Improving quality of granulometric composition of potash ore produced by «Ural-20R» heading-and-winning machines

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Abstract. Processes of cutting and movement of potash ore during operation of «Ural-20R» heading-and-winning machines are followed with its breakage leading to the increase of number of non-washable powdered classes (particle size less than 0.25 mm) in the breakage products. The sources analysis of dust-like classes formation during the work of «Ural-20R» machines is performed. The regions of rational (by minimum output of dust-like classes) values of breaking parameters of potassium solid mass in use of checkered and consistent cutting schemes are defined. The analysis of the operating parameters compliance of the planetary-disk operating members of «Ural-20R» machines of various modifications with rational cutting parameters is carried out. Technical proposals on improving the operating members of «Ural-20R» machines by use of the crossed procedure of potassium solid mass breaking are reported. It is proved that the proposed solutions will reduce the number of dust-like classes in the breakage products and reduce the specific energy consumption of the potash ore production process.

1. Introduction

The potash ore production by the underground method at domestic enterprises is carried out in widely used «Ural-20R» heading-and-winning machines produced by JSC «Kopeysk Machine-Building Plant», equipped with combined operating members of the drill type and caterpillar mounting [1].

The operating members of «Ural» machines perform destruction of potassium solid mass and loading of broken rock mass to the area transport means [2]. The ore cutting and moving processes are followed by its breakage leading to the increase of the number of non-washable powdered classes (particle size is less than 0.25 mm) in the breakage products. «–0.25 mm» ore classes almost completely fall within waste, since high content of dust-like particles makes it necessary to use complicated circuits for processing the raw material to get dust-free potassium chloride, and also use of granulation to improve the quality of granulometric composition of the final product increases the expenses of the mining enterprise [3]. In the flotation enrichment method the 1 % increase of «–0.25 mm» mass fraction particles leads to decrease of useful component extraction to at least 0.1 % [4-6] and reduction of annual profit of extracting companies for several hundred million roubles.

Improving the quality of granulometric composition of ore by increasing in it the mass fraction of the washable class is an actual scientific and practical task that is possible by study of rational parameters of concretion cutting operating members of «Ural-20R» machines as well as the development and implementation of operating members and loading equipment putting into action prospective cutting
schemes of formation.

2. The sources of dust-like classes formation during the work of «Ural-20R» machines

The granulometric composition of potash ore [7] and energy parameters of breakage during solid mass breaking [8, 9] are influenced by the depth of cut h, which rational value for checkered and sequential cutting patterns is 12-15 mm. In accordance with the results of experimental studies [10] use of traditional patterns of potassium array destruction (checkered and sequential) at h ≤ 5 mm stipulates the increased output of dust-like classes «0.25 mm» (Figure 1). Each depth of cut h in the 5 to 15 mm values range corresponded to rational cutting step t, determined by the relation t / h = 2 to 4 [11].

![Figure 1](image1.png)

**Figure 1.** The dependence of percentage of the «0.25 mm» class of the cutting step on t various values of cutting depth h: a – in potash ore blocks destruction by successive cuts; b – checkered cuts (by PC-14 tangential nonrotational cutter).

The main difference of «Ural-20R» machines from the similar machines of foreign production is use in their structure of the spatial planetary-disc packaged disk operating members, which destroy rock massif by sequential splayed radial-tangential cuts of variable depth h. The half-moon chip section and the variable cutting step t impede optimization of potassium solid mass destruction process by cutters of spatial planetary-disc operating members [12, 13].

The kinematics of movement of planetary-disc operating members of «Ural-20R» machines defines destruction of the central and peripheral parts of the face (zones of cutters entry and exit from contact with the massif) with cuts of depth h ≤ 5 mm.

Work of «Ural-20R» machines of the most modern modifications («Ural-20R-11/12») at rated capacity of Q = 8 t/min is characterized by destruction of the main part of the face area when t / h < 2 (figure 2, graph 1; table).
Figure 2. Dependencies of the t/h ratio on the rotation angle of the cutting disc $\varphi$ ($0^\circ$ – cutter entry into contact with the massif in the central part of the face; $180^\circ$ – output of the contact with the massif on the periphery of the face) of the planetary-disc executive body of «Ural-20P» machines on various modifications at various productivity values.

Table 1. Influence of design and operational mode of the «Ural-20R» machine on the parameters of face processing with concretion cutting tools

| Machine version, productivity | The share of the face area, %, processed by the cutters of the planetary-disc executive body of the machine with the cuts parameters: |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
|                              | $t/h < 2$                                         | $t/h > 4$                                         | $t/h = 2–4$                                        |
| 1. Ural-20R-11/12 ($Q = 8$ t/min) | 65.9                                     | 10.7                                      | 23.4                                           |
| 2. Ural-20R ($Q = 7$ t/min)    | 47.5                                     | 16.4                                      | 36.1                                           |
| 3. Ural-20R-11/12 ($Q = 8$ t/min with modified parameters) | 42.4                                     | 19.8                                      | 37.8                                           |

The cuts of previous modifications discs of «Ural-20R» machines with nominal performance ($Q = 7$ t/min) of the winning machine are characterized by $t/h$ values closer to rational ones (see Figure 2, graph 2; table).

The cutters of the baffle and berm devices of the «Ural-20R» machine destroy the potash massif with cuts of small depth $h < 5$ mm with values $t/h = 10-12$. The effective energy consumption at destruction of the potash massif by the cutters of the baffle device and berm milling cutters is 2-2.5 times greater than in work of planetary-disk operating members [14, 15].

The above disadvantages determine the significant content of the fraction «$\leq 0.25$ mm» in ore leaving the conveyor of «Ural-20R» machines – up to 10%.

Transportation of broken ore from mining combine complexes, as a rule, includes the following steps [16-19]:
- reloading through the ore pass to the belt panel conveyor;
- transshipment through the panel bunker to the main conveyor;
- overload to the common stock bunker;
- loading into skips for lifting to the surface of the mine;
- skips unloading into the head bins;
- unloading bins to the conveyor belts;
– loading of ore into crushers at the grinding sites.

As a result of ore overloading, its grinding is performed; the share of «0.25 mm» class in a lump ore when entering the grinding portion is not less than 13 % [20]. Ore flow entering the processing plant after grinding contains 17-18 % of the necessary class.

It is rational to form a predetermined granulometric composition of ore distribution by creation of sequential elementary chips of a stable form that stipulates lower rock mass grindability during overloads and in the crushing equipment of the grinding sections [21].

3. Proposals for improving the design of new executive organs and work equipment of «Ural-20R» machines

Improvement of the ore granulometric composition during the destruction of the potash massif with the cutters of the planetary-disc executive bodies of «Ural-20R-11» and «Ural-20R-12» machines is possible by changing the step t and cutting depth h values. The simplest way that requires minimal design changes is to reduce the number of cutters Zp on the rotary disks from 17 to 12 pieces. In this case, the ratio of the pitch to the cut depth t/h will take values closer to the area of rational values (see Figure 2, graph 3; table).

One of the advantages of using planetary-disk executive bodies is the possibility of creating a grid of intersecting cuts on the surface of the face.

It is known that use the induced cracks and stress concentration regions at the cuts intersection during massif development makes it possible to reduce power and energy performances of separation ore from massif to 20-25 % [22] and reduce by an order of the output of dust-like classes of the breakage products (Figure 3) as a result of creation in a slice of the consecutive elementary chips of the given shape [21].

In case of using a criss-cross cutting scheme, the content of the dust-like fraction «0.25 mm» in the broken ore is decreased as the cutting depth h decreases, reaching the lowest values at h = 5-10 mm.

The analysis of the dependences presented in figure 3 shows that in the use of criss-cross cutting circuit the most rational values of the ratio t/h (according to the criterion of the minimum ore yield of
the class «–0.25 mm») for cutting depth \( h = 5.0, 7.5, 10.0 \) and 12.5 mm are, respectively, the value ranges \( t/h = 10-12, 6-8, 4-6 \) and 3-5. The ranges values of the of rational cutting steps at the respective cutting depths \( h \) are presented in Figure 4. Using the polynomial approximation method, equations describing the behavior of the functions \( t_{\text{rat min}} \) and \( t_{\text{rat max}} \) depending on cutting depth \( h \) in the range of its values from 5.0 to 12.5 mm are obtained and presented.

![Figure 4](image)

**Figure 4.** Dependences of minimum and maximum values rational cutting step of \( t_{\text{rat}} \) on cutting depth \( h \) at fracture of potash ore blocks by criss-cross cuts (PC-14 nonrotational cutter).

Solution of the problem of increase of efficiency of the potash ore breaking process by cross-cutting is possible by using the structure of the planetary-disc executive body of heading-and-winning machines represented in Figure 5.

![Figure 5](image)

**Figure 5.** Scheme of the executive body: a – front view; b – side view.

The executive body consists of four rotary discs 1-4 destroying the face by cross-cuts by means of cutters 5 mounted on them. Discs 1 and 3 destroy the face by radial-tangential cuts directed from the
face center to its periphery. Disks 2 and 4 rotate about their axes in the opposite direction processing the face by tangentially-radial cuts directed from the center of the face to its periphery. Disks 1-4 are mounted on the shafts of rotary gearboxes 6. Torque is transmitted on them from the transfer gearbox 7. The transport rotation of the discs is performed around the axis 8 of the transfer gearbox 7.

The cutting discs have pair-wise differently directed relative rotation. As a result, in the face a mesh of intersecting cuts (Figure 6, [23, 24]) 1 and 2, having tangential-radial (from the face periphery to its center) and radial-tangential (from the face center to its periphery) directions is formed. Implementation of criss-cross cutting circuit by the proposed executive body allows one to increase the face area treated by cuts with the parameters of pitch t and the cutting depth h the most rational for criss-cross circuit, which will provide significant decrease of specific energy consumption and the amount of fine classes in broken potash ore.

Improving the efficiency of the massif destruction process by auxiliary bodies (baffle and berm device) may be provided by transition from the sequential cutting scheme to checkered one. In accordance with the result of the experimental studies, the transition from the sequential cutting scheme of potassium array destruction to the checkered one with a 5 mm cutting depth causes reduction in the specific energy consumption from 6 to 3.2 kW·h/m³ [25], and reduction of classes «<0.25 mm» output from 6.5 to 5%.

4. Conclusion
Improving the executive bodies of heading-and-winning machines, providing use of the criss-cross scheme of face breaking in combination with use of upgraded auxiliary executive bodies will improve the quality of granulometric composition and efficiency of the machines work.

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