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WEAR TESTING OF BUTTONS IN BITS FOR BLASTHOLE DRILLING

BADANIA ZUŻYCIA SŁUPKÓW W KORONKACH WIERTNICZYCH DO WIERCENIA OTWORÓW STRZAŁOWYCH

Key words: rock mining, blasthole drilling, button bits, wear testing of buttons.

Abstract The article presents the results of the wear testing of buttons in selected types of bits with the diameter of 95 mm used for blast hole drilling in a rock mining. The purpose of the testing was to determine the type of the wear of peripheral and frontal buttons in the actual operating conditions of bits and the impact of selected parameters of the drilling process and of sharpening the buttons on their durability. Tests of button wear were carried out by the blasthole drilling in deposits of the Devonian and Triassic dolomites. For the blast hole drilling with tested bits, drilling rigs HSB 500 and HBM 60, equipped with down-the-hole impact mechanisms VKP 95-2 from the company Permon were used. Tests on the wear of buttons were carried out according to the adopted methodology, taking into account both their abrasive wear and wear through crushing or falling out. During the drilling of holes, every effort was made to use fixed values of parameters of the drilling process, except for the value of drill stem rotation speed, because one of objectives of the research was to determine its impact on the abrasive wear of tested bits buttons. The obtained results of tests proved that the predominant type of wear of button bits for blast hole drilling is an abrasive wear of frontal buttons, and regular sharpening of the buttons allows increasing the operating time of rock bits by up to 35%.

Słowa kluczowe: górnictwo skalne, wiercenie otworów strzałowych, koronki słupkowe, badania zużycia słupków.

Streszczenie W artykule przedstawiono rezultaty badań zużycia słupków w wybranych typach koronek wiertniczych o średnicy 95 mm stosowanych do wierceń otworów strzałowych w górnictwie skalnym. Celem badań było ustalenie rodzaju zużycia słupków obwodowych i czołowych w rzeczywistych warunkach eksploatacji koronek oraz wpływu wybranych parametrów procesu wiercenia oraz ostrzenia słupków na ich trwałość. Badania zużycia słupków zostały przeprowadzone w złożach dolomitów dewońskich i triasowych w wierceniu otworów strzałowych. Do wierceń otworów strzałowych z wykorzystaniem badanych koronek były zastosowane wiertnice HSB 500 oraz HBM 60, wyposażone we wgłębne mechanizmy udarowe VKP 95-2 firmy Permon. Badania zużycia słupków przeprowadzone zostały według przyjętej metodyki uwzględniającej zarówno ich zużycie ścierne, jak i zużycie poprzez wykruszenie lub wypadnięcie. Podczas wiercenia otworów starano się stosować stałe wartości parametrów procesu wiercenia z wyjątkiem wartości prędkości obrotowej przewodu wiertniczego, ponieważ jednym z celów badań było ustalenie jej wpływu na zużycie ścierne słupków badanych koronek. Uzyskane rezultaty badań dowiodły, że dominującym rodzajem zużycia koronek słupkowych do wiercenia otworów strzałowych jest zużycie ścierne słupków czołowych, a regularne ostrzenie słupków pozwala zwiększyć czas eksploatacji koronek nawet o 35%.

INTRODUCTION

In the Polish mining of rock raw materials, at the exploitation of deposits, the method of using blasting materials prevails. In the first stage of obtaining raw materials, this method requires the drilling of grid of blast holes with a depth up to 20 m and diameters 80–105 mm, which are then loaded with an explosive. The effect of the blasting works is a separation from the deposit disarranging the cohesion of the rock mass, the corresponding batch of the rock material, which is then subjected to processing works aimed in obtaining the required fraction of the acquired raw material [**L. 1**].

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Technologies of the blast hole drilling in Polish mines of raw rock materials are very diversified and depend mainly on the properties of the exploited raw rock materials and mining-geological conditions characterizing the exploited raw materials deposits. In the case of medium and very compact rocks, for blasthole drilling, the rotary-impact method is used. In its essence, it is a combination of the rotary drilling method with impact drilling, while mechanisms implementing both drilling methods assembled on a drilling rig are of separated construction.

In drilling rigs drilling blasting holes, independent mechanisms that perform an impact and rotation of the drilling tool are placed in two ways. In the first of them, independent mechanisms of impact and rotation are mounted on the mast guide forming a rotary-impact drilling machine with a hydraulic drive commonly known as the upper hammer. In the second case, the rotation mechanism is mounted on the mast guide and the impact mechanism with a pneumatic drive is located at the end of the drill stem. In this case, it relates to down-the-hole impact mechanism (the lower hammer) [**L. 1–2**]. In both cases, there are assembled bits at the end of the drill stem by means of a threaded connection (upper hammer) or splined connection (lower hammer), which directly implement the process of mining rock masses. These bits are called button bits due to the shape of elements mining the bottom of a drilled hole.

CONSTRUCTION OF BUTTON BITS

Button bits used for drilling of blast holes by a down-the-hole impact mechanism (down-the-hole hammer) consist of a body and buttons made of sintered carbides, inserted in the frontal part of the bit, mostly by an interference fit [**L. 2, 4, 10**].

In the body is a flushing hole drilled for the compressed air as drilling fluid fed to the bottom of the hole. The rear part of the bits body, so called the gripping part, is in a form of an external spline with dimensions adapted for connecting with the internal spline of the down-the-hole hammer. The most important element of the button bit is its frontal part (bit dome) carrying out the process of mining the bottom of the hole, **Fig. 1**.

The frontal part of button bits consists of two surfaces. The first of them is a frontal face on which are inserted sintered carbide buttons implementing the process of mining the bottom of the hole. On this surface, there are also flushing holes through which the drilling fluid, flowing along the hole in the body, is delivered to the contact areas of bits and the drilled rock. The second surface, peripheral surface, is usually inclined in relation to the frontal surface at a certain angle of 30–35°. On this surface, there are buttons which are designed to calibrate the diameter of the drilled hole. The peripheral surface also includes side flushing grooves that allow for removal of bore dust.

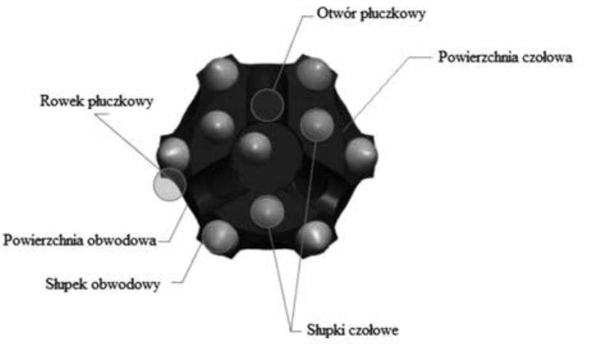

Fig. 1. Construction scheme of the frontal part of a button bit [L. 14]
Rys. 1. Schemat budowy części czołowej koronki słupkowej [**L. 14**]

Buttons inserted in button bits are their most important elements directly implementing the process of mining the rock masses. The efficiency of blasthole drilling processes and the durability of the whole button bit depend from a proper selection of diameters, quantities, spacing, and materials, according to the properties of drilled rocks.

Currently, to reinforce bits for the blasthole drilling there are used four types of buttons, **Fig. 2**:
Semi-spherical buttons,
Parabolic buttons,
Conical buttons, and
Ballistic buttons.

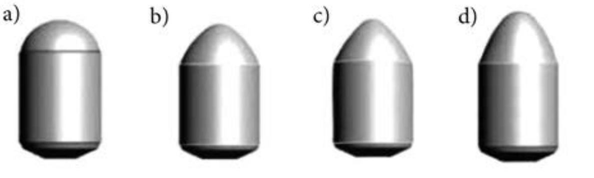

Fig. 2. Types of buttons used in bits [L. 14]: a – semi-spherical buttons, b – parabolic buttons, c – conical buttons, d – ballistic buttons
Rys. 2. Rodzaje słupków stosowanych w koronkach wiertniczych [**L. 14**]: a – słupki półkoliste, b – słupki paraboliczne, c – słupki stożkowe, d – słupki balistyczne

Most often, in bits for the blasthole drilling semi-spherical buttons are used, which prove to be correct when drilling a hole in very compact, low abrasive rocks and withstand pressures up to 300 MPa. For drilling in rocks requiring fast penetration and having different abrasive properties, there ballistic buttons are used, which ensure a smaller contact area of the button with a mined rock. **Fig. 3** presents an influence of a button shape on the process of a rock penetration.

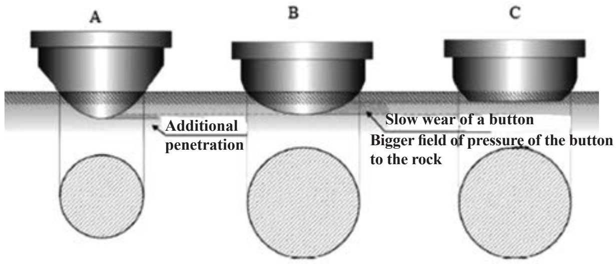

Fig. 3. An influence of a button shape on the rock penetration [L. 7]: A – ballistic button, B – semi-spherical button, C – worn button

Rys. 3. Wpływ kształtu słupka na penetrację skały [**L. 7**]: A – słupek balistyczny, B – słupek półkolisty, C – słupek zużyty

The shape of buttons on the frontal face has a decisive influence on the process of mining the bottom of the hole [**L. 7**]. The drilling speed, but also a degree of the abrasive wear of the bit, depends on the selection of their correct shape according to properties of the drilled rock. For this reason, manufacturers offer a wide range of button bits with the same diameters equipped with buttons of various shapes and different diameters and spacing [**L. 10–12**]. It should also be noted that the buttons are inserted in bits used for the blasthole drilling, usually by an interference fit, and the hardness of the bit body reaches 60–62 HRC [**L. 4**].

TESTING METHODOLOGY OF BIT BUTTONS WEAR

Manufacturers and users of button bits use different testing procedures and the wear examination of button bits. As a rule, for these tests to be reliable, in each testing method, only one factor that causes damage or wear to the bit is taken into account [**L. 7**].

Among many methods used to examine the bits, specific types can be specified, e.g., test of bit wear rate BWI (Bit Wear Index), rock scratch test Cerchor-CAI (Cerchar Abrasiveness Index), and rock abrasivity index RAI (Rock Abrasivity Index) [**L. 7, 9**]. The above mentioned methods, considered as simplified, allow for approximate determining, among others, the nature and speed of wear of the tested tools.

The most reliable method of testing the button bit wear are examinations carried out in real operating conditions with the application of drilling machines and original drilling equipment with which the tested bit is mating. In this type of testing, it is possible to take into account all the parameters of the drilling affecting the process of bits wear as well as to determine the output and energy consumption of the drilling process for holes drilled by the tested bit [**L. 9**]. However, these are test involving high costs, which is why it was decided to carry out testing during the normal mining of dolomite deposits and to accordingly adapt the testing methodology.

It was assumed that investigations of the bits wear would be carried out on the drilling equipment provided by mining plants operating the deposits, during which bit tests would be applied with constant parameters of the drilling process and constant parameters of the compressed air supplying down-the-hole hammer (taking into account deviations covering the variations in the dolomite deposits run). The only parameter that was supposed to change during the tests was the drill stem rotational speed. The tests were to be carried out for the stem speeds $n_1 = 26\ min^{-1}$, $n_2 = 40\ min^{-1}$, and $n_3 = 60\ min^{-1}$. Drilling holes with different rotational speed of the stem was aimed at determining an effect of this speed on the rate of the bit buttons abrasive wear at a fixed value of the drilling speed.

For the tests, button bits of diameter 95 mm made by the company Permon were selected [**L. 6**]. These are bits with two flushing holes on the frontal face and 4 main grooves and also 4 auxiliary flushing grooves placed symmetrically on the perimeter of a bit dome. The bits are equipped with 13 sintered carbide buttons with the diameter of 12 mm (5 buttons on the frontal face and 8 buttons on the peripheral surface). It was assumed to investigate a process of the buttons wear in 15 pieces of ballistic button bits and 3–5 pieces of semi-spherical button bits, which would allow determining differences in the wearing process of buttons of a different shape. **Fig. 4** presents the construction of a bit KR 95–105 DBBs equipped with ballistic buttons.

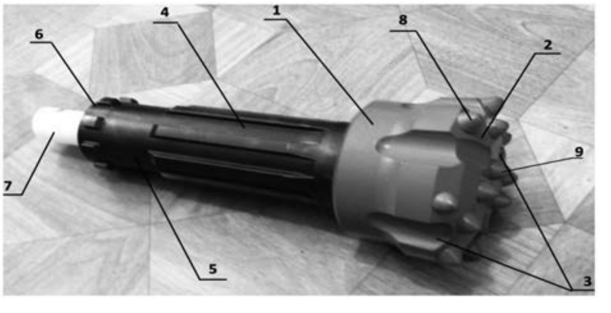

Fig. 4. Construction of the bit KR 95-105 DBBs: 1 – bit dome, 2 – frontal face, 3 – holes and flushing grooves, 4 – outer splines, 5 – recess for safety bolt, 6 – impact surface, 7 – flushing pipe, 8 – peripheral buttons, 9 – frontal buttons

Rys. 4. Budowa koronki KR 95-105 DBBs: 1 – czasza koronki, 2 – powierzchnia czołowa, 3 – otwory i rowki płuczkowe, 4 – wielowypust zewnętrzny, 5 – wybranie pod sworzeń zabezpieczający, 6 – powierzcnia udarowa, 7 – rurka płuczkowa, 8 – słupki obwodowe, 9 – słupki czołowe

According to data of the bit manufacturer, their buttons are made of tungsten carbide (WC) with a grain size of 2 mm on a cobalt matrix (Co), wherein the cobalt content amounts to 6%. Due to this composition, the buttons are applied for blasthole drilling in rocks with the increased resistance to abrasion.

Defects that enable one to assess the process of buttons wear in bits are their damages resulting from th following [**L. 7, 9**]:

– Abrasive wear of bits buttons, and
– Buttons wear as a result of their crushing or breaking.

The measurement of an abrasive wear of the bit buttons is quite complicated in real operating conditions, due to the difficulty in determining a measuring base in relation to which it is possible to measure the button wear.

It has been assumed that gauges will be used to measure the wear of both frontal and peripheral buttons with their shapes corresponding to the shape of examined buttons and with appropriate measuring scales, **Fig. 5** [**L. 15**].

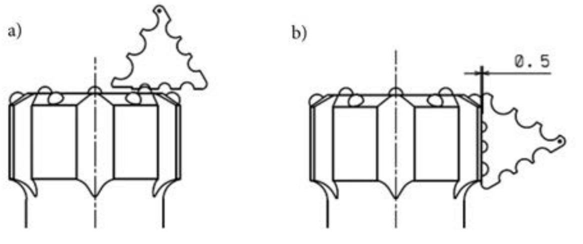

Fig. 5. Measuring the wear of bit buttons by means of the gauge: a) – checking the wear rate of frontal buttons, b) – checking the wear rate of peripheral buttons

Rys. 5. Pomiar zużycia słupków koronki za pomocą sprawdzianu: a) – sprawdzenie stopnia zużycia słupków czołowych, b) – sprawdzenie stopnia zużycia słupków obwodowych

The application of gauges for the measurement of the buttons' abrasive wear also allows one to precisely determining the degree of wear qualifying buttons to be sharpened.

As a general indicator determining the buttons abrasive wear of the tested bit the "linear button wear index" was accepted, which was calculated separately for frontal and peripheral buttons. It was a ratio of the sum of worn bit button heights to the sum of new bit button heights expressed in percentages.

During tests, the measurements of the buttons wear were to be carried out after the drilling of 3 blast holes. After the drilling of each hole, the bit was subjected to an inspection in order to detect possible crushing or breaking of buttons. In such case, an immediate sharpening of damaged buttons or their complete regrinding was provided.

In addition, in order to determine a real impact of the regular sharpening of buttons on the operating time of button bits, it was assumed that two of the tested bits with ballistic buttons will not be sharpened, which is a common occurrence in rock raw material mines.

PLACE OF TESTS AND APPLIED DRILLING EQUIPMENT

The investigation of a process of the bit button wear was carried out during blasthole drilling in the Devonian and Triassic deposits located in the vicinity of Siewierz [**L. 3**]. Dolomites in which holes were drilled were characterized by the following:

– Compressive strength up to 278.6 MPa (dry condition) and 193.4 MPa (frozen condition),
– A non-uniform run of the deposit (numerous interbeddings, especially to a depth of 4–6 m),
– An average apparent density 2640 kg/m^3,
– An abrasive wear on Boehme disc up to 5.80 (average 0.59),
– An increased SiO_2 content with an average percentage of 3.67%,
– A high Al_2O_3 content of average 2.11%, and
– A relatively high content of iron oxides reaching up to 4.63% (average 1.13%).

Taking into account the physicochemical properties of the drilled dolomites, it should be noted that drilling of holes with the tested button bits took place under difficult conditions, especially due to the high content of SiO_2 and Al_2O_3 as well as high compactness of the rock.

The drilling of holes was mainly done using the Hausherr HSB 500 self-propelled drilling rig [**L. 5**]. The construction of this drilling rig, shown in **Fig. 6**, was designed mainly for blasthole drilling by the rotary-impact method using the down-the-hole impact mechanism ("down-the-hole hammer"), although it can also successfully drill holes with the rotary method using cutting bits.

The HSB 500 drilling rig allows the drilling of blast holes with diameters 85–105 mm and depth up to 36 m. Its technical parameters allowed the implementation of the assumed examination program (clamping force 0–2.5 kN). The compressor installed on the HSB 500 drilling rig had a capacity 11 m^3/min at a supply pressure 1.4 MPa and a capacity 14 m^3/min at a supply pressure 1.6 MPa, which fully covered a requirement of the down-the-hole hammer for compressed air and allowed an effective cleaning of the bottom of drilled hole from a bore dust.

In the final stage of the examination, due to the need of increasing the number of drilled blast holes for operational reasons, a HBM 60 drilling rig was also used. It is an older type of the drilling rig with much higher values of technical and operational parameters (clamping force 0–60 kN, torque on rod 0–4.1 kNm) and a maximum compressor capacity 18 m^3/min at a pressure of 2.5 MPa.

The drilling was performed by drilling rods with a length of 4000 mm and a diameter of 79 mm. They were included in the drilling rigs equipment (one rod was twisted with the rotary head by a spindle and eight pieces were deposited in the rod store).

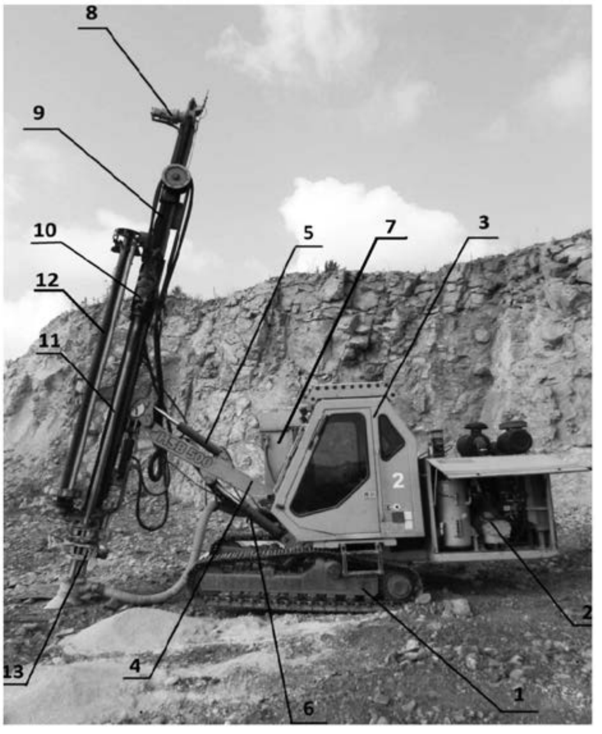

Fig. 6. Construction of the HSB 500 Hausherr drilling rig: 1 – tracked chassis, 2 – Diesel engine with hydraulic unit and compressor, 3 – operator's cabin, 4 – mast boom, 5 – mast servo-motor, 6 – boom servo-motor, 7 – bore dust extractor, 8 – feed mechanism motor 9 – feed chain transmission, 10 – rotary head, 11 – drill stem with down-the-hole hammer, 12 – rod store, 13 – jaws unit

Rys. 6. Konstrukcja wiertnicy HSB 500 firmy Hausherr: 1 – podwozie gąsienicowe, 2 – silnik wysokoprężny z agregatem hydraulicznym i sprężarką, 3 – kabina operatora, 4 – wysięgnik masztu, 5 – siłownik masztu, 6 – siłownik wysięgnika, 7 – odsysacz zwiercin, 8 – silnik mechanizmu posuwu, 9 – przekładnia łańcuchowa posuwu, 10 – głowica obrotowa, 11 – przewód wiertniczy z młotkiem wgłębnym, 12 – magazynek żerdzi, 13 – zespół szczęk

At the end of the drill stem there was fixed (by a screw joint API 23/8" reg.) a box for the down-the-hole hammer of type VKP 95-2 made by the company Permon. The hammer was powered by compressed air at a pressure of 0.12±0.2 MPa supplied through holes in rods of the drill stem. The absorbing power of the hammer at this supply pressure was 6–6.5 m^3/min, and the frequency of impacts of the hammerhead on the gripping part of the tested bits reached the value of 30–32 Hz [**L. 13**]. The hammer manufacturer does not specify data on the energy of a single hammerhead impact; however, according to the analysis of its construction-operational parameters, it can be assumed that the energy of the single impact of the hammerhead is 100–100 J.

Efforts were made to apply constant parameters during the examination of the drilling process. It is beneficial in this case to avoid the necessity of performing drilling tests at the beginning of examination, which allow selecting a pressing force of the bit to the bottom of the hole and the value of the torque on the drill stem for an optimum drilling speed. Due to the experience of drilling rigs operators, the values of these parameters were determined before the examination (pressing force 12±1 kN, maximum torque 1.8 ±0.2 kNm).

CONCLUSIONS

Obtained results of the bit buttons wear tests with diameters of 95 mm [**L. 16**] allowed the authors to draw the following conclusions:

- The predominant type of wear of buttons in the tested button bits was abrasive wear, both in the case of frontal buttons and peripheral buttons.
- The domes of the frontal ballistic buttons, due to their abrasive wear take a conic form, **Fig. 7**, and for this reason, they are not often regenerated by sharpening. This is a serious mistake of users of the bits, because with this shape of the button, the dome decreases the contact surface of buttons with the bottom of the hole and thus decreases a penetration of the drilled rock.
- Frontal buttons, both ballistic and semi-spherical buttons, non-uniformly wear out by abrasion. Higher abrasive wear is characteristic of buttons inserted closer to the bit axis and their rate of abrasive wear should qualify the bit to be sharpened.
- The domes of the peripheral ballistic buttons, due to the abrasive wear, take the form of a flat surface, **Fig. 8a**. The degree of their abrasive wear is lower than for the frontal buttons, which is due to the lower impact loads transmitted by these buttons. In the case of peripheral buttons, crushing or breaking of individual buttons was also found, **Fig. 8b**, which took place in the last stages of drilling with bits and were the result of a decrease of the bits peripheral surface.
- Regular sharpening of buttons in the case of all tested bits allowed for increasing their service life by 25–30%. It is extremely important to accurately determine the degree of wear of the buttons qualifying them for sharpening.
- Choosing the right shape of a button in compliance with the properties of the drilled rock is of fundamental importance for the speed of the process of the bits wear. The examination of bits with semi-spherical buttons, commonly used in the rock mining, proved that, when drilling holes in abrasion-resisting deposits of dolomites, despite the regular sharpening, their life is over 30% lower than in the case of ballistic buttons,

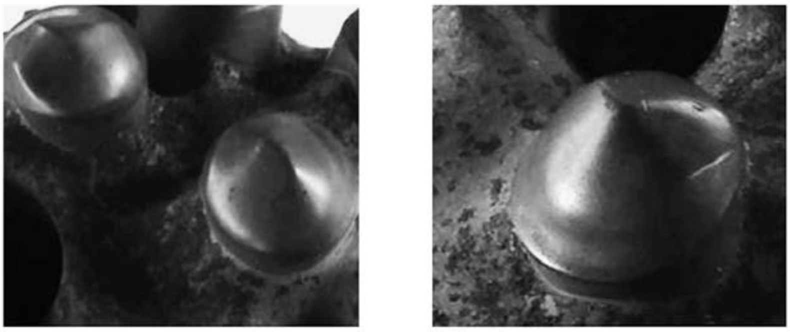

Fig. 7. Forms of wear of the ballistic frontal buttons in the tested bits
Rys. 7. Postacie zużycia słupków czołowych balistycznych w badanych koronkach

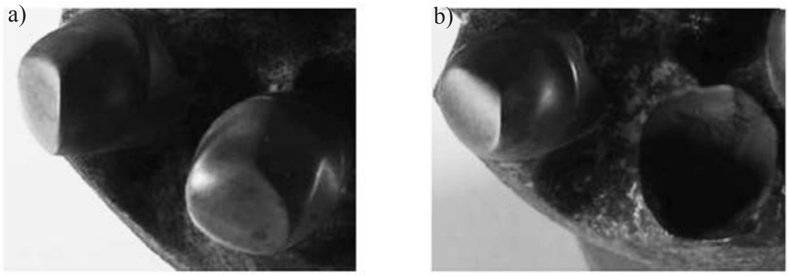

Fig. 8. Types of wear of the peripheral ballistic buttons: a) – abrasive wear, b) – breaking of a button
Rys. 8. Rodzaje zużycia słupków balistycznych obwodowych: a) – zużycie ścierne, b) – wyłamanie słupka

– The process of abrasive wear of buttons at a constant clamping force influences, in a significant way, the rotational speed of the drill stem. If the value of this speed is too high, the speed of drilling holes increases by approximately 10%, but this increase results in a significant acceleration of the abrasive wear of both facial and peripheral buttons. However, if the value of the stem rotational speed is too low, the drilling speed of holes can be reduced even by approximately 40%.

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