds to the deformations in the main part of the cylinder which are slightly smaller than deformations in pp. 1 and 5.

Point 4 (p. 4) is located at the position of the first seal on the side of the piston cavity of the hydraulic leg. Radial deformations at this point directly form a clearance to be sealed in order to prevent the flow of working fluid from the high pressure zone into the rod cavity, i.e. directly affect the tightness of the leg.

Key point 3 (p.3) is located on the deformation curve having the minimum value with a (-) sign. If this point is located within the limits of the piston, the excess of deformations in it (dR3) of the total tolerance zone for the manufacture of the piston and cylinder will lead to damage to the working cylinder mirror in the form of longitudinal scratches through which leakages of the hydraulic fluid will occur. This will make it impossible for the leg to perform its main functions in supporting the roof and controlling the rock pressure.

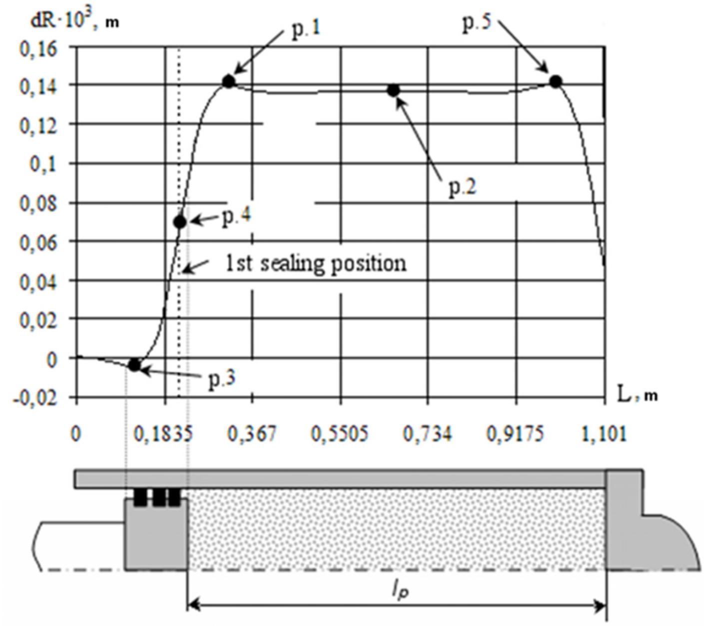

Fig. 1. Example of radial deformations (dR) of the working cylinder of M130 support hydraulic leg along the length of the working cylinder (L) at its full extension (*lp)*, working liquid pressure 50 MPa, and location of key points (p.1-p.5)

The value of radial deformations of the working cylinder in the area of the sealing gap (dR_4) is also determined by the pressure of the working fluid in the piston cavity of the hydraulic leg and its expansion. These dependences are linear in nature and they are shown for hydraulic legs of different types of powered supports in Fig. 2 and Fig.3.

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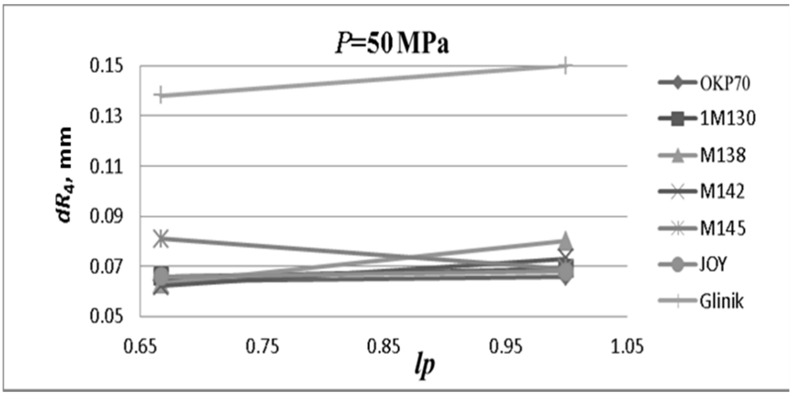

Fig. 2. Dependences of radial deformations of the working cylinder in the area of sealing (dR_4) on pressure of the working liquid in the piston cavity of the leg (P) at its full extension (*lp)*

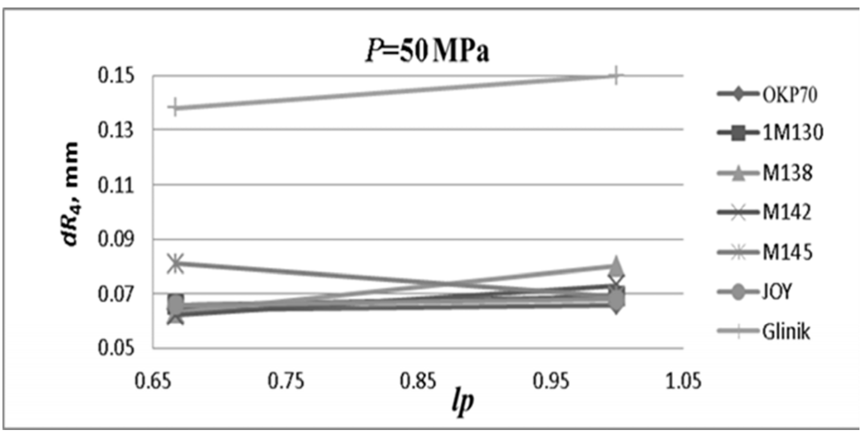

Fig. 3. Dependences of radial deformations of the working cylinder in the area of sealing (dR_4) on extension of the hydraulic leg (*lp)*

In order to increase the passages for the movement of miners, hydraulic legs are installed at angle α to the support elements of the support section (Fig. 4). In this case, the load on the rod and the bottom of the cylinder is applied eccentrically, that is, the direction of the forces from these loads do not coincide with the longitudinal axis of the leg. In this case, additional forces Fa and Fb arise in the leg, under the action of which the axis of the rod deviates from the axis of the cylinder by angle γ, the value of which is determined by the angle of inclination of the hydraulic leg to the support surfaces in the support section, by the leg extension, and also by the clearances in the joints between the rod and the sleeve, and clearances in the joints between the piston and the working cylinder.

The location of the hydraulic leg in the section of the powered support, the scheme of forces application, and the formation of the clearance are shown in Fig. 4.

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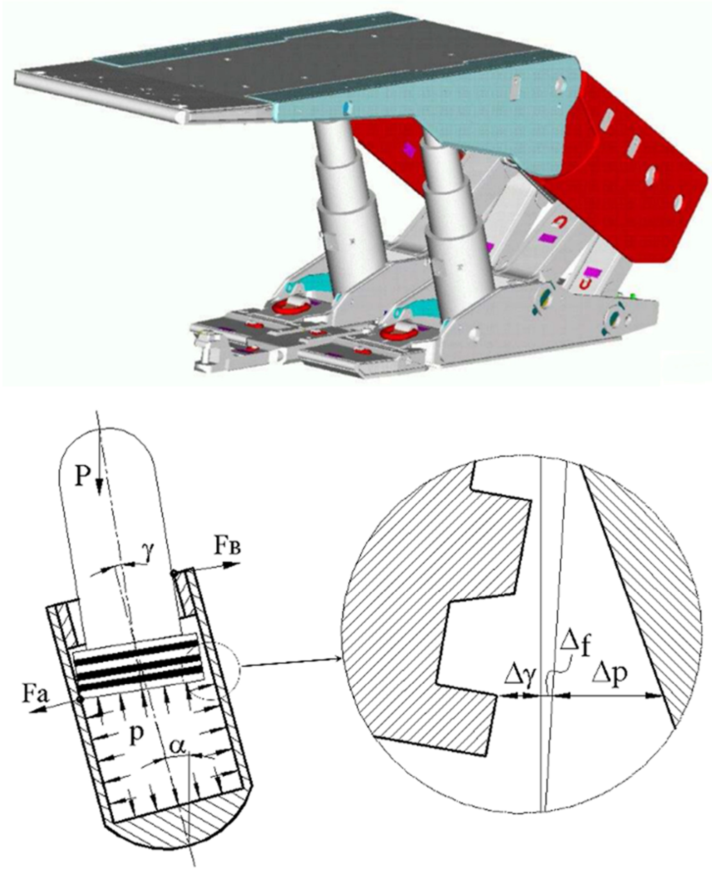

Fig. 4. Location of the hydraulic leg in the section of DBT powered support крепи DBT and the scheme of a sealing clearance formation when rod misalignment occurs

Due to its kinematic connections, the angle of installation of the hydraulic leg in the support section (α) also depends on the extracting seam thickness, i.e. in fact, on the leg extension.

To study the effect of the parameters of this phenomenon, a special finite element model was developed that takes into account the geometric dimensions of the cylinder, piston, rod, bush, leg extension, the direction of the external load from the rod and cylinder supports, the pressure of the working fluid in the piston cavity, the clearances between the piston and the cylinder, as well as between the rod and the bushing, determined by their tolerance zones, and the properties of the cylinder material.

The solution was carried out in two stages. First, the deformations of the cylinder from the action of the working fluid pressure (Δp) were identified, the identified values were used to define forces Fa and Fb (see Figure 4), arising in the joints due to the misalignment of the rod and the cylinder. After this, the final calculation is performed and the total deformations from all loads (Δp+Δf) are determined.

The total largest clearance to be sealed is

$\Delta = \Delta\gamma + \Delta p + \Delta f$,

where Δγ – the clearance determined by the dimension tolerance zones and mutual location of the piston in relation to the cylinder;

Δp – radial deformations caused by working fluid pressure;

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Δf – radial deformations caused by the additional forces Fa and Fb resulting from misalignment of the rod in relation to the cylinder.

Fig. 5 shows the results of the calculations made using the model described above applied to displacement (dR) of the internal walls of the working cylinder (1 and 3) of the hydraulic leg (M130 powered support) along its length (L) at the nominal operating resistance, zero installation angle, maximum extension and sealing of the cylinder support. The symmetry axis displacement is shown as a dotted line (2).

Analysis of calculation results showed that the initial maximum possible clearance in the compaction area determined by the tolerance zones of the cylinder and piston (280 μm) increased under load up to 490 μm (on the right side in Figure 4), which could result in its insufficient overlapping by the piston seals.

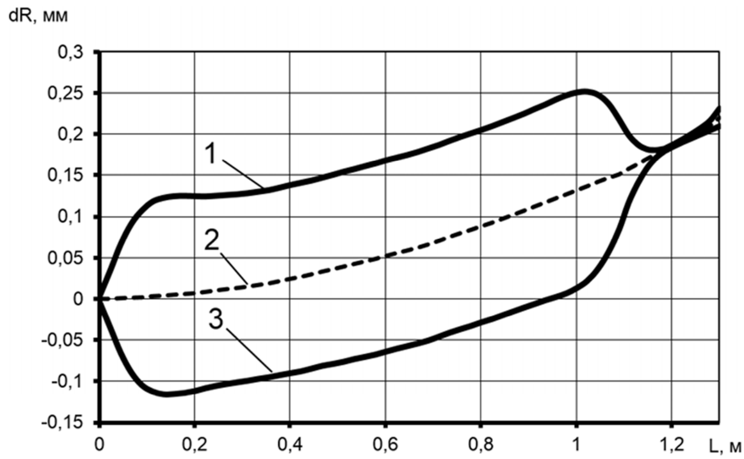

Fig. 5. Displacements of M130 leg cylinder walls dR under load taking into account rod misalignment

For double- and triple-acting legs, this effect is enhanced, because the total misalignment value is determined by the total clearances at all stages of the hydraulic leg in the joints between pistons and working cylinders and joints between bushings and rods.

When the external loads, which are dynamic or periodic in nature, influence the powered support, the frequency of these influences can coincide with the natural oscillation frequency of both the hydraulic leg and the system as a whole "support section - roof - coal seam" [10-15]. In this case, a phenomenon of resonance may occur, in which the radial deformations are further increased reducing the tightness of the legs.

Such loads are possible during secondary settling of the main roof when periodic fluctuations of fragile rock blocks occur. In addition, the frequency component of the load on the support can be transferred from the closely located rotating cutting body of the shearer crushing the coal mass of the seam.

As shown by theoretical studies, the frequencies of natural oscillations of the “powered support-roof-seam” system are close to the possible frequencies of external loads, and, consequently, the development of resonant phenomena has a very high probability.

3 Results and discussions

From all said above, it is possible to highlight main factors affecting the radial deformations of the working cylinders of hydraulic legs and formation of clearances that are to be relia-

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bly sealed to prevent loss of legs tightness and to maintain the working capacity of the complete set of mining equipment.

Fig. 6 shows the main factors that form the size of sealed clearances on hydraulic legs of the powered supports. Arrows indicate the direction of the subordination of factors and their increasing impact. For example, the frequency of natural oscillations (2) is determined by the geometric parameters (4) and the pressure of the working fluid (8).

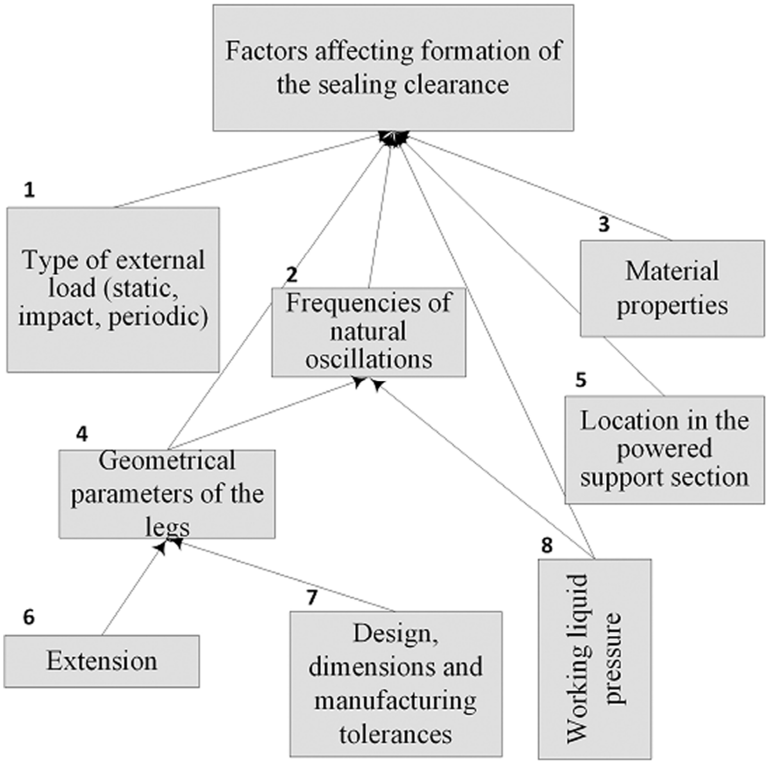

Fig. 6. Classification of factors affecting formation of the sealing clearance of the hydraulic leg

4 Conclusions

The size of the sealing clearance in the hydraulic legs of the powered supports is determined by their strength and geometric parameters, their location in the support section, properties of the materials and the type of external load. The integrated record of these parameters for the specific operating conditions of the mining set of equipment will help to avoid loss of tightness of the main support assembly and increase reliability and safety of mining operations.

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