About the Destruction of Grain in the Working Chamber of the Crusher

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Abstract**: *The article shows the process of grain destruction in the working chamber, the influence of the inclination angles of the stator and rotor on the quality of grain destruction is determined, in addition, the results of calculating the limiting values and diameters of the crushed material particles are given.***

Keywords: Rotor, stator, working chamber, tilt angle, diameter, radius, grains.

I. INTRODUCTION

Determining the optimal parameters of the working chamber of the crusher is of great importance in ensuring high-quality grain destruction. To ensure the first destruction of grain or, what is also the provision of a working process at the very beginning, we consider the scheme in Fig. 1. [1,2] It is seen that when the grain touches the surfaces of the grooves of the rotor and stator at points m and n_1 with a gap $\delta = 0$, the points ρ and ρ_1 coincide, the distance

$$mP = r_3 \cdot ctg\frac{\alpha_c}{2}$$

and the distance from the axis of rotation to the center of the grain

$$r = r_к - r_3 \cdot ctg\alpha\frac{\alpha_c}{2}$$

Where is α_c the angle of inclination of the bottom of the stator?

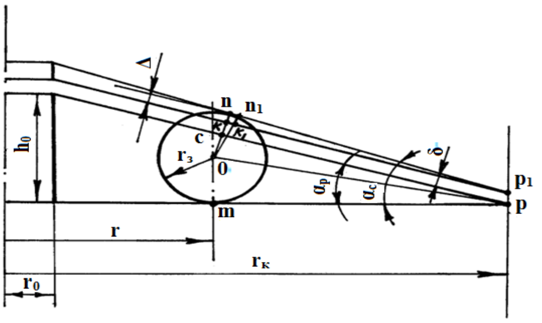

Figure. 1. On determining the initial position of grain r and the minimum allowable angle αc

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If the distance n_k in this case will be equal to the value of the destructive deformation Δ, then the angle αc will have a limiting value, and a decrease in it will lead to the impossibility of the initial destruction of the grain. Figure 1 shows that [3,4]

$$OP = \frac{r_3}{\sin\frac{\alpha_c}{2}}; \qquad r_3 = \Delta + OC; \qquad OC = OP\sin\left(\alpha_p - \frac{\alpha_c}{2}\right) = r_3 - \Delta$$

here is the angle of inclination of the rotor groove; from here, given that

$$\sin\left(\alpha_p - \frac{\alpha_c}{2}\right) = \sin\alpha_p \cdot \cos\frac{\alpha_c}{2} - \cos\alpha_p \cdot \sin\frac{\alpha_c}{2}$$

after appropriate transformations, we obtain the boundary value of the angle α_c depending on the initial grain size, angle α_p and the outer radius of the working chamber:

$$\alpha_c \geq 2arctg\frac{r_3 \cdot \sin\alpha_p}{r_3(1+\cos\alpha_p) - \Delta} \quad (1)$$

Accordingly, the distance from the axis of rotation of the rotor to the center of the grain at the time of its first destruction

$$r = r_к - \frac{r_з(1+\cos\alpha_p) - \Delta}{\sin\alpha_p} \quad (2)$$

When installing the rotor and stator with a gap δ, we obtain

$$r = r_к - \frac{r_з(1+\cos\alpha_p) - (\Delta+\delta)}{\sin\alpha_p} \quad (3)$$

It can be seen from equation (3) that as δ, r also increases, i.e. the minimum possible r corresponds to the calculations according to equation (2).

As

$$\cos\alpha_p = \frac{r_k - r_0}{\sqrt{h_0^2 + (r_к - r_0)^2}},$$

$$\sin\alpha_p = \frac{h_0}{\sqrt{h_0^2 + (r_к - r_0)^2}}$$

Then equation (3) can be represented as a function of the geometric parameters of the working chamber

$$r = r_к - \frac{1}{h_0}\left\{r_3(r_к - r_0) + \left[r_3 - (\Delta + \delta)\right]\sqrt{h_0^2 + (r_к - r_0)}\right\}$$

(4)

When the crushed particles exit the working chamber and when

$$2r_3 \succ P_1P = \frac{\delta}{\cos\alpha_p}$$

it inevitably assumes a position when contact occurs (wedging) at points n_1 and mof the stator and rotor. If the deformation of the particle is less than the necessary value for the destruction of Δ, then practically no destruction can occur, and the particle will not freely leave the working chamber. In this case, especially when

δ = 0, the mass will clog the working chamber at the exit, a sharp decrease in productivity with a significant increase in specific energy costs due to friction losses and heating of the working parts of the machine. The free exit of particles, and therefore the maximum throughput of the working chamber, is ensured by reducing the external calculated radius r_k to its working value r_{cp},

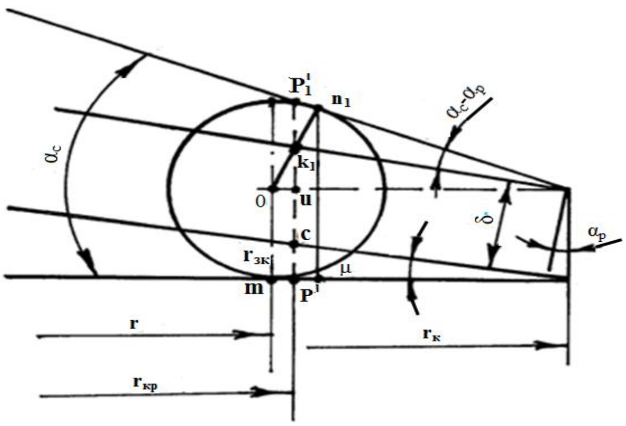

Figure. 2. To the analysis of the exit of particles of crushed material from the working chamber, which is determined by the position of the cross section $P_1^1P^1$.

II. MATERIALS AND METHODS

To obtain the desired dependencies, we take it with a slight simplification $n_1k_1 = \Delta$ (since relatively little r_3). Then from Fig. 2 we get:

$$n_1p_1 = \frac{\Delta}{tg(\alpha_c - \alpha_p)};\quad m\mu = r_{зк}\cdot\sin\alpha_c;\quad \mu P = n_1P_1\cdot\cos\alpha_c$$

$$n_1\mu = \delta/\cos\alpha_p + \mu P\cdot tg\alpha_c, \qquad n_1\mu = r_{3k}(1+\cos\alpha_c)$$

from here

$$\mu P = \frac{1}{tg\alpha_c}\left[r_{3к}(1+\cos\alpha_c)\delta/\cos\alpha_p\right] \text{ also}$$

$$\mu P = \frac{\Delta}{tg(\alpha_c - \alpha_p)}\cdot\cos\alpha_c$$

Equating the right-hand sides of the last two equations and, having carried out the corresponding transformations, we obtain an equation for calculating the final value (before leaving the working chamber) of the particle radius

$$r_{зк} = \frac{1}{1+\cos\alpha_c}\left[\frac{\delta}{\cos\alpha_p} + \frac{\Delta\cdot\sin\alpha_c}{tg(\alpha_c - \alpha_p)}\right]$$

(5)

As can be seen from Fig. 2, the position of the grain relative to the axis of rotation is easily determined from equation (3) with the corresponding substitution $r_z = r_{zk}$, and the working radius of the rotor (working chamber)

$$r_{кр} = r_к - P^1P$$

Because,

$$P_1^1P^1 = 2r_{зк},\quad UP_1^1 = 2r_{зк} - P_1P = 2r_{зк} - \delta/\cos\alpha_p \quad UP_1 = P^1P = (2r_{зк} - \delta/\cos\alpha_p)ctg\,\alpha_c$$

$$r_{кр} = r_к - (2r_{зк} - \delta/\cos\alpha_p)ctg\,\alpha_c$$

(6)

At the same time, the depth of the stator groove ($\kappa_1 P_1^1$)

$$h_{кс} = 2r_{кз} - \left[tg\alpha_p\cdot ctg\alpha_c\left(2r_{кз} - \frac{\delta}{\cos\alpha_p}\right) + \frac{\delta}{\cos\alpha_p}\right]$$

(7)

and the depth of the groove of the rotor (P^1C)

$$h_{кр} = tg\,\alpha_p\cdot ctg\,\alpha_c\left(2r_{кз} - \frac{\delta}{\cos\,\alpha_p}\right)$$

(8)

Research prof.S.V.Melnikova [Zavrazhnov A.I. and others. Mechanization of the preparation and storage of feed. M., "Agropromizdat", 1990.] the strength properties of cereal grains show a significant nonlinearity of the dependence of the strain on stress and the relative magnitude of the compression of the grains, which indicates the inconsistency of the characteristics of their elastically viscoplastic properties. The data on the destructive forces and deformations presented in this and other sources for various types of grain and the main loading schemes allow us to implement equations (5) and (6) and evaluate the parameters of the working chamber depending on the minimum possible size of the crushed particle. For example, for a working camera with parameters r_k=100mm, b=a=h_0=10mm, r_0=15mm with clearance δ=0 and fracture strains Δ=0,44mm (for barley) we get

$$\alpha_p = arctg\left(\frac{h_0}{r_\kappa - r_0}\right) = arctg\frac{10}{100-15} = 6{,}71^0$$

$$\alpha_c = arctg\left(\frac{2h_0}{r_\kappa - r_0}\right) = arctg\frac{2\cdot 10}{100-15} = 13{,}24^0$$

Here the height of the groove of the stator and rotor are equal. Substituting the obtained values of the angles in equation (5), we obtain [5, 6]

$$r_{з\kappa} = \frac{1}{1+\cos 13{,}24}\cdot\frac{0{,}44\cdot\sin 13{,}24^0}{tg\left(13{,}24^0 - 6{,}71\right)} = 0{,}445мм$$

those. the smallest possible diameter of the crushed particles d_{3min}=0,89mm.

In order for a particle of this diameter to freely leave the working chamber, it is necessary to reduce the outer radius of the rotor and stator to a value (6)

$$r_{\kappa o} = 100 - 0{,}89\frac{1}{tg13{,}^0 25} = 96{,}2мм$$

III. RESULT AND DISCUSSION

From equation (5) and Fig. 2 it can be seen that for $\alpha_c = 2\alpha_p$ the central point "0" of the particle will coincide with the point k_1 and the distance $k_1n_1 = r_{зк} = \Delta$ (for δ = 0).

For $\alpha_c > 2\alpha_p$, point 0 is located on the segment k_1n_1 and $r_{zk} < \Delta$.

For $\alpha_c > 2\alpha_p$ we get $k_1n_1 = \Delta$ for $r_{зк} < \Delta$.

Therefore, an increase in αc relative to αp leads to a finer grinding of the grain material. For example, when $\alpha_p = 7^0$, $\alpha_c = 30^0$, and Δ=0,44mm we get $r_{зк}$=0,27mm a $r_{кр}$=99mm.

Table 1 shows the results of calculating the limiting values of the particle diameters of the material d_{3k} at the outlet of the working chamber, as well as the necessary radii of the rotor and stator, providing free exit of the crushed particles.

Results of calculation of limit values of crushed particles d3 and working radii of rotor and stator GCR depending on height of grooves h0 at Δ=0,44 mm for GCR =60mm for GCR =60mm

Table 1

Estimated figures		h_0, mm			
		10	15	20	25
α_p^0		6,71	10,00	13,24	16,39
α_c^0		13,24	19,44	25,20	30,40
$(\alpha_c - \alpha_p)^0$		6,03	9,44	11,96	14,0
$\delta = 0$	$r_{зк}$, mm	0,445	0,453	0,464	0,477
	$d_{зк}$, mm	0,89	0,906	0,928	0,954
	$r_{кр}$, mm	97,01	97,40	98,02	98,37
$\delta = 0{,}5$ мм	$r_{зк}$, mm	0,609	0,714	0,734	0,757
	$d_{зк}$, mm	1,218	1,428	1,468	1,514
	$r_{кр}$, mm	96,96	97,76	97,97	98,31
$\delta = 1$ мм	$r_{зк}$, mm	0,864	0,976	1,003	1,036
	$d_{зк}$, mm	1,728	1,952	2,006	2,072
	$r_{кр}$, mm	96,92	97,34	97,92	98,24
$\delta = 1{,}5$ мм	$r_{зк}$, mm	1,119	1,234	1,23	1,316
	$d_{зк}$, mm	2,238	2,468	2,546	2,632
	$r_{кр}$, mm	94,64	65,89	96,77	97,29
$\delta = 2$ мм	$r_{зк}$, mm	1,374	1,499	1,543	1,596
	$d_{зк}$, mm	2,748	2,998	3,086	3,192
	$r_{кр}$, mm	92,59	94,39	95,62	96,37

From table 1 it is seen that the growth of αp and αc with the equal height of the grooves of the rotor and stator at the input leads to an increase in d_{zk} and r_{kp} for all values. An increase in only the gap at fixed values of α_p and α_c leads to an increase in d_{zc} and a decrease in r_{kp}.

IV. CONCLUSION

With an increase in the angle of inclination of the stator plate relative to the angle of inclination of the rotor groove, finer grinding of the grain material occurs.

An increase in the values of the slope of the stator plate and the rotor groove, and if the heights of the rotor and stator grooves at the inlet of the outer radius of the working chamber are equal, lead to an increase in the limiting value of the particle diameter of the material for all values of the crushed particle.

The increase in the gap with fixed values of the angles of inclination of the stator bottom and the stator groove leads to an increase in the limiting value of the diameter of the schastits and a decrease in the radius of the working chamber.

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