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# Improved Operating Performance of Mining Machine Picks

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**Abstract.** The reasons of low performance of mining machine picks are stated herein. In order to improve the wear resistance and the cutting ability of picks a new design of a cutting carbide tip insert to be fixed on a removable and rotating pick head is developed. Owing to the new design, the tool ensures a twofold increase in the cutting force maintained longer, a twofold reduction in the specific power consumption of the breaking process, and extended service life of picks and the possibility of their multiple use.

## 1. Introduction

The main cutting tools used for breaking rock and minerals in coal, salt, ore mines and etc. by mining machines are conical rotary picks. Having a pointed body and being reinforced with a hard-alloy tip, such picks ensure considerable cutting force and a relatively long service life. Easy replacement, operational reliability, self-sharpening while rotating promote a wide use of this type of picks. Thus, for the last two decades shearers and road headers in the Russian Federation are fitted mainly with these picks. Annually about 80 mln. tons of coal in the Russian mines are broken by conical rotary picks. Their consumption rate is up to 250-300 thousand pcs per year. Milling drums of surface miners widely used in quarries of the United States, Australia, South Africa and other countries for layer-by-layer breaking of rock are also fitted with conical picks. Over 200 picks can be mounted on a milling drum at a time. The consumption rate of wear resisting picks produced by *BETEK* is up to 1.6 pcs per every 1,000 tons of broken rock mass [1]. Due to a poor quality of picks, the consumption rate may increase up to 14-27 pcs per 1,000 ton of broken rock mass [2].

The pick is designed as a steel cylinder shaped body with a tapered head. A conical reinforcing hard-alloy insert tip for rock breaking is soldered in the top of the head. The practice of using picks in coal mines of Russia, India, and Australia shows that one of the disadvantages significantly reducing the service life of picks mounted on mining machines is early wear of the pick body [3,4] resulting in reduced efficiency of the joint and the reinforcing insert falling out which leads to premature pick failure. Thus, the consumption of cutting tools increases and mines incur significant purchase costs.

## 2. Results and Discussion

The wear of picks mounted on roadheaders and shearers was tested in Kuzbass mines during 2008-2015. Road headings and coal faces of twenty mines were examined. The wear degree of picks mounted on a mining machine is presented in Fig. 1.

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Picks are used on a mining machine until a hard-alloy tip wears out; then picks are removed and replaced with new ones. The picks in Fig. 1 are worn evenly after long time operation. However, in terms of research different wear patterns were identified which determine their operation periods. Table 1 shows the reasons of conical rotary picks failure [5].

Figure 1. Picks wear over time

**Table 1.** Percentage of *RSH* picks failure by types

| № | Failure type | Failure percentage, % |
|---|---|---|
| 1 | One-sided wear of pick body with further breaking-out of cutting insert | 45 |
| 2 | Even wear of pick body | 27 |
| 3 | Loss of picks | 25 |
| 4 | Break of pick body | 3 |
| | **TOTAL** | **100** |

According to these experimental results, only 27% of RSH picks are worn out during rock breaking operations. Almost 50% of picks break down prematurely and do not pay back; and 25% are lost, and mines bear direct losses.

One of the reasons of early breaking out of a cutting insert is a high wear of a steel body around it. Premature thinning of the body walls results in the inability of the metal to resist the side force affecting the tip, therefore, the insert is broken out of the holder (Fig. 2) [2].

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Figure 2. RKS-1 pick with a hard-alloy insert broken out

Similar deformation of picks in the Indian and Australian mines are identified and described by foreign researches (Fig. 3) [3, 4 ]. The examination of failures shows an early wear of a steel body around the hard-alloy tip. At the same time, the tip itself has an insignificant wear rate, retains its shape, and can be used again. However, the strength of steel is considerably lower than the strength and wear resistance of ceramic alloys. Another uncovered reason is uneven hardening of the pick head during heat-treatment [6].

Figure 3. Early wear of a pick body around the tip

Many research papers of scientists around the world deals with examination and elimination of such types of picks deformation [7-10]. The solutions aim at ensuring uniformity of heat treatment and increasing strength of the steel body, balancing the wear resistance of the inserts and the holder, providing additional head protection around the tip, etc. One of the recent practical solutions is that of *Sandvik* offering a carbide ring *TriSpecTM* placed on the pick body and protecting an insert joint area (Fig. 4) [11]. The ring covers the front part of the pick head in the place of soldering the tip, protects the steel body from premature wear, and extends the service life of the hard-alloy insert.

A


B

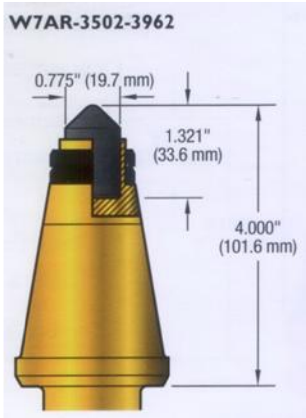


Figure 4. Pick with *TriSpecTM* protecting ring:
A – general view; B – pick head in section

A similar solution was developed by *Kennametal* offering *U119HF 80 16* and *AM521HF.74* picks with a protecting ring on the head nose. Despite the innovative nature of the solution, it has significant disadvantages. The first disadvantage is that this solution increases the pick cost and does not allow its further utilization after the hard-alloy insert wears out. Besides that, a conical insert is not suitable for cutting rock mass. Its breaking mechanism is deformation and chipping out that requires high power consumption and mechanical efforts that result in overgrinding and lower-grade coal being produced [4, 12]. High dust generation contaminates the atmosphere and poses a risk of explosion in mines. During such contact with the rock mass the pick is exposed to considerable friction resulting in sparkling, thus high water consumption is required to reduce sparkles and dust.

The new design of the pick with a head and a tip of a special shape protected by patent in Russia contributes to elimination of the disadvantages above (Fig. 5). The basis of the tool is an advanced design of the pick with a removable head [13,14]. Mine tests showed that such picks can be used up to 10 times, and only the replaceable head need to be changed.

The proposed pick consists of high-strength steel rotary body; the main conical head has a replaceable part changed when worn out and enabling multiple use of the pick holder. The replaceable head is fitted to the main one by an axial lug secured in the main head. A distinguishing feature of the new tool is a ceramic tip which is not soldered in the replaceable head (as it used to), but put on it enabling rotation. A tip is secured in the replaceable head by a small metal pin. Thus, for the picks mounted on roadheaders *KP-21* and *KSP-35* diameter and height of the tip is 35mm, and a securing pin is 40-45 mm long and has a diameter of 5 mm.

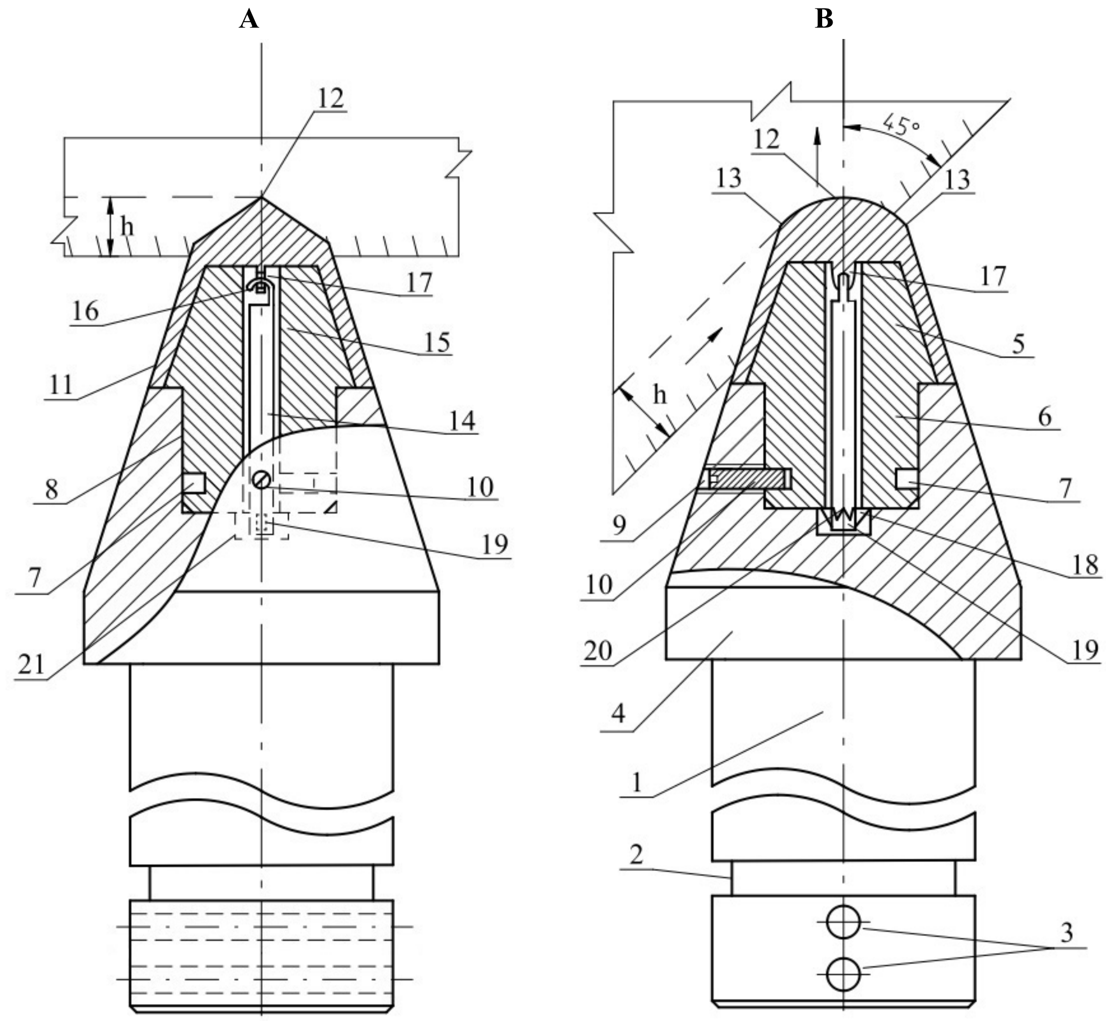


Figure 5. Pick with hard-alloy cutting tip:
A – front view; B – side view;
1 – cylinder shaped holder; 2 – circular groove; 3 – split pin holes; 4 – main head; 5 – replaceable head; 6 – axial lug of replaceable head; 7 – circular groove on axial lug; 8 – socket; 9 – screw hole; 10 – retaining screw; 11 – hard-alloy tip; 12 – cutting edge of tip; 13 – rounded face; 14 – securing pin; 15 – axial bore; 16 –hook; 17 – tip eye ring; 18 – lock; 19 – locking petals; 20 – spring; 21 – pin receiver

It is proposed that a new tip should be shaped as a semi-circle with a cutting edge, rather than as a cone. A cutting edge is sharpened at 50-80 degree angle with due account to hardness of rock to be broken.

The solution follows the modern line of improving rock breaking methods by using disk tools acknowledged recently as the most promising [15]. In addition to that, the service life of the proposed cutting tip made of tungsten-cobalt alloy will be longer than that of a steel disk tool. Currently its production of hard alloys is deemed cost-inefficient due to large size (200-250 mm).

A pick produced in the way above is utilized as follows. A pick mounted on the cutting body of a mining machine or a surface miner is brought to the coal or rock surface and a breaking process begins, wherefore the pick is forced into the rock to a depth of *h* and is moved there. The angle of inclination of the pick mounted on modern machines to the cutting surface (angle of attack) is 45-55 degree. Once the pick

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contacts the rock mass, owing to friction and three rotary groups (pick in block; replaceable head in the main head; tip in replacement head), the tip 11 rotates along the line of least resistance. Its cutting edge 12 is aligned with the line of pick movement over the rock surface, penetrates into it and cuts. Rock is broken with less effort in a light duty mode as the penetrating power and the cutting ability of the cutting edge 12 of the tip 11 is higher than those of the conical tip. Mining machine mechanisms operate without dynamic overloads and consume less energy. Beveled cutting edge 13 of the tip encourages easier cutting and movement of the pick in the rock mass. A special pattern of mounting picks on the cutting tools of a mining machine ensures the required frequency of cutting lines to separate parts of rock.

The tip 11, owing to its conical shape, covers the replaceable steel head 5 and protects it from the contact with the rock and wear. After a long-lasting operation of the pick and inevitable wear of its tip 11 a retaining screw 10 is unscrewed, and the replaceable head 5 is taken out of the main head. Then by clasping petals 19 of the lock 18 the securing pin 14 is released and taken out of the axial bore 15 of the replaceable head. The worn out tip 11 is replaced with a new one, the tip is attached in the reverse order to the replaceable head secured to the main head 4 by the retaining screw 10, and another operating cycles begins. It ensures extended service life of the replaceable head. In case of unforeseen excessive wear of the tip 11 and damage to the replaceable head, the latter is replaced with a new one. However, the holder 1 and the main head 4 are utilized multiple times. The service life of the pick increases significantly as compared to the picks used at this moment.

Three rotating parts of the proposed pick (holder, replaceable head, and tip) prevents jamming of the tool in one position and significantly reduces its accelerated one-sided wear. Two parts (tip and replaceable head) replaced in terms of gradual wear ensure extended service life of the pick.

A cutting edge of the tip encourages cutting and chipping of rock without its crushing, and no compacted core is formed under the pick. As the length of the cutting edge 12 of the tip greatly exceeds that of the cutting edge of the conical carbide insert, the cutting ability of the new tip is maintained longer. Destruction of the rock mass with a blunt pick results in increased operational load of mining machines and high energy consumption. According to the research, in order to penetrate into the rock mass at the depth of 1mm the force of 4.7 kN is required for a sharp tool, the double force is required for a blunt tip (Fig. 6) [5].

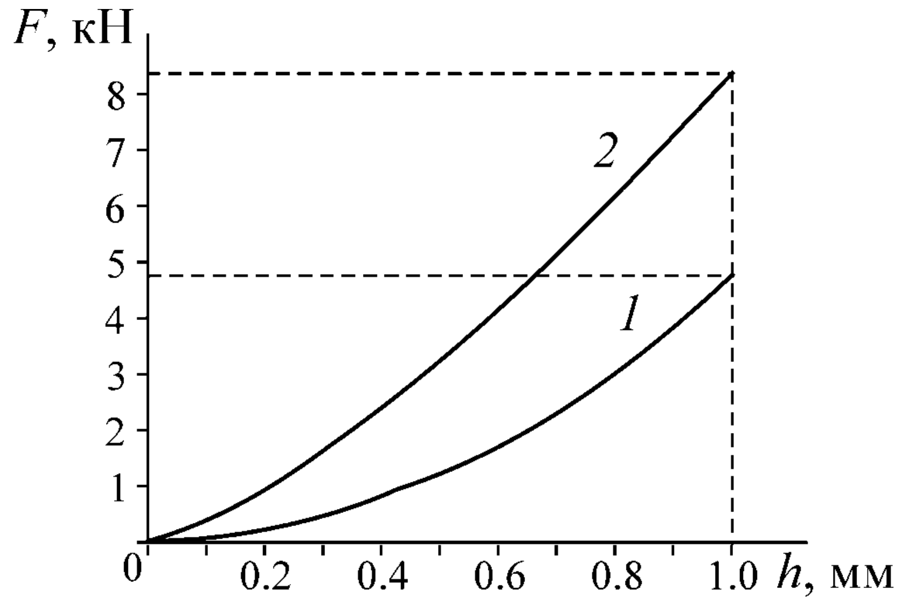


Figure 6. Force required for penetration of a sharp (1) and blunt (2) tools into the core

Other tests showed impact of the cutting angle of the tip on the cutting force with ultimate uniaxial compression strength of 52.3 MPa and sandstone density of 2.5. t/m$^3$. It was revealed that rock breaking with *Sandvik* conical pick *P9QA-2560-3562* having a tip of 12 mm ∅ and cutting angle of 70 degree at the depth of 15-20 mm (normal depth for mining conditions) requires the cutting force of 40-70 kN, and for a pick with the cutting angle of 110 degree (blunt) the cutting force should be 80-120 kN (Fig. 7). It was also revealed that the specific energy consumption of rock breaking increased two- or threefold with a pick blunting from 70 to 110 degree [16].

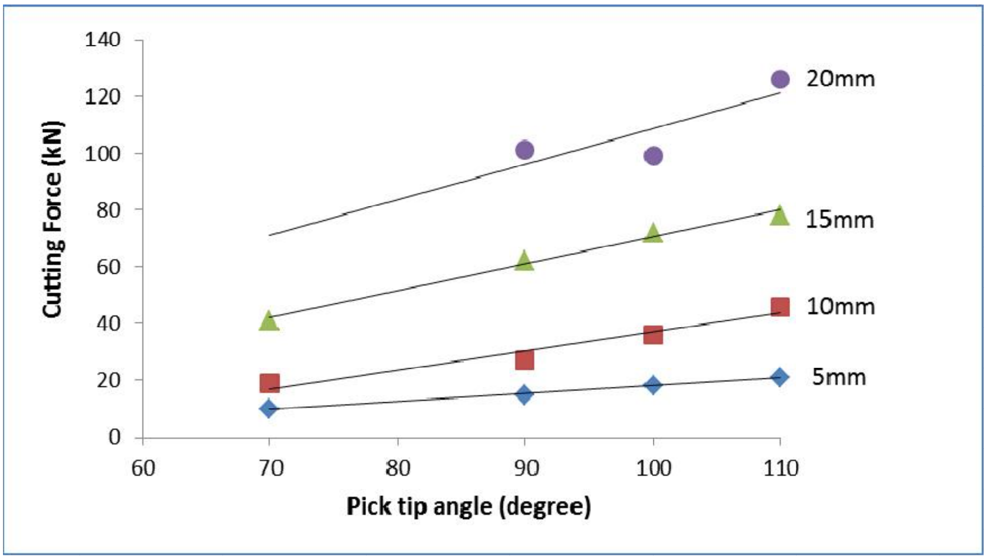

Figure 7. Cutting force vs. cutting angle and penetration depth

The tests conducted in mines showed that the specific energy consumption of KPD mining machines equipped with conical picks increases at least by 20% during the first operation as picks become blunt [17].

Great and continuous cutting ability of the proposed pick considerably reduces the energy consumption of rock breaking operations, frictional sparkling of the pick, enhances security of underground mining. Switching from destruction and chipping out to cutting reduces dust and fines, and increases the coal grade. The given advantages of the designed tool determine the prospects of its utilization in coal, sole, and gypsum mines, etc.

## 3. Conclusion

Wide use of conical rotary picks on mining machines and surface miners all over the world is accompanied by high consumption of cutting tools. One of the reason of frequent replacement of picks is early wear of the steel body around the carbide pick that results in chipping out of the tip from the holder. The recent innovative solutions are not perfect yet. Besides, the conical shape of the pick tip determines the destruction and chipping nature of the rock breaking process that results in high energy consumption.

A design of the pick with a cap tip and a cutting half-disk edge was developed and patented. The carbide tip is not soldered, but mounted on the replaceable head of the pick and secured by a small pin through an axial bore which enables rotation of the tip. The replaceable rotary head is secured by an axial lug in the socket of the main head and retained by a screw. Once the pick contacts the rock mass, owing to the attack angle and three rotary groups (pick in block; replaceable head in the main one; tip on replacement head), the tip rotates along the line of the least resistance; its cutting edge is aligned with the line of pick movement over the rock surface, penetrates into it and cuts. Rock is broken with less efforts in a light duty mode as the penetrating power and the cutting ability of the pick cutting edge are maintained longer with the wear rate twice as less as of the blunt conical insert.

Mining machine mechanisms equipped with the proposed picks will operate with less dynamic loads and energy consumption. The specific energy consumption of the rock breaking process can be reduced two- or threefold. Besides, cutting of coal and rock, instead of crushing, results in reduced friction and sparkling in coal faces, less production of fines and dust, reduced risk of explosions in the dust-methane-air atmosphere in coal faces. The possibility to replace worn tips and changeable heads ensures operation of a pick holder during 5-10 cycles and reduces purchase costs.

## 4. References

[1] Pichler M et al 2013 Commissioning of combine Wirtgen 2200SV at JSC "Kovrov Kar'eroupravlenie" *Mining industry* vol 2 pp 110-116
[2] Romanovich A S and Kalukiewich 2015 The requirement for energy efficient tangential cutter used for the development of potassium salt *Mining industry* vol 1 pp 2-4
[3] Saurabh Dewangad, Somnath Chattopadhyaya and Sergey Hloch 2015 Critical damage analysis of WC-Co tip of conical pick due to coal excavation in mines *Advances in Material Science and Engineerin* 292046
[4] Sun Y and Li X S 2014 Ineffective rock breaking and its impacts on pick failures *The 31st International Symposium on Automation and Robotics in Construction and Mining* (ISARC 2014)
[5] Khoreshok A A et al 2013 *Production and operation of destructive mining machines tool* (Tomsk) p 296
[6] Bolobov V I, Bobrov V L, Talerov M P and Bochkov V S 2012 The reason of quick wearing of tangential cutters *Notes of Mining Institute* vol 195 pp 238-240
[7] Sarwary E and Hagan P 2015 The effect of tool geometry on cutting performance *Mining education Australia – Journal of research projects revie* vol 4 number 1 pp 43-48
[8] Xiaohui Liu, Songyong Liu, Lie Li and Xinxia Cui 2015 Experiment on Conical Pick Cutting Rock *Material Assisted with Front and Rear Water Jet Materials Science and Engineering* 506579
[9] David R. Hall 2014 Patent US 8,777,326 B2 Pick with hardened core assembly. Data of Patent Jul.15
[10] Prokopenko S, Sushko A and Kurzina I 2015 New design of cutters for coal mining machines *IOP Conference Series: Materials Science and Engineering* 91 012058
[11] Cutting tool for rocks 2014 Mining RC 100 *Sandvik product catalogue* p 52
[12] Kolesnichenko E A, Kolesnichenko I E, Lyubomischenko E I and Demura V N 2012 Techniques for Face Ventilation According to Dust-making Ability of Roadheader *Coal* 6 pp 39 -42
[13] Prokopenko S A, Ludzish V S, Kurzina I A and Sushko A V 2015 Results of industry testing of multiple use rock-cutting picks *Gornyi zhurnal/ Mining Journal* 5 pp 67-71
[14] Prokopenko S A and Ludzish V S 2014 Problems of innovative development of the mining Enterprises of Russia *Gornyi zhurnal/ Mining Journal* **1** pp 47-49
[15] Khoreshok A A, Mametev L E, Borisov A Yu and Vorobev A V 2015 Stress state of disk tool attachment points on tetrahedral prisms between axial bits *Applied mechanics and materials* vol 770 pp 434-438
[16] Esmat Sarwary and Paul Hagan 2015 Changes in Cutter Performance with Tool Wear *15th Coal Operators' Conference (*University of Wollongong, The Australasian Institute of Mining and Metallurgy and Mine Managers Association of Australia) pp 283-290.
[17] Shabaev O E, Hitsenko N V and Bridun I I The formation of the cutting forces on the incisors of the Executive body of roadheaders based blunt Available at: http://ea.dgtu.donetsk.ua:-8080/jspui/bitstream/123456789/26246/1/shhicbri.pdf (Last accessed date 20.03.2015)