E3S Web of Conferences **177**, 03016 (2020) https://doi.org/10.1051/e3sconf/202017703016
Ural Mining Decade 2020

Determination of the working area of a hydraulic excavator

Nikolay Suslov[1], and *Stanislav* Chernukhin[1]

[1] Ural State Mining University, 620144, Kuibyshev st., 30, Ekaterinburg, Russia

Abstract. The article discusses the mechanisms of walking used on dragline excavators. The disadvantages of each mechanism are identified and based on this, the most promising movement mechanism is selected – a three-legged walking mechanism with a hydraulic drive. For this mechanism, the main disadvantages are also identified. The following is a technical solution that allows you to save this mechanism from the main drawback – the need to raise the center of mass of the excavator to a significant height to ensure the maximum step value. The technical solution includes the presence of a flat hydrostatic support that allows to increase the efficiency of the mechanism in open-pit mining operations. The calculation of oil consumption through a flat hydrostatic support in the conditions of its use on quarry soils with different bearing capacity is made.

1 Introduction

One of the most effective ways to conduct overburden operations is a transportless technology with the use of dragline excavators on a walking course. The use of single-bucket excavators for excavating soil dates back to 1832-1836 in the United States during the creation of the Otis steam single-bucket excavator. Over time, the design of single-bucket excavators changed, the bucket volume increased, the length of the boom and the total weight of the machine increased. Together with this, the movement mechanism was also modernized, the requirements for the speed of movement and the ability to move on various soils increased. So, the mechanism of movement was improved over time from the railway to the walking course [1]. The walking undercarriage meets the main requirements- it provides a low specific pressure on the ground with huge masses of the excavator, is reliable in operation and provides a fairly high speed of movement.

2 Research method

Today, heavy single-bucket excavators that use a walking mechanism for moving remain the main special equipment for excavating overburden rocks in quarries. Walking running equipment used on draglines is classified by the number of supports – three-support mechanism, four-support and multi-support. The most widely used tricycle mechanism due to the simplicity of design and performance. The three-pronged walking mechanism is equipped with a mechanical drive and a hydraulic one. When using a mechanical drive, the movement is carried out by using an eccentric. With a hydraulic mechanism, the role of moving and lifting is performed by lifting cylinders, which ensure the separation of the leading edge of the base, and traction hydraulic cylinders that move the machine. The use of a mechanical drive has a major drawback – due to the use of an eccentric, it is not possible to adjust the pitch value, which is a very important factor when moving the dragline over the soils with low load-bearing capacity that prevail in quarries. This fact makes a three-legged mechanism with a hydraulic drive more promising, but this mechanism also has a significant drawback – the need to lift the center of mass of the excavator by a significant amount to ensure the maximum step. There is a direct relationship between the pitch length and the height of the excavator's center of mass. In addition, when the dragline is moved by the thrust cylinders, the trailing edge of the base is loaded, forming an extra resistance to movement [2, 3]. To solve these problems in the mechanism [4], a technical decision was made to install a sliding support in the support shoes, as in the four-support walking mechanism of THE esh-100.100 excavator[5]. This system allows you to provide the necessary amount of step with a minimum separation of the leading edge of the base from the ground, with a minimum amount of lift of the dragline center of mass[6].

In the mechanism [4], as in the four-bearing mechanism, a hydrostatic bearing is used. The use of such a sliding bearing is widely used in mechanical engineering. Hydrostatic bearings can significantly reduce the friction resistance between moving surfaces relative to each other and the wear of these surfaces. In a hydrostatic bearing, the surfaces of parts moving towards each other do not have direct contact, the connection between them is carried out by means of a liquid fed into the gap between the surfaces. In this case, the little working fluid serves as a transfer link, perceiving the gravity of the machine and transmits them to the support shoes, and they, in turn, to the ground. The oil film between the surfaces in a hydrostatic bearing works as rollers in a rolling pair[6]. The movement of the excavator takes place on sliders on plates mounted on support shoes. The main surface of the slide in the case of movement is the lower horizontal surface, but the other surfaces are important – two side and the upper horizontal.

The technical solution presented in figure 1 consists of a housing 1, on which the lifting hydraulic cylinders 2 are fixed by means of longitudinal rods 4, the rods of these cylinders are pivotally fixed on the slides 3. the Slides are supported on the support shoes 5. By means of traction hydraulic cylinders 6, due to the hydrostatic principle between the contacting planes of the slides and the support shoes, the slides are moved along the support shoes. The sliders are connected to the body by means of cross rods. To hold the support shoes in a horizontal position when the excavator is stationary and leaning on the base 8, stops 7 are mounted on longitudinal rods[4].

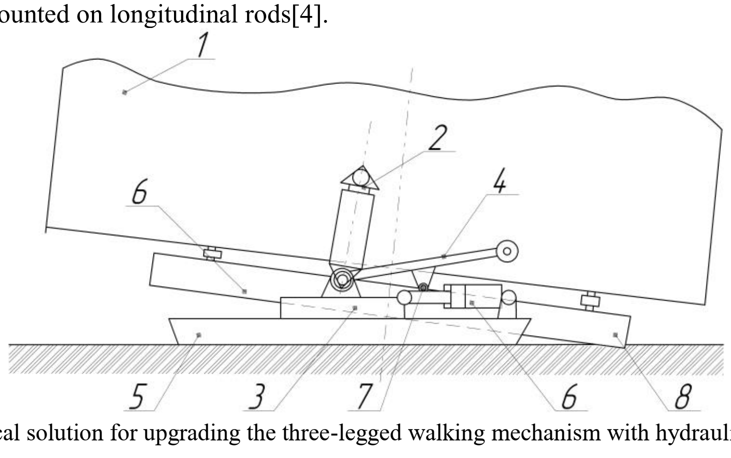

Fig. 1. Technical solution for upgrading the three-legged walking mechanism with hydraulic drive:

1-dragline body, 2-lifting hydraulic cylinders, 3-sliders, 4-longitudinal rods, 5-support shoes, 6-traction hydraulic cylinders, 7-stops, 8-base.

This mechanism works in a graying way. As the lifting cylinder rods are extended, the front edge of the base breaks off from the surface of the paved track in the direction of movement. Then the traction hydraulic cylinders start working on the extension of the rods and the body moves forward relative to the support shoes. In this case, the forces from the traction hydraulic cylinders are transmitted to the sliders and the body through the longitudinal rods. After moving the excavator to the spacing rods of the lift cylinders retracted, the front-facing edge of the base is lowered to the ground, and support shoes separated from the surface are included to the retraction of the traction cylinders is the anchor shoes are moved to the next step. At the end of the step, the rods of the lifting hydraulic cylinders are retracted until the contact of the support shoes with the stops – the shoes occupy a horizontal position. Simultaneously with the rotation of the body, the support shoes held in the raised position due to cross rods make a turn [4, 6].

The movement of the slides on the shoes is carried out by a hydrostatic force – a hydrostatic bearing. The transfer of the machine load to the support shoes is performed by the working fluid, which is fed under pressure through the holes in the slide into the space between the contacting surfaces of the support shoes and the slides, creating a layer between them, causing the slide to "float". The hydraulic fluid in the chamber takes the load that falls on the support when lifting and moving the excavator. When making a step along the tracks at an angle, the side sliding surfaces perceive a side load, and these surfaces are lubricated by means of working fluid leaks. During maneuvering operations with shoes (extending them in the direction of movement, returning to the position before the step or when turning the body of the machine), the main support is the upper horizontal sliding surfaces. The flow of liquid for surface lubrication is carried out at the expense of chambers, through unloading devices.

The main parameters of flat hydrostatic supports are the oil consumption required to maintain a certain gap created by the working fluid, the lubrication pressure when pumping oil[7, 8].

3 Results

To calculate the oil consumption of a flat hydrostatic bearing, a method has been developed for a stable gap formed by the oil supply between the contacting planes[9, 10]:

$$Q = \frac{\pi h^3 p_0}{6\mu \ln R/r} \tag{1}$$

where: h-thickness of the oil film,
μ-dynamic viscosity,
p_0 – the value of the pressure in the chamber.

Our case of using a hydrostatic bearing does not allow us to apply this calculation due to the deflection of the support shoes when moving over the roughness of the quarry ground, since the value of the resulting deflection depends on the size of the gap between the sliding surfaces, which leads to an increase in the flow of lubricating fluid through the flat hydrostatic bearing.

The greatest deflection will be observed when the support Shoe perceives the force P in the middle of the span, relative to which the deflection line will be symmetrical (Fig. 2).

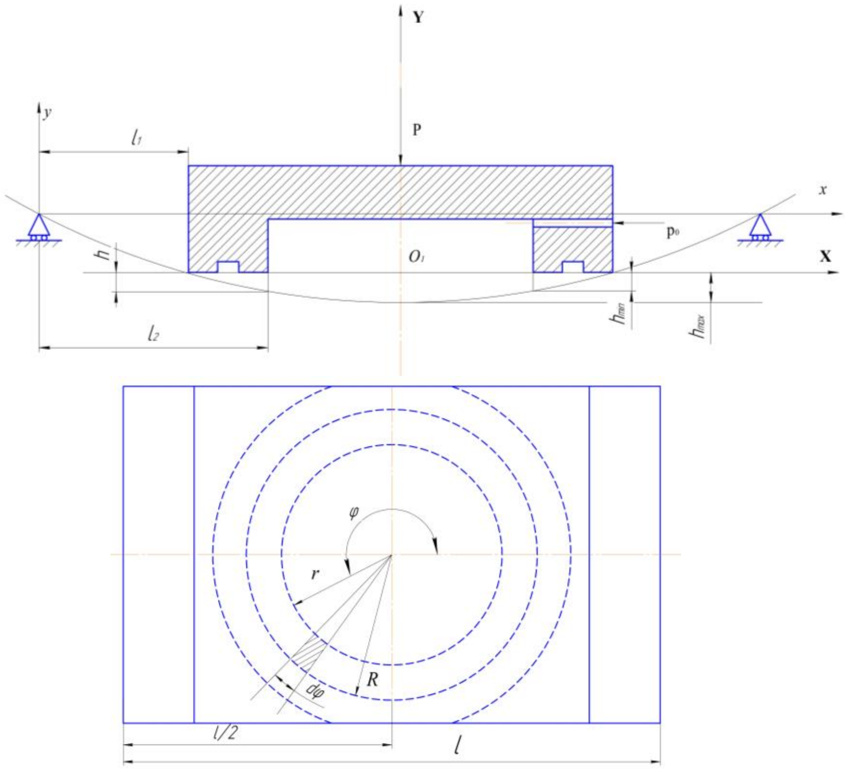

Fig. 2. Design scheme of a flat hydrostatic support.

Let's define the oil consumption for this case through the entire bearing, expressing it as the oil consumption through the third quarter of the bearing, multiplied by 4[11, 12, 13].

$$Q = \frac{p_0}{3\mu \ln(R/\ r)} \int_{\pi}^{3/\ 2\pi} [f_1(\varphi)]^3 d\varphi , \tag{2}$$

where φ – is the angle of an infinitesimal sector of the n-th section of the bearing in cylindrical coordinates.

After the transformations, we get the following dependency:

$$Q = \frac{p_0 P^3}{192\mu \ln(R/rE^3)} \int_{\pi}^{3/\ 2\pi} \left(Ar^3 \cos^3\varphi + Br^3 \cos^3\varphi - Cr\cos\varphi - D\right)^3 d\varphi , \tag{3}$$

where $A = 1/3I$;

$B = l/2I$;

$-C = k/0{,}2F$;

E – modulus of elasticity in tension (compression);

I – moment of inertia of the cross section of the support Shoe relative to the y axis.

l – length of the support Shoe;

P – load transmitted by the bearing;

k – is a coefficient that depends on the shape, size of the section, and direction of the y axis.

F – is the cross-sectional area of the contact between the support Shoe and the slide.

Integrating expression (3) and dropping the first ten terms because of a small value that does not exceed 2-5% of the total result, we get:

$$Q = \frac{p_0 P^3}{192\mu \ln\left(R/rE^3\right)} \left(\begin{array}{l} \frac{9\pi}{8} ACDr^4 + \frac{9\pi}{16} BC^2 r^4 - \frac{9\pi}{16} B^2 Dr^4 - 2AD^2 r^3 + \\ + \frac{2}{3} C^3 r^3 - 4BCDr^3 + \frac{3\pi}{4} C^2 Dr^2 + 3CD^2 r - \frac{\pi}{2} D^3 \end{array} \right). \quad (4)$$

According to the pressure equation in the chamber[4]:

$$p_0 = \frac{2P \ln\left(R/r\right)}{\pi\left(R^2 - r^2\right)}. \quad (5)$$

Substituting it in expression (4), we get:

$$Q = \frac{P^4}{96\pi\left(R^2 - r^2\right)\mu E^2} \left(\begin{array}{l} \frac{9\pi}{8} ACDr^4 + \frac{9\pi}{16} DC^2 r^4 - \frac{9\pi}{16} B^2 Dr^4 - 2AD^2 r^3 + \frac{2}{3} C^3 r^3 - \\ - 4BCDr^3 \frac{3\pi}{4} BD^2 r^2 - \frac{3\pi}{4} C^2 Dr^2 + 3CD^2 r - \frac{\pi}{2} D^3 \end{array} \right) \quad (6)$$

4 Findings

The oil consumption through a flat hydrostatic bearing mounted on a three-legged stepping mechanism of a dragline excavator that transmits the load through the support shoes depends on the load to the 4th degree.

Thus, the proposed technical solution allows using a three-legged walking mechanism with a hydraulic drive to ensure the adjustment of the lifting value of the center of mass of the machine, without losing the step value, and to create conditions for moving the machine with minimal loss of energy to friction by placing a flat hydrostatic support on the dragline shoes.

References

1. A.Yu. Prusov, A.V. Morozova, History and prospects of transport development in the North of Russia, **1**, 30-35 (2013)
2. S.A. Chernukhin, Bulletin Of Zabgu, **9** (2018)
3. A. Komissarov, Y. Lagunova, V. Shestakov, O. Lukashuk, IOP Conference Series: Materials Science and Engineering, **323(1)**, article no. 012015 (2018) doi: 10.1088/1757-899X/323/1/012015
4. P. A. Kasyanov, N.M. Suslov, Mechanism of the excavator step, A. S. № 825806, CL. E 02 F 9/04 (1981)
5. V.N. Nikolaev, Mining equipment and electromechanics, **2**, 4-5 (2007)
6. N.M. Suslov, S.A. Chernukhin, News of the Ural state mining University, **3(51)**, 108-113 (2018)
7. G.S. Averyanov, Hydrostatic support of increased rigidity with a membrane regulator of liquid flow, **3(60)** (2007)
8. O.A. Lukashuk, A.P. Komissarov, K.Y. Letnev, IOP Conference Series: Materials Science and Engineering, **709 (2)**, article no. 022083 (2020) doi: 10.1088/1757-899X/709/2/022083

9. M.S. Bundur, V.A. Prokopenko, I.A. Chernov, Scientific and technical Bulletin of information technologies, mechanics and optics, **6(64)** (2009)
10. D.N. Popov, D.S. Chvyalev, Bulletin of the Bauman Moscow state technical University. Mechanical Engineering Series, **3(64)**, 15-23 (2006)
11. L.A. Kondakov, G.A. Nikitin, V.N. Prokofiev, etc., Engineering hydraulic drive, 496 (M., Mashinostroenie,1978)
12. V.N. Popov, N.M. Suslov, Izv. Higher educational, Mountain journal, 69-72 (1973)
13. N.A. Pelevin, V.A. Prokopenko, I.A. Chernov, Scientific and technical Bulletin of information technologies, mechanics and optics, **5** (2016)