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PROBLEMS OF HARD ROCK CUTTING

PROBLEMY ZWIĄZANE Z URABIANIEM SKAŁ TWARDYCH

***Summary**: Cutting tools for high-hardness non-metallic materials are subjected to intense wear. This is caused by impact loads, frictional and thermal processes, and corrosive influences. The picks used to date do not provide an adequate durability. To increase their durability and reduce energy losses in the cutting process of hard materials, a tangential-rotary pick design was developed with turbine-assisted pick rotation during each cutting cycle. This pick design allows for reprocessing and reuse. Recovered worn carbide tips can be used in a recycling process, where the tungsten carbide grains are reused. The use of picks in the mining of rocks and minerals will allow for significant technical and economic benefits while maintaining high environmental values.*

***Keywords**: cutting of hard non-metallic materials, tangential-rotary picks, turbine rotation system*

Streszczenie: Narzędzia skrawające do materiałów niemetalicznych o dużej twardości podlegają intensywnemu zużyciu. Przyczyną są obciążenia udarowe, procesy cierno-termiczne oraz wpływy korozyjne. Stosowane dotychczas noże nie zapewniają odpowiedniej trwałości. Celem zwiększenia trwałości i obniżenia strat energetycznych w procesie skrawania twardych materiałów opracowano konstrukcję noży styczno-obrotowych z turbinowym wspomaganiem obracania noży w każdym cyklu skrawania. Konstrukcja noży zapewnia możliwość ich regeneracji i wielokrotnego wykorzystywania. Odzyskane zużyte ostrza z węglików spiekanych mogą być wykorzystane w procesie recyklingu, w którym ziarna węglików wolframu będą ponownie użyte. Zastosowanie noży w praktyce urabiania skał, w tym kopalin użytecznych pozwoli na uzyskanie dużych efektów technicznych i ekonomicznych z zachowaniem wysokich walorów ekologicznych.

Słowa kluczowe: skrawanie twardych materiałów, nóż styczno-obrotowy, turbinowe wspomaganie obrotu noży

Introduction

Many fields of technology require cutting of hard, non-metallic materials, such as natural underground rocks and surface mining, tunnel construction, quarries, construction of various facilities, road and airport repairs, and other applications. During the operation of cutting tools in these applications, particularly intense destructive processes occur, including high impact loads, intense abrasive wear, and fretting-thermal fatigue processes that damage the surface layer of the cutting tips [1]. These effects are often further intensified by corrosive influences.

Sintered tungsten carbides in a cobalt matrix, commonly applied for rock cutting tips, despite several advantages, such as high hardness and resistance to abrasive wear at room temperature, often significantly degrade their properties under rock cutting conditions due to the high temperatures that are generated during the cutting of hard and very hard rocks and similar materials. At higher temperatures, the hardness of cemented carbides and their resistance to erosive wear are significantly reduced [2].

This necessitates the use of effective cooling, usually with water, for cutting tools during cutting, while simultaneously striving to reduce water consumption. This need is particularly required in underground mining because the water for the cooling of cutting tools must be transported from the surface over a long distance, and after use, it must be pumped out along with the deposit water, consuming significant amounts of energy.

The extremely high loads on the cutting tips during the cutting process require particularly strong and reliable mounting in the cutting tools.

Currently, the most common is the application of tangential-rotary picks, which offer numerous advantages [4]. The main advantage of these picks is that when they are allowed to rotate successively around their own axis, their abrasive wear is favourable and uniform, even resulting in a kind of "self-sharpening" during operation. To ensure the pick's rotation, they are most often rotationally mounted in the cutter heads, operating under the angle so-called lateral twist [1]. This method is ineffective in the conditions of fine-dispersed rock dust and corrosive influences.

With this type of pick mounting, there is a tangential component of cutting resistance, which is intended to ensure the required rotation of the tangential-rotary picks. When cutting very hard rocks, the discussed method is often insufficient to ensure pick rotation; it causes high consumption of the energy of the mining process, which further increases the tip temperature [1]. The frequent strong influence of highly corrosive deposit waters, primarily due to their salinity, is also significant [3]. Corrosion products significantly increase the resistance to pick rotation and often completely block the rotation of tangential-rotary picks. This necessitates the development of more effective and reliable methods for achieving successive rotation of tangential-rotary picks during each cutting cycle.

Another significant problem is the development of a more reliable method for securing the tips in the shanks of tangential-rotary picks. The brass soldering of the tips, as currently used, does not provide sufficiently strong tip attachment, as the soldering material softens or even melts under conditions of high temperature increases. This sometimes even leads to the loss of tips, and then the load on adjacent picks increases significantly, which rapidly accelerates their destructive processes, while the efficiency of the machines decreases and the energy consumption increases.

The present article describes a proposed design and technological solution for tangential-rotary picks, which significantly addresses the problems encountered when cutting rocks and similar materials [5, 6].

Concept of a pick with improved performance properties for cutting hard rocks

A new design and technological concept for a tangential-rotary pick designed for cutting rocks of high and very high hardness, developed at the Department of Mining Mechanization and Robotisation at the Silesian University of Technology, is presented in Figures 1 and 2. Figure 1 is a longitudinal cross-section of the pick's tip section, illustrating the method of mounting a carbide tip in the tangential-rotary pick's shank, along with a tip cooling and cutting zone spraying system. Figure 2 shows a solution that ensures rotation around the pick's axis using a water-powered turbine to cool the tip and spray the cutting area. The cutting tip 1, e.g., a pillar-type tip made of sintered tungsten carbides in a cobalt matrix, has longitudinal grooves 1a for the flow of water to cool the tip during the rock cutting process. The depth of the grooves 1a increases towards the conical base of the tip, creating confusor-like nozzles that accelerate the water flow, improving spraying and more effectively wetting the cutting zone. This is important for dust reduction and also ensures lubrication and cooling of the tip 1. The tip, mounted in the pick shank 2 (with cylindrical part 2c), is firmly secured by a holder 3 connected to the pick shank by a circumferential weld 6. During tip mounting, the steel holder 3 is firmly pressed onto the tip 1 after being heated to a partial softening temperature. After pressing the holder with longitudinal force N, exerted by hold-down device 4, a circumferential weld 6 is immediately performed, preferably simultaneously on at least two sides of the holder using electrodes 7, while maintaining force N.

A high thermal resistance lining 5 limits excessive heat transfer from the holder to the hold-down device 4. Hold-down device 4 (pressure N) is removed after the holder 3 has cooled significantly, and the weld 6 has fully hardened. After the weld is completed, it is advisable to turn on air-cooling of the holder, which allows for increased hardness through thermo-mechanical treatment of the steel holder.

To increase the effectiveness of the thermo-mechanical treatment of the holder, it is advantageous for the starting angle of the inner cone of the holder to be reduced by 1°÷2° compared to the cone angle of the cutting edge. This increases the range of plastic deformation of the upper zone of the holder 3, and in its lower zone, favourable, small, plastic outflows of the holder material 3a can be formed more easily. Plastic deformation of the holder also eliminates manufacturing deviations, especially angular ones, of the holder in relation to the conical surface of the carbide tip 1.

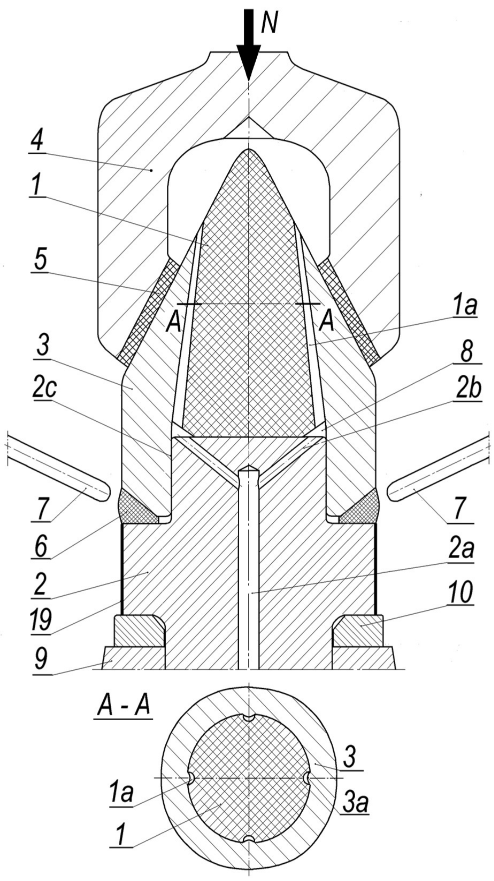

Fig. 1. Longitudinal cross-section of the pick tip, showing the method of mounting the carbide tip in the pick shank, as well as the pick cooling and cutting zone spraying system

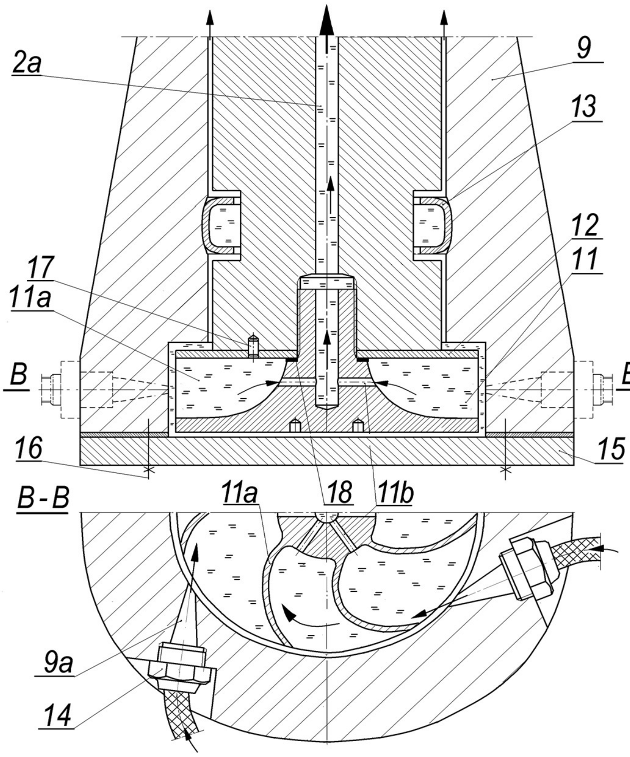

Fig. 2. A solution ensuring rotation around the pick axis using a water turbine powered by water that simultaneously cools the tip and sprays the cutting area

A fully analogous tip mounting method can also be used with the ring-type tips, which have a number of advantageous properties compared to the column-type tips. The most desirable advantage of the ring-type tips is that the cutting work on the mined rock is performed by a different segment of the ring-type tips as a result of the successive rotation of the tips around their axis. This favours very favourable wear patterns and more effective cooling, especially when cutting very hard, highly abrasive rocks. As a result of this procedure of embedding tip 1 in pick shank 2, significant thermal shrinkage of the holder 3 is achieved, ensuring a high load-bearing capacity of the shrink-fit connection between the holder and the pick shank, additionally with very strong, permanent clamping of the tip into the shank socket. This ensures a strong and reliable embedding of the tip in the shank, effective even with significant temperature increases generated during the rock cutting process.

The load N should be selected so that the partially softened material of holder 3 creates small but distinct flashes 3a in the slots of tip 1a. This serves to additionally secure the tip against rotation relative to the holder 3 due to very high impact loads on the pick during operation, which often occurs with other tip mounting methods, including hard soldering. Making the grooves 1a directly in the tip material significantly increases its cooling efficiency by providing an increased heat exchange surface between the tip and the cooling water stream. The chamfer of the tip 1 at its conical base creates a circumferential channel 8 for the cooling of the tip along the entire circumference of the base and, through holes 2b, for supplying water from a central channel 2a that runs along the entire length of the handle. This completes the highly effective cooling system for the entire tip and sprays away dust generated during rock cutting.

The pick shank 2 rests with its shoulder on the face of the pick holder 9 through an adapter ring 10. This allows for a large transition radius between the pick portion of the shank and its gripping portion. This significantly increases the shank's fatigue life, ensuring its high resistance to breakage under the action of high, periodically varying loads resulting from the cutting resistance of hard rocks.

For a tangential-rotary pick, it is crucial to ensure effective successive rotations around its axis. This is a necessary condition for achieving self-sharpening during operation. In this pick design, its rotation around its axis is achieved through the use of an efficient water turbine driven by the pick's cooling water. The turbine has the profiled tips 11a, to which water is supplied via nozzles 9a installed in the pick holder 9 (Fig. 2). The turbine rotor 11 is screwed into the pick shank using a fine-pitch thread with a thread direction selected so that the torque generated in the tip system tightens the connection.

The arrows in Fig. 2 illustrate the water circulation driving the turbine. After passing through the rotor, the water flows through radial holes 11b and through a longitudinal channel in the rotor to the central channel 2a, which supplies the previously described cooling system for the pick components, primarily its tip, and then generously sprays the cutting zone.

Water is fed to the pick through the ports 14 at moderate pressure p, where it is significantly accelerated, receiving the kinetic energy before entering the turbine rotor tips 11a. The turbine's high efficiency in ensuring the pick's successive rotation also results from its outer diameter, which is larger than the shank diameter of the pick. The design of the water turbine rotor shown in Fig. 2 allows for its convenient construction as an open rotor, which becomes a highly efficient closed rotor after the addition of disc 12. Disc 12 is secured against rotation relative to the pick shank by pin 17. Additionally, a washer 18 made of a highly friction material is used.

The most favourable conditions for rotating the pick around its axis occur when the pick leaves the contact with the rock mass being mined. Furthermore, the pick rotates most easily when, as a result of the rotation of the cutting element, the pick is in the downward position. The load in this position consists solely of the pick itself, with the attached turbine. The pick then rests on the front surface of the retaining ring 13, whose surface is preferably coated with a Teflon layer to reduce friction.

In this position, the pick can rotate around its axis at a significantly reduced supply pressure p, which significantly reduces water consumption. This is particularly important when cutting rock in deep mines, where water must be supplied from the surface over a long distance and then pumped out along with the deposit water. In addition to the primary water flow that flows through the turbine rotor, cooling the pick components and spraying the rock-cutting zone, some water flows out through the gaps between the pick shank and the pick holder, facilitating the pick's rotation through lubrication. This also prevents dust particles from entering the pick's seating zone in the holder.

For convenience, visual inspection of the crucial process of the successive pick rotation around the axis, shallow longitudinal grooves 19 should be made on the cutting edge of the pick shank, filled with a bright, contrasting varnish. These grooves observed under the light of a stroboscopic lamp allow for easy verification of the correct operation of the pick rotation system, even under the harsh operating conditions of rock-cutting machinery.

After the tip is inserted into the pick shank, installation in the working unit of the mining machine is as follows. After placing the retaining ring 13 on the pick shank, the shank with the ring 10 should be firmly pressed into the bore in the pick holder 9. Then, from the opposite side of the holder, the water turbine thread with the disc 12 and washer 18 should be firmly screwed in. Then, the pick holder cover 15 should be screwed in with screws 16. First, the water lines with connections 14 should be attached to the pick holder.

The pick design presented in this concept is highly susceptible to regeneration and recycling. In practice, the carbide tips and, if applicable, the holders are most susceptible to wear and tear.

When the wear limit is reached, then cut a circumferential weld 6 using a parting cutter on a lathe and remove the worn holder using a standard bearing puller. After replacing the tip and holder with new ones, the described procedure for mounting the new tip should be performed.

All other pick components can be reused after inspecting their technical condition.

Recovered used carbide tips can be used for other purposes or subjected to known recycling processes, during which the tungsten carbide micro grains can be completely recovered for the production of cutting elements, including pick tips for cutting rocks and minerals.

Summary

The described solution of the tangential-rotary picks for the rock cutting is characterized by a number of advantageous operational properties. The method of mounting the tips in the pick shanks ensures high strength and reliability, even with significant increases in cutting temperature and high impact loads. The turbine rotation system around the pick axis during each cutting cycle ensures high operational efficiency throughout its service life.

The water-cooling of the tips and the spraying of the cutting zone are highly efficient while maintaining economical water management.

The design of the picks makes them highly recyclable, and many of the components can be reused. The recovered used carbide picks can be used in the recycling process, including for the recovery of tungsten carbide grains for reuse.

The use of picks in the practice of mining rock and mineral deposits will allow for significant technical and economic benefits while maintaining high environmental values.

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