INVESTIGATION OF THE INFLUENCE OF VELOCITY ON UNIT ENERGY CAPACITY OF THE PROCESS OF EXCAVATING OF SOIL

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***Abstract**: Paper presented investigations of dependence on the new design of without dipper rotor carrying out the removal of chips during rotation of the "top down" relative to the bottom and allowing operating at high speeds.Three types of cutting elements used for comparative experiments. They are: dipper without bottom, cutting perimeter and cutting element of without dipper rotor which have the same dimensions. In paper discussed method of calculating the work for transportation of soil expended by dipper without a bottom regarding theorem of change of kinetic energy of point of variable mass. The paper include the results of experiments which showed that underground mines "top down" by knife cutting element of dipper without bottom is the least power intensive from the investigated variants of cutting elements.*

Keywords: ENERGY, CAPACITY, ROTOR, KNIFE

1. Introduction

It was established by the previous researches that with the increasing of the digging speed the specific energy capacity of the working process increases also. These studies provide various data about the nature of this dependence which can be explained by the variety of working bodies' constructions and poster facilities, properties of the developed soils, shapes and sizes of the cutting elements, and also the differences among the research methods.

In connection with this, of special interest is the study of the pointed dependence on the base of the new construction of without bucket rotor [1, 2] exercising the development of the slaughter by means of vertical shavings in the direction of «top down». In contrast to the ordinary rotor, the rotation speed of which is limited by the buckets' gravitational unloading, without bucket rotor allows to work in the large range of speeds. There were selected three types of cutting bodies for the comparative researches: the bucket without a bottom, the perimeter of the arch type and the knife cutting element, installed at the angle of 72-74 degrees to the forming cylinder. During the digging by the bucket without a bottom, cut soil is transported along the surface of the bottom and unloaded along the rotor and the perimeter and the knife realizes the process of actually cutting - separated from the array shaving falls at the bottom of the slaughter.

The same sizes of the bucket's cutting visors and the perimeter allows you to present a digging work by the bucket without a bottom as a cutting work, determined experimentally during the perimeter development of the slaughter, and also as a transportation work, which could be determined analytically as it was proposed. By means of calculation it is possible to determine a work, spent by the bucket without a bottom for the transportation of the cut soil $(A_т)$.

2. Investigations

In this case is acceptable to use the theorem of the changing of the kinetic energy of the variable mass point [2], according to which the increment of the kinetic energy of a variable mass point on the final interval amounts the algebraic sum of all active and reactive forces work on the same interval:

$$\frac{m_1 v_1^2}{2} - \frac{m_0 v_0^2}{2} = \int_{r_0}^{r} p d\bar{r} - \int_{r_0}^{r} R d\bar{r}, \qquad (1)$$

where $\frac{m_1 v_1^2}{2} - \frac{m_0 v_0^2}{2} = A_p$ is the increment of the kinetic energy of a variable mass point on the final interval (the work which is spent for the acceleration of the soil):

$\int_{r_0}^{r} p d\bar{r}$ is the work of all active forces on this interval;

$\int_{r_0}^{r} R d\bar{r} = A_{реакт}$

s the work of the all reactive forces, caused by the nonconstants of the masses on the same interval.

Under the active forces are understood all the set (or attached) forces, including all the driving forces, the resistance forces and the gravity forces. So the work of the active forces is composed of the work of the rotor's drive $(A_{пр})$, the work of the gravity force $(A_в)$ and the work of the friction force of the cut soil of the cutting surface $(A_{тр})$.

Then the work spent on the transportation of the soil on the slaughter, on the basis of equation (1) will be equal to:

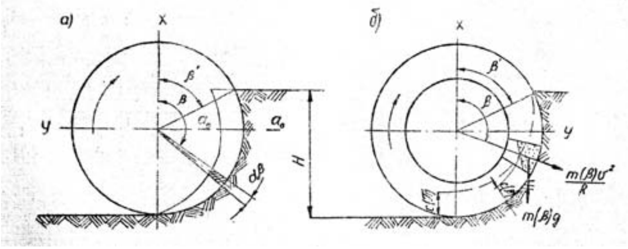
$$A_т = A_{пр} = -A_в + A_{тр} + A_р + A_{реакт} \qquad (2)$$

To determine these costs, it may be assumed that the bucket filling with the soil is uniform in the length and the width, and the increment of the soil in the bucket is uniform in its height on some regularity C(β).

Then the volume of friable soil is equal to the (Fig.1b):

$$q(\beta) = BlC(\beta), \qquad (3)$$

where B - is the average width of the bucket; l- the length of the bucket



a) the digging b) the transportation

***Fig.1.** The scheme of the soil development "top down" by the bucket without a bottom*

On the other hand, having in mind that the thickness of a shaving in the radial direction is changed according to the law of sines, the amount of shavings in the dense body, in one bucket during the turning from the corner to the β can be expressed by the following formula:

$$q_c(\beta) = \int_{\beta}^{\beta} \alpha_0 \sin_{\beta} b_0 R d\beta = Ra_0 b_0 (\cos\beta - \sin\beta) \quad (4)$$

where a_0 and b_0 is the thickness and the width of the shaving;

R is the radius of the rotor.

Comparing the equations (3) and (4), taking into account the loosening coefficient it is possible to get an expression C(β):

$$C(\beta) = \frac{Ra_0 b_0 (\cos\beta' - \cos\beta) k_p}{Bl}, \quad (5)$$

The work of the weight, friction forces and the work which is spent for the soil disband can be represented by the formulas:

$$A_в = \int_{\beta}^{\beta'} m(\beta) g \sin\beta \left[R - \frac{C(\beta)}{2}\right] d\beta, \quad (6)$$

$$A_{тр} = \mu \int_{\beta}^{\beta'} \left[\frac{m(\beta) v^2}{R - \frac{B(\beta)}{2}} - m(\beta) g \cos\beta\right] R d\beta, \quad (7)$$

$$A_р = \frac{m(\beta) v^2}{2}, \quad (8)$$

where $m(\beta) = \frac{\gamma p_c(\beta)}{g}$; γ is the volumetric weight of the soil;

g is the acceleration of gravity; μ is the coefficient of the friction of the soil on the soil;

v is the rotation speed of the rotor.

The work of the reactive forces in this case can be admitted as a work consisted of the work of the impulsive forces, neglecting the work of the Coriolis and variational forces. The impulsive force, appearing as a result of the variability of the soil mass in the bucket, is equal to

$$\Phi = \frac{dm_1}{dt} v_1 - \frac{dm_2}{dt} v_2, \quad (9)$$

where $\frac{dm_1}{dt}$, $\frac{dm_2}{dt}$ is a quantity of attached and separated soil mass per second;

v_1, v_2 is the relative speed of the attached and separated particles.

To determine the quantity of the attached soil mass per second $\frac{dm_1}{dt}$, the elementary volume of the shaving is considered in Fig 1a)

$$dq_c = a_0 b_0 R \sin\beta d\beta, \quad (10)$$

Multiplying both parts of the equation (10) on $\frac{y}{g}$ and expressing $\beta = \omega t$ it is possible to write:

$$dm_1 = \frac{\gamma}{g} a_0 b_0 R\omega \sin\omega t dt, \quad (11)$$

from this:

$$\frac{dm_1}{dt} = \frac{\gamma}{g} a_0 b_0 v \sin\beta, \quad (12)$$

Accepting $v_1 = v$ and $v_2 = 0$, we can find the impulsive force:

$$\Phi = \frac{\gamma}{g} a_0 b_0 v^2 \sin\beta, \quad (13)$$

Hence, the work of the impulsive force is equal to the

$$A_{реактив} = \int_{\beta}^{\beta'} \frac{\gamma}{g} a_0 b_0 v^2 \sin\beta R d\beta, \quad (14)$$

Under the simplified calculations can be considered

$$\Phi = \frac{\gamma}{g} F_{ср} v^2, \quad (15)$$

where $F_{ср}$ is the average cross-section of the shaving on the arc cutting.

Then

$$A_{реактив} = \int_{\beta}^{\beta'} \frac{\gamma}{g} F_{ср} v^2 R d\beta, \quad (16)$$

For the approximate calculations with the relative height of the bucket $K_к = \frac{R}{h_k} \leq 4$, changing $R - \frac{C(\beta)}{2}$ on R and making simplifications, these equations can be written:

$$A_в = -\gamma R^2 a_0 b_0 (\cos\beta' + \cos^2\beta' + \frac{1}{2}\sin^2\beta') \quad (17)$$

$$A_{mp} = \frac{\mu\gamma R a_0 b_0}{g} \left[(\beta - \beta')\left(\frac{g}{2} + \frac{v^2}{2}\cos\beta'\right) + \left(\frac{g}{2} + \frac{v^2}{2}\cos\beta'\right) + \left(\frac{v^2}{R} + g\cos\beta'\right)\sin\beta - \frac{1}{2}\sin^2\beta \right]$$

$$A_р = \frac{Rv^2 \gamma a_0 b_0 (\cos\beta' - \cos\beta)}{2g}, \quad (19)$$

$$A_{реакт} = \frac{\gamma}{g} R a_0 b_0 v^2 (\cos\beta' - \cos\beta), \quad (20)$$

or

$$A_{реакт} = \frac{\gamma}{g} R F_{ср} v^2 (\beta - \beta'), \quad (21)$$

Then the specific energy capacity of transportation of the cut soil by the bucket without a bottom can be expressed as:

$$K_т = \frac{+A_{тр} + A_р + A_{реакт} - A_в}{q_c(\beta)} \quad (22)$$

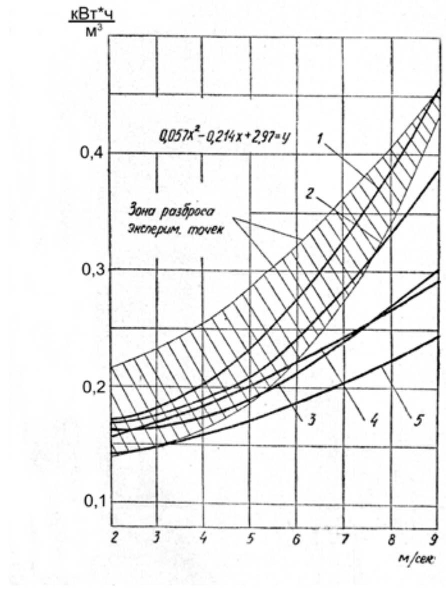
The rotary stand installation mounted on the mobile field booth was used for the experimental verification of the received formulas. Description of the stands, the system of the measurements and the list of the used equipments are set out in the work and in the present article are not presented.

Different modes of the digging were carried out at the expense of the rotation speed changes and the rotor lateral filing. The first is achieved by the replacement of the drive pulleys of the rotor, the second – by the change of the productivity of the drive carriage pump. The technical capabilities of the stand and the rotor installation allowed to work in the speeds diapason from 2 to 9 m/sec. During the development of the slaughter by means of the cutting perimeter, there was installed the scraping bucket with the increased capacity.

The digging radius of this bucket is 15 mm more, so it carried out at the same time the development and the scraping of the slaughter for the next perimeter cutting. Bucket and perimeter digging was carried out in the stable sizes of the shaving and cross-section, which was closed to the square, and during the development of the slaughter by means of the knife, the cross-section of the shaving had a rectangular form of the same size. The studies were carried out in the clays of the II-III category with the natural moisture 23-25%, volume weight 1,95 tons/cubic meter. According to the received coefficients of the porosity and moisture, the angel of the internal friction of this soil on the rolling border was 20 degrees. The oscilloscope recording was carried out at a high speed (160 mm/sec), which allowed obtaining a clear idea of the nature of the digging parameters changes and making a free plan of the torque diagrams square.

Each value of specific energy capacity was calculated as an overage on the 4-6 cuts, and the statistical analysis of these average values allowed to receive the parabolic curves of dependence of the digging process energy capacity and soil transportation from the rotor speed (Fig. 2). From the comparison of the curves 4 and 5 is seen, that the specific energy capacity of the soil development by the slant knife is lower than the specific energy capacity of the perimeter development.

For the bucket without a bottom with the cutting corner of 32-53 degrees, the changes of the digging speed from 2 to 9 m/sec cause the increasing of the specific energy capacity more than two times. The close matching of the curves 3 and 4 shows a good agreement of the results of the analytical and experimental determination of the energy consumption for the transportation. At the same time for the digging speed 3, 6 and 9 m/sec, the specific energy consumption for the soil transportation by means of the rotor bucket on the slaughter amounted 7,2; 20 and 30%. Within the limits of rotor speed changes from 2 to 9 m/sec during the digging by the perimeter and slant put knife, the specific energy capacity of the working process has been increased by 52% and 45%.



1– by the bucket without the bottom; 2 – by the bucket with the subtraction of the energy costs for the friction of the cut soil with the surface of the development soil; 3-by the bucket with the subtraction of the energy costs for the cut soil transportation along the slaughter surface; 4 – by the arc type perimeter; 5- by the knife cutting element of the rotor without bucket (1, 4, 5 –experimentally determined, 2, 3 -analytically).

Fig.2. *The dependence of the specific energy capacity from the digging speed during the slaughter development*

3. *Conclusions*

1. The development of the «top-down» slaughter by means of the knife cutting element of the rotor without bucket is the least energy-intensive of the investigated variants of the cutting elements as for the absolute volume of the specific energy capacity so as for the level of its increasing with the increasing of the speed.
2. It is experimentally shown that the suggested calculations methods of the specific energy consumption for the soil transportation by means of the bucket without a bottom with the account of the mass changes are sufficiently reliable and can be recommended for the calculation practice.
3. Experimental data of the growth of the specific energy capacity of the high-seed digging by means of the knife and the perimeter are similar to the results, received by the other researches.

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