

Conical Picks for Underground Mining

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INTRODUCTION

In underground mining, shearers are mainly equipped with conical picks. Under difficult working conditions and in the case of abrasive rocks mining, the durability of tools significantly decreases. This translates into reduced operating efficiency and increased costs. Replacement of conical picks, which may be necessary even after a few hours, is particularly problematic. A typical cutting head of the shearer is usually equipped with approximately 40-60 picks, up to over a hundred in the case of linear shearers or other machines. Therefore, given the price and the number of picks, as well as logistics issues, this subject has an important practical and economic dimension. Cutterheads are used as cutting elements for many machines, not only in underground or opencast mining, but also in the construction industry, tunnel building and road construction. This article, however, focuses on picks typically applied in the heads of cutting machines used in underground mining.

Conical picks are the subject of research and development works carried out in many centres around the world. These investigations are mainly aimed at finding a solution with the highest abrasion resistance. Tests were conducted for picks with the body protected against abrasive wear by abrasion resistant coatings, hardfacing or carbide rings (Chang & Chulho, 2017; Krauze et al., 2016). Works were carried out to discover the mechanism of abrasive wear and wear prediction (Gajewski et al., 2013), the possibilities of supporting the mining process (Kotwica, 2011) and the regeneration of picks (Prokopenko, 2018). Tests were done for cemented carbide (Nahak et al., 2015), steel (Gajdzik & Sitko, 2014, 2016) as well as for the complete pick (Songyong et al., 2017) or picks forming the cutting head (Krauze et al., 2015, Krauze & Kotwica, 2007). Implementation works were also carried out with the aim of applying modern tools and heads in difficult conditions (Bołoz & Krauze, 2018), (Krauze & Bołoz, 2018), as well as applying alternative tool solutions (Gospodarczyk et al., 2013, 2016), (Kotwica, 2018, Bołoz, 2019). Also the procedures for assessing the

quality of picks enabling the best offer to be chosen by the user during public tenders were subjected to research (Bołoz, 2018).

CONICAL PICKS

The name „tangential-rotary” pick fully reflects the nature of the work and the shape of these tools. However, in the Polish nomenclature also the English name "conical" pick is used. The conical pick has the form of a solid of revolution and consists of a working and a gripping part. The gripping part is made of a cylindrical one- or two-stage mandrel, whereas the working part is a tapered solid of revolution of various shapes. It is equipped with a tip in the form of a cemented carbide insert. The working part of the pick used in underground mining in Poland is usually 64, 65, 70, 89 or 90 mm. The gripping part of the pick can be one- or two-stage, with diameters usually reaching 30 mm or 38 mm, 30 mm/38 mm, rarely 35 mm.

The conical picks of cutting heads are mounted directly in pick holders. The holder may have an integrated sleeve or the sleeve may be an additional intermediate element between the holder and the pick. The shape of the picks and the appropriate manner of their mounting enables an even wear of the tip. The method of mounting in the holder consists in securing the pick against falling out while allowing its free rotation relative to the axis of symmetry. Although there are several dozen solutions of the pick, only four of them are used in underground mining. The most common kinds of protection include:

- PS circlips, so-called Seger rings, also widely applied in machine construction (Fig. 1 a),
- PR expanding rings (Fig. 1b, c),
- round TC friction sleeves and oval TCO friction sleeves (Fig. 1d),
- HERT HZ split pins (Fig. 1e).

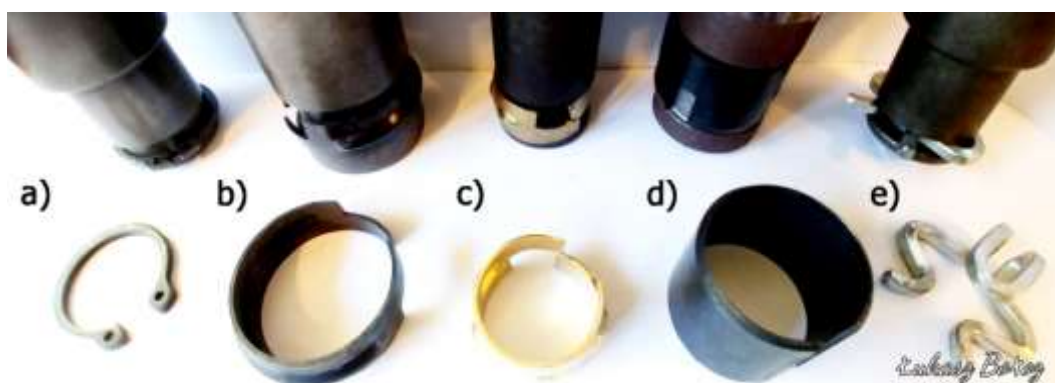


Fig. 1 Most common types of conical picks in holders:
 a. seger ring, b. expanding ring with full embossing, c. expanding ring with spot embossing, d. expansion sleeve, e. HERT HZ split pin

The above markings are given after the manufacturer of the safety devices, HERT Sp. z o. o. (Hert, 2020). However, some producers of picks use their own markings. The expansion rings come in two types: with continuous (Fig. 1d) and spot embossed areas (Fig. 1b). The spot embossing was developed and

registered as a design patent (PL 20395) by HERT. It is characterized by a lower expansion force and greater durability, and is equally effective. In addition, PR expanding rings may be straight-ended, or may have a notch working as a lock – in such a case, there is an additional Z at the end of the marking. The pins commonly called HERT HZ or HERT, previously designated as HS4, come in one size adapted to the diameter of the gripping part – 30 mm. The external dimension of the HZ split pin is 42 mm, so in practice this pin can also be used for the 35-mm or even 38-mm gripping part. HERT HZ pins are covered by patent protection (PL 209632 B1, PL 12515). There is also the HERT HZW ejector for facilitating the assembly and disassembly of split pins.

Uniform wear and simultaneous shortening of the working part of the pick ensures correct static and dynamic friction cutting angles, which allows for the picks' proper continuous work. The body together with the gripping part are one element, made of steel with appropriate impact strength and tensile strength as well as resistance to abrasive wear. The working part is sometimes reinforced with padding welds or carbide rings. Optional wear-resistant layers made of stellite or cemented carbides based on cobalt, nickel or iron are applied by hard facing. The tip is made of cemented carbides of various grades characterized by high hardness. The durability of tools is primarily determined by their proper adjustment to the anticipated mining and geological conditions, and, in particular, by the physical properties of the excavated face. Important parameters influencing the proper course of the cutting process are the geometrical and kinematic parameters of the pick in the holder and the cutting machine head (Bołoz, 2019).

INNOVATIVE SOLUTIONS OF PICKS AND HOLDERS

The most common and the only solution used in engineering practice is the holder with a cylindrical hole in which the pick is mounted directly or through a sleeve. Dust gets into the unsealed space between the pick and the holder, increasing resistance to rotation, which can result in the pick's blocking and unsymmetrical wear. In difficult working conditions, with the presence of abrasive rocks, the pick is often blocked in the holder, which causes its very fast and catastrophic wear, necessitating its immediate replacement. To solve this problem, a number of solutions have been developed; they include subjects of inventions, utility models or only patent applications. One of the many solutions developed by Zenon Wasylęczko is the pick holder described in application P.349498 (Fig. 2a), which on the face has a hard, plasma-sprayed padding weld in the form of a ring. This ring improves the cooperation of the pick and increases the durability of the holder. Cooperation between the pick and the holder has also been improved in the invention of CMG KOMAG, described in PL 049915 B1 (Fig. 2b). In this solution, the flange sleeve has a circumferential groove in the rear part and is fastened by KOMAG's protection in the form of a pin embedded in the through hole of the pick holder. The invention, also developed by Zenon Wasylęczek, is the method of mounting the pick described in PL 177 278 B1 (Fig. 2c).

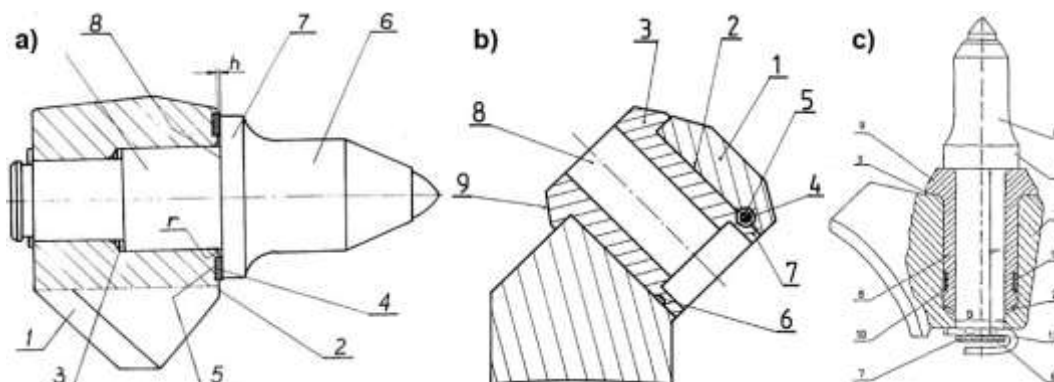


Fig. 2 Patented methods of improving pick rotation in the holder:
 a. application P.349498, b. patent PL 049915 B1, c. patent PL 177 278 B1

The swivel sleeve is mounted in the holder and secured against falling out together with the pick by means of one safety device, for example a spring ring. In these solutions, commercial picks can be used.

The idea solving the problem of blocking the pick in the holder has been described in patent PL 209 806 B1, developed at AGH University of Science and Technology (Fig. 3). According to this invention, the slide surfaces are supplied with a liquid medium, which lubricates and simultaneously flushes the space between the pick and the holder. The liquid medium is supplied under pressure through a system of holes and channels in the cutting head. The holder is equipped with a sleeve, which through the longitudinal grooves (Fig. 3b) or spiral grooves (Fig. 3c) directs the liquid outwards, to the sleeve flange, while taking away the dirt. Commercial conical picks can be used in this solution.

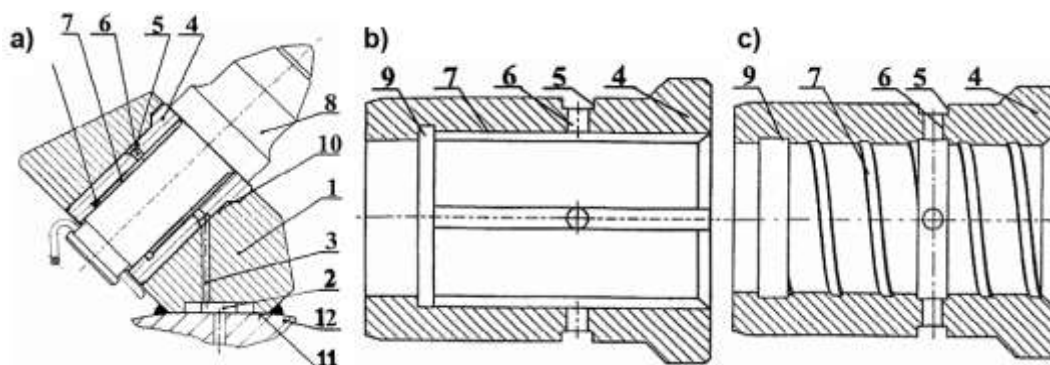


Fig. 3 Lubricated holder according to patent PL 209 806 B1:
 a. reference drawing, b. sleeve with straight grooves, c. sleeve with spiral grooves

Another solution developed at AGH University of Science and Technology is the pick with a holder described in PL 209 241 B1 (Fig. 4). The purpose of this solution is also to increase durability by improving the rotation of the pick in the holder. The pick's rotation is forced by curvilinear grooves on the working part of the pick, which due to contact with the excavated face and mined rock should cause the pick's rotation. In addition, the gripping part of the pick is closed on both sides by sealing rings and also has curvilinear grooves, which are filled with grease. The use of rings and a lubricant allows for better cooperation

of surfaces in the slide bearing unit. Due to the use of sealing, not only the pick, but also the holder must be made in a special way.

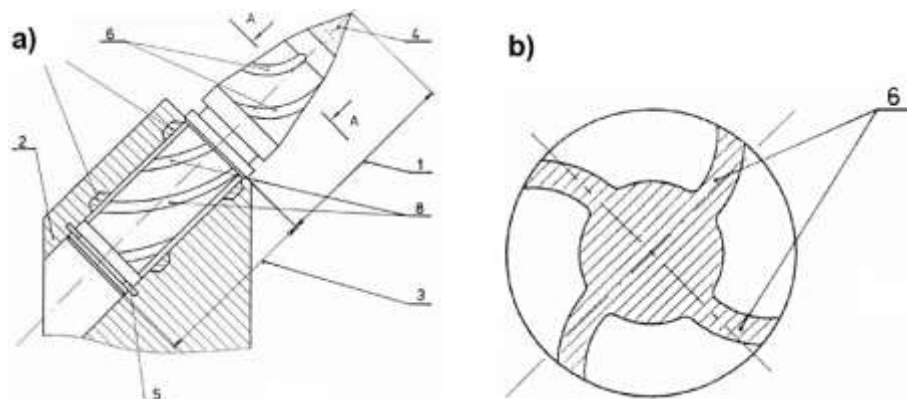


Fig. 4. Pick with spiral grooves according to patent PL 209 241 B1
a. reference drawing, b. A-A cross-section of the working part

In contrast to slide bearings, in the solution, which was also developed at AGH University of Science and Technology, the pick in the holder is equipped with rolling bearings. The invention PL 178 171 B1 (Fig. 5a) is relatively complicated, but allows for uninterrupted rotation of the pick. The essence of this idea is the use of transverse needle bearing and longitudinal support of the pick shank on a ball. The entire unit is enclosed in a blind hole of the holder with an "O" seal. A similar way of solving the problem was presented in the Chinese patent CN207568604U (Fig. 5b). In this case, longitudinal and lateral forces are transmitted by two cone bearings, which are tightened by means of a bolted back cover of the holder. The patent does not provide seals. These solutions require significant interference in the construction of the pick and the holder; therefore, the use of conical picks is not possible.

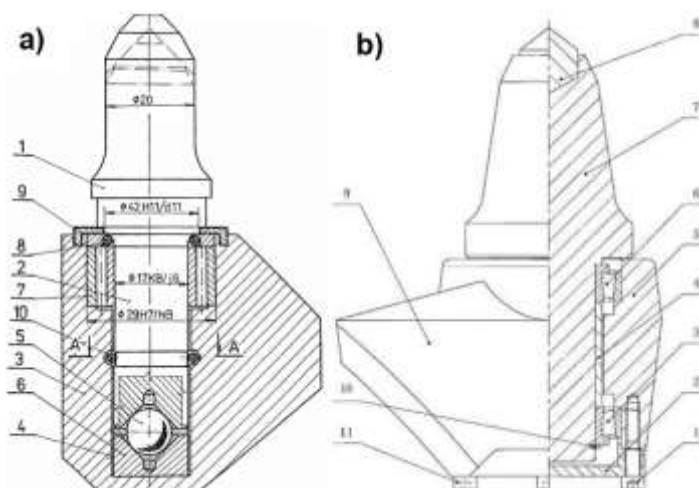


Fig. 5 Picks with roller bearings in the holder:
a. according to patent PL 178 171 B1, b. according to patent CN207568604U

In addition to patents which, in principle, solve the problem of free rotation of the pick, there are a number of sprinkling solutions developed by AGH University of Science and Technology in Cracow (PL 193576 B1), CMG KOMAG

(PL 173702 B1 and W.103143) or Krummenauer (PL 172 259 B1). The most complicated construction is the subject of the Chinese invention which applies to the entire cutting head (WO2012051803A1). The unique solution in this invention is the use of a complex mechanical gear that drives not only the head, but also the conical picks. As a result, the picks rotate regardless of the conditions, at the expense of considerable structural complexity.

Also known are a number of inventions regarding only the pick, especially its working part. The US patent US9476299 B2 (Fig. 6 a) proposes a special shape of the working part of the pick which forces its rotation in the holder. The idea can be implemented in several possible designs through spiral grooves in different directions and in different numbers. A similar, though differently implemented idea is proposed in the utility model PL 66082 Y1, where grooves are made with a padding weld on the working part surface (Fig. 6 b).

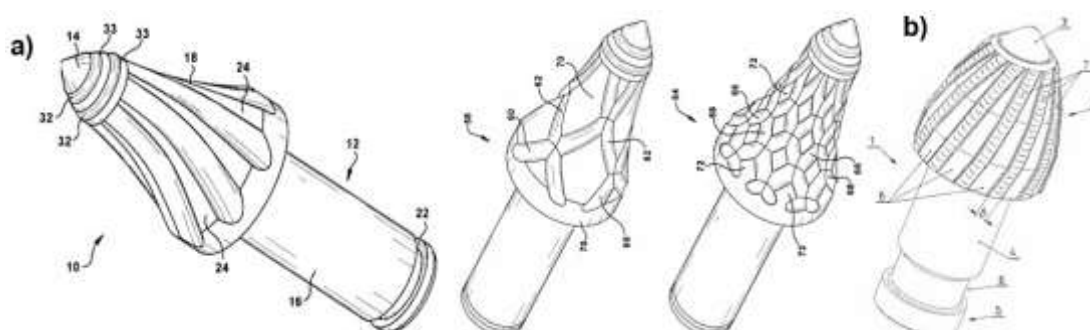


Fig. 6 Picks with grooves forcing the pick's rotation:
a. according to patent US9476299 B2, b. according to utility design PL 66082 Y1

Mr Zenon Wasylczko is also the author of a number of solutions (P.350271, P.103808, P.348958, P.344555) based on the use of a loose sleeve between the pick's gripping part and the holder, which is aimed at improving the free rotation of the pick, thus minimizing the asymmetrical wear of the tip. This inventor is also the author of other less typical designs of the pick (PL 057 846 B2, P.315415, P.346504).

Apart from the above presented methods, also another way of strengthening the working part has been developed and described in a patent by Sandvik (US 7204560 B2), where the working part of the pick is reinforced with a cemented carbide ring or rings. This solution is applied in practice.

The presented solutions mostly relate to holders with a more complex construction than commercial ones, where the pick is equipped with rolling bearings and the bearing assembly sealing is provided. Such solutions improve working conditions, thus increasing the durability of picks. However, frequent replacements of picks requires the replacement process to be quick and efficient. On the other hand, the use of bearing units between the pick and the holder causes that they are exposed to dirt and damage. In addition, care and precision are required during disassembly and assembly, which is difficult in underground conditions. Due to the above reasons, these solutions are not currently applied.

PROPRIETARY SOLUTIONS

The information presented earlier concerns typical, most commonly applied solutions of conical picks and solutions being the subject of inventions. In general, the greatest durability of tools is sought by the use of appropriate materials and coatings or by ensuring the possibility of free and random rotation of the pick relative to its axis. In order to solve the problem of conical picks' durability, two solutions developed at the Department of Mining, Dressing and Transport Machines of AGH University of Science and Technology (currently the Department of Machinery Engineering and Transport) have been proposed: one concerning the pick holder, and the other one – the conical pick. The first is a holder with roller bearings. Holders with a bearing support are known, but not used due to the previously mentioned disadvantages. Replacing the used pick in the discussed holder is simple and quick. Also, the possibility of contaminating the bearing socket has been eliminated. Importantly, the developed solution relies on commercial conical picks. This holder is distinguished by the fact that its bearing assembly has an additional flange sleeve. The sleeve is mounted on radial needle bearings and on a longitudinal roller bearing. Sealing rings are seated at both ends of the sleeve. In addition, the sealing rings are protected against damage by steel shielding rings. Instead of roller bearings, one can use slide bearings, which will also fulfil their task, but will be characterized by greater tip rotation resistance. The hole in the sleeve has the shape and dimensions corresponding to those in commercial holders, which allows for using standard conical picks. The holder ensures very low resistance to the pick's rotation.

The operating practice has shown that in many cases the reason for the wear of picks is not the wear of the cemented carbide tip, but of the steel body. As a result, the carbide insert gets chipped or broken, and the pick needs to be replaced. The previously presented treatments quoted in the subject literature (Bołoz, 2019) allow for increasing the durability of the pick, especially by protecting its working part, but do not protect the body throughout the service life. By analysing both the construction of conical picks and the form of their wear, a new solution of the conical pick has been developed. The solution is to make the pick's tip in a shape similar to the form of wear of the pick's working part. The tip of a special shape can be made entirely of cemented carbide or another wear-resistant material. The tip can also consist of two permanently connected elements and can be mounted in the standard way - by soldering, or separately, for example by means of a spring ring. The separate mounting enables fast replacement of the tip without removing the pick. Moreover, one can also consider the use of a mobile connection between the tip and the pick by applying a slide bearing. Applications for patent protection have been filed for both the holder and the pick as P.428397 of 27.12.2018 and P.428184 of 14.12.2018, respectively. Both solutions can be used independently or simultaneously. Fig. 7 shows examples of the possibilities of implementing both solutions. Fig. 7a shows a slide-bearing holder 1 with a pick 2, whose cemented carbide tip is mounted on a spring ring. In contrast, Figure 7b shows

a rolling-bearing holder 3 with a pick 4, the cemented carbide tip of which is permanently attached, e.g. by soldering.

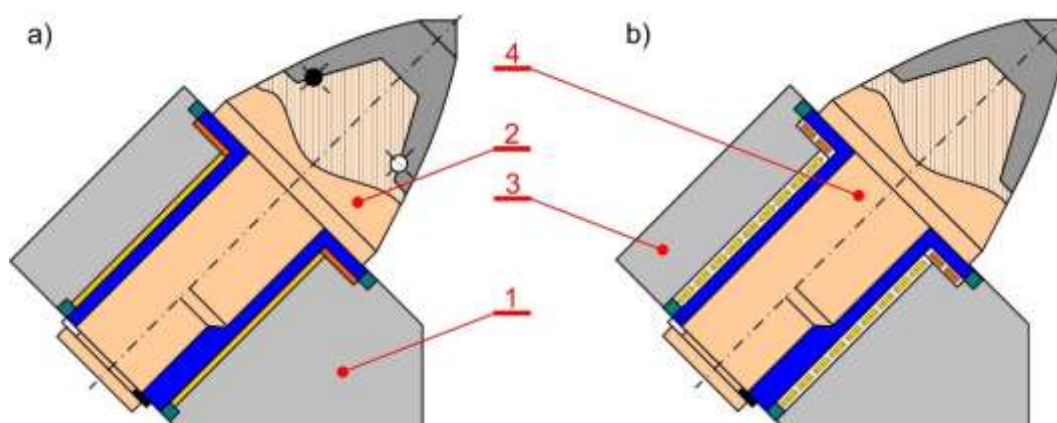


Fig. 7 Proprietary solution of the holder and the pick: a. slide-bearing holder with a pick equipped with a quick-change tip, b. roller-bearing holder with a pick equipped with a soldered tip

CONCLUSIONS

Cutting as a method of mechanical rock mining is applied in many industries, but the main and largest market for cutting tools is underground mining. Rock cutting with conical picks, especially in difficult and demanding conditions, entails their rapid wear and necessity of replacement. During work conical picks are in direct contact with the excavated face, so their wear is inevitable. The working time, however, tends to be constantly increased. At present, the direction of conical picks' development is the use of abrasion resistant steel for bodies, coatings and cemented carbides for tips. Therefore, new materials are developed and tested in many industrial and scientific centres. The second direction of development for these tools are new constructions of holders and picks, which frequently have a patent potential and become protected inventions.

Although the presented inventions regarding the solutions of picks and holders indicate a multitude of possibilities, most often they are based on various shapes and coatings of the working part of the picks, as well as roller or slide bearing units of the holders. On the other hand, the two proprietary solutions of the holder and the pick that have been presented above are worth noting as prospective directions of development, which will allow the durability of picks to be considerably enhanced. Currently, a design and prototype of a pick with a cemented carbide insert corresponding to the shape of a typical form of wear has been developed. Tests of wear rate in comparison with commercial solutions are to be conducted in near future. This pick can be used in difficult conditions, where high efficiency of the mining process is required. The high price of the pick will be offset by much greater durability and increased machine available time.

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Abstract.

Mechanical cutting in underground mining faces increasingly difficult challenges. Deteriorating working conditions result in the development of automation and robotization, and the insufficient durability of cutting tools remains a serious problem. In addition to drilling, the technology of cutting provides a huge market for tools. Currently, mainly conical picks are used in the process of cutting. The cutterheads of shearers are equipped with at least several dozen conical picks, which, due to their workability and abrasiveness, sometimes work for merely a few hours. Hence the interest of users and manufacturers in the development of tools with increased durability. The article briefly presents the applied solutions of conical picks, their construction, dimensions and materials used. Attention was paid to the issues related to the protection applied and its marking. A review and analysis of commonly known construction solutions for picks and holders have also been carried out, and proprietary patent pending solutions for the pick and holder have been presented.

Keywords: conical picks, durability of tools, bearing-equipped pick, bearing-equipped holder, innovative solutions