ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 2, February 2019

Methods of evaluating the working bodies of rotary machines on the newly formed surfaces of crushed soil lumps

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ABSTRACT: The article discusses the issue of evaluating the working bodies of rotary machines, proposes a new method of evaluation based on newly formed surfaces after the destruction of soil lumps, derived dependencies to determine the specific work and specific energy spent on crushing soil lumps, gives methods for conducting experiments and the results of experiments based on the findings are conclusions.

KEYWORDS: evaluation method of the working body, elastic deformation, plastic deformation, specific work, specific energy, degree of grinding, fraction, newly formed surfaces, diameter of soil lumps, impact speed, humidity of soil lumps.

I.INTRODUCTION

Assessment of the working bodies of rotational machines for energy consumption is a very important indicator when comparing the working bodies and designating the speed limit of the process of grinding soil lumps and lumps, since the working body of the rotary machine rotates at a higher speed than the translational speed of the unit. It is known that the energy intensity of the tillage process according to V.P. Goryachkin is proportional to the square of the speed of movement of the working body in the soil environment, the higher the speed, the more energy is spent on processing.

There are many methods for evaluating rotational working bodies, but they do not allow rationally choosing the speed limits for tillage.

II. LITERATURE SURVEY

Degraf G.A. [1], Baymetov R.I. [2], Ahmetov A.A. [3], Inoyatov I.A. [4], Otahanov B.. [5,6,7], and many others worked on the destructibility of soil lumps and methods for evaluating the working bodies. The studies conducted by these researchers were limited to the substantiation of the parameters of the working body, with different evaluation criteria. Among the works performed, special attention should be paid to the experiments carried out by Baymetov R.I. [2], where the specific work for crushing was taken as the criterion for evaluating the work of a deformer. The specific work on crushing does not reveal the essence of the question, it can only be used to compare the results of the work of the working bodies under study, since the specific work on crushing will always decrease with increasing speed, at which the degree of crumbling of soil lumps increases. Therefore, it is impossible to determine the optimal crushing rates. In addition, the work does not take into account the destructible soil lumps, depending on the size, humidity and impact speed of the working body.

Based on the above, it is necessary to determine the limits of the critical speed at which the destruction begins, depending on the size of the soil clump, the optimal crushing rate.

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III. METHODOLOGY

1. Definition of specific work on crushing soil lumps and lumps. It is considered established that the general scheme for the destruction of a solid body consists of a consistent elastic and plastic deformation and its rupture.

The work of the compression force of the soil lump is expended on elastic, plastic deformations and on the destruction of the sample. The general work of crushing can be represented as

$$A_t = A_e + A_p, \qquad (1)$$

where A_e- is the work spent on the elastic deformation of the sample,

A_p - work spent on plastic deformation and the formation of new surfaces.

The work of elastic deformations is proportional to the deformed volume of the body, i.e.

$$Ay = \frac{\sigma_p^2}{200 \cdot E} \cdot \Delta V = k \cdot \Delta V, \qquad (2)$$

where σ_p- is the stress corresponding to the limit of proportionality, Pa;

E- is the modulus of elasticity, Pa;

ΔV - deformed body volume, m^3.

The work expended on plastic deformations and on the formation of new surfaces, we take proportional to the magnitude of the last

$$A_p = \alpha_1 \cdot \Delta S, \qquad (3)$$

whereΔS- is the newly formed surface in the process of crushing the material, which can be defined as the difference,

$$\Delta S = S_2 - S_1, \qquad (4)$$

whereS_1- is the total surface of the piece before crushing, m^2;

S_2 - total surface of all particles after crushing, m^2.

To determine the values of S_2 and S_1, we accept, as some authors [2, 3] suggest, that pieces of crushed material before and after crushing consist of cubes whose dimensions are equal to the average diameter of sample D and particles of crushed product d.

Then the number of particles (n) resulting from the crushing of the sample

$$n = \frac{Q}{q_1} = \frac{D^3}{d^3}, \qquad (5)$$

here, Q and q_1 are the mass of the pieces before and after crushing.

If we assume that as a result of crushing, particles of the same size are obtained, then

$$S_l = 6D^2 \text{ and } S_2 = 6nd^2, \qquad (6)$$

Substituting the values of n, S_1 and S_2 in the relation (2.6) we get

$$\Delta S = 6D^2\left(\frac{D}{d} - 1\right), \qquad (7)$$

or denoting $i = \frac{D}{d}$, then you can write

$$\Delta S = S_1(i-1). \qquad (8)$$

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From this it is obvious that the new surfaces formed in the process of crushing samples are equal to the surface of the original sample multiplied by the degree of grinding without one.

Substituting the value of ΔS from equation (8) into (3), we get

$$A_n = 6\alpha_1 D^2 (i-1). \tag{9}$$

When crushing lumps, the crushed particles usually have not the same dimensional characteristics, which entail large errors in their averaging. This is especially noticeable if there are large pieces in the crushed product. To take into account the heterogeneity of the grinding composition, the particles were divided into fractions and from them the newly formed surfaces were determined during crushing as follows:

$$\Delta S = S_2 - S_1 = \frac{q_1}{\gamma_0 \cdot d_1^3} \cdot 6 \cdot d_1^2 + \frac{q_2}{\gamma_0 \cdot d_2^3} \cdot 6 \cdot d_2^2 + \ldots + \frac{q_n}{\gamma_0 \cdot d_n^3} \cdot 6 \cdot d_n^2 - 6D^2 =$$
$$6D^2 \left[\frac{D}{Q} \left(\frac{q_1}{d_1} + \frac{q_2}{d_2} + \ldots + \frac{q_n}{d_n} \right) - 1 \right] = 6D^2 \left(\frac{D}{Q} \Sigma \frac{q_i}{d_i} - 1 \right), \tag{10}$$

where Q - is the mass of soil lump, kg

q_i- mass of individual fractions, kg;

ρ_0 - fraction density, kg / m^3;

$d_i = (d_u + d_l) / 2$ - average diameters of narrow classes, m; d_u- is the upper diameter of the fraction, i.e. the size of the sieve opening through which the material passed; d_l - is the lower diameter of the fraction, i.e. the size of the sieve opening on which the material was held.

In the same way, it can easily be shown that when crushing a q'kilogram of bulk material consisting of identical pieces with an initial size D_a, the newly formed surfaces will be

$$\Delta S = \frac{6}{\gamma_0} \left(\Sigma \frac{q_i}{d_i} - \frac{q'}{Da} \right). \tag{11}$$

Moreover, if we assume $d_i = d_a$, then obviously $\Sigma q_i = q'$ then

$$\Delta S = \frac{6q'}{\gamma_0} \left(\frac{1}{d_a} - \frac{1}{D_a} \right). \tag{12}$$

If pieces of material before and after crushing are taken for a ball, then the newly formed surfaces will be equal

$$\Delta S_b = \frac{\pi}{6} \Delta S_i, \tag{13}$$

whereΔS_b, ΔS_i - newly formed surfaces during the crushing of spherical and cubic samples.

Samples and pieces of lumps after crushing are taken by us for a cube from the following considerations:

a) We could not get samples that have exactly a spherical surface;

b) there are always irregularities on the surface of the sample and the pieces after crushing, which will increase the overall irregularity;

c) Particles after crushing have an arbitrary shape.

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International Journal of AdvancedResearch in Science, Engineering and Technology
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Now, substituting the values of ΔS when crushing a single piece from the formula (10) into (3), we get

$$A_p = 6\alpha_1 D^2\left(\frac{D}{Q}\Sigma\frac{q_i}{d_i}-1\right). \qquad (14)$$

The total work of crushing is equal to the kinetic energy of the sample, which, is determined from the formula

$$A_t = \frac{Q\cdot\vartheta_{is}^2}{2g}, \qquad (15)$$

where Q - sample mass, kg;

υ_{IS}- the velocity of impact of the pendulum, determined by the formula [6].

From the formula (1) we have:

$$A_p=A_t-A_e. \qquad (16)$$

If we substitute in the last equality the values of their components; then we get

$$\alpha_1\cdot\Delta S = \frac{Q\cdot\vartheta_{is}^2}{2} - k\cdot\Delta V. \qquad (17)$$

From this expression it is possible to determine the magnitude of the specific work required for the formation of units of the newly formed surface when the sample is crushed.

$$\alpha_1 = \frac{Q\cdot\vartheta_{is}^2}{2\cdot\Delta S} - \frac{k\cdot\Delta V}{\Delta S} \quad \text{or} \quad \alpha_1 = \frac{1}{\Delta S}\left(\frac{Q\cdot\vartheta_{is}^2}{2} - k\cdot D^3\right). \qquad (18)$$

In determining the work expended on the formation of new surfaces, it is necessary to collect and take into account all the particles obtained during the crushing of the sample. For this purpose, after crushing by a blow on a pendulum device, the soil collected on a sailing film was divided into fractions in sieves with sizes up to 10, 25, 50, 100 mm.

When processing the experimental data, the value of ΔS - newly formed superstructures was determined by the formula (10).

2. Kinetic energy spent on crushing soil lumps and lumps. When a soil lump collides with a working body in motion, the conservation equation for the amount of motion is:

$$m_1\overline{U_1} + m_2\overline{U_2} = m_1\overline{\upsilon_1} + m_2\overline{\upsilon_2}, \qquad (19)$$

where m_1, m_2- are the masses of the pendulum and the soil lump, respectively, kg;

$\overline{U}_1$, $\overline{U}_2$ – speed before the impact of the pendulum and the soil lump, m / s;

$\overline{\upsilon}_1$, $\overline{\upsilon}_2$ - speed after the collision, respectively, of the pendulum and soil clot, m / s.

Projecting (19) on the X-axis we get

$$m_1U_{1x} + m_2U_{2x} = m_1\upsilon_{1x} + m_2\upsilon_{2x}, \qquad (20)$$

If, take into account that

$$U_{2x}-U_{1x}=k(\upsilon_{1x}-\upsilon_{2x}) \qquad (21)$$

we have

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International Journal of AdvancedResearch in Science, Engineering and Technology
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$$U_{1x} = \upsilon_{1x} - (1+k)\cdot\frac{m_2}{m_1+m_2}\cdot(\upsilon_{1x} - \upsilon_{2x});\ U_{2x} = \upsilon_{2x} - (1+k)\cdot\frac{m_2}{m_1+m_2}\cdot(\upsilon_{1x} + \upsilon_{2x}). \quad (22)$$

When $\upsilon_{2x} = 0$, we get

$$U_{1x} = \upsilon_{1x} - (1+k)\frac{m_2}{m_1+m_2}\cdot\upsilon_{1x}; \quad U_{2x} = -(1+k)\cdot\frac{m_2}{m_1+m_2}\cdot\upsilon_{1x};$$
$$S_{1x} = S_{2x} = -(1+k)\cdot\frac{m_1\cdot m_2}{m_1+m_2}\cdot\upsilon_{1x}. \quad (23)$$

In our case, the blow is not elastic, therefore $k = 0$. Then

$$U_{1x} = \upsilon_{1x} - (1+k)\cdot\frac{m_2}{m_1+m_2}; \quad U_{2x} = -\frac{m_2\cdot\upsilon_{1x}}{m_1+m_2}; \quad S_{1x} = S_{2x} = -\frac{m_1\cdot m_2}{m_1+m_2}\cdot\upsilon_{1x}. \quad (24)$$

Kinetic energy lost on impact

$$\Delta T = \frac{S_x^2}{2m_1} + \frac{S_x^2}{2m_2} = \frac{S_x^2}{2m_1m_2}\cdot(m_1+m_2). \quad (25)$$

Considering (23) then

$$\Delta T = T_1 - T_2 = \frac{m_1m_2\upsilon_{1x}^2}{2(m_1+m_2)}. \quad (26)$$

One of the main constant values of indicators of soil lumps is the value of specific energy for crushing.

The value of the "specific energy by mass" during crushing is defined as the ratio of the kinetic energy expended in crushing to a unit mass, i.e.

$$\alpha_m = \frac{\Delta T}{m_2} = \frac{m_1\cdot\upsilon_{1x}^2}{2(m_1+m_2)}. \quad (27)$$

The value of the specific energy of the newly formed surfaces during crushing is defined as the ratio of the kinetic energy expended on crushing to a unit of newly formed surfaces defined by the formula (10), i.e.

$$\alpha_s = \frac{\Delta \mathrm{T}}{\Delta S}. \quad (28)$$

IV. EXPERIMENTAL RESULTS

To determine the correctness of the assumptions and the derived dependences, experiments were carried out on the destructibility of lumps and lumps on a pendulum device. For this purpose, samples were prepared, soil clumps with diameters of 10, 20, 30, 40, 50, 60, 70, 80, 90, 110 mm. The destruction of lumps was carried out on a pendulum device. The speeds of the end of the pendulum were determined by the deviation of the rod of the pendulum at a certain angle from the vertical. All conditions for obtaining reliable data are met.

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The process of sample preparation is as follows.

Lumps and lumps are taken from the surface of the field, the dimensions of which exceed the dimensions of the samples to be manufactured. A parallelepiped and large cubes are cut out of these boulders and lumps with a hacksaw. Then they are cut into several pieces. The dimensions of parallelepipeds and cubes prepared in this way should be 3-5 mm larger than the dimensions of the finished samples. Prepared samples are placed in plastic bags, tightly tying them.

The prepared samples were destroyed by a blow in a pendulum device. Fragmented soil lumps were collected on sailing plastic wrap. The collected lumps were sieved through sieves with hole sizes of 50 mm, 25 mm, 10 mm and 5 mm. The sieved fractions were weighed to the nearest 0.1 gram.

The results of experiments to determine the specific energy per unit of newly formed crushing surfaces are shown in Fig. 2.

From these results it can be seen that the energy costs of crushing lumps of large sizes (more than 80 mm) are reduced when moving from static to dynamic effects. This indicates that at all impact speeds, the degree of crumbling of a large-sized soil clump is insignificant.

When crushing lumps of smaller sizes (up to 60 mm), the specific energy consumption per unit of newly formed surfaces grows in a straight line relationship, but with less intensity.

The dependence of the specific energy intensity on the formation of new surfaces on the size of soil lumps only confirms the conclusions made above and indicates that at lower speeds and with lump sizes over 90 mm, the energy intensity of crushing grows along a logarithmic curve.

Based on the data obtained, we can conclude that for crushing of soil lumps from the point of view of energy intensity, the impact velocity of 7 ... 9 m / s is optimal.

The decrease in specific energy during the transition from static loads to impact ones can be explained by a decrease in the yield zone. A further increase in energy intensity with an increase in the rate of success is due to the fact that the temporary resistance of the soil increases with increasing speed.

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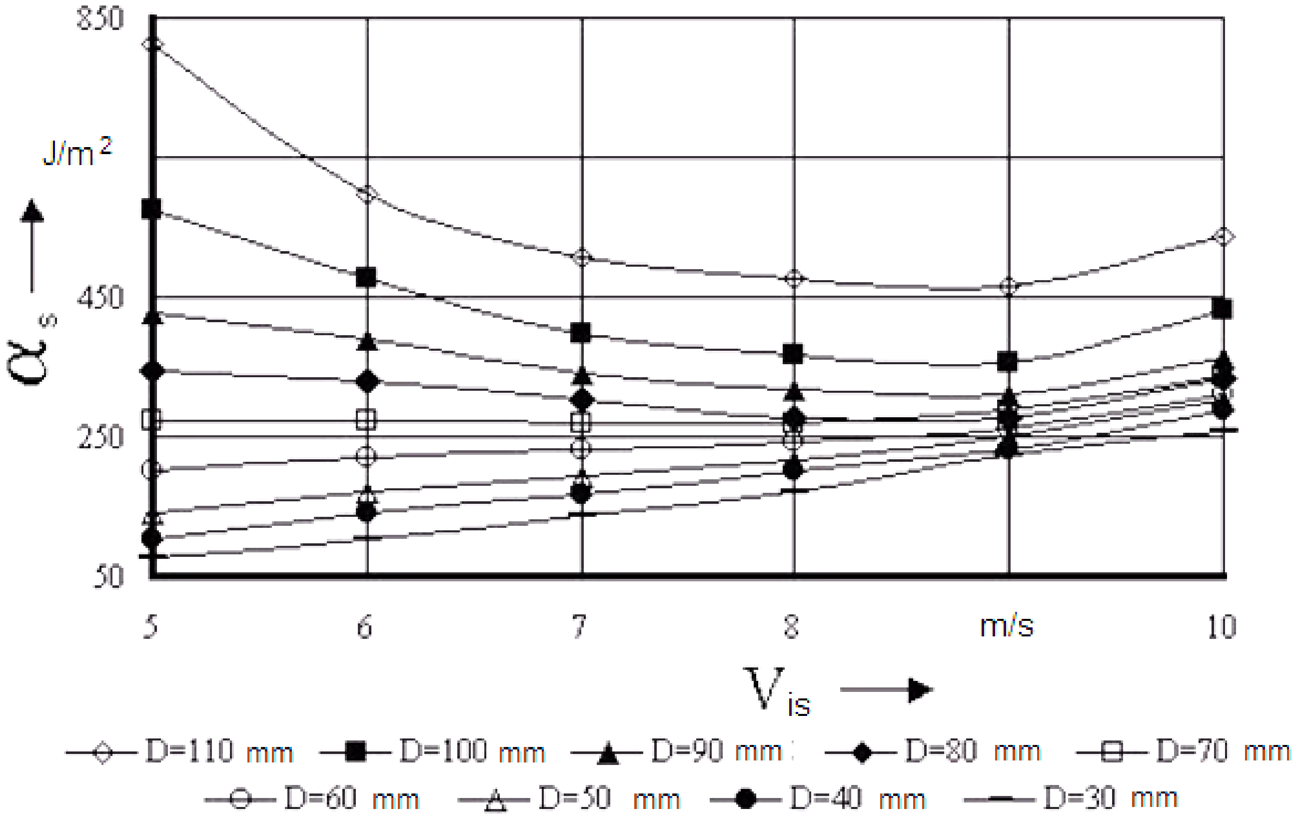

Fig.2.The dependence of the specific energy per unit of the newly formed surfaces of crushed lumps on the impact velocity at W = 9.4%

V.CONCLUSION

1. An increase in the diameter of a lump at all humidity entails a decrease in its critical rate of destruction according to the law of hyperbola.

2. A soil lump when exposed to a shock load is destroyed by the cross sections of weak bonds, which are usually larger in large lumps than in small ones. Therefore, in the destruction of small lumps, the speed of impact must be greater.

3. In the impact of the working bodies on the material, the movement is reported only to particles closest to the point of impact. The sharper and faster the blows, the deformation penetrate to a smaller depth, i.e., the deformation in the material is local in this case. Therefore, to increase the degree of crumbling of lumps of large sizes, it is necessary to make a blow with a speed not exceeding the speed of propagation of plastic deformations of the soil.

4. Increasing the impact velocity to 7 ... 9 m / s contributes to increasing the degree of crumbling of the soil lump, a further increase will entail an increase in the cost of specific energy for crushing the soil lump.

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