THE NEW SOLUTION OF LUBRICATED HOLDER FOR TANGENTIAL ROTARY PICKS REDUCING THEIR WEAR DURING THE MINING OF HARD ROCKS

KRZYSZTOF KOTWICA[1]

Abstract: The article presents the solution of holders lubricated with water under pressure to provide proper conditions of tangential rotary picks work in the holder. The results of laboratory tests of tangential-rotary picks fixed in the folders were presented and compared with results of picks only supported or sprayed with high-pressure water jets.

Keys words: Hard rock, tangential rotary pick, mining, wear, high pressure water jet assistance, lubrication

1. INTRODUCTION

Nowadays, in Polish coal mining industry most of the first working and preparatory headings are drilled with mechanical methods applying arm roadheaders. Heading excavations, particularly the first working ones, are already performed in rocks of very unfavourable conditions. It concerns mainly the strength of the mined rock centre against uniaxial compression that often exceeds 120 MPa, high rock compactness and its structure. Another important factor is the content of minerals and inclusions in rocks causing fast abrasion and wear of the mining tools, and, in case of inclusions e.g. sphaerosiderites, occurrence of strong sparking during operation. Also, deeper and deeper level of exploited coal depositions has an influence on worsening of physico-mechanical properties of rocks [3, 4, 6].

The mining speed is significantly affected by cutting tools mounted on roadheaders mining heads, mainly tangential rotary picks and their wear. An increased wearing process of the tools not only limits the mining advance, but it also increases consumption of energy and costs of mining and generates threats such as sparking and

---

[1] *Ph.D. Eng., AGH University of Sciences and Technology, Krakow, kotwica@agh.edu.pl*

the danger of gas explosion and dustiness.

The shape of the tool and proper method of its mounting in correctly selected holder allows its free rotation and even wear, frequently treated as the self sharpening process. An example of such ideal wear is presented in fig. 1. Obviously, the shape of the tool expressed by linear and angular dimensions and properties of the material used for constructing the body, holder and edge have to meet certain requirements connected with proper realization of the cutting process (motion cutting angles) and the length of operation time (durability). Determination of the requirements will allow to minimize the wearing process of cutting tools in defined mining and geological conditions in which a suitable mining machine operates or is dedicated to operate. Failing to meet the above listed requirements may result in improper operation of the tool and decay of its rotation in the holder and subsequently its fast wear. A view of a catastrophic wear of the tangential rotary pick edge at incorrectly selected conditions, after about 2 minutes operation on a special laboratory stand is presented in fig. 2 [5, 6].

Fig. 1. An example of even wear of cutting tools obtained in laboratory conditions by the Krupp-Widia company [5, 6]

Fig. 2. An influence of a tangential rotary pick rotation decay on the edge wear, a laboratory tests result [5, 6]

However, even proper selection of the shape and constructional and material parameters of a tool is often insufficient to provide its required durability. It is mainly connected with the lack of a possibility to rotate the tool in the holder. That is why other solutions are being investigated. One of them is application of individual assistance of the mining process with a tool with high pressure water jet. They are more widely described below.

High pressure water jets assisting the process of mining with tangential rotary picks used on roadheaders heads have been applied for many years. Initially, they were used only as external sprinkling in a form of so called water curtains. Currently is used so called inner system of sprinkling or assisting cutting tools. This system is presently applied in most of the manufactured roadheaders and shearers. It enables directing the high pressure water jet exactly in the area of the cutting tool operation [3, 6].

At mining with tangential rotary pick, there are two possibilities of assistance of the tool operation with a high pressure water jet. According to fig. 3 the location of the high pressure nozzle may be in front of or in the rear of the cutting tool. The nozzles are located in the tool axis. A view of exemplary applications of high pressure assistance systems on roadheaders heads is presented in fig. 4 [3, 6].

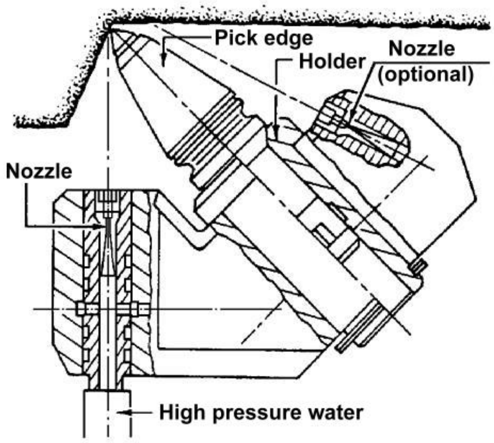

Fig. 3. A diagram of high pressure nozzles distribution at assistance of mining process with a tangential rotary pick [3, 6]

Benefits connected with applying high pressure water jets assistance of tangential rotary pick operation are significant. The high pressure jet from a nozzle located in front of the tool is forced into the area of cracked rock and moistens it which makes the mining process easier by lowering the rock strength. Additionally, at higher amounts of forced water, there is a possibility of easier output removal outside the plough through hydrotransport.

Fig. 4. A view of exemplary applications of high pressure assistance systems on roadheaders heads: on left – in the rear, on right- in the front [3, 6]

Whereas, at high pressure of the assisting jet, a crack cut by it in the tool axis should lower the mining resistance and decrease the energy needed to disintegrate the rock by weakening its structure. The tool edge penetrates the cut gap as a wedge and tears the rock apart. However, in this option the moistening of the rock from the side of application surface cannot be taken for granted so it can cause increased friction of the surface against the rock and creation of sparks behind the cutting edge in the plough.

This possibility is reduced to zero when the high pressure jet is directed from the rear of the tool directly into the plough. Though moistening the bottom and sides of the plough, a potential spark is put out immediately. The moistened rock also decreases coefficient of rock friction against the tool sides, and consequently the wear of the tool. It also limits the amounts of produced dust, especially at a blunt edge. Apart from direct factors listed above, there should be also considered indirect influence of the jet on decrease of dustiness due to edge wear through intensive cooling of the tool. It is connected with phenomena accompanying the decrease of friction coefficient like decrease of holding down force and the edge operation temperature.

Most of the performed tests on the influence of the introduced water assistance of tangential rotary picks on their wear confirmed its reduction. However, the tests were performed in the aspect of quantity and not quality. Lower wear was confirmed but its character was not examined neither was even wear during mining. Moreover, it was observed several times that after finishing tests the tools rotation in the holders got blocked due to sedimentation and drying of wet dust from the mined rock. Consequently it led during further tests to uncontrolled, very uneven wear. That is why the Department of Mining, Dressing and Transport Machines at AGH University of Science and Technology in Cracow started works towards limiting or eliminating the phenomenon. The works results are presented below.

2. NEW SOLUTIONS OF TANGENTIAL ROTARY PICK'S HOLDERS

As already mentioned increased and uneven wear of tangential rotary picks edges results from mainly reduction or even decay of the tool rotation in the holder. One of the main causes of the situation is worsening of cooperation conditions of the tool shank surface and the inner surface of the holder sleeve due to elements of dust and output penetrating both of them. It increases resistance of the tool rotation in the holder.

In order to solve the problem the Department of Mining, Dressing and Transport Machines at AGH University of Science and Technology in Cracow undertook attempts to bear the shanks of tangential rotary picks in holders to change dry or semi dry friction for mixed or half liquid friction. Because of limited constructional space defined by the tools dimensions, their holders and heads bodies as well as low rotary speed, obtaining liquid friction was not possible. It was then suggested to force lubrication of cooperating surfaces of the holder sleeve and the tool shank [3, 5, 6].

In the elaborated solution the dry friction was replaced with boundary friction or mixed one which gets created as a result of partial division of unevenness tops and their moistening or covering with e.g. emulsion or liquid. The solution of modernized holder of RM8 system with forced lubrication is presented in fig. 5. In the solution the lubricant (low-grade oil and water emulsion or clean water) is distributed under pressure through the hole of the tubing barb 2 to four grooves in the sleeve 3 mounted in the tool holder 1.

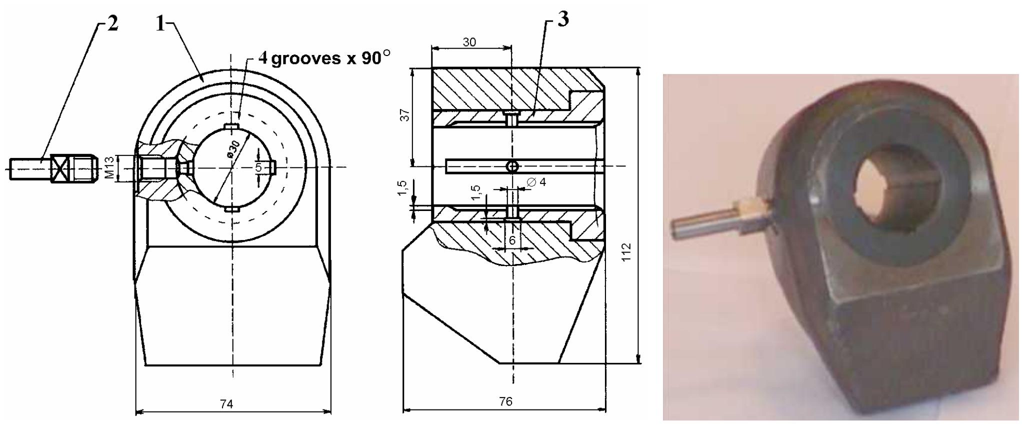

Fig. 5. Modernized, lubricated holder of tangential rotary picks of the RM8 system:
1 – tool holder, 2 – supply tubing barb, 3 – sleeve [3,6]

Alternative methods of rolling bearing of tangential rotary picks were elaborated. The solution of one of these holders is presented in fig. 6 [1, 2]. In order to check efficiency of the suggested solutions, two prototype holders were manufactured – one with a rolling bearing, the other one lubricated and they underwent preliminary examinations on a special laboratory stand to determine the influence of the method of the tool mounting on the number of their rotations in the holder.

Fig. 6. Bearing of the tangential rotary tools with the supportive bearing globule in the holder [1, 2]

3. TEST STAND AND MEASUREMENT PROCEDURE

The test stand (fig. 7) allows mining a concrete sample on side surface at stable mining parameters such as depth, cutting pitch and speed and defined angles of the machine setting. The tests were performed as comparative ones for new solutions of holders and the standard RM8 holder with the tool shank bearing in an exchangeable sleeve. For all tests tangential rotary picks were used with the diameter of carbide insert of 20 mm. The number of tools rotations was measured. During the tests the depth of cutting g = 9 and 12 mm was changed as well as side deflection angle ν within the range from 0 to 45°. The rock sample resistance to single axis compression R_c = 65 MPa was stable as well as the cutting speed v at about 1,25 m/s and the pitch t = 12 mm. The sample mining was performed at its whole width and markers on the tools shanks or heads allowed counting the number of rotations per 1 minute. The

Fig. 7. View of the test stand for single picks [3, 6]

measurement was performed for determined conditions of the tool operation. The lubricated holder was fed with 1,5% oil water emulsion in one of the cases and with clean water in the second one. In both cases the value of feed pressure *p* = 1,5 MPa [3, 5, 6].

Tests of mining with the use of holders assisted with water and low-grade emulsion were performed and comparative tests of mining using tools of the same type without and with high pressure jet assistance in front of and in the rear of the tool were also conducted for toll edge wear measurement. The tests with assisted holders were performed for tools of the Boart Longyear company of 138 – 139 mm height, 55 mm head diameter and carbide post diameter of 22 mm and two mining depths of 9 and 12 mm, assisted by 1,5% emulsion and water at pressure of about 1,0 MPa and flow rate of 1 dm^3/min. Whereas, mining without and with assistance with the use of the same tools was conducted only for depth of 9 mm, at water pressure of 45 MPa and diameter of 0,8 mm. Annular concrete samples were mined at the side surface. Their resistance against single axis compression was about 105 MPa at cutting speed of 3 m/s and total path of cutting at 2500 m at side deflection angle at about 9°. A view of tools during mining tests without and with assistance is presented in fig. 8, whereas a view of the lubricated holder, assisted with low-grade emulsion at intervals of every 0,5 s from the assistance inclusion is presented in fig. 9.

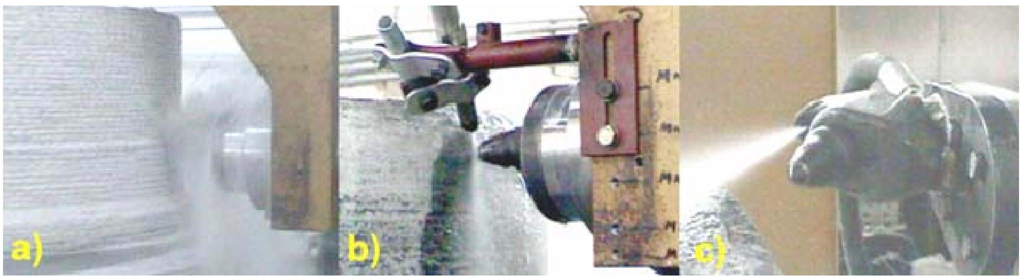

Fig. 8. Artificial sample cutting using RM8 V5-25 pick:
a) "dry" cutting; b) cutting with high-pressure water jet assistance of the front;
c) cutting with high-pressure water jet assistance at the rear [3, 6]

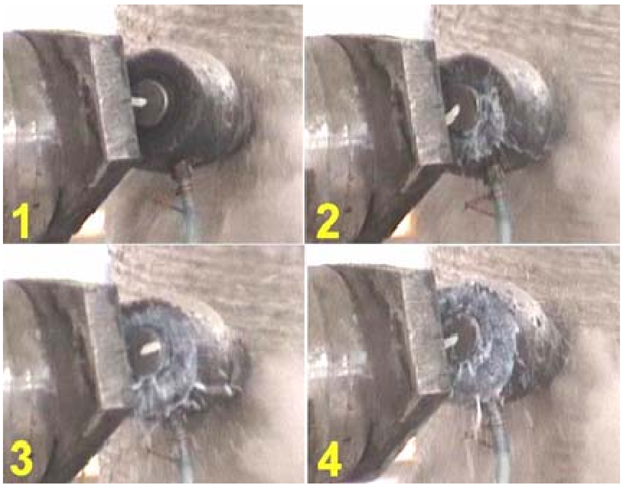

Fig. 9. View of modernized, lubricated holder during the cutting of rock sample every 0,5 seconds since the beginning of lubrication with lubricant [3, 6]

4. RESULTS OF LABORATORY TESTS

The tests indicated that in case of rolling bearing, even at zero deflection angle of the tools, they rotate in the holder. Also good, though not so favourable results were obtained with the holder with forced lubrication. However, it this situation the side deflection angle had to be at least 6°. Whereas, for the sleeve holder even the tool deflection by 45% did not cause its higher or even irregular rotations. An increase of the cutting depth from 9 to 12 mm influenced the number of rotations, especially in the sleeve and lubricated holders. High pressures at deeper levels of cutting significantly increased resistance and slowed the tool rotation. However, the complicated construction of rolling bearing, requiring high precision at assembling processes may not be accepted for application in underground conditions on mining heads. That is why the lubricated holder solution got examined more thoroughly in the further part for pick edge wear measurement.

During mining with tools mounted in holders lubricated by both water and emulsion, occurrence of more or less regular rotation of the tools was observed. It caused regular and slight wear of the tools edges. Moreover, it was found that both the tool surface and cooperating surfaces of the tool heads are clean without pollution which does not take place in case of tools assisted with high pressure water jets or dry operating. A view of one of the tools and the surface of a holder with closed sleeve, after tests of rock sample cutting at the length of about 1000 m, with holder water feed is presented in fig. 11. The obtained results of tools edges wear measurements during the tests seem to be interesting. A view of tools mining without assistance and with front or rear assistance, as well as a tool mounted in open holder assisted with emulsion is presented in fig. 12.

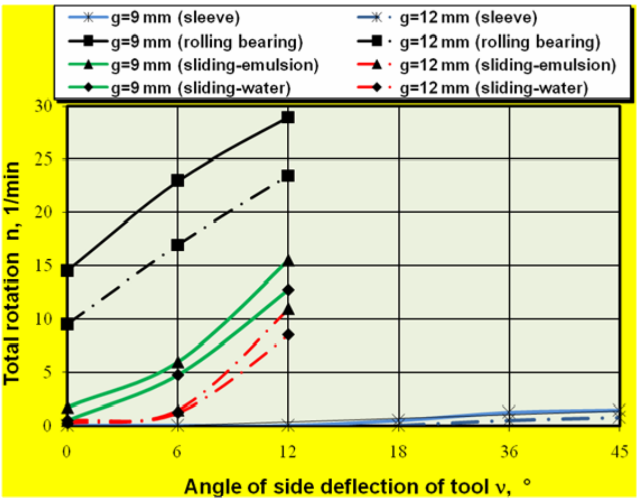

Fig. 10. Impact of side angle of tool deflection ν on the number of its rotations in the function of cutting depth and the kind of holder [3, 6]

Fig. 11. A view of a tool edge and holder surface after tests of rock sample cutting at the length of about 1000 m, with holder water feed [6]

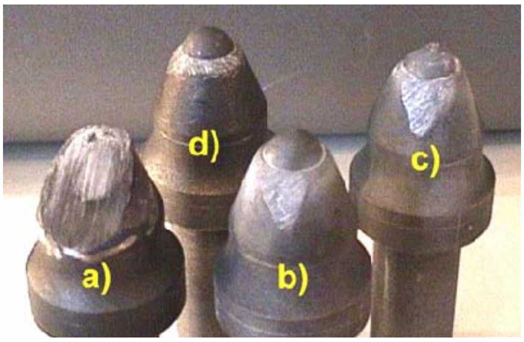

Fig. 12. The view of the rotary -tangential picks after the test along the length of ca. 2500 m: a) "dry" cutting; b) cutting with high pressure water jet assistance from front; c) cutting with rear high pressure water jet assistance; d) cutting in the lubricated holder, cutting depth 9 mm [3,6]

The results of both quantitative and qualitative wear are significant. The wear measurement was conducted with the use of optical microscope allowing imaging the tool edge profile. Such measurement enables not only calculation of volumetric tool edge wear, but also determination of the wear character, even or uneven. For tools presented in fig. 12 their volumetric wear results are presented in fig. 13. Mining without assistance caused catastrophic wear of not only edge itself but also the half of the tool head. Whereas, wear of tools edges with application of high pressure water jet assistance was a few times lower and comparable for location of the jet in front and rear position.

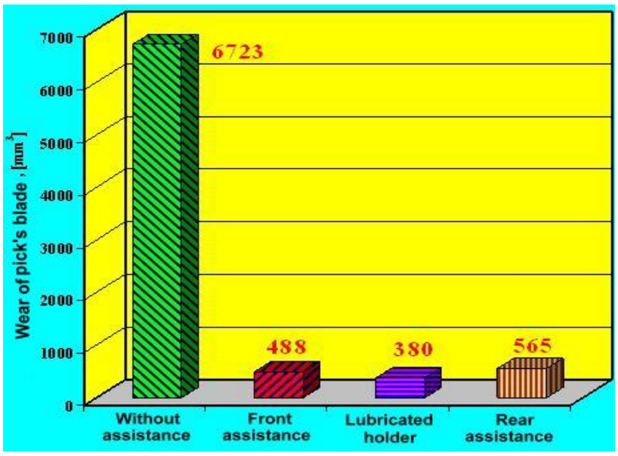

Fig. 13. Wear of the rotary-tangential picks' edged after the test along the length of ca. 2500 m: "dry" cutting, cutting with high pressure water jet assistance and cutting in the lubricated holder [3,6]

Lubrication of the holder with low-grade emulsion caused even higher, by more than 25 – 30% reduction of wear. Comparing the character of the wear, it can be visually ascertained that for mining with high pressure water jet there occur traces of uneven wear which subsequently may lead to fast tool destruction. The tool edge mounted in a lubricated holder is worn very evenly. It is confirmed by results of profiles measurement under an optical microscope. Exemplary profiles for a tool edge assisted with water jet from rear and a tool in a lubricated holder are presented in fig. 14.

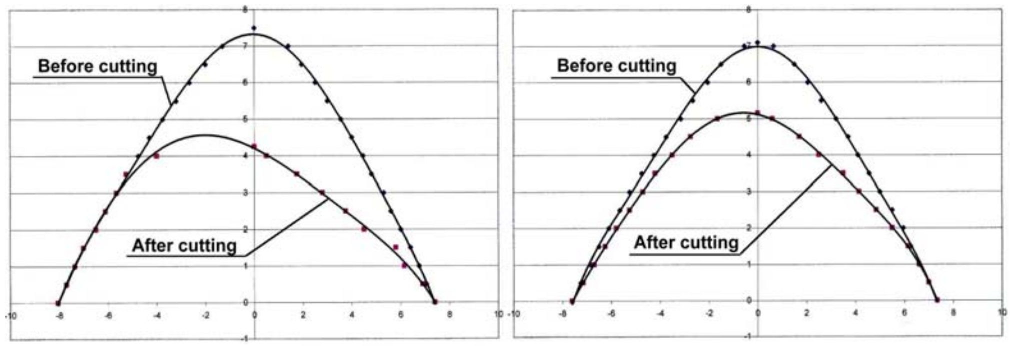

Fig. 14. The profiles of rotary -tangential picks' blades before and after cutting: A) cutting with high pressure water jet assistance from front; B) cutting in the lubricated holder [6]

5. CONCLUSIONS

Both the analysis of references and the results of the own tests proved that the rotation of tangential rotary tools is affected not only by the angle of side deflection □, blade and cutting angles as depending on the properties and lithology of the rocks to be mined but also by the way of their bearing, and first of all on the kinds of holders and catches fixing the tools at their slide bearing. That is why the authors suggested some constructional solutions, which after they had been laboratory tested, gave satisfactory results. However, they can be verified when the large scale industrial research is carried out. It must be mentioned that sample holder solutions with the lubrication of rotary-tangential tools, applied in the units of shearers and roadheaders, may be additionally fitted with ejector internal sprinkling with water stream under the pressure. It reduces the level of dustiness to be breathed in, protects against explosion of coal dust or methane and additionally allows to increase the life of cutting tools.

Pre-industrial test carried out in one of polish cola mines, using the AM-50 roadheader has shown the usefulness of the new holder solution for rotary-tangential picks with pure water as the lubricant. Application of pure water lubricated holders increased almost twice working time of picks, as well as reduced the dustiness. The view of the "dirty" cutting head of AM-50 roadheader with standard holders after mining is shown in figure 15 (left), and the "clear" cutting head with lubricated holders is shown in figure 15 (right).

Fig. 15. View of the "dirty" cutting head of AM-50 roadheader with standard holders after mining (left) and the "clear" cutting head with lubricated holders after mining (right) [3, 6]

REFERENCES

[1]. **Bęben, A., Maziarz, M., Tylek, R.**: 1999, *Węzeł łożyskowy obrotowego noża stycznego głowicy organu urabiającego*. Patent nr PL-313464, (in polish)

[2]. **Kotwica, K., Maziarz, M.**: 2004, *Impact of the Mounting of Tangential Rotary Tools on their Proper Operation*. Archives of Mining Sciences. Vol. 49,

[3]. **Kotwica, K.**: 2010, *Effect of selected working conditions of cutting picks on their wear during the mining of hard rocks*. Quarterly Mechanics and Control, Vol. 29 No. 3, AGH Kraków,

[4]. **Kotwica, K.**: 2003, *Results of laboratory investigations into operating conditions of cutting tool*. Journal of Mining Sciences. Vol. 39, No. 2.

[5]. **Kotwica, K.**: 2005, *Wpływ wprowadzenia smarowania uchwytów noży styczno-obrotowych na ich zużycie*. Transport przemysłowy. Nr 3 (21)/2005, Wrocław (in polish)

[6]. **Kotwica, K.**: 2011, *The influence of water assistance on the character and degree of wear of cutting tools applied in roadheaders*. Archives of Mining Sciences. Vol. 56, 3.