ROCKS CUTTING PARAMETERS OF INDUSTRIAL MINING SYSTEMS

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Abstract: The share of coal mining within the global mining industry, as well as the nature and physical-mechanical properties of coal, they favored and determined the continuous development of mechanization systems specific to their extraction process. A significant moment regarding the evolution in the mechanization of coal mining, it was represented by the emergence of mining combines that represent infrastructures of high complexity that can ensure the complete mechanization of the extraction process and its performance in continuous flow. Mining combines are high-productivity machines that allow simultaneous execution of cutting, crushing and loading of dislocated material from the working front. The main advantages that characterize them against other means of exploitation are: the rhythmic development of the work process in the abattage; the improvement of the conditions for directing the mining pressure; the increase of the speed of advancement of the front, increase production and labour productivity; improve working conditions and safety. In this paper, the authors analyze the parameters of cutting rocks by the following methods: cutting with a single knife, the following, cutting with groups of knives and cutting with executing organs and how the knives behave in the production process.

Keywords: rocks cutting parameters, industrial mining systems.

1. INTRODUCTION

Cutting is the process of splitting splinters in the presence of two free surfaces. The knife is a wedge-shaped instrument that penetrates the rock under the influence of the F_y advance force, at depth H (thickness of the splinter) and moving parallel to the front surface with cutting force F_z. The knife makes the cutting of rocks in the chips. On the knife acts parallel to the vector of the travel speed v, the cutting force F_z, and perpendicular to the velocity vector v on the knife, the forward force F_y acts. The knife is the only tool that can dislocate any kind of rocks (fragile or plastic). Thus, dislocation

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can also occur fragile, plastic or mixed, depending on the nature of the rocks and their dislocation properties. [1, 3]

The rock dislocation process involves the following phases (fig.1):

- under the force action of F_z the knife deforms the volume of V_o into the rock, forming a compression core. The compression core moves in the direction of the F_z force and defeating the P reaction of the surrounding rocks, causes the second volume of rock V to detach;
- the knife then moves without resistance from the rock, but after a very short time the rock resists again and the cycle repeats**.**

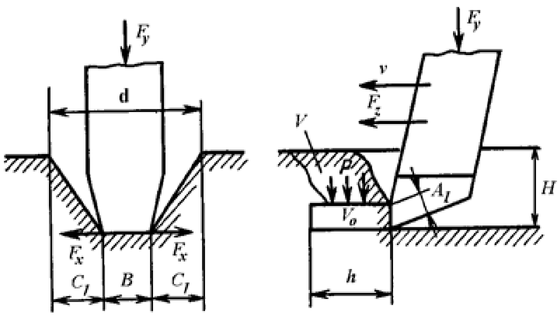

Fig. 1. Scheme of cutting rocks with the help of knives

As you can see, the knife performs cyclic dislocations, and the knife movement speed and forces change periodically over time with the T period (fig. 2). Plastics break almost without interruption, but still some changes in the size of V, F_z and F_x occur. In mixed rocks, cyclic dislocation is evident even if at the time of detachment of the rock volume V , the F_z force does not decrease to the value 0. [1, 2]

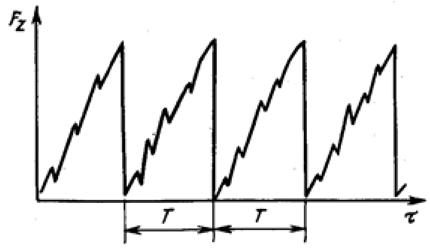

Fig. 2. The nature of the dependence of force cutting Fz according to time τ

2. DETERMINATION OF CUTTING PARAMETERS

2.1. Cutting with a single knife

The main parameters for cutting rocks using knives are determined as follows. If the thickness of the knives is B and the width of the edge of the tais is A_1, then the surface of the contact of the tais with the rock will be:

$$S = A_1 B \tag{1}$$

The value of the massif reaction to the expansion of the compression core is equal to the ratio between the force required to dislocate the volume V of rock, σS_p and the actual S_{Vo} surface of the compression core:

$$P = \sigma S_p / S_{Vo} \tag{2}$$

where:

- *compressive strength;*
- *S_p - dislocation surface, that is the section surface, after which the volume V of rock breaks off from the massive.*

This size can be written as follows:

$$S_p = Vb / H \tag{3}$$

where:

- *V - volume of rock detached in a cutting cycle;*
- *H - splinter thickness.*

The relationship (3) shows the interdependence of the main parameters of knife cutting. In this relation, b is the form coefficient of volume V. If b = 1, then according to S_p only one side surface of volume V (fig is considered. 3). The second side surface and the front surface formed in front of the knife must be taken into account with the coefficient b. It is obvious that the size of the S_p surface depends on the working conditions of the knife, that is, whether the knife works alone or with the adjacent knives[1, 4]

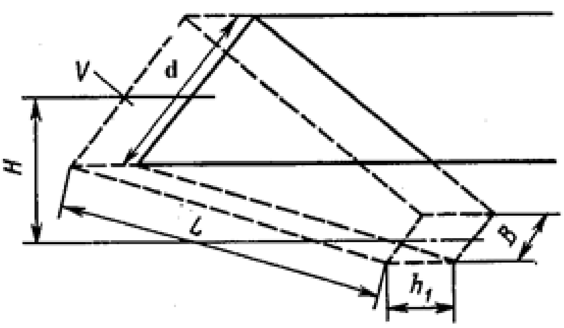

Fig. 3. Theoretical scheme for single knives

If the knives work together, the amount of rock detached for each knife is:

$$V = Hh_1d \tag{4}$$

where:

- *h_1 - the width of the volume prism V in the direction of the movement of the knife;*
- *d – the distance between the cutting lines.*

In this case, the surface of the rock dislocation is:

$$S_p = Ld \tag{5}$$

where:

- *L - length of the formed front surface.*

Fig. 3 shows that when knives work together, the dislocation of rocks is carried out in the direction of their movement.

By using equality (3), (4) and (5), we will have:

$$Lt = Hh_1 db / H \tag{6}$$

where from:

$$b = L / h_1 \tag{7}$$

For a single knife, the size L of the dislocation surface is identical for the side and front surfaces, so we will have:

$$V = 0,5(B + d)Lh_1 \tag{8}$$

The area of the dislocated surface is:

$$S_p = 2Lh_1 + 0,5(B + d)L = 0,5L(4h_1 + B + d) \tag{9}$$

From here: $4h_1 << B+d$

$$S_p = 0,5L(B + d) \tag{10}$$

Using the above relationships, we will have:

$$0,5L(B + d) = (B + d)Lh_1 b / H \tag{11}$$

and:

$$b = 2H / h_1 \tag{12}$$

Comparing relationships, it follows that when cutting with a single knife, b is twice as big as when cutting with multiple knives. About the size h_1 we can say that it is smaller than h. If F_z increases, H increases, and correspondingly h_1.

Taking $h_1 \cong H$ of the relation (31) for compound cutting, and considering that $L = \sqrt{H^2 + h_1^2}$ we will have: $b = \sqrt{2}$

For single knives in the relation (12) it follows that b = 2.

From the figure it is seen that the surface area of the Sv_0 compression core, on which the reaction of the massive P force acts, is equal to:

$$S_{Vo} = Bh + 2A_1 h = h(B + 2A_1) \tag{13}$$

Usually B>>A1 , that's why you can write:

$$S_{Vo} = Bh \tag{14}$$

Are observed B ≥ 10mm and A1 ≥ 1mm.

$$P = sb\ V / \left(HBh\right) \tag{15}$$

where:

- *h - the size of the compression core in the direction of the force action F_z .*

The distance at which the action of the F_o force can be determined from the relation (16) considering the limit of resistance: σ_o = 0,1 E, where E is the longitudinal modulus of elasticity.

$$h = F_o / (\sigma_o B) \tag{16}$$

Size:

$$V_o = A_1 B\ h \tag{17}$$

Using size h, we have:

$$P = sb\ Vs_o / \left(H\ F_z\right) \tag{18}$$

$$V_o = A_1 F_z / s_o \tag{19}$$

$$A = \frac{2V_o \mu PF}{ES} - \frac{V_o P}{2E_o} \tag{20}$$

The first dimension to the right of equality is the effort of the compression core, without taking into account its deformation under the effect of the P reaction, and the second dimension is the effort of deformation of the compression core under the effect of the P reaction.

$$A = \frac{2\mu F_z \sigma bV}{BEH} - \frac{3A_1 \sigma^2 b^2 V^2 \sigma_o (1-2\mu)}{2H^2 EF_z} \tag{21}$$

It follows that the effort made by the compression core depends on the dislocation parameters of the rock F_z, V, B, H, A_1 and the properties of the rock σ, E and μ. The E and E_o sizes depend very little on the F force, so we can consider them constant. Using size A, we can formulate the relationship of the law of conservation of energy for cutting rocks with knives:

$$A = \frac{2\mu F_z \sigma bV}{BEH} - \frac{3A_1 \sigma^2 b^2 V^2 \sigma_o (1-2\mu)}{2H^2 EF_z} = \frac{\sigma^2 kV}{E} \tag{22}$$

We can determine the volume size V in a dislocation cycle:

$$V = \frac{2H^2 F_z \mu}{3A_1 \sigma b \sigma_o B(1-2\mu)} \left[\frac{2\mu F_z k}{BH} - \sigma k \right] \tag{23}$$

Assuming that V=0, we can determine the minimum force of the cut, which performs the dislocation of the rock with a thickness of the chips H:

$$F_{zmin} = sk\ B\ H\ \ /\,(2mb) \tag{24}$$

If we write the relationship (23) in the form:

$$V = \frac{4H^2 F_z \mu}{3A_1 \sigma b \sigma_o B(1-2\mu)} - \frac{2H^2 F_z k}{3A_1 b^2 \sigma_o (1-2\mu)} \tag{25}$$

it will follow that the volume of the V rock, cut in a dislocation cycle, is, moreover, also a function of H, that is, the thickness of the splinter. The thickness of the chip is a technological parameter whose value can be imposed. Can formulate the relationship:

$$\frac{\partial V}{\partial H} = \frac{4F_z^2 \mu}{3A_1 \sigma b \sigma_o B(1-2\mu)} - \frac{4HF_z k}{3A_1 \sigma (1-2\mu)\sigma_o} \tag{26}$$

where to determine the optimal thickness of the chip:

$$H_{opt} = mF_z b\ \ /\ \ (sBk) \tag{27}$$

After the size given by H in the relationship (27), we will determine the cutting force on the knife, which provides an optimal cutting regime for the rock:

$$F_{zopt} = sB\ k\ H\ \ /\,(mb) \tag{28}$$

Comparing $F_{z\ min}$ from the relationship (24) and F_{zopt} from the relationship (28), we get that the optimal size F_{zopt} is twice the minimum F_{zmin} .

At an optimal thickness of the H_{opt} chip in the relationship (27), the volume V of the rock, cut in a dislocation cycle, will be maximum.We will determine the size of V_{max}, the, introducing into the relationship (24) H_{opt} .

$$V_{\max} = \frac{2F_z^3 \mu^2}{3A_1 \sigma^2 b^2 \sigma_o B^2 (1-2\mu) k} \tag{29}$$

Volume V_{max} determines the productivity of cutting rocks with knives. From the relationship (28) it follows that V_{max} is proportional to F_z^3. We determine H_{opt} from the relationship (27) and obtain V_{max} as a function of the thickness of the chip:

$$V_{\max} = \frac{2\sigma B k^2 H^3}{3A_1 b^2 \sigma_o (1-2\mu) k} \tag{30}$$

Because:

$$\frac{2\sigma B k^2}{3A_1 b^2 \sigma_o (1-2\mu)k} < 1 \tag{31}$$

when H is raised, V will grow less than H^3.

Specific energy consumption in the rock dislocation process using knives:

$$q = Q / V \tag{32}$$

where:

- *Q - the energy consumed for the dislocation of the volume V (determined as the work of the force F_z to the deformation of the rock mass V).*

When forming the compression core with the knife:

$$Q = F_z \times Dh \tag{33}$$

The size Δh will be determined as an absolute deformation of the compression core according to the depth.

$$Dh = he = h F_z / (SE) \tag{34}$$

Using the size h in the relationship (1.40) and the size S in the relationship above we get:

$$Dh = F^2 / (E A_1 B^2 s_o) \tag{35}$$

Considering Δh we will determine the energy consumed by the knife when cutting the volume V of the rock in a dislocation cycle:

$$Q = F^3 / (E B^2 A_1 s_o) \tag{36}$$

Specific energy consumption will be minimal in the knife cutting process only if the chip thickness is optimal, and the volume of the rock cut in a dislocation cycle will be minimal V_{max}.

By introducing Q and V_{max} from the above relationship, we obtain the minimum specific energy consumption:

$$q_{\min} = \frac{3\sigma^2 (1-2\mu)k}{2\mu^2 E} \tag{37}$$

The relation for q_{min} can be written:

$$q_{\min} = \frac{\sigma^2 k}{E} \frac{3(1-2\mu)}{2\mu^2} \tag{38}$$

$$\frac{3(1-2\mu)}{2\mu^2} \quad cu \quad \frac{1}{\eta} \tag{39}$$

result:

$$q_{\min} = \frac{\sigma^2 k}{E}\frac{1}{\eta} \tag{40}$$

The specific energy consumption shall be determined as the ratio between the specific energy consumption at rock dislocation σ^2k/E and the efficiency of the mechanical work of compression η.

We will write the relationship (57) in the form:

$$\Delta h = hs_o a / E \tag{41}$$

where F_za/S=σ_0 and a >1. Replacing h, we get:

$$\Delta h = F_z a / (BE) \tag{42}$$

Therefore, using Δh we determine:

$$Q = F_z^2 a / (BE) \tag{43}$$

By introducing the Q and V_{max} sizes, we obtain the minimum specific energy consumption when cutting with knives, in the form of:

$$q_{\min} = \frac{3A_1\sigma^2 B\sigma_o a(1-2\mu)k}{2EF_z\mu^2} \tag{44}$$

or:

$$q_{\min} = \frac{\sigma^2 k}{E}\frac{3(1-2\mu)}{2\mu^2} - \frac{A_1 B\sigma_o a}{F_z} \tag{45}$$

Taking into account the size η , we get:

$$q_{\min} = \frac{A_1\sigma^2 B\sigma_o ak}{E\eta F_z} \tag{46}$$

From here it follows that at the increase of the cutting force F_z , the specific energy consumption when cutting rocks using knives decreases.

If we exclude the thickness of the H_{opt} chip:

$$q_{\min} = \frac{3A_1\sigma(1-2\mu)ba\sigma_o}{2E_z\mu H_{opt}} \tag{47}$$

At an increase in the thickness of the chip, the specific energy consumption decreases. Therefore, in order to achieve increased productivity and lower specific energy consumption, it is preferable to increase the cutting forces and the thickness of the chip.

To determine the width of the chip in a single cut, it starts from the relationship of the cutting depth of the chip:

$$d = B + 2C_1 \tag{48}$$

where:

- *C_1 - is determined as for the chip from the second free surface under the action of the F_x force after the relation (49)*

$$F_{\min} = \sigma kHB / (2\mu) \tag{49}$$

If the force on the knife is greater than F_{min}, then the dislocation of the rock takes place, and if it is less than F_{min}, the dislocation of the rock will not take place.

The F_x force is expressed through the relationship:

$$F_x = F_z 2\, A_1 h \;/\; (Bh) \tag{50}$$

where the coefficient of proportionality is taken as the ratio between the surface by which the force F_x ($A^2_1/2$) and the force F_y (A_1 B) acts. By introducing Fx from the relationship (50) into the relationship (1.49) we obtain:

$$C_1 = \frac{2\mu F_z^2}{3B^3\sigma b\sigma_o(1-2\mu)k} \tag{51}$$

The above relationship allows us to determine the thickness of the rock chip with a single knife at a free cut.

Cutting with several knives, as well as cutting rocks under conditions of blockage of surface limited dislocation are explained below:

The advance force F_y can be determined from two conditions:

- 1 - the knife to cut a new layer of the additional free surface;
- 2 - the knife enters the rock under the action of the F_y force at depth H.

In the first case the F_y force must hold the knife to the given depth so that the knife continuously cuts the H-thick chip. In the second case the knife should be inserted at depth H in the presence of a free surface and then be kept at this depth in the rock cutting process. It is obvious that in the second case the size of the advance force F_y must be greater than in the first case. These cases are extreme cases. Variations between these limits are also possible. We will continue to study these variants.

It is assumed that the B-width knife enters the massif of the rock limited by a free surface under the action of F_y force. When the knife is inserted into the rock at the depth Δh, the volume V cutting of the rock occurs on the free surface, after which the knife deepens in the rock massif at depth H and further moving the knife parallel to the free surface takes place cutting the rock in nominal regime. Thus in this case, it is necessary to solve the problem of cutting the rock to a free surface by inserting the knife into the rock, having the angle of release γ. This problem is solved by the method used to calculate the penetration of a punch in the rock. [1, 5]

Fig.4 shows the relation 52:

$$\Delta h = he = F_y / (SE) \quad (52)$$

where:

$$S = B\,l \quad (53)$$

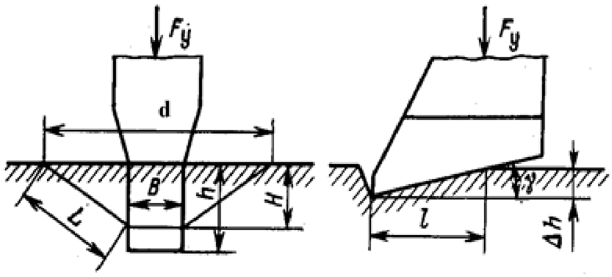

Fig. 4. The scheme of introducing the knife into rock under the action of the Fy advance force

So:

$$L = \Delta h_c (tg\gamma)^{-1} = 2\Delta h\ (tg\gamma)^{-1} \quad (54)$$

Taking into account the size h and replacing S from the relation 1.53, we get:

$$S = 2\,B\Delta h\ (tg\gamma)^{-1} \quad (55)$$

Using size h and S we will get the relationship:

$$H_{opt} = \mu F\ / (\sigma B\ k) \quad (56)$$

$$\Delta h = \frac{F_y}{B^2 \sigma_o E l} = \frac{F_y}{2\sigma_o B^2 E \Delta h (tg\gamma)^{-1}} \quad (57)$$

Since Δh changes from Δh_{max} to zero, we will determine the average size:

$$\Delta h_{med} = \frac{F_y}{B(2E\sigma_o (ctg\gamma)^{1/2}} \quad (58)$$

Using Δh_{med} we determine the surface of the contact of the knife with rock:

$$S = 2F_y\sqrt{tg\gamma}\,/\,(2E\sigma_o)^{1/2} \quad (59)$$

Compression core volume:

$$V_o = S\ h \quad (60)$$

Introducing S and h we get:

$$V_o = F_y^{\,2}\sqrt{2tg\gamma}\,/\,(B\sigma_o\sqrt{E\sigma_o}) \quad (61)$$

The P-size is determined after the relation 26, and the S_p is the cross-sectional area of the chip.

The newly formed surface can be calculated as follows:

$$S_p = L\ B_2 + 2\ L\ A_1 = 2\ L\ (2\ +\ A_1) \quad (62)$$

where L-size of the dislocation surface

Because B>>A , we can write:

$$S_p = 2\ L\ B \quad (63)$$

Dislocated volume of rock:

$$V\ = B\ H\ d\ /\ 3 \quad (64)$$

Using the above equality we obtain:

$$2\ L\ B\ = B\ H\ d\ b\ /\ (3H)$$

from where:

$$b\ = 6\ L\ /\ d \quad (65)$$

The angle between L and t is close to 30^o. That is why we can write:

$$d\ = 2\ L\ cos\ 30^o \quad (66)$$

From where result: b=$2\sqrt{3} \cong 3.5$.

From fig.4 result:

$$S_{Vo} = 2\ h\ B\ +\ 2\ h\ l\ =\ 2\ h\ (\ B\ +\ l\ ) \quad (67)$$

Since B>>l, we can write:

$$S_{Vo} = 2\ h\ B \quad (68)$$

Considering h, we get:

$$S_{Vo} = 2\, F_y / \sigma_o \tag{69}$$

By introducing the sizes S_p and S_{vo}, we will have:

$$P = \frac{\sigma V \sigma_o b}{2 F_y H} \tag{70}$$

The above relations allow the determination of the work performed by the compression core, provided that the cutting takes place on a single free surface:

$$A = \frac{\mu \sigma V F_y \eta b}{EHB} - \frac{3(1-2\mu)\sigma^2 V^2 \sigma_o b^2 \sqrt{2tg\gamma}}{8BEH^2 \sqrt{E\sigma_o}} \tag{71}$$

The conservation law of energy in this case has the form:

$$\frac{\mu \sigma V F_y \eta b}{EHB} - \frac{3(1-2\mu)\sigma^2 V^2 \sigma_o b^2 \sqrt{2tg\gamma}}{8BEH^2 \sqrt{E\sigma_o}} = \frac{\sigma^2 k V}{E} \tag{72}$$

We will determine the volume of dislocated rock:

$$V = \frac{8BH^2 \sqrt{E\sigma_o}}{3(1-2\mu)\sigma \sigma_o b^2 \sqrt{2tg\gamma}} \left(\frac{\mu b F_y \eta}{HB} - \sigma k \right) \tag{73}$$

Assuming V = 0 is determined:

$$F_{ymin} = \sigma k\ H\ B / (\mu b \eta) \tag{74}$$

For the given rock, if $F_y > F_{ymin}$ will take place the dislocation of the volume V of rock and the knife will penetrate to the depth H. One can consider F_{ymin} as a force of advance, if this size increases by 10-15%, that is:

$$F_y = 1{,}1 \sigma k\ H\ B / (\mu b \eta) \tag{75}$$

Comparing F_z and F_y from the above relations we obtain:

$$F_y / F_z = 1{,}1 / \eta \tag{76}$$

that is, the advance force for inserting a single knife increases the cutting force approximately 13 times.

If the knives are arranged in such a way that they cut the rock together, then, b= $\sqrt{2}$, so:

$$F_y / F_z = 1{,}1 / \eta \tag{77}$$

it follows that when placing knives working together in the limited massif with a single free surface, the cutting force F_z is less than the advance force 10 times; thus we will have very large sizes for the advance force, which in some cases are difficult to achieve in practice, this and because the resistance of the knife may be small. In such cases, the gradual introduction of the knife as it moves along the trajectory is used.

We will analyze the case where the F_y advance force is only necessary to keep the knife at depth H, that is, ensuring the nominal cutting regime. We break down the F_y advance force after the N and W components and determine the G force, directed towards the rock dislocation surface. The force vector G is pointing in the direction opposite to the vector W and does not allow the knife to slip on the dislocation surface, thus preventing the knife from exiting on a free surface. The N-force forms the F_f friction force on the newly formed surface, which prevents the knife from sliding on this surface. [1, 6]

$$F_f = N f \tag{78}$$

where:

- *f - the coefficient of friction of the knife material on the surface of the rock.*

From fig. 5 we determine:

$$N = F_y cos\alpha \tag{79}$$

$$W = F_y sin\alpha \tag{80}$$

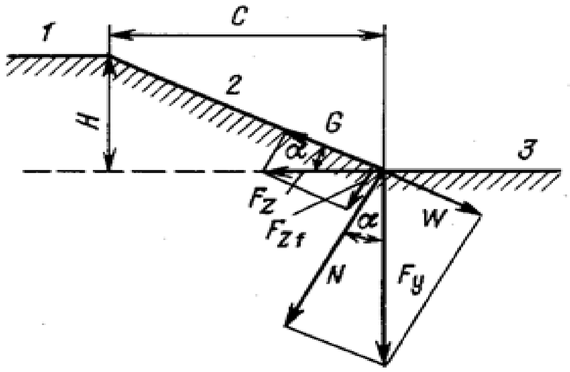

Fig. 5. Scheme for calculating the advance force Fy
1 – old front surface; 2 – chip surface; 3 – new front surface

In the absence of movement of the knife on the dislocation surface:

$$W + F_f + F_z f \sin\alpha > G \tag{81}$$

or, if we consider the N-sizes in the relationship (80) and W in the relationship (81), we get:

$$f\ F_y \cos\alpha + F_y \sin\alpha + F_z f\ \sin\alpha > F_z\ \cos\alpha \tag{82}$$

where can we determine the required size of the advance force:

$$F_y > \frac{F_z(\cos\alpha - f\sin\alpha)}{\sin\alpha + f\cos\alpha} \tag{83}$$

The sizes fsinα and fcosα are small compared to sinα and cosα, because f does not exceed the value of 0,5; therefore we will be able to omit the first sizes. Then we can write:

$$F_y > F_z\, ctg\,\alpha \tag{84}$$

From fig. 5. result that:

$$ctg\,\alpha \geq c / H \tag{85}$$

size C is determined with the relation (86).
If V = V_{max}, we will have:

$$C = \frac{4\mu F^2}{3B^2\sigma b\sigma_o A_1(1-2\mu)k} \tag{86}$$

That's why:

$$F_y \geq \frac{4kF_z^{\,2}}{3BA_1\sigma_o(1-2\mu)} \tag{87}$$

The relation of the advance force and the cutting force becomes:

$$\frac{F_y}{F_z} \geq \frac{4kF_z}{3BA_1\sigma_o(1-2\mu)} \tag{88}$$

Taking into account the thickness of the chip, the last relationship can be written as follows:

$$\frac{F_y}{F_z} \geq \frac{4F_z^{\,2}\mu b}{3B^2A_1\sigma_o(1-2\mu)H} \tag{89}$$

If the F_z size is constant and the chip thickness increases, the F_y/F_z ratio will decrease. In any case, the advance force is determined after the above relationship, expressing the cosα and sinα through the following known sizes:

$$\cos\alpha = C / \sqrt{C^2 + H^2} \tag{90}$$

$$\sin\alpha = H / \sqrt{C^2 + H^2} \tag{91}$$

If we assume that only the cutting force F_z (see fig.1.10) acts on the knife, then, by superimposing this force over the force G, directed at the surface of the rock chip and over F_{zf}, by, perpendicular to this surface, we will find that the G-force tends to move the knife towards the surface of the chip, and the F_{zf} friction force acts contrary to it: G = $F_z$cosα. But the friction force, which is a component of F_z, that is, $F_z$fsinα , may be too small to compensate for the action of the force G, and the knife may slip on the newly formed surface of the chip 2, leaving the old surface 1, and as a result the cutting process to end.

If the coefficient of friction f is high, it may happen that the cutting process occurs only in the presence of the cutting force F_z . In order to compensate for the G = F_z f sinα force difference, it is necessary to introduce the W force against the G force. The W-force appears as a result of the distribution of the F_y-force, which in this case is the advance force. The downside of introducing F_y force is that there is a considerable, important friction force that leads to knife wear.

$$F_y \geq F_z (C - H f) / (H - C f) \approx C F_z / H \tag{92}$$

In general form,

$$F_y \geq F_z \frac{4F_z k - 3bfB\sigma_o A_1(1-2\mu)}{4F_z kf + 3bBA_1\sigma_o(1-2\mu)} \tag{93}$$

The F_y/F_z relationship takes the form:

$$\frac{F_y}{F_z} \geq \frac{4F_z k - 3bfB\sigma_o A_1(1-2\mu)}{4F_z kf + 3bBA_1\sigma_o(1-2\mu)} \tag{94}$$

from which we do not see the influence of the thickness of the splinter on the size of F_y, but it follows that the advance force F_y will be much lower than the determined one. From here it follows that the most correct would be to start cutting on an additional free surface. Since this is relatively difficult to achieve due to the lack of an additional free surface, it is practiced to gradually introduce the knife into the rock massif as the knife moves towards the front. In a cycle of the front, at a complete rotation of the executing organ, the knife must be inserted into the massif at depth H. Thus, the dislocation of the rock must take place continuously, observing all the extreme conditions. The introduction of the knife into the massif occurs after the dislocation of the volume V of rock, when the force of F_z acting on the knife decreases as a result of the decrease of the knife movement resistance on the rock side. At this point the knife enters the massif at the size of ΔH, because the cutting process takes place on the newly formed surface. At a single knife pass on the trajectory, that is, at a rotation on the circumference, L_H =2π R0, where:

R_0 - the radius of the circumference after which the knife moves.

The number of volumes V cut is expressed by the size:

$$n_1 = L_H / h_2 = 2\pi R_o / h_2 \tag{95}$$

where h_2 is smaller than h, determined by the formula (40), that is, h_2 = ha , where a - subunit numerical coefficient. That is why:

$$n_1 = 2\pi R_o B\sigma_o a / F_z \quad (96)$$

The size ΔH we will report to the number of volumes V resulting at a complete rotation of the executor: ΔH = H/n or taking into account the size n of the relation (1.96) we will obtain:

$$\Delta H = HF_z / (2\pi R_o B\sigma_o a) \quad (97)$$

Because the cutting force is proportional to the chip thickness of the H & the F_y advance force is dependent on the F_z cutting force by a coefficient, the increase in the advance force of F_y is proportional to the increase in the chip thickness, that is, ΔH. Therefore, the total cutting force is:

$$F_z = F_z H + \Delta F_z \quad (98)$$

The size of F_zH can be determined with the above relationship, that why:

$$F_z = \frac{\sigma Bk}{\mu b} H + \frac{\sigma Bk}{\mu b} \Delta H = \frac{\sigma Bk}{\mu b} H (1 + \frac{\Delta H}{H}) \quad (99)$$

but from the above relationship it follows that ΔH/H = 1/n.

$$F_z = \frac{\sigma Bk H_{opt}}{\mu b} \left(1 + \frac{F_z H}{2\pi R_o B\sigma_o a} \right) \quad (100)$$

Introducing the size of F_y we will get :

$$F_y = \frac{\sigma Bk H_{opt}}{\mu b} \left(1 + \frac{F_z H}{2\pi R_o B\sigma_o a} \right) \left(\frac{C - Hf}{H + Cf} \right) \quad (101)$$

From here result that for the gradual introduction of the knife into the massif in a rotation of the executing organ at a depth equal to the thickness of the H_{opt} chip, an increase in the advance force and bringing these forces up to a size determined by the formulas (100) and (101).

From the above relations result that the size of the forces for knives, established for different rays of the executing organ, must be different: [2, 6]

- for knives installed at greater distances from the center of rotation, the size of the forces is half a percent;
- for knives at smaller distances from the center of rotation, the size of the forces is a few percent.

This is due to the fact that at small rays of the knife's trajectory there are fewer rock dislocation cycles.

If the path of movement of the knife is rectilinear, then the corresponding relations take the form:

$$F_z = \frac{\sigma BkH}{\mu b}\left(1 + \frac{F_z}{HB\sigma_o}\right) \tag{102}$$

$$F_y = \frac{\sigma BkH}{\mu b}\left(1 + \frac{F_z}{HB\sigma_o}\right)\left(\frac{C - Hf}{H + Cf}\right) \tag{103}$$

Thus, a low-value F_z cutting force allows the knife to be inserted into a single cycle at a distance equal to the thickness of the H_{opt} chip without using too much forward force. The above considerations are valid for flat surfaces of the knife edge. In practice, this form of knives is common, but the rounded shape of the knife edge is also used, with a rounding radius R.

$$r = \sqrt[3]{F_o R / E} \tag{104}$$

$$S = 2rB = 2B\sqrt[3]{\frac{F_z R}{E}} \tag{105}$$

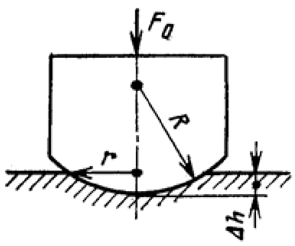

Fig. 6. Scheme for calculating the introduction of the instrument cutting spherical head with radius R in the rock massif r – surface of contact between instrument and rock

Using size S, we get the volume of the compression core V_0, given by the relation :

$$V_o = 2B\frac{F_z}{B\sigma_o} = 2B\sqrt[3]{\frac{F_z R}{E}} \tag{106}$$

By introducing the V_o and S sizes for the rounded-edged knife in the formula for determining the effort received from the compression core, the effort size A will be expressed. Based on the amount of effort A obtained, write the equation of conservation of energy for the dislocation of the rock using a rounded-edged knife, from which the volume of the rock is determined, cut by the compression core in a dislocation cycle:

$$V = \frac{H^2 F_z \sqrt[3]{E}}{3\sigma b\sigma_o(1-2\mu)\sqrt[3]{F_z R}}\left(\frac{2\mu F_z b}{BH} - \sigma k\right) \tag{107}$$

From here, by solving the equation ∂V/ ∂H = 0, we determine the optimum thickness of the H_{opt} chip, the size of which in the given case is equal to that of the flat-edged knife. Correspondingly, the cutting force in this case will be equal to the size obtained in the above formula. After entering the H_{opt} size in the relationship (1.107), we determine the maximum size of the rock volume , cut into a dislocation cycle:

$$V_{\max} = \frac{\mu^2 b F_z^3 \sqrt[3]{E}}{3\sigma^2 (1-2\mu)\sigma_o B^2 k \sqrt[3]{F_z R}} \tag{108}$$

The specific energy consumption when cutting the rock using the rounded-edged knife is determined by the above formula, where the Q energy consumed for cutting the volume of V_{max} is equal to:

$$Q = \frac{F^3 \sqrt[3]{E}}{2\sigma_o B E \sqrt{F_z R}} \tag{109}$$

The size of the penetration of the knife into the rock before the dislocation of the rock is:

$$\Delta h = \frac{F^2 \sqrt[3]{E}}{2\sigma_o B E \sqrt{F_z R}} \tag{110}$$

Depending on the amount of Q energy consumed for cutting the volume of V_{max} in a dislocation cycle and the volume size of V_{max} , the specific energy consumption when cutting with knives is calculated. The calculations made show that there is no difference between the specific energy consumption when cutting the rock with a rounded edged knife and the specific energy consumption when cutting the rock with a flat-edged knife. The dislocation step and the advance force for the rounded-edged knife will be the same as for the flat-edged knife. It should be noted that this conclusion refers only to the optimal cutting regime. [3, 4]

The productivity of the knife cutting process can be expressed as the ratio between the volume of displaced rock V and the time consumed when cutting:

$$P_t = V / \tau \tag{111}$$

From the above figure we will determine the volume cut in a cycle:

$$V = 0{,}5\left(d + B\right)H\ h_1 \tag{112}$$

where to determine h_1 – linear volume size V in the direction of knife movement:

$$h_1 = 2V / \left[H\left(d + B\right)\right] \tag{113}$$

The time taken to cut volume V is:

$$t = h_1 / V = 2 / \left[H\left(d + B\right) \right] \tag{114}$$

We enter the τ size in the relation (136) , achieving cutting productivity:

$$P_t = 0{,}5\, H\, v\, \left(d + B \right) \tag{115}$$

From here result that the productivity of the cutting depends on the speed of the knife movement, the thickness of the chip, the cutting step d and the thickness of the knife B. Since H and d are maximum in the optimal regime, then it follows that the optimal effort ensures maximum cutting productivity of the rock.

We will introduce in the last relation the size of the cutting step, taken from the above relation and we will obtain:

$$P_t = H\, v\, \left(C_1 + B \right) \tag{116}$$

or, using H and C sizes, we will express the productivity of cutting rocks as a function of the properties of the rock and the cutting parameters, as follows :

$$P_t = \frac{F_z \mu V}{\sigma B k}\left(\frac{2\mu F_z^{\,2}}{3B^3 \sigma b \sigma_o (1-2\mu) k} + B \right) \tag{117}$$

From here result that productivity increases proportionately to the third power of the cutting force, the speed of the knife movement, and decreases proportionately to the square of the resistance of the displaced rock.

To determine the knife effort in normal regime, from the above relationship we will explain the thickness of the chip:

$$H = \frac{F\mu b}{\sigma B k} - \frac{F\mu b}{\sigma B k}\sqrt{1 - \frac{3VkA_1 B^2 \sigma^2 \sigma_o (1-2\mu)}{8\mu^2 F^2}} \tag{118}$$

If the condition is met:

$$\frac{3VkA_1 B^2 \sigma^2 \sigma_o (1-2\mu)}{8\mu^2 F^3} \to 1 \tag{119}$$

then the thickness of the chip tends to the optimal one.

Optimal condition:

$$3VkA_1 B^2 \sigma^2 \sigma_o (1-2\mu) = 8\mu^2 F^3 \tag{120}$$

it may not be respected due to the use of the knife, that is, the increase of A_1 and the decrease of the dislocated volume V. To compensate for the negative influence of knife use and increase the resistance of the rock, you can act in two ways:

- the cutting force is increased;

- if the first case is impossible, then it is necessary to decrease the size of the dislocated volume V, that is, to decrease the thickness of the chip.

$$3VkA_1B^2\sigma^2\sigma_o(1-2\mu)/8\mu^2F^3 \to 0 \quad (121)$$

Thus, when the knife wear increases, the cutting force is constant and A_1 increases, the chip thickness decreases. From the above relationship we determine the cutting force:

$$F_z = \frac{H\sigma Bk}{4\mu b} - \frac{H\sigma Bk}{4\mu b}\sqrt{1-\frac{12\mu VA_1b^3\sigma_o(1-2\mu)}{\sigma BH^3k^2}} \quad (122)$$

From here result that:

$$12\mu VA_1b^3\sigma_o(1-2\mu)/\sigma BH^3k^2 \to 0 \quad (123)$$

the cutting force tends to an optimal size, determined by the formula (54). The decrease of this size is possible by decreasing the width of the knife cutting edge, A_1. If H and V are kept constant, then the force of F_z will increase in proportion to the increase in the width of the cutting edgewhen the knife $\sqrt{A_1}$ will wear out; and in order to maintain the dislocation productivity, an increase in the cutting force is required.

In order to determine the specific energy consumption at the dislocation of the rock in general, we start from the above relations and get:

$$q = \frac{3F^2\sigma b^2(1-2\mu)}{2EBH(2F\mu b-2Hk\sigma B)} \quad (124)$$

From here result that if the cutting force is constant, the decrease in the thickness of the H-chip occurs as a result of the increase in the width of the knife cutting edge, that is, because of its use, and the specific energy consumption at dislocation increases.

$$C = 2V/(BH) \quad (125)$$

$$P_t = HV\left(aA_1H^2/B^2 + B\right) \quad (126)$$

The increase in the width of the cutting edge of the A_1 knife causes the thickness of the chip to decrease; and the dislocation productivity of the rock decreases, that is: $H \to 0$, $P \to 0$.

Therefore, deviating the cutting regime from the optimal one leads to a decrease in the dislocation productivity and to an increase in the specific energy consumption when the rock is dislodged. Deviation from the optimal regime occurs, as a rule, as a result of the use of the cutting tool. The use of the cutting tool can be compensated by increasing the cutting force, but this is not always possible, because the machines usually work with maximum power, without reserve, and the increase in cutting force will lead to increased knife wear. From here result the recommendation to change the worn knives if there is a sharp decrease in productivity. [1, 4]

2.2. Cutting with groups of knives

Cutting with groups of knives can be carried out in two ways:

- the knives on the executing organ are distributed equidistant on the line, at equal intervals the adjacent knives having a combined dislocation effect.
- after passing a single knife, on the front surface remains a trace, which for other knives is actually the additional free surface, this increasing the efficiency of the compression core effect.

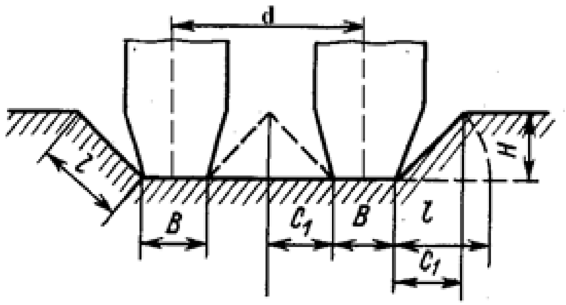

Fig. 7. Combined dislocation scheme the rock with the help of knives

From figure 7 result that at a combined dislocation of the rock with the help of knives, the surface of the rock on which the knife edges move will be flat. The tension of stretching occurs as a result of the combined action of the F_x forces of the adjacent knives. The l-length line, on which the dislocation of the rock occurs when cutting with a single knife, is also preserved in case of combined dislocation (with several knives). [1, 6, 7]

In case of correct choice of the parameters of dislocation of the rock after the passage of the executing organ on the front surface, a new surface without rock pillars is formed between the knife traces. For this, the condition must be met: $t_c = 2l$, where:

$$l = \sqrt{H^2 - C_1^2}$$

Using the optimal size H and C_1, determine the size of the rock dislocation step for the combined effect of the knives:

$$t_c = \frac{2\mu F_z}{\sigma Bk}\left(\frac{2F_z^{\ 2}}{9B^3b^2\sigma_o^{\ 2}(1-2\mu)^2} + b^2\right)^{1/2} + B \tag{127}$$

Here $b = \sqrt{2}$ as for the continuous dislocation of the rock. Since $l > C_1$ means that for the same force and cutting parameters, the displacement productivity in the case of the combined effect of knives is higher than in single-knife dislocation. For the combined effect of knives, the displacement productivity will take the form:

$$P_c = H\,V\,(\,l + B\,) \tag{128}$$

The increase in productivity is proportional to the P_c/P relation:

$$P_c\,/\,P = (l + B\,)/(C_l + B) \tag{129}$$

From here result that if $C_1 \approx B \approx H$, the productivity increase for combined cutting will be about 20%. Experiments have shown that the combined effect of knives raises productivity by 15-20 %. If the step between the knives is less for combined cutting, then the combined effect of the knives allows for the same productivity when cutting with a single knife, reduction of the cutting force on the executing organ by 15-20 %. However, the drop in cutting force is unjustified, as the machine does not work with all available power, and the specific energy consumption when dislocating the rock increases.

When dislocating with a single knife, the working conditions are more difficult than the combined one, so we should distribute the knives on the executing organ with a smaller tc placement step, adopting the appropriate value for a more common rock. In this case, the combined cutting will be ensured, and following an increase in the cutting force compared to the optimal one, the thickness of the H chip will also increase, which will increase the productivity of the machine. An ideal machine is one that would modify the step of installing knives on the executing organ, corresponding to the modification of the properties of the rock, thus ensuring a combined dislocation of the rock, hard work to accomplish in practice. [1, 6, 7]

2.3. Cutting with executing organs

Two cutting methods are distinguished: folding and milling.

When folding, the knife moves to the front surface so that it is always in contact with the rock, the chip being cut at a constant thickness H_{opt}. The movement trajectory of the knife at the rebate can be straight or curved. When cutting the rock by milling, the knife moves on a curved trajectory, being in contact with the rock only on one side of the trajectory (not more than half). Thus, the thickness of the chip is a variable, taking values between 0 and H_{max}. The most common knife trajectory in the cutting method is the circular one.

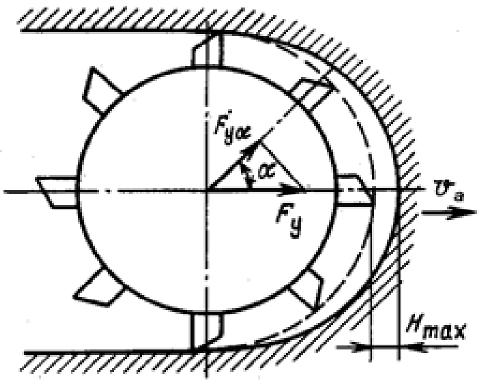

Fig. 8. Scheme of milling cutting

Fig. 8 shows that the advance force F_y depends on the position of the knife on the front, in correlation with the direction of the movement of the executor's body v_p.

$$F_{y\alpha} = F_y \cos\alpha$$

where:

- *F_y - maximum size of the advance force;*
- *α -the angle between the direction of movement of the executing organ and the position of the knife.*

With the change of the advance force, the cutting force also changes, because these two forces are dependent on each other:

$$F_{z\alpha} = F_y \alpha D = F_y D \cos\alpha \tag{130}$$

where:

- *D - a constant size.*

Corresponding to the change in the direction of the forces acting on the knife, the thickness of the chip also changes.

$$H_\alpha = H_{max} \cos\alpha = \mu b \, F_z \cos\alpha \, / \, (\sigma B \, k) \tag{131}$$

From equality (130) and (131) indicate that the advance force changes depending on the position of the knife on the trajectory, from 0 to $F_{y\,max}$, and the chip thickness will change from 0 to H_{max} . The change in the forces and thickness of the chip leads to the change in the cutting step of the rock. Using the relation, the cutting step relation is obtained:

$$d = \frac{4\mu F_z^2 \cos\alpha}{3B^3 \sigma b \sigma_o (1-2\mu) k} + B \tag{132}$$

From this it turns out that the cutting step of the rock changes corresponding to the position of the knife on the trajectory, the minimum level being obtained at the entrance to and exit from the contact with the rock of the knife. If the knives are placed on the executing organ so that their trajectories are parallel, then in the area at the beginning and at the end of the cutting will be formed thresholds (portions of rock left unblocked) provided that the step of placing the knives is constant. These thresholds break after their height rises above a certain value. Keeping the optimal dislocation regime throughout the entire length of the trajectory is difficult to achieve in the case of milling cutting. This is why it is aimed to obtain an optimal dislocation regime in the central area of the trajectory, where the maximum volume of rock is detached. In this case, the step of placing the knives on the executing organ will have to be taken equal to the average step of dislocation of the rock:

$$d_{med} = \frac{2\mu F_z^2}{3B^3 \sigma b \sigma_o (1-2\mu)k} + B \quad (133)$$

But in this case too, thresholds will be formed between the knife marks at the beginning and end of the trajectory. Their formation, working in a different regime from the optimal one, leads to the intensification of the use of knives, to the increase of the specific energy consumption when cutting and to the decrease of the productivity of the rock dislocation. In order to remove these disadvantages, a complicated trajectory should be imprinted on the knife so that at the ends of the cutting path corresponds to the decrease in the thickness of the chip. The main advantage in the dislocation of the rock by the milling method is that part of the trajectory is carried out by the knife in the hollow, without touching the rock massif, thus allowing it to cool down, and, which reduces the use effect of the knife.

Two procedures are used to cut the rock from the massif using knives:

- the continuous process;
- cutting by scheme path – threshold.

In the continuous cutting process, after a cycle of movement of the executing organ on the front, a layer of rock with the thickness H is cut. After each cycle of movement of the executing body , the displacement limit conditions return to the initial position. In the case of the second rock cutting process, cutting the chip from the massif is done with one or more knives. Cutting the rock into a single knife is related to the blocked dislocation of the rock on both sides of the knife. The blockage is conditioned by the presence of the surface of the path, perpendicular to the surface of the knife. When connecting these surfaces, dislocation occurs by displacement, which leads to increased specific energy consumption at dislocation and decreased productivity. In addition, there is also an increase in cutting force and advance force, which leads to increased wear of the knife.

Cutting thepath with several knives allows to decrease the specific volume of the rock, dislocated by displacement. In connection with this, at an increase in the number of knives working in the path, the specific energy consumption at the dislocation of the rock decreases, but it always remains higher than that of the continuous cutting method. When cutting the rock in paths, the main laws of rock dislocation remain the same as for continuous dislocation: the optimal thickness of the chip for the given size of the cutting force is known, ensuring maximum productivity at a specific minimum energy consumption. The difference is that when cutting in the path, as a result of the influence of its side surfaces, the cutting step changes. When several knives are working in the path, at their correct location, the blocked cutting takes place only at two of the knives, that work in the connection area of the work front with the side surface of the strip. Thus, dislocation by displacement occurs with a side edge of the knife pointing to the side surface of the strip. In the other knives working near the side surface of the strip, the dislocation of the rock takes place with partial blockage and chips. The increase of cutting forces and advance to the blocked cutting takes place in proportion to the coefficient k_ε:

$$k_\varepsilon = \frac{2\varepsilon^2 V_\varepsilon (1+\mu)}{\sigma^2 V_\sigma} \tag{134}$$

where:

- *V_ε - volume of rock dislocated by displacement;*
- *V_σ - volume of rock dislocated by traction efforts;*
- *ε - the limit of resistance of the rock to displacement.*

The remaining thresholds between the jaws dislocate under the effect of F_x forces, edge knives and vibrations. For the dislocation of these thresholds, special tools called rollers, similar to disc-type milling machines, can also be used. The rollers are placed between the knives, and exert a force on the thresholds, producing their dislocation. The energy consumed for the dislocation of such a threshold is given by the relation:

$$Q = \sigma B\, l\, l_f \tag{135}$$

where:

- *B - the width of the rock threshold not displaced between two adjacent cuts;*
- *l - the length of the rock threshold undislocated between two adjacent cuts;*
- *l_f - critical width of the path.*

If instead of δ we use the relation (135), we get the relation (136):

$$l_f = 2\sigma k\, L / E \tag{136}$$

where:

- *L – volume size deformed V, mm.*

$$Q = \sigma^2 B\, l\, L / E \tag{137}$$

The specific energy consumption at the dislocation of the thresholds is determined with the relation (58), where Q is determined with equality (137), their volume being $V = B\,H_1\,l$. That is why the specific energy consumption when cutting the thresholds is:

$$q = \sigma^2 L \;/\left(EH_1\right) \tag{138}$$

From here result that if the height of H_1 increases, the specific energy consumption when the rock is dislodged from the thresholds decreases.

Because of this, the thresholds that are higher in height dislocate without additional tools. Therefore, it is important to increase the height of the threshold, even if in this case, the specific energy consumption at the dislocation of the rock in the path will increase as a result of the increased resistance of the rock in the path.

In general, the specific energy consumption at the dislocation of the rock after the fast-threshold process consists of the specific energy consumption in the path and the specific energy consumption in the thresholds:

$$q_d = q\,k_\tau\,c_\varepsilon + \sigma^2 L\,(1 - c_\varepsilon)/\left(EH_1\right) \tag{138}$$

where:

- *q is determined with the relation (1.70);*
- *c_ε - the relative volume of the rock, dislocated by cutting in the path;*
- *c_ε) - the relative volume of the rock, cut into thresholds.*

In the relation (139), the first term is greater than the second, therefore the volume of the rock to be dislocated in the thresholds should have increased, but it increases the energy to be consumed for the dislocation of the threshold, which will require the use of devices for splitting the thresholds and the consumption of large forces for it. In connection with these, it becomes clear the need to determine the optimal relationship of the volumes dislocated in the slot and in the threshold.

In general, in relation to the optimal volumes of displaced rock, the specific energy consumption consumed when cutting the rock after the "path – threshold" process is lower than in the case of the continuous dislocation process, due to the specific low energy consumption in the thresholds, that is 0.1 - 0.2 kW/m^3. The productivity of the displacement of the rock at a constant size of the power of the N machine is determined by means of specific energy consumption:

$$P_t = N\,\tau\,/\,q \tag{140}$$

Because the specific energy consumption in the case of the "path – threshold" process is lower than in the case of the continuous dislocation process, then the productivity in the "path – threshold" process must be higher (if the use of knives and the time needed to change them is not taken into account). But at a longer effort in the "path – threshold" process, more time is spent on changing knives than in the process of continuous dislocation of the rock, this is due to the intensive use of knives on the effort made in the path, because of the higher cutting force acting on the knives working in the path. As a result of faster use of knives, the productivity of cutting in the groove decreases faster, thus decreasing the productivity of the "path – threshold" process. For changing knives a certain time is spent in which the machine does not work and therefore the actual working time of the machine decreases. Changing knives is related to the increase in operating expenses. Thus, it follows that for a longer term (annually, monthly), machines that work after the continuous displacement process are more productive than those that work after the "path – threshold" process. The cost of production of the displaced rock by machinery working after the continuous displacement process will be lower than for working machines after the other process; this is because the first machines have higher productivity in the long run and the expenses for replacing knives are lower. The biggest disadvantage of the process "path -threshold" is a more important dust release. The advantage of this process is that it is possible to dislodge large pieces of the thresholds. The use of one of these processes is based on technical and economic calculations. It should be noted that currently all machines are working after the continuous displacement process. [1, 6, 7]

3. CONCLUSIONS

Due to the technological advantages it presents, the abattage combines are the main equipment for mechanizing the cutting in the abattage of coal mines. The cutting organs of modern abattage combines are in most cases of the snail drum type which are equipped with knives (radial or tangential).

Due to the fact that it works under heavy conditions (uniform cutting forces frequently exceeding 5 - 8 times the average forces, uneven speed of advance of the combine, transportation of small material, etc, the presence of hard intercalations in the layer), they must meet a number of requirements: to be resistant to wear and shock, to have the appropriate shape and size, and, to present a simple system of fastening in the jaws allowing rapid change and wear protection of the jaws, to admit the possibility of reconditioning**.**

The application regime of knives, on which their resistance to wear depends, durability and indirectly the performance of the entire combine, depends largely on the constructive parameters of the cutting organ, among which the most important are the parameters of the knife placement scheme, which influence the shape and dimensions of the chip, as well as the size and variability of the cutting and advance forces. The constructive type of knives, the geometric parameters, the constructive peculiarities have a particularly important influence on their stress regime and on the use quality, durability and resistance.

The mechanical physical properties of the rocks in combination with the kinematic and geometric parameters of the executing organ and the geometric and constructive characteristics of the knives are the determinants of the complex interdependencies that characterize the study of the cutting regime of rocks with the help of knives.

It is important the interdependence relations between the kinematics and the geometry of the executing organ and the parameters of the chips, the relations between them and the request of the knife, and finally the global values that refer to the forces, the moments and power required to actuate and the specific productivity and energy consumption of the combination.

On all of them, a great influence exerts the wear of knives, and on the other hand the process of use is determined by the parameters of the operating range of the combine. The phenomena are complex and strongly interdependent, and it is necessary to study them globally, in a systemic vision.

Lately, there is a focus of research efforts towards finding new constructive forms and new materials to make knives with a high level of quality, and, ensuring an optimal compromise between resistance, hence durability that leads to increased productivity, and maximizing the risks related to ignition of methane, increased danger of expanding the power and productivity performance of modern combines.

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