Improvement of rock-breaking tools of heading-and-winning machine of potash mines

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Abstract. Conducted a statistic research of the construction features of heading-and-winning machine actuator members for the extraction of potash ores. It is shown that increasing the efficiency of the destruction process of a potash massif with the cutters of heading-and-winning machine actuator members is possible by means of the potential cross-cutting technique. The methods of potash layers destruction by cross cuts were considered. Designs of the heading-and-winning machine actuator members that implement the cross-cutting scheme of potash massif are presented.

1 Introduction

The efficiency of mining enterprises that produce potash ore by an underground mining method is determined by the technical level of the mechanic means of the main technological processes. A significant reduction of the prime cost can be achieved by the development and usage of high-performance heading machines that destroy the potash mass and load the broken rock with minimal specific energy consumption and low yield of small, row ore classes.

Nowadays heading-and-winning machines “Ural”, manufactured by OJSC “Kopeisk Machine-Building Plant”, are most widely used. They are equipped with actuator members of a drilling type and a crawler attachment. Machines of this type have been used in potash mines for more than four decades and are generally positively characterized by employees of engineering and technical services of mining enterprises. However, the task of improving domestic heading-and-winning machine actuator members with a view to enhancing their energy efficiency and reliability remains relevant [1].

2 Materials and methods

One of the drawbacks of “Ural” heading machines planetary activator members is the destruction of the massif by successive radial-tangential cuts of variable depth. It is known that the energy indicators during the destruction of the potash mass and the output of small classes of ore is most affected by the depth of cut h. Its optimum value is 13 ... 18 mm, according to pilot studies for chessboard and sequential cutting patterns [2]. Each cutting depth corresponds to an optimal cutting step, determined by the ratio t / h = 2 ... 4. The feature of the planetary elements of the Ural heading machines is that at the initial stage of

the movement of a single cutter, the depth and cutting step increase, then the depth h decreases, and the step t continues to increase to its maximum value. Consequently, a significant part of the face is destroyed by the blocked cuts at a ratio t / h> 7.

One of the advantages of planetary-disk activator members is the possibility of creating a grid of intersecting cuts on the surface of a destructible face [1, 3]. Experimental studies carried out by employees of the Perm National Research Polytechnic University display that the use of a cross destruction scheme for a potash mass is promising since successive elementary chips with stable rational values of geometric parameters are formed in a slice. This reduces the specific energy consumption of the destruction process by 20 ... 25% and lowers the amount of raw ore in the products of breaking more than two times in comparison with traditional cutting schemes - staggered and sequential. Effective destruction of potash samples is provided by cuts of small thickness (h = 5 ... 10 mm), with the lowest energy consumption at a cutting step t = 30 mm, and with a minimum yield of fine fractions in ore at t = 40 ... 60 mm [2].

3 Results and discussions

For the first time, the method of destroying a mountain range with cross cuts was proposed in 2008 at OJSC “Silvinit” [4]. The implementation of the method is based on the use of a combined activator member, consisting of disks 1 mounted on the arms 2 and rotor 3, made in the form of a two-beam faceplate mounted on the case of the transfer gearbox 4 (Fig. 1).

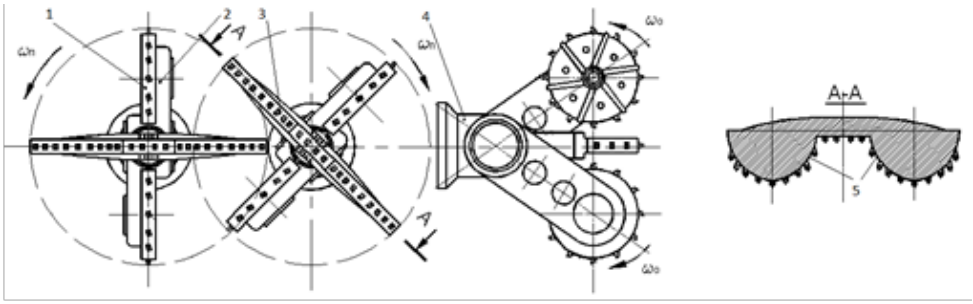

Fig. 1. Scheme of a combined twin planetary-disk activator member with double-beam faceplates.

According to [5], if the supporting surface 5 of the rotor 3 is made in the form of a semicircle with a diameter equal to the diameter of the cutter wheels, then when placed together, the depth of cuts at the intersection points will be different, with the exception of one cut at the current angle value of the cutter position equal to: $\varphi = \pi / 2$. As a result, the efficiency of breaking the rock mass with cross cuts is reduced.

Due to the increase in the step of the radial cuts on the peripheral part of the face, it is impossible to implement a cross-cutting scheme. To eliminate this drawback, an activator member (Fig. 2, a), consisting of obliquely mounted disks 2, performing relative and figurative movement of the cutters 3, was proposed. The rotor combs 1 are located behind the front and rear cutting edges of the disks 2 and are rigidly attached to the gear housing 5 via a fixed shaft 4 [6].

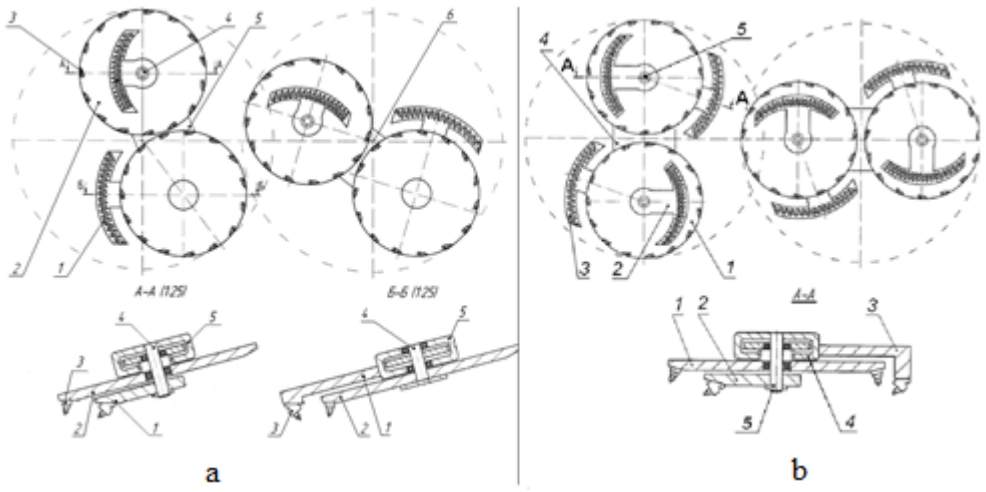

Fig. 2. Schemes: a - dual rotary-disk activator member, b - dual flat-disk activator member.

The advantage of planetary inclined-disk elements is that along the entire length of the cuts there is a direct relationship between the depth and the cutting step. If the disks 2 of the planetary member are installed with an inclination in opposite directions, then the face will be destroyed by the leading edge of one disk and the trailing edge of the other [1]. In this case, the central and peripheral parts of the face (relative to the axis of rotation 6) are destroyed by cross cuts of the disks, and the middle part of the face is destroyed by intersecting cuts of disks and rotor combs (Fig. 3). This arrangement allows to reduce the number of incisors on the rotor combs.

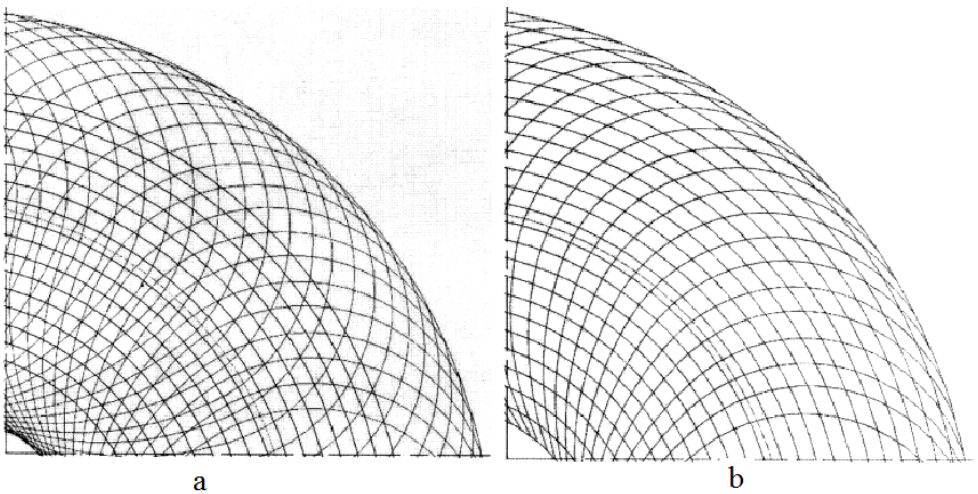

Fig. 3. The cutting pattern of the combined inclined-disk activator member: a) when the disks are tilted in different directions; b) when the disks are tilted in one direction.

High-performance work of heading machines with a shallow depth of cuts is possible with a high cutting speed or with an increase in the number of activator members. To implement the second option, there is a destruction method, based on the use of flat-disk activator members (Fig. 2, b), in which rotor combs are installed behind the front and rear cutting edges of the disks [7].

The main disadvantage of the stated designs is the large number of cutters that are in contact with the face simultaneously. It is determined by the need to maintain the values of the cutting parameters in intervals that ensure minimal energy consumption. To eliminate this drawback, the staff of the Department of Mining Electromechanics, Perm National Research Polytechnic University proposed a method of destruction of a rock massif by a realized planetary-disk member (Fig. 4) [8].

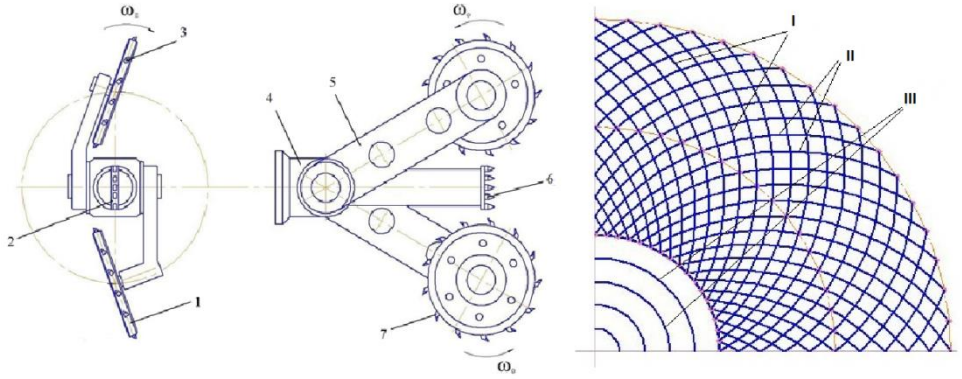

Fig. 4. Planetary-disk activator member with a tilt of the cutting disks relative to the plane of symmetry and its cutting pattern: I, II - cuts of disks rotating in opposite directions; III - cuts of the burster.

The design of the proposed activator member consists of disks 1 and 3, rotating in opposite directions and installed at an angle to the plane of symmetry 2. The cutters of the rotary disk 3 destroy a rock massif by sequential radial-tangential cuts going from the center to the periphery of the face. The incisors of the disk 1 implement tangential-radial cuts from the periphery to the center of the face. The torque on the disks 1, 3 with the cutters 7 is transmitted by the distributing reduction gear 4 and the rotary gears 5. Multidirectional rotation and portable movement of the disks create a grid of intersecting cuts on the surface of the potash array (Fig. 4). The center of the face is processed by the burster 6.

The design and drive of the planetary member slightly differ from the serial actuator members installed on “Ural” heading machines. Therefore, their implementation will require low costs.

In addition to the main planetary-disk actuator members, the auxiliary actuator elements of “Ural” heading-and-winning- machines need to be improved, such as Berm milling machines, augers, and a top breaker [9–11].

Cutters of fender and berm devices of a heading machine destroy a potash array with semi-blocked cuts of small depth at increased energy consumption and a significant amount of small unreinforced ore fractions in the products of the break. According to experimental studies, the specific energy consumption during the destruction of the potash mass by cutters of the breaker device and berm cutters is 2 ... 2.5 times greater than by planetary-disk actuator members [2, 12, 13].

It is possible to provide an increase in the efficiency of the destruction process of the rock massif with auxiliary organs by switching from a sequential scheme of destruction of the rock mass by half-blocked cuts to a chess scheme. The results of pilot studies performed by the authors show that when the array is destroyed by chess cuts with a depth of 5 mm, in comparison with successive cuts of the same depth, the specific energy consumption

decreases from 6 to 3.2 kWh / m3, the yield of small classes decreases from 6, 5 to 5% [2, 3].

4 Conclusion

1. Cross cutting schemes implemented by the proposed actuator members reduce the average values and dynamics of the loads on the cutters, which leads to an increase in the reliability of heading machine drives, a decrease in the specific energy consumption and the number of small classes in broken potash ore.

2. Reducing the specific energy costs of the potash array destruction process and lowering the number of raw ore classes during the operation of heading-and-winning machine actuator members is possible by switching from a sequential scheme of destruction of the array with half-blocked cuts to a checkerboard pattern.

References

1. V.L. Dolgov, *Rock electromechanics and mechanisation of mining activities*: Textbook, 383 (M.: Publishing House Nedra, 1969)
2. L.I. Starkov, N.A. Harlamova, Mountine magazine, **7-8**, 74-76 (1997)
3. V.V. Buevich, N.V. Chekmasov, D.I. Shishlyannikov, V.V. Gabov, University News. Mountain magazine, **4,** 52-55 (2016)
4. N.V. Chekmasov, A.N. Chistyakov, V.V. Semyonov, D.I. Shishlyannikov, The method of destruction of the rock mass by cross cuts, RU2375571 (2009)
5. N.V. Chekmasov, V.A Nemtsev, Bulletin of Perm State Technical University. Oil and gas, **6**, 238 (2005)
6. N.V. Chekmasov, The method of destruction of the rock mass by cross cuts, RU2460882 (2012)
7. N.V. Chekmasov, G.D. Trifanov, The method of destruction of the rock mass by cross cuts, RU2465458 (2012)
8. N.V. Chekmasov, D.I. Shishlyannikov, The method of destruction of the rock mass by cross cuts, RU2522111 (2014)
9. A.E. Suhanov, A.B. Maksimov, *Problems of development of hydrocarbon and ore mineral deposits: proceedings of the 11th Conference*, 433 (2018)
10. I.E. Zvonarev, *High Technologies in Modern Science and Technology: Collection of Scientific Proceedings of the VI International Scientific and Technical Conference of Young Scientists, Graduate Students and Students*, 301–302 (2017)
11. R.H. Teterina, L.Ya. Sabirov, L.N. Kirichenko, *The flotation technology of a potash ore beneficiation*: Textbook, 485 (P.: Publishing House Solikamskaya tipografiya, 2002)
12. N.V. Chekmasov, D.I. Shishlyannikov, L.A. Loskutov, E.O. Vagin, Master Journal, 264 (2016)
13. D.I. Shishlyannikov, A.B. Maksimov, G.D. Trifanov, N.V. Chekmasov, News of Tula State University. The Earth Sciences, **2**, 231-24 (2019)