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# RECOVERY OF WORN-OUT PICKS IN ROCK BREAKING*

*Mining is the most resource-intensive industry in the world. One of the critical and expensive resources is a rock-breaking tool. Widely used tangential-rotary pick, although advantageous, are expendable. A tool with a worn body (often insignificantly) is discarded. Such rejects are never reclamated.*

*This article authors propose to sort available rejects and select picks with heads worn-out not more than by 50% of initial length. Such picks are suitable for equipment with replaceable cutting noses to be further used in rock breaking. Aside from low cost, the recovered picks become nonexpendable.*

*By computer modeling, the optimal values of diameter and length of the nose shank, which ensure the highest strength characteristics of the picks in operation, are determined. Based on the obtained results, reconditioned picks fitted with noses with the optimal parameters were manufactured. The picks were tested on roadheader KSP-35 in a mine in 2014. Two picks were installed in the second row of the crown-type cutting head. The noses were replaced at wear limit. All in all, 18 noses were tested. The wear and tear process was uniform, no failures were observed. The life of the noses reached 3–4 weeks, which corresponded to heading for a length of 60–90 m.*

*The calculations show that recovery and multiple use of worn picks cut the requirement of mines for purchasing new picks by an order of magnitude. Manufacture of 9 replaceable noses needs 1935 g of metal, which replaces 9 regular picks with a gross weight of 9600 g. Waste level of coal mining with respect to cutting machine picks lowers 5 times. Purchase cost of new picks is cut by 1.5–1.7 times.*

***Key words:*** *mine, pick, wear, rejects, recovery, replaceable nose, design, resource efficiency*
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## Introduction

Mining is the most resource-intensive industry in the world. In gradually deeper-level mining under difficult ground conditions, it is crucially important to enhance resource efficiency of technologies and processes [1–4].

Salt, gypsum, coal and other mineral mines use roadheading and shearing machines. The machines are tooled with cutting heads and shearing drums equipped with tangential-rotary picks (TRP). These picks have replaced radial picks owing to such advantages as self-sharpening, comparatively long service life, lower energy consumption in rock breaking, simple installation and operation. Many researchers in different countries focus on further improvement of picks for roadheaders and shearers. The influence of rake angles on cutting depth of picks is studied in [5, 6]. The analysis of the relationship between loosened coal volume, pick temperature and cutting depth is given in [7]. The effect of the pick tip composition on the pick wear as well as the tungsten carbide degradation at rock–tool contact are described in [8, 9].

Extra reinforcement of pick tip and welding of steel body for extending the tool life is proposed in [10, 11]. Alternative designs of the pick geometry and shape to improve the tool cutting ability are put forwards in [12–14]. Effect of water flow to cutting zone on the cutting efficiency is investigated in [15, 16].

The TRP test results in mines in Kuzbass and recommendations on their design improvement are given in [17–20]. The promising designs of picks with replaceable reinforcing elements, reliable shank locking mechanisms etc. are described in [21–24]. Substitution of taped nose for elliptical and the effect of the latter on rock cutting efficiency are discussed in [25].

An essential drawback of TRP is expendability [26]. No viable solutions on utilization of worn-out picks have been proposed so far. Eventually, a tool with a somewhat (often insignificantly) worn body becomes waste. Such picks are either discarded in mines, or placed for a long time in open surface storage, rust and loose value. At best, they are sold as scrap metal for remelting at metallurgical plants. Such situation governs low resource efficiency and economy of cutting tools in mines.

## Methods and materials of research

The research material was the picks of roadheading and shearing machines employed in mines in the Kuznetsk Coal Basin (Kuzbass). The tests were carried out in mines operating in the north, center and south of the coal basin, in different geotechnical conditions. Structurally, a TRP consists of a steel holder, cylindrical shank and a conical head with a wear-resisting high-strength alloy cutting pick. The shank is fixed in the holder to prevent the pick from spontaneous fallout. The lockers may be steel clamps or plastic half-rings put in the shank groove.

A cutting head of a mining machine can be equipped with 28–56 picks and more, while their total number on a shearer can be 150. Picks for heading and shearing machines have basically the same design. The difference is the size and shape of tips and shanks.

The reinforcing element experiences abrasive wear during rock cutting. The life of picks is governed by a number of factors, the basic of which are hardness of rocks, strength and quality of picks, state of holders, reliability of locking and qualification of machine operator. In Kuzbass mines, the life of picks ranges from a few weeks (in coal) to a few hours (in sandstone). The average expenditure is 200–300 picks per cutting machine per month, which increases to 150–250 picks

*The studies have been implemented in the framework of the competitive capacity upgrading program of the Tomsk Polytechnic University.


**Fig. 1. Worn-out picks of coal cutting machines**

per day in hard and abrasive rocks. The cost of one pick 1 kg in weight is comparable with the cost of 1 t of coal produced in a mine and amounts to 900–1400 rubles.

According to operating procedures of heading and shearing machines, picks cannot be used after wear of tungsten carbide tip as it fails to cut rock mass, and are to be replaced. Worn-out picks from various mining machines are shown in **Fig. 1**.

The studies were carried out on worn picks from seven Kuzbass mines. The studied parameters included the pick size after operation, shape, nature of wear and weight. All in all, round 500 picks were examined.

The pick design parameters were evaluated in the tests of pick RGP 33-87-70/16M on roadheading machine KSP-35. This machine is widely used in Kuzbass mines in medium-hard and hard rocks. Actual sizes of the pick were used for the geometrical modeling and strength calculation based on the finite element method in SolidWorks Simulations. The SolidWorks Simulation environment is extensively applied in the analysis of stresses and strains of structures, including mining machines [18, 27]. The calculations were aimed to determine diameter and length of a replaceable nose so that ensure maximum strength of the design. In the studies, the solver FFEPlus was used, which is more efficient for large-scale problems due to improved matrix ordering.

The check test of the composite design pick with the proposed parameters was implemented in 2014 in the Pervomaiskaya Mine (Kemerovo Region, Russia) on the machine KSP-35 in heading of a conveyor drift with a cross section of 16.5 m$^2$ in coal seam 24 having average thickness of 1.03 m in rocks mass with Protodyakonov's scale hardness $f$ = 4÷7 (up to 8).

### Results and Discussion

According to the checkup of sizes and shapes of worn-out picks, 70–80% of holders preserve their integrity. Only tips get worn. However, without the tungsten carbide tips, the operation of picks is prohibited because of the jump in the cutting forces, violent sparking under friction and higher mining machine transmission load. More often than not the picks removed from the cutting machines have wear not more than 10–15%. Thus, to 85–90% of an original tool manufactured of high-strength and expensive steel go to waste. Since a new pick has weight of 1050 g, then 890–945 g of the pick weight becomes lost.

Resource efficiency of mining can be increased using engineering solutions aimed to restore usability of castaway picks. The research into the nature and degree of wear, as well as into design features of picks allows reactivating considerable number of picks discarded in coal mines. To this end, it is suggested to select picks with the head wear not more than 50% of initial length from castaway picks. By experts' estimates, reusable tools can make 70–80% and more of all rejects. Then, the worn-out nose is removed, and 50–70% of the initial length of the pick head is left. In this left head, an axial socket is drilled with a diameter $d$ and a length $l$ depending on the pick size.

After that, a new nose with tungsten carbide tip is worked out to have the shape of the original nose piece. The new nose has an axial projection to be inserted in the pick head socket. At the end of the axial projection, in the groove, an expansion semi-ring is installed to keep the nose in the holding socket and to prevent their mutual rotation. The length and shape of

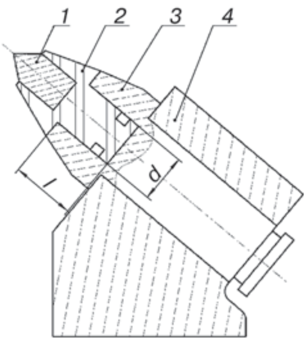


**Fig. 2. Reconditioned pick design:**
***1* — tungsten carbide tip;**
***2* — replaceable nose;**
***3* — tool socket head;**
***4* — pick holder**

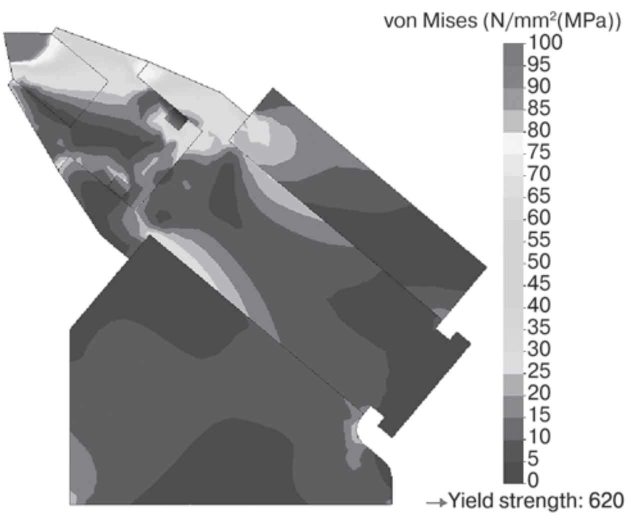


**Fig. 3. Von Mises stress distribution in the elements of reconditioned pick**

the nose should repeat the original parameters of the tool head (**Fig. 2**).

Parameters of the replaceable nose shank (RNS) were determined by computer modeling for different RNS with varied diameter and length. As a result, the influence of geometrical parameters *d* and *l* on von Mises stress distribution in elements of the composite pick under operational loads was determined. As an illustration, **Fig. 3** shows the stress diagram for the pick design with *d* = 28 mm and *l* = 23 mm.

The stress diagram demonstrates distribution of stresses in the holder, shank and socket head of the pick, as well as in the replaceable tungsten carbide tip nose in the range of 0–100 MPa. The highest stresses are at the cutting edge of the tip (to 100 MPa), the lowest stresses — in the holder (5–35 MPa). An increased stress zone (60–80 MPa) arises at the bedding point of the replaceable nose and the holding socket head on the opposite side relative to the cutting direction of the pick.

The calculations were performed for 70 variants of RNS parameters. The dependences between the maximum stresses in the holding socket head and the RNS diameter at different RNS lengths generally have the same behavior with the minim stresses in the range of the RNS diameters from 18 to 22 mm. Beyond this range, the maximum stresses grow. The minimum stress is 68 MPa for RNS with the diameter *d* = 22 mm and length *l* = 29 mm (**Fig. 4**, ***a***).

The curves of the maximum stresses in the replaceable nose in **Fig. 4, *b***, although more complex and nonuniform, also have a minimum stress range for all lengths in the range of the shank diameters from 28 to 32 mm. The minimum stress is 75 MPa for the diameter *d* = 28 mm at the shank length *l* = 17 mm.

Since the minimum stress ranges for the holding socket head and the nose mismatch, the plot of the arithmetical averages of stress between the relevant points in the two preceding plots was drawn (**Fig. 4, *c***). As a result, a common minimum at *d* = 28 mm and *l* = 23 mm was revealed for all variants of dimensions.

Based on the research findings, the picks with the noses having the optimal shank diameter *d* = 28 mm and length *l* = 23 mm were manufactured. The picks were subjected to trial on the heading machine KSP-35 in the Pervomaiskaya Mine within 2014. Two picks were placed in the second row of the crown-type cutting head. The noses were replaced at the limit wear (**Fig. 5**).

All in all, 18 noses were tested. The wear and tear process was uniform, no failures were observed. The life of the noses reached 3–4 weeks, which corresponded to heading operations for a length of 60–90 m.

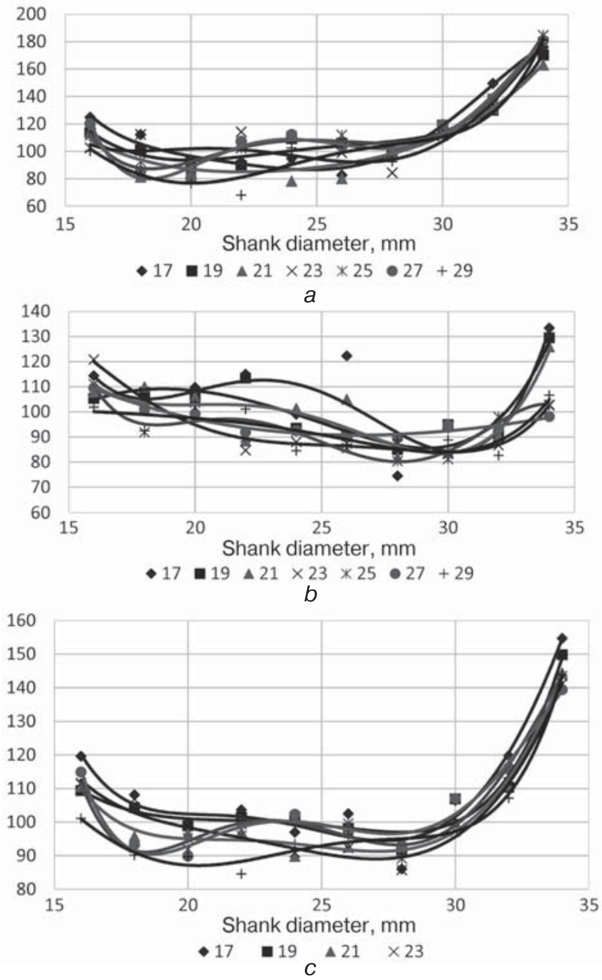


**Fig. 4. Maximum stress as function of the nose shank diameter at different shank length of 17, 19, 21, 23, 25, 27 and 29 mm:**
***a* — holding socket head; *b* — replaceable nose;**
***c* — average values**

**Fig. 5. Reconditioned pick:**
***a* — holder from rejects;**
***b* — installation of replaceable nose**

Such picks, alongside a low cost, are advantageous for multiple usability [28], which only requires installation of a new nose after the previous nose is worn-out. Furthermore, owing to additional rotation joint in the structure (aside from the pick shank in the holder), the pick rotation conditions facilitate and the tungsten carbide tip is worn more evenly, which extends its service life. The full-scale tests of the picks in mines demonstrated good results: one and the same holder served for the use of 9 cutting noses, thus, replacing 9 conventional non-composite picks.

According to the calculations, the return of picks into service and their multiple use cut the requirement of mines for purchasing new picks by an order of magnitude. Manufacture of 9 replaceable noses needs 1935 g of metal, which replaces 9 regular picks with a gross weight of 9600 g. Waste level of coal mining with respect to cutting machine picks lowers 5 times. Purchase cost of new picks is cut by 1.5–1.7 times. Considering the current annual use of 200–300 thousand picks in mines in the Kemerovo Region, for example, the re-use of rejects allows reduction in metal consumption to 40–60% per year and enables saving of 75–113 million rubles annually.

### Conclusion

As a result of the implemented studies, an engineering solution is proposed to solve the problem of improving resource efficiency of cutting tools of mining machines. It is suggested to recondition and multiply reuse accumulated worn-out cutter picks through their minor redesign and equipment with replaceable cutting noses. The developed design of a composite pick includes the holder of a worn tool and a new nose. The proposed shape and locking mechanism of the nose ensure reliable coupling.

Computer modeling determines optimal values of diameter and length of the nose shank to provide the highest strength characteristics of the tool in cutting rocks with the Protodyakonov index 6–8. The lowest stresses in the tool are observed at $d$ = 28 mm and $l$ = 23 mm. The prototype noses with the optimal parameters were tested on roadheader KSP-35 in a mine. The tests confirmed validity of the recommended parameters. The noses run undamaged until total uniform wear. The studies have shown that the holder can maintain operation of nine and more replaceable noses. Thus, the core of a pick becomes nonexpendable after reconditioning. This ensures considerable saving (to 1.5–1.7 times) in terms of money resources spent to purchase new picks, reduces rejects of picks to 5 times and improves resource efficiency of coal mining.

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