Prospects for improvement of mining machines' cutting picks

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Abstract. Advantages and disadvantages of tangential rotary picks widely used in mining machines are described. A prospective line of picks design improvement has been found based on a change in the principle of destruction. A new design of blade-type cutting picks with a reinforcing tip is proposed having extended service life, requiring less energy for rock breaking, reducing yield of fine dust and increasing the grade of the mined coal.

1. Introduction

Mining machines currently used in mines of Russia, China, the USA, Australia and other countries are equipped mainly with tangential rotary picks (TRP) for rock breaking. Such picks are fixed on screw-, bar-, and crown cutting tools of shearers and road headers. In terms of design a pick presents a steel holder made up of a cylinder shaped tail and a tapered head (Figure 1).

Figure 1. A tangential rotary pick of a mining machine.

The holder is reinforced with a hard tip of the high-tensile tungsten and cobalt alloy. The reinforcing tip is made in a cylinder- or mushroom shape. The protruding end of the reinforcing is pointed (Figure 2).

a b

Figure 2. Hard-alloy tips of picks: *a* – cylinder shape; *b* –mushroom shape.

The following advantages of the picks have ensured their widespread use:
– ease of installation and replacement;
– even wear due to rock hardness while breaking and self-sharpening;
– small effect of the bending moment on the reinforcing due to the pick inclined to the cut surface;
– relatively long service life.

Despite the named advantages the tool has significant disadvantages. One of which is that such picks are not suitable for re-use. As a result, after the tool is 20…30 % worn out, the remaining 70…80 % go to waste, which is rather improvident from the view point of resource efficiency requirements to the modern production. Besides, a lot of dust and small particles are generated during coal mining, which decreases the grade of coal products.

2. Methodology of simulation

The research methodology is based on the study of the picks wear pattern and degree in terms of underground mining in Kuzbass. The research was conducted in eight mines at more than thirty roadheaders and shearers of models GPKS, KP-21, P-110, KSP-35, SL-500, Sandvik, Joy, EL-3000. More than five hundred picks were examined. For measurements the laboratory equipment of Tomsk Polytechnic University was used. The research base was replenished by the research results and analytical materials of other researchers dealing with improvement of rock breaking tools. References were made to industrial catalogues of cutting tools manufactured by the leading Russian and foreign manufacturers, such as Kopeysky Machinery Works, Kuznetskiy Machinery Works, Gorniy Instrument, Kennametal, Sandvik, BETEK [1-5].

3. Results and discussion

The research indicates that when a TRP impacts the mass coal (or rock) contacting the tip, at first it is compacted, then it collapses and breaks. Fine dust and relatively large (∅ 10…50 mm and over) shapeless particles are generated. The mechanism of such pick breaking the rock is presented in Figure 3 [6].

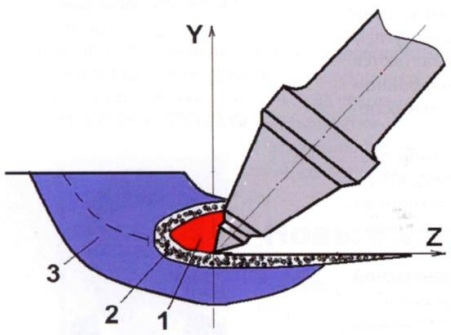


Figure 3. A mechanism of rock breaking by a tangential rotary pick:
1 – compacted core (fines) in triaxial compression; 2 – zone of rock collapsing; 3 – zone of elastic deformation of surrounding rock sectors.

For breaking and chipping of the rock by the tool the high energy consumption and considerable efforts are required to penetrate into the rock; it causes great resistance which results in accelerated destruction of the pick tip and friction sparkling.

High dust formation and friction sparkling are major causes of ignition of explosive dust and methane mixtures in road headings. According to the scientists of the State Technical University of Kuzbass the scope of use of TRPs due to their design features is restricted to low abrasive rock (less than 15 mg) with hardness of up to 60 MPa [7, 8].

Currently works on picks improvement are in progress. They include an increase in surface strength of the tool, a change in the form of the head, protection of the highest wear degree zone [9-14]. However, for considerable extension of service life and an increase in efficiency the picks should be re-designed.

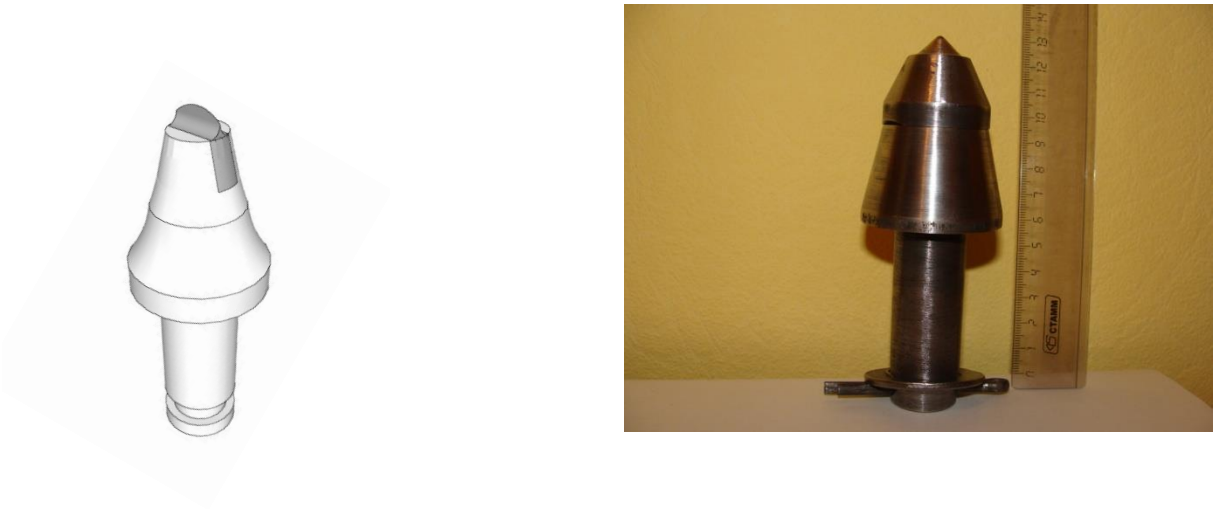
Understanding of the concept ‘cutting pick’ shows that such a tool, by definition, should not tear, but rather cut the rock dividing it into pieces by even cuts. This will reduce the yield of fines and coal and rock dust, as well as sparking in the mine. Large (but properly sized) and smooth parts are more convenient for transportation and storage operations. The cutting process requires less energy costs for the rock breaking than crushing and separation of parts.

According to the above mentioned information TRPs shall be further improved with regard to the change in the operating principle: from rock breaking to rock cutting. The principle may be changed if the pointed tip is replaced with a cutting blade. This blade can be made of a hard metal plate placed in the axial slot of the pick head. In this respect a part of the head with the cutting blade should be able to rotate on the holder about its axis. This will ensure that the movement direction of the cutting blade will be aligned with that of the pick in the rock. The penetrating power of such reinforcing of the pick fixed on the cutting tool of the mining machine will be higher as compared to the currently used pointed tips. Rock will be cut with less efforts and energy costs. Parts of the cut rock will have a more regular shape, which will increase the grade of the mined coal. In addition, the yield of fines and dust will be significantly reduced. The proposed improvement of the tool ensures correspondence with the meaning of the word ‘cutting pick’.

The design of the pick with a hard-alloy reinforcing plate having one cutting edge is shown in Figure 4a. The plate protruding above the head is designed as a blade with a cutting angle of 50…70 degrees and rounded edges. The blade is fixed in the head by brazing or by screws, which makes it possible to replace the plate once the blade is blunted. The working part of the head equipped with a hard-alloy plate is made rotatable about the axis of the pick. In case of excessive wear of the plate and damage to the working part of the head the junction allows for replacement of the latter, and the pick may be used further on. A general view of a pick with a replaceable rotating head is shown in Figure 4b.

The cutting blade is much longer than the pointed tip of the currently used hard-alloy inserts. It ensures a longer service life of the insert. Furthermore, after the rotating part of the head is worn out it can be replaced with a new one, which significantly extends the service life of the pick. Industrial tests showed that the pick can be used for up to 8…10 cycles provided the worn rotating heads are replaced [15].

Two rotating assemblies available at the proposed picks (a pick in the pick holder and a replaceable head in the head holder) provide for easy rotation of cutting blades and their alignment with the direction of the pick moving along the rock surface. Due to the friction forces the cutting edge of the plate will turn along the line of the least resistance and the pick will cut the rock, instead of crushing and chipping it out as the currently used picks do.



a b

Figure 4. Design of a pick with a cutting blade (a) and a pick for 1-GPKS roadheader with a replaceable rotating cutting part of the head (b).

The cutting power of the pick maintained for a long time (owing to the great length of the cutting edge) and a small area of contact with the rock reduce friction sparkling, heating of the pick, the risk of explosions in the coal and methane atmosphere, the energy costs of the rock breaking are reduced as well. Changing of the principle of destruction from deformation and chipping out to cutting decreases the yield of fines and rock dust, and increases the grade of the coal mined.

4. Conclusion

The conditions and mechanism of rock breaking by a pick in mines have been analyzed. The advantages and disadvantages of the current pick design have been identified. Reusable blade-type tangential rotary picks having good prospects have been designed. The proposed picks are more cost efficient, have more extended service life, increase the grade of the coal mined and improve safety of underground mining operations.

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