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PARAMETRIC FACTORS FOR THE TANGENTIAL-ROTARY PICKS QUALITY ASSESSMENT

WSKAŹNIKI PARAMETRYCZNE OCENY JAKOŚCI NOŻY STYCZNO-OBROTOWYCH

Procedure of the quality assessment of tangential-rotary picks used in various types of mining machines, has been described in the present study. Authorial method of the quality assessment of tangential-rotary picks based on examination of geometrical and material factors, including pick wear rate, has been discussed. The method is based on parametrical factors and the described examinations tailored to determined conditions of the machine operations, including user requirements. Testing results collected in form of measurement cards allow selection of the optimal pick, including the influence of chosen parameters into the pick wear rate.

Keywords: quality assessment, tangential-rotary picks, bids

Frezujące organy są elementami roboczymi wielu maszyn takich jak górnicze kombajny ścianowe i chodnikowe, frezarki pracujące w przemyśle skalnym oraz frezarki drogowe i spągowe. Urabianie organami wyposażonymi w noże styczno-obrotowe znajduje obecnie wiele zastosowań do skrawania węgla, rud metali, skał, betonu oraz asfaltu. Noże te wyparły starsze rozwiązania, czyli noże styczne oraz promieniowe, dzięki większej trwałości oraz zachowaniu podczas eksploatacji odpowiedniego kształtu ostrza czyli prawidłowych kątów skrawania.

Maszynom urabiającym, a w szczególności kombajnom ścianowym oraz chodnikowym stawia się coraz bardziej restrykcyjne wymagania dotyczące wydajności, niezawodności, bezpieczeństwa i komfortu pracy załogi. W celu zapewnienia prawidłowej pracy maszyny należy w pierwszym rzędzie zadbać o prawidłowy dobór narzędzi skrawających wraz z uchwytami nożowymi oraz organem urabiającym.

Mając na uwadze procedury przetargowe oraz prawo zamówień publicznych obowiązujące w Polsce opracowano taki sposób badania noży, aby możliwe było jednoznaczne wybranie najlepszej oferty przy zachowaniu jak najniższej ceny. Wskaźniki oceny jakości noży zostały sparametryzowane, dzięki czemu możliwe jest dostosowanie opracowanych procedur do badania noży styczno-obrotowych stosowanych do zbrojenia organu dowolnej maszyny urabiającej pracującej w dowolnych warunkach.

Nóż styczno-obrotowy podczas eksploatacji jest elementem będącym bezpośrednio w kontakcie z urabianą calizną. Nóż mocowany jest w uchwycie przyspawanym do organu frezującego będącego częścią

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maszyny urabiającej. Prawidłowa praca samego noża uzależniona jest od parametrów geometrycznych organu i uchwytu, parametrów kinematycznych maszyny urabiającej oraz organu jak również parametrów materiałowych uchwytu. Dopiero gdy parametry te są poprawnie dobrane oraz zachowane możliwe jest zapewnienie prawidłowych warunków pracy noża. Wtedy też jego jakość ma duży wpływ na realizację procesu skrawania, a przede wszystkim na energochłonność oraz trwałość.

Zagadnienia teoretyczne związane z procesem frezowania nożami styczno-obrotowymi są podstawą do opracowania metody oceny ich jakości. Jednak w pierwszej kolejności konieczne jest sprecyzowanie odpowiednich założeń, które przedmiotowa metoda musi spełniać:

- możliwość porównywania jakości wykonania noży,
- możliwość kontroli utrzymania jakości dostarczanych noży,
- możliwość zastosowania do prawa zamówień publicznych,
- parametryczność pozwalająca na dostosowanie do różnych warunków pracy.

Uwzględniając istotne z punktu widzenia prawidłowej pracy noży styczno-obrotowych czynniki określono następujące elementy oceny jakości noży:

- pomiar parametrów geometrycznych całego noża oraz samego węglika spiekanego,
- badania parametrów materiałowych korpusu noża,
- badania parametrów materiałowych ostrza,
- pomiar twardości części roboczej i chwytowej korpusu,
- pomiar twardości ostrza,
- określenie szybkości zużycia noża w warunkach laboratoryjnych.

Mając powyższe na uwadze zaproponowano przeprowadzenie badań w trzech etapach [1,7]:

- pomiar parametrów geometrycznych noży styczno-obrotowych,
- badania parametrów materiałoznawczych noży styczno-obrotowych,
- badania szybkości zużycia noży styczno-obrotowych.

Prawidłowa praca noży styczno-obrotowych gwarantuje ich wysoką trwałość oraz wpływa na trwałość organów frezujących przy niskiej energochłonności procesu, małym zapyleniu oraz iskrzeniu. Jednak uzyskanie takiego rezultatu wymaga poprawnie dobranych parametrów kinematycznych i geometrycznych organu wraz z całą maszyną urabiającą oraz parametrów geometrycznych i materiałowych noży wraz z uchwytami. Aby osiągnąć założony cel trzeba zadbać o zgodność wymienionych parametrów z przyjętymi w fazie projektowania, czyli uzyskać jak najwyższą jakość produktu. Poprzez jakość noży należy rozumieć spełnienie stawianych wymagań oraz jak najwyższą trwałość.

Przedstawiona procedura badania jakości noży styczno-obrotowych została obecnie wdrożona w trzech polskich spółkach węglowych. Podczas czterech przetargów wybrano noże dla ponad dziesięciu kopalń. Podczas tych badań przebadano łącznie ponad czterdzieści typów noży dostarczanych przez pięciu różnych producentów.

Słowa kluczowe: ocena jakości, noże styczno-obrotowe, przetargi

1. Introduction

Cutting drums are used as operational elements of a number of machines, such as mining longwall and roadway shearers, shearers operated in rock industry, as well as road and mining road bottom shearers. The cutting drums are used for cutting various types of natural and synthetic mineral resources. The cutting drums have various design, kinematic and energy parameters and these differences result from the machine operational location and type of the cut material. Cutting with use of the cutting drums equipped with tangential-rotary picks is commonly used for cutting hard coal, metallic ores, rocks, concrete and asphalt. In mining industry, exploitation of longwall and roadway headings is usually conducted with use of the mechanical cutting method. Mechanical cutting comprises direct acting of the cutting pick onto the rock body. The most common is rock cutting with use of shearers and plows equipped with cutting picks. Actually, tangential-rotary picks are commonly used for cutting heads of roadway arm shearers and longwall shearers. These picks replaced older solutions, i.e. tangential picks and radial picks as they have longer life time and keep suitable shape of the pick, i.e. proper cutting angles. It should be underlined that the new solutions of the underground exploitation machines and cutting heads assume using disc-type (Krauze, 2009c) and tangential-rotary picks (Bołoz, 2013).

Cutting machines, particularly longwall and roadway shearers are exposed to more and more restrictive requirements due to their capacity, reliability, operational safety and personnel comfort. First of all, in order to assure proper machine operation, suitable cutting picks should be selected, including cutting pick holders.

Standard tangential-rotary pick show in Fig. 1 is built of cone-shaped operational part, cylinder-shaped mandrel being holding part of the cutting pick and pick edge in form of sintered carbide insert.

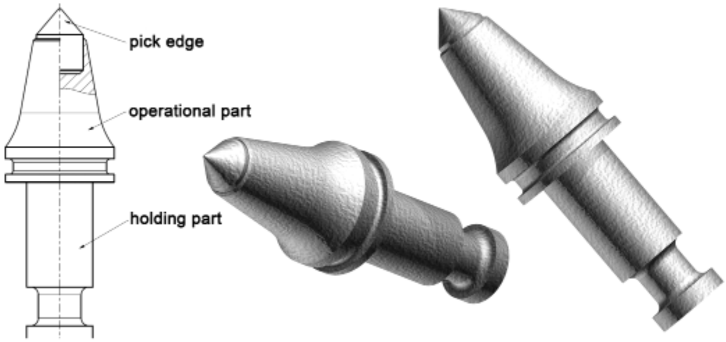

Fig. 1. Structure of tangential-rotary cutting pick

Shape and suitable mounting of the pick in the holder allows its free rotation what assures uniform pick wearing. The body and holding part are made of steel having high impact and abrasion resistance. Pick edge is made of various types of sintered carbides soldered to the pick body. Shape of the cutting pick described by linear and angular dimensions and properties of material used must satisfy definite requirements related with proper realization of the cutting process and its durability. It should be noted that mentioned parameters depend on the machine type and type of the cut rock body.

Taking into consideration a problem of mutual comparison of cutting picks, special procedure of selecting the best (optimal) solution, has been developed. Pick quality factors were expressed by suitable parameters what allowed tailoring optimal procedures for examination of tangential-rotary picks used In cutting heads of cutting machine working in optional conditions.

2. Significant parameters of the tangential-rotary cutting picks

During exploitation the tangential-rotary pick is an element being In continuous contact with mined rock. The pick is fixed in the holder welded to cutting head being a part of the mining machine. Proper operation of the cutting pick depends on geometrical parameters of the head and the holder, kinematic parameters of the mining machine and its cutting head, as well as on material parameters of the holder. Proper conditions of the pick operation is assured only if the mentioned parameters are suitably selected, what influences realization of the cutting process, and first of all power consumption and durability (Krauze, 2012a, 2012b).

2.1. Geometrical and kinematic parameters

Structural parameters of the cutting pick result from mining process requirements, construction and kinematic parameters of the holder and cutting head, as well as from properties of mined rock body (Jonak, 2002; Jankowski, 2005).

Construction of the tangential-rotary cutting pick is determined by pick rake angle α, pick edge angle β and angle of repose γ (Krauze, 2002a, 2009a, 2009b). During cutting with use of tangential-rotary pick the pick edge is sinking into the rock body to the depth g_s. Proper operation of the pick in question is assured if suitable operational angles are obtained. It is particularly important that operational pick rake angle α_r was always positive.

Pick mounted in the holder constitutes upper part of the cutting head (Fig. 2), thus operational cutting angles α_r and γ_r depend not only on structural parameters of the pick, but also on cutting v_s and advance v_p rates. Thus for the cutting head of diameter D_s, cutting rate v_s and advance rate v_p, holder height H_u and inclination angle δ_u, proper tangential-rotary pick of required length L_n and pick edge angle $2\beta_u$ should be selected (Krauze, 2002a, 2009a, 2009b). In such situation the other structural parameters of the cutting pick must possess values assuring optimal conditions of cutting process resistances transfer. Cutting process takes place only if operational pick rake angle α_r is bigger than zero. In case of its negative values process of rock body crushing occurs instead of the cutting process. Such situation results in power-consumption increase, dustiness and sparking what causes critical destruction of the pick.

Relations between cited values can be described with a series of formulas: Height of holder H_n:

$$H_n = H_u + L_r \sin(\delta_u), \quad [\text{mm}] \tag{2.1}$$

Position of the pick on the cutting head can be described with angle of rotation φ. For pick fixed like shown in Fig. 3 angle φ has value of the pick geometrical rotation angle φ_g. Geometrical rotation angle is defined as an angle between radius crossing the pick cutting edge and radius, which is perpendicular to the pick holder base. Value of this angle is constant independently on the location of the pick during cutting operation. Angle φ_g is calculated from the formula:

$$\varphi_g = \text{arc}\tan\left(\frac{b - b_{u1} \cdot \sin(\delta_u) + L_r \cdot \cos(\delta_u)}{0.5 \cdot D_b + H_n}\right), \quad [°] \tag{2.2}$$

Diameter of the cutting tool D_s is calculated from the formula:

$$D_s = \frac{D_b + 2 \cdot H_n}{\cos(\varphi_g)}, \quad [\text{mm}] \tag{2.3}$$

Whereas initial pick rake angle a amounts for:

$$\alpha = \delta_u - \beta_u + \varphi_g, \quad [°] \tag{2.4}$$

And angle of repose γ amounts for:

$$\gamma = 90 - \delta_u - \beta_u - \varphi_g, \quad [°] \tag{2.5}$$

In result of the summation of advance speed v_p and cutting rate v_s angle of repose pick rake angles changed by values of angle δ according to the following relations:

Operational pick rake angle:

$$\alpha_r = \alpha - \delta, \quad [°] \tag{2.6}$$

Operational angle of repose:

$$\gamma_r = \gamma + \delta, \quad [°] \tag{2.7}$$

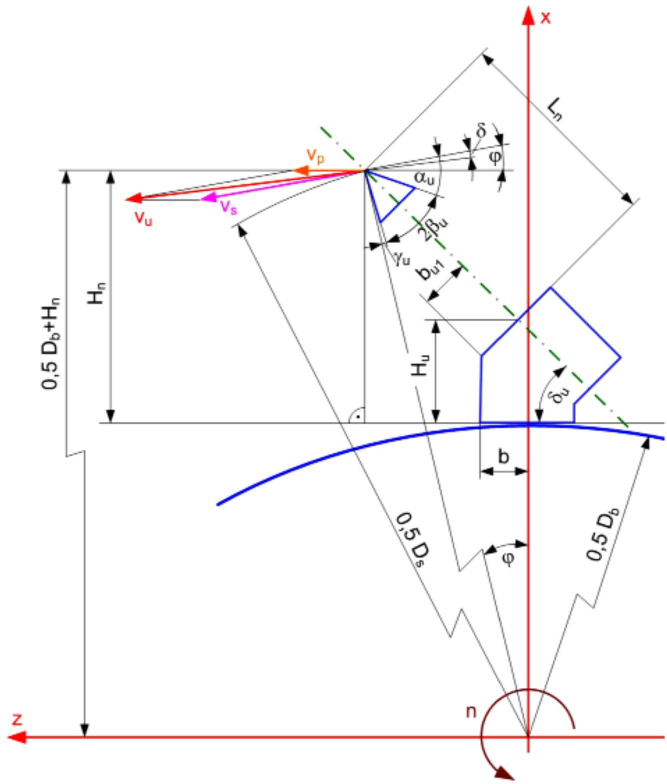

Fig. 2. Parameters of the holder and tangential-rotary pick fixing

Value of the angle δ is changing during the cutting in function of angle φ. Value of the angle δ can be calculated from formula:

$$\delta(\phi) = \arccos\left(\frac{v_s + v_p \cdot \cos(\varphi)}{\sqrt{v_s^2 + v_p^2 + 2v_s \cdot v_p \cdot \cos(\varphi)}}\right), \quad [°] \tag{2.7}$$

Value of the angle δ is changed according to the pick position and reaches its maximum at the moment when pick crosses horizontal axis of the cutting tool. Examples of the changes of angle δ for chosen values of the parameters during single cutting cycle is show in Fig. 3. Course of the operational cutting angle γ_r and of the pick rake angle α_r are also shown in the diagram. Values of angles of repose are changed, however operational pick rake angle must always be positive.

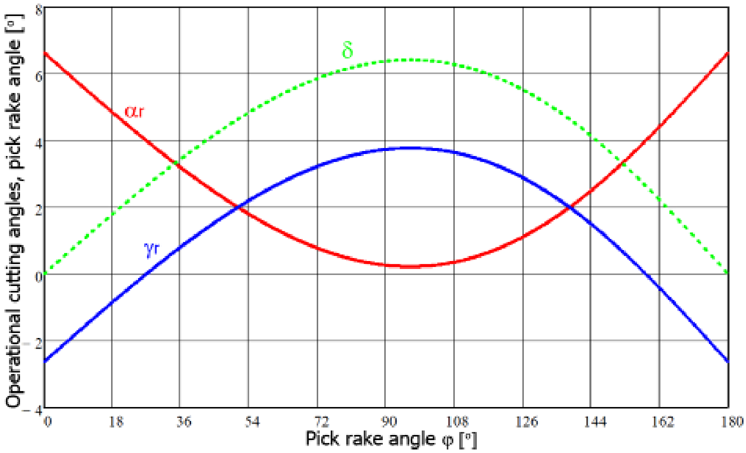

Fig. 3. Course of operational cutting angles in function of pick position

On the basis of scheme illustrating pick parameters during cutting and suitable formulas, evident influence of the advance rate onto operational values of cutting angles is observed. Example of the course of operational cutting angles in function of the advance rate is shown in Fig. 4. I this case, when advance rate v_p is higher than 12 m/min, operational pick rake angle has negative values and cutting is no longer possible.

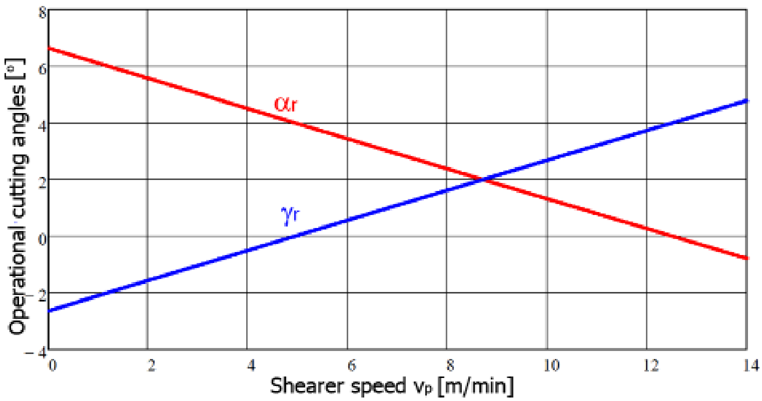

Fig. 4. Course of operational cutting angles in function of shearer speed

The presented analysis refers to full pick course and full scope of the advance rate, however calculation of values of the angles for maximal advance rate and angle in order to check correctness of the selection of geometrical and kinematic pick parameters and angle φ equal to 90° is sufficient.

Calculation of operational cutting angles, particularly several variants of input parameters is very time-consuming. That is why physical and mathematical model and program allowing determining the influence of structural parameters of the tangential-rotary pick, its holder and worm-type cutting head onto operational cutting angles, have been developed in the Department of Mining, Dressing and Transport Machines of the University of Mining and Metallurgy in Cracow – Poland (Krauze, 2002b). After loading of all necessary design data, the program allows calculation of the pick operational cutting angles. Each change of any of the parameters causes immediate re-calculation of the results. The program also allows calculation of individual operational parameters of the worm-type cutting head, including drum diameter, pick height, advance rate and all needed angles. Moreover, the program allows testing individual parameter variants and selection of the user.

Examples of structural solutions of tangential-rotary picks, which are used In cutting heads of longwall and roadway shearers are show in Fig. 5.


a) b) c) d) e)

Fig. 5. Tangential-rotary picks used for: a) longwall shearers, b) roadheaders, c) shearers used for salt mining, d) milling machines for concrete cutting, e) milling machines for asphalt cutting

Local conditions related with cutting process force suitable selection of the pick, its holder and cutting head structural parameters, but material parameters considerably influence durability/life time of the tangential-rotary pick.

2.2. Materials and thermal-chemical processing

Body and holder of tangential-rotary picks are made of steel having high impact resistance, as well as strength and abrasion resistance. Usually steel of high content of manganese, molybdenum, chromium an nickel are used.

Depending on the tool role, steel of the type 12HN3A, 40H, 40HN, 36HNM or 35HGS, which can be exposed to thermal and chemical treatment In order to improve abrasion resistance of surface layer, are used. Sintered carbide or hardy abrasive pudding wells, sintered carbide rings or sintered carbides of the type CAP are used for picks of lowered bodies (Fig. 6).

Sintered carbides used for cutting edges of tangential-rotary picks have suitable shape, size, chemical composition and mechanical properties. Usually, sintered carbides B2, B20, B23, G15 and others having similar chemical composition and mechanical properties, are used. Rapid drop of their mechanical properties in temperature over 500°C is characteristic and important feature of sintered carbide (Krauze, 2009a, 2009b).

Shape of the sintered carbide inserts used for tangential-rotary picks has form of rotary solid (Fig. 7) consisting of cylinder, cone or ballistic parts. Linear and angular dimensions of the inserts in question are selected depending on properties of the mined rock and related mining resistances, as well as depending on predicted wear.

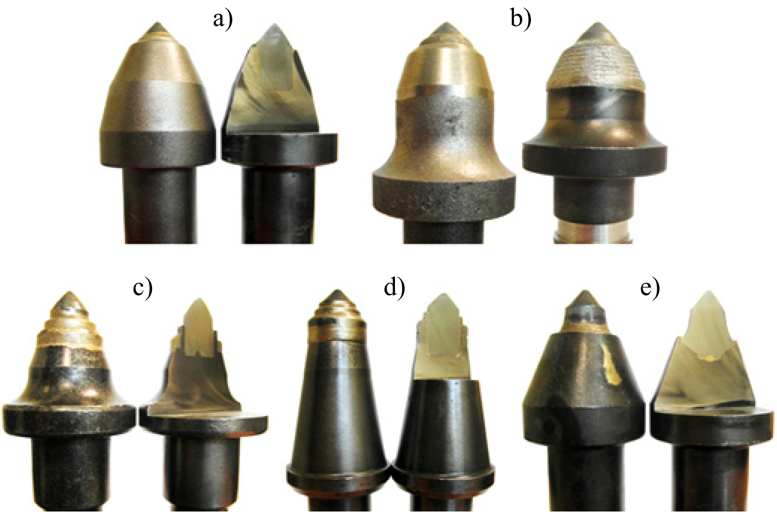

Fig. 6. Options of additional protection of the tangential-rotary picks against abrasive wear (Sandvik, 2013)
a) standard pick, b) welded picks, c) pick with ring made of sintered carbide, d) pick with two rings made of sintered carbide, e) pick with lowered body and sintered carbide of the type CAP

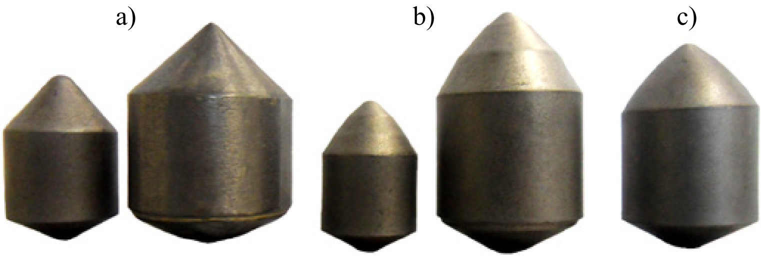

Fig. 7. Examples of sintered carbides used for cutting edges of tangential-rotary picks
a) cone-shaped, b) multi-cone-shaped, c) ballistic-shaped

3. Procedure of the quality assessment of the tangential-rotary picks

Fundamental problems related with cutting with use of tangential-rotary picks constituted basis of the development of quality assessment procedure. However, the following assumptions should be satisfied:

- ability to compare picks quality,
- ability to control quality of delivered picks,
- parameters allowing adaptation to various operational conditions.

Taking under consideration factors, which are important for proper operation of tangential-rotary picks, the following criteria of the quality assessment have been determined:

- measurement of geometrical parameters of complete pick and its sintered carbide edge,
- examinations of pick body material parameters,
- examinations of sintered carbide edge material parameters,
- measurement of operational and fixture hardness of the pick body,
- measurement of the sintered carbide edge hardness,
- determination of pick wear rate in laboratory conditions.

Considering the above, execution of three-stage examinations, has been proposed (Krauze, 2012a, 2012b):

- measurement of geometrical parameters of the tangential-rotary picks,
- examination of material parameters of the tangential0rotary picks,
- examination of the wear rate of tangential-rotary picks.

3.1. Measurement of geometrical parameters

Examination of complete tangential-rotary pick is aimed at determination of its geometrical parameters via measurement of chosen linear and angular dimensions. The results obtained should be compared with manufacturer's documentation and compatibility of real and assumed dimensions should be assessed (Krauze, 2012a).

The most important linear and angular dimensions of the tangential-rotary pick are as follow (Fig. 8):

- length of operational part L_n,
- total length L_c,
- diameter or diameters of the holder part d_u,
- diameter of the stopper ring flange d_k,
- cutting edge angle (cutter tip angle) $2\beta_u$,
- sintered carbide cutting edge height h_w,
- sintered carbide cutting edge diameter d_w.

Linear measurements were made with use of height gauge of maximal terror ±40 mm and slide caliper of maximal error ±30 mm, the angle was measured with use of protractor with maximal error ±2'. Picks located on special measurement plate with height gauge, caliper and protractor, are shown in Fig. 9. The results were gathered in special measurement cards, and

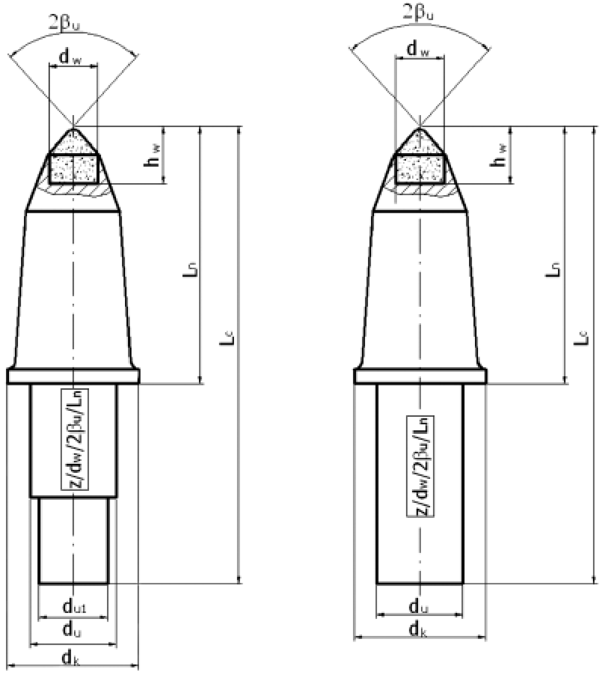

Fig. 8. Measured geometrical parameters of the single and double stage pick (Krauze, 2012a)

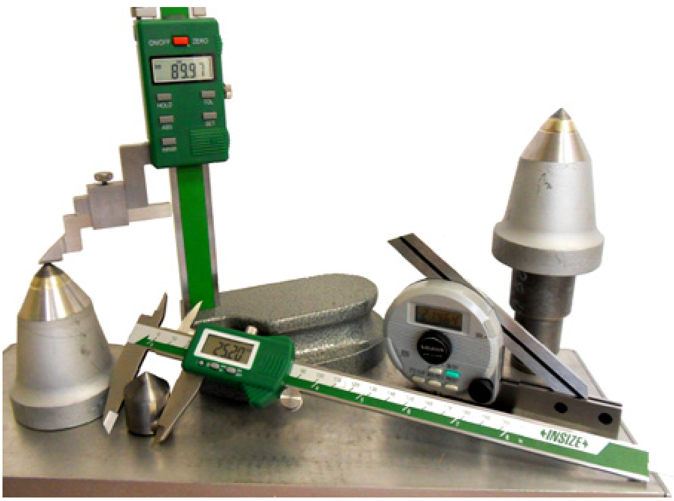

Fig. 9. Picks on the marking-off table with measuring tools

then their compatibility with requirements of potential user were checked, including deviations marked in Figure, according to suitable standards.

3.2. Examination of material parameters

Determination of the tangential-rotary pick material properties calls for separation of the pick body made of steel from the cutting edge made of sintered carbide. Thus examinations of two different materials should be executed (Figs 10-11):

- pick body material – determination of the steel chemical composition, including its hardness and thermal processing (metallographic examinations),
- sintered carbide cutting edge – determination of the composite content, density and hardness.

Analysis of the pick body material was executed with spark method using special device. However, measurements of the hardness were made in points marked in Fig. 8.

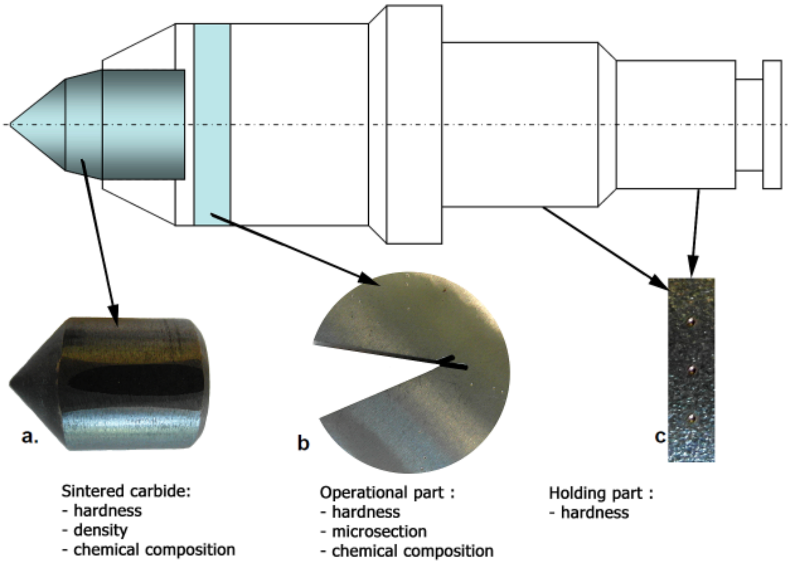

Fig. 10. Tangential-rotary pick with marked measurement points
a) sintered carbide measurement, b) measurement of the operational part surface,
c) measurement of the holding part surface

Sintered carbides used for tangential-rotary cutting edges possess definite chemical composition and mechanical properties needed for proper mining process, and particularly resistance to abrasion. However it should be noted that execution of all needed measurements is related with examination cost increase. That is why considering examination cost and their further application, determination of quantitative analysis of density and hardness of given sintered carbide, are proposed (Krauze, 2012a).

Testing results are gathered in special measurement cards. Then they are compared with requirements of potential user, including values declared by manufacturer and those resulting from concerned standards.

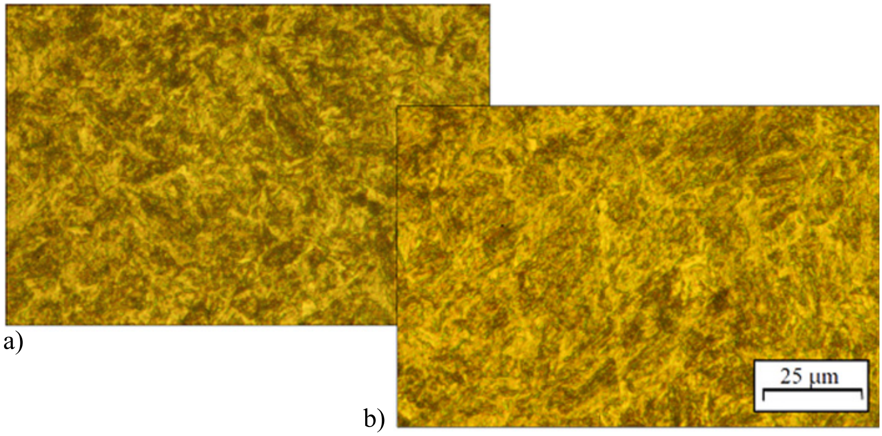

Fig. 11.Tempered martensite – ex ample structure of tested pick body material
a. distance of 1 mm from the surface, b. distance of 10 mm from the surface

3.3. Examination of wear rate

Measurement of the tangential-rotary picks determines their durability. The measurement in question should be realized in the same conditions for all picks of given series, what assures reliable, repeatable and comparable results. This allows assessment of the pick durability, as well as comparison of various picks in this aspect.

Pick or picks wear rate defined as relation between pick mass loss and volume of the obtained winning was used in the pick durability assessment. Additionally, mode of the wear of tested picks can be determined. Pick wear rate (durability) can be described with suitable factor using one of the following formulas:

$$X1 = \frac{\Delta m}{m} \cdot \frac{V}{V_u} \tag{3.1}$$

$$X2 = \frac{\Delta m_{\max} - \Delta m}{m} \cdot \frac{V}{V_u} \tag{3.2}$$

$$X3 = \frac{m}{\Delta m} \cdot \frac{V_u}{V} \tag{3.3}$$

where:

$X1, X2, X3$ — wear rate [-],
Δm — mass loss of the pick during testing (pick body with cutting edge) [g],
m — pick mass before testing [g],
V — standard volume of the sample [m^3],
V_u — volume of the sample mined during examinations [m^3],
$\Delta m_{\max}$ — maximal mass loss of the pick from given series [g].

Pick wear rate, depending on the used formula is described by increasing linear characteristics $X1$, decreasing linear characteristics $X2$ of hyperbolic characteristics $X3$. Characteristics of these indicators have been drawn for example values – see Fig. 12. During the tests we tried to mine the same sample volume for each set of the picks. Thus, assuming chosen values as constant we could compare these characteristics in order to choose optimal and satisfying option for determined requirements or bid procedures. In a case of the characteristics described by formula $X1$ pick of the best durability has minimal value of the indicator. Whereas values of this indicator are proportional to the pick mass wear. In case of characteristics $X2$ and $X3$, the smaller value of the indicator the more durable is given pick. Whereas, indicator determined by formula $X2$ is proportional to the loss of the pick mass. And indicator described by formula $X3$ is inversely proportional to the mass pick wear. In addition, in case of the characteristics $X2$, procedure allowing automatic elimination of the pick having maximal mass loss vie prescribing to it zero-value of the indicator, has been developed. Thanks to that, independently on the pick price the pick is not taken under consideration in the selection of the optimal offer. Each of the presented characteristics can be modified In such manner that the worst pick was or wasn't be eliminated.

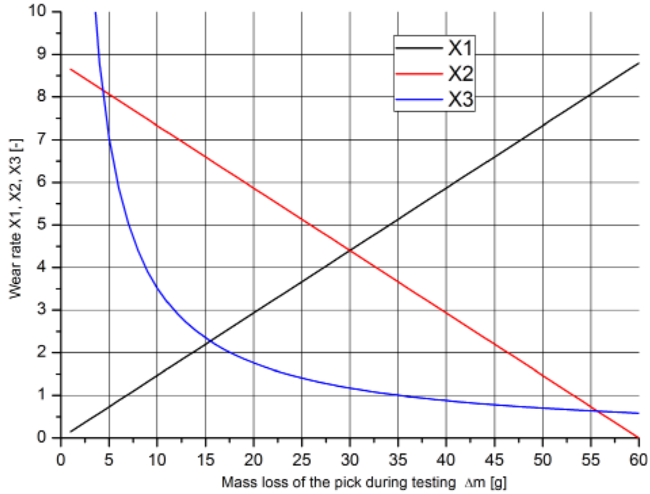

Fig. 12. Characteristics of various indicators of the wear rate

The presented definition of the parameter determining durability of picks, as well as requirements related to examinations of the wear rate result in necessity of assuming the following testing procedure (Krauze, 2012a):

- preparation of cement-sand sample having assumed composition (cement, sand, aggregate, water) and uniaxial compression resistance,
- measurement of the pick mass,
- fixing of four tangential-rotary picks in special holders (Fig. 14),
- cutting in laboratory conditions,
- measurement of the pick mass after cutting process,
- calculation of the volume of the winning obtained during tested picks operation,
- determination of real properties of cut sample,
- calculation of the parameter reflecting wear rate.

It should be noted that the assessment on the basis of mass loss concerns quality assessment of whole pick. i.e. its cutting edge and pick body. However, indicators based on pick length loss can also be used for determining the cutting edge life-time. In such case, it is very important that pick system and cutting parameters allow such cutting that mainly cutting edge is worn – and not the pick body.

Realization of laboratory examinations requires examinations executed in special testing stand, which satisfy requirements of assumed testing procedure. That is why the examinations in question were conducted in testing stand adapted to examinations of the cutting process with use of cutting heads accessible in the Department of Mining, Dressing and Transport Machines of the AGH University of Mining and Metallurgy in Cracow – Poland.

The testing stand (Fig. 13) is composed of two sub-assemblies: cutting head drive system and advance system of the block used for cutting. Working element comprises special disc with holders of the tangential-rotary picks (single and double stage). With respect to various modes of the fixture the authors developed special solution allowing fixing of each pick of definite diameter in a single holder.

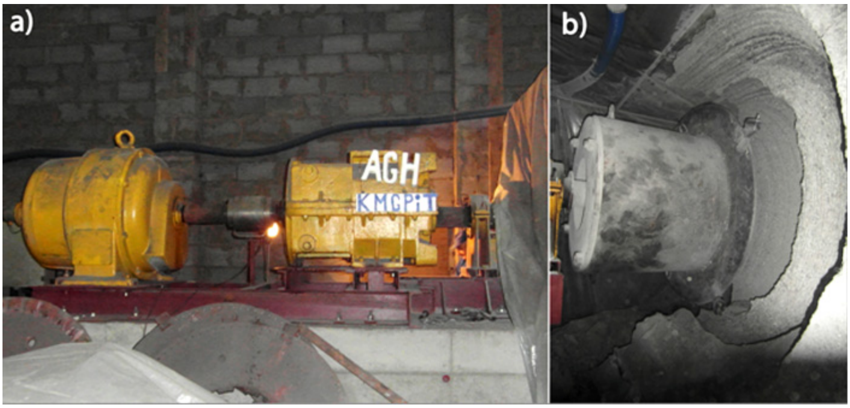

Fig. 13. Testing stand for examination of the quality of tangential-rotary picks
a) drive of the testing stand, b) disc and sample after examinations

The cutting head rotation is forced by its driving system and rectilinear movement of the rock sample allow realization of the cutting process during operations with definite web. Hydraulic advance system allows shirting the table with the tested block. Motor rotation is controlled via control system located In the control cabinet, whereas the advance rate value during cutting is controlled via hydraulic motor operator.

Mineral or artificial sample was placed on the testing table. In case of testing the wear rate of tangential-rotary picks, mining artificial rock having high resistance to abrasion (cement-sand sample), as well as uniform and isotropic properties, is recommended. The testing stand is equipped with measurement system being its integral part (torque meter, pressure transducers, distance transducers and measuring computer). It allows measurement of the cutting element load, including velocity and pressure in the advance system, thus resistances and power-consumption of the cutting process can be easily determined.

Picks on the testing disc are located along the disc circumference every 90° forming a system shown in Fig. 14. Each set of picks is mounted in numbered (from 1 to 4) holders on the disc. The holders allow fixing the picks independently on the manufacturer's fixing recommendations. The pick were weighted before and after testing with use of the weight AXIS (legalization scale 1g). Obtained mass loss and volume of cut sample are a basis of calculation of parameter determining pick wear rate. Finally, each pick is photographed in the planes located every 120°. Example photographs of a single series of tested picks is shown in Fig. 15.

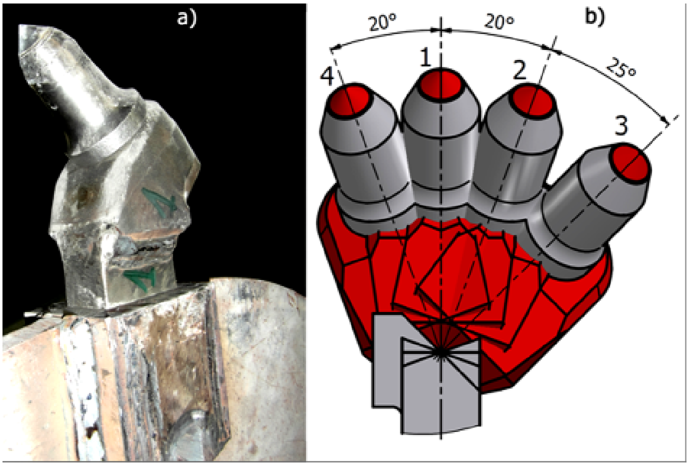

Fig. 14. Example of the pick system with numbered picks
a. view of the pick No 1 in the holder after examinations, b. scheme of the distribution of picks

Testing results, including photographs of the picks after testing are gathered in measurement cards. Pick wear rate indicators determine their quality expressed with suitable numerical value. Prescription of definite numerical values allows unique selection of the best pick.

3.4. Quality control of delivered tangential-rotary picks

Testing procedure proposed In this study allows selection of the best quality picks. However, in case of application these procedures in case of ordering picks by the mine, necessity of delivery control with respect to assumed quality should be taken into consideration. Thus procedure of random control of picks from given delivered series was developed. Additionally, in case of pick quality claims announced by the users, suitable control procedures are executed. Such control comprises examinations of material and geometrical parameters of the delivered picks. Results of such examinations can be directly compared with results of standard picks. However, in order to check the pick wear rate, suitable comparative examinations aimed at re-testing the standard picks on the same rock sample should be executed. Even in such situation we can determine whether pick wear rate was changed. Necessity of conduction of two-stage pick wear rate is required in order to compare the testing results. In case of long time interval between testing and bid and control tests, artificial cement sample can be replaced with a new one.

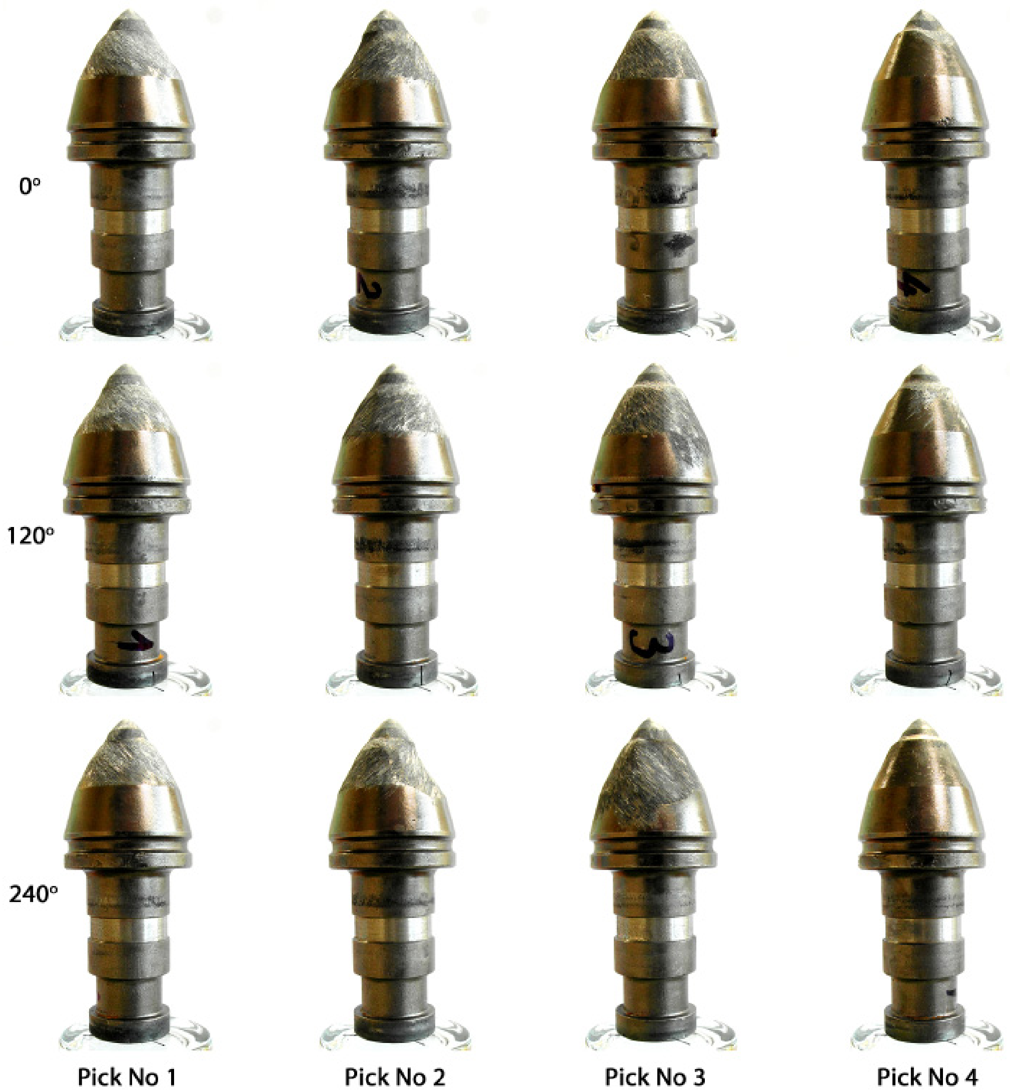

Fig. 15. Examples of tangential-rotary picks after examinations

4. Summary

Proper operation of the tangential-rotary picks assures their long life time and influences durability of the cutting heads at low power consumption, reduced dustiness and limited sparking. However, obtaining of such results calls for proper selection of kinematic and geometrical parameters of the cutting head, together with whole cutting machine, including proper selection of geometrical and material parameters of the tangential-rotary picks and their holders. In order to attain assumed target, compatibility of mentioned parameters with parameters assumed in design phase is needed, what assures the highest quality of the product. Pick quality should be understood as ability of satisfying mentioned requirements assuring the highest pick lifetime. Testing procedure of the quality of tangential-rotary picks, which thanks to parametrization of substantial values allows adaptation of the machine for any conditions and potential user needs, has been presented in this study. The analysis of testing results allows selection of the best option.

The presented procedure of tangential-rotary picks testing has been implemented in three Polish hard coal companies. In four bids, cutting picks for over ten mines, have been selected. Over forty types of the cutting picks delivered by five different manufactures, have been tested.

However, it should be noted that in spite of executed examinations, cutting heads and pick holders should be tested in the future in order to obtain suitable life time of the machine operational elements.

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