Testing the selected parameters of conical picks

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Conical picks are characterized by the structural and material parameters, affecting the effectiveness of mechanical mining of coal and rock with roadheaders and longwall shearers in mining plants. Unsatisfying the specific technical parameters of cutting tools by manufacturers, especially pick length and not proper type and quality of materials used for their manufacture may result in excessive asymmetric wear, break of holding part or fall out what means a necessity of their frequent replacement. There is no standardized method for assessing the cutting picks quality and durability. That is why, to reduce conical picks rate of wear, the scientific organizations have undertaken the research projects on new designs of cutting picks and materials for their manufacture as well as on the development of laboratory and computational methods for determination of conical picks rate of wear. Results of testing the cutting picks, used in roadheaders and longwall shearers, conducted according to the unique author's procedure, are presented. The test results indicate for the need of improving the methods for assessing the quality of cutting picks, especially in the scope of testing the connection of sintered carbide with a body of a cutting tool.

Keywords: *Conical picks, Sintered carbides, assessment of the quality*

Introduction

Mechanical mining based on the direct action of cutting drums of mining machines on solid coal is one of the methods for hard coal mining. Conical picks fixed to the drum of roadheaders and longwall shearers are commonly used (Kotwica, 2018; Krauze et al., 2009). The body of a cutting tool consists of a pick holder and a conically shaped working part with a carbide tip soldered to it. Cutting picks are exposed to high mechanical stresses and temperature, generated in the areas, where the cutting tool contacts the mined rock. This leads to relatively rapid wear, causing changes in both the geometrical shape and loss in sintered carbide mass and the working part (Barker et al., 1981; Krauze and Mucha, 2016; Baranov et al., 2017). It is also important to select the proper cutting picks for the specific design of mining drums, where inappropriate manufacturing and improper operation may contribute to mechanical damages, including excessive, and uneven abrasion as well as falling off or cracking the sintered carbide – Fig. 1.

Fig 1. Examples of conical picks used in the cutting drum of a roadheader withdrawn from operation

Such a failure causes a roadheader's break in the operation due to a replacement of cutting picks what results in significant financial losses in the mining plants (Biały and Beno, 2016; Biały, 2017; Biały and Fries, 2019; Bołoz, 2018).

In order to obtain proper durability of conical picks, the selection of their shape and type of the material used for their manufacture should be based on the analysis of geological and physical-mechanical properties of rocks (Biały, 2013; Biały, 2014), parameters and conditions of the cutting process and the cutting tool design (Gospodarczyk, 2013; Krauze and Bołoz, 2015).

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The conical picks are made of sintered carbides of various grades, having high hardness, compressive strength as well as resistance to abrasion, to brittle fracture and high temperature (Ścieszka and Filipowicz, 2001). The bodies of the picks are made of steel of high impact strength by an increased content of manganese, molybdenum, chromium, nickel and boron. The steels are subjected to heat treatment, consisting of hardening and tempering to obtain hardness above 40 HRC and thus high resistance to abrasion. In the case of conical picks and working parts of the cutting tool bodies, their resistance to abrasion increases by padding the outer conical surface with abrasion-resistant materials (Krauze et al., 2016; Qazizada and Pivarčiová, 2018). It is also important to ensure the declared linear and angular parameters.

Due to the lack of a standardized method for assessing the quality and durability of conical picks, various test procedures were used, including those developed by the AGH University of Science and Technology and implemented in the selected mining plants (Krauze and Kotwica, 2007; Krauze et al., 2015; 2017b). Scientific papers focus on the design solutions of conical tool holders and methods for testing the rate of the tools' wear on the laboratory testing stands, as well as applying computational methods using the neural networks (Kotwica, 2015; Krauze et al., 2014; 2017a; Gajewski and Jonak, 2009; Božek and Pivarčiová, 2013). One of them (Bołoz, 2018) presents the results of the quality assessment of conical picks delivered to six mining plants in the form of public tender. They show the high quality of the conical picks as well as single cases of failure to meet the requirements of geometric parameters. The hardness of the pick holder and content of carbon, chromium and manganese in the material of the tools' bodies are the most common parameters that do not meet the requirements. There are, however, no literature data on the assessment of sintered carbide parameters, i.e. the degree of filling the soldering gap with solder and the embedment depth from the edge of the working part, having an important impact on the durability of carbide fixation in the cutting tool's holder.

The results of research work on assessing the geometrical parameters of conical picks and the properties of the materials used to manufacture them carried out at the KOMAG Institute (Grynkiewicz-Bylina and Rakwic, 2019), are given. They complement the state-of-the-art in the above-mentioned scope. The assessment of the degree of filling the soldering gap with solder and of the embedment depth of the sintered carbides from the edge of the working part is also presented.

Material and Methods

The research work was realized in four stages. In the first stage, the documentation from the conical picks tests, carried out in the KOMAG accredited Laboratory of Material Engineering and Environment within the years 2006-2017, was analyzed. The focus was on the conical picks. The geometrical parameters and properties of the materials used for their manufacture were tested. The assessment covered 10 types of conical picks, with sintered carbides of diameters from 18 to 25 mm and cutting tool lengths from 140 to 195 mm. The conical picks were delivered by six manufacturers, marked from A to F, and they were intended to be used in roadheaders (three types) and longwall shearers (seven types) – Fig. 2. In total 23 sets of conical picks, including twenty one-step and three two-step tools, were tested.

a/ conical pick used in cutting drum of a longwall shearer

b/ conical pick used in a roadheader's cutterhead

Fig. 2. Conical picks used in cutterheads of longwall shearers and roadheaders

In the second stage, on the basis of the test documentation, the following technical parameters of the conical picks, important for an assessment of their manufacture quality and durability, were specified:

- geometric parameters of the cutting tool, its working part and pick holder as well as of the sintered carbide,
- hardness, impact strength KCU/energy of impact test KV and tensile strength Rm of the working part,
- hardness and embedment depth of the sintered carbide from the edge of the working part and the degree of filling the soldering gap with solder.

The geometrical parameters of the cutting tool are marked in Fig. 3.

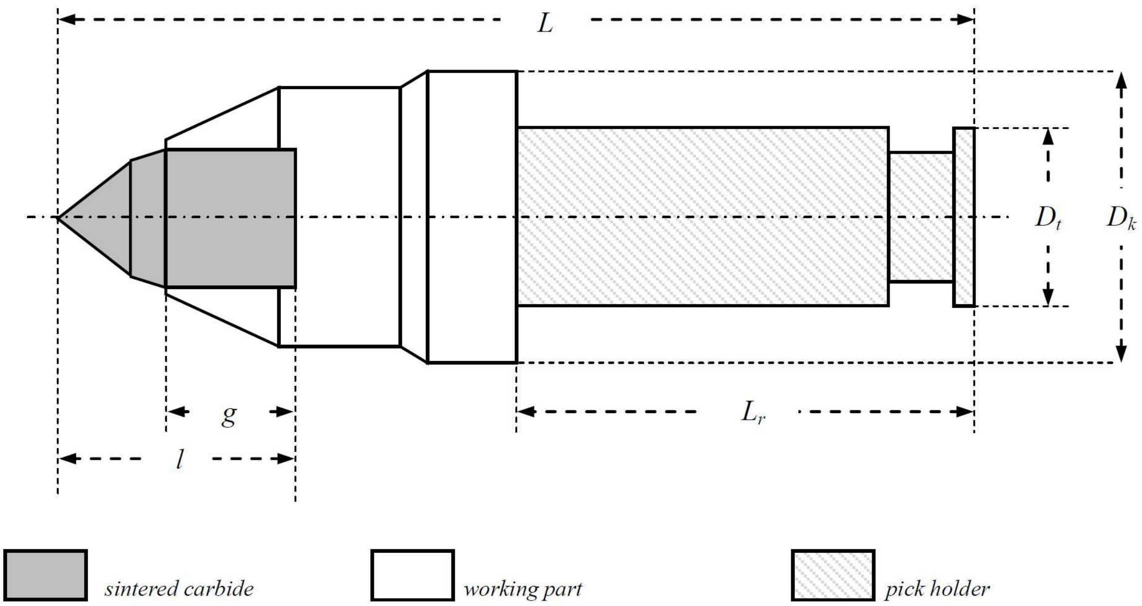

Fig. 3. The geometrical parameters of the cutting tool in the roadheader's cutterheads

In the third stage, the criteria for the assessment of conical picks were defined based on the analysis of the manufacturer's specifications and the requirements of the mining plants – Table 1.

Tab. 1. Criteria for the assessment of technical parameters of conical picks

Conical picks/pick component	Technical parameters		Criteria for the assessment of technical parameters
Conical pick	total length, L		deviation from the nominal dimension: ±1 mm
Working part of the pick body	length, L_r		
	flange diameter, D_k		
	hardness		from 40 to 46 HRC
	impact resistance / energy of impact	*KCU*	> 28 J/cm^2
		KV	> 25 J
	tensile strength R_m		> 1250 MPa
Pick holder	diameter, D_t		deviation from the nominal dimension: ±0.2 mm
Sintered carbides tip	degree of filling the soldering gap with a solder		> 90%
	embedment depth of the sintered carbide from the edge of the working part, g		> 22 mm for the sintered carbide insert of 25 mm dia
			> 19 mm for the sintered carbide insert of 22 mm dia
			> 12 mm for the sintered carbide insert of 18 mm dia
	length, l		> 37 mm for the sintered carbide insert of 25 mm dia
			> 34 mm for the sintered carbide insert of 22 mm dia
			> 27 mm for the sintered carbide insert of 18 mm dia
	hardness		> 1000 HV_{30}

The criteria for the assessment of geometric dimensions, including L, L_r, D_k, D_t and strength parameters, i.e. hardness of the working part of the body and the carbide as well as KCU, KV and R_m, were the same for all the tested conical picks. In the case of sintered carbide parameters, l and g, the criteria for their assessment depend on the sintered carbide diameter.

In the fourth stage, the results of the cutting tool tests were assessed. The tests were carried out in the KOMAG Laboratory and the following cooperating laboratories: Baildonit and ZDT-GLIMAG (Grynkiewicz-

Bylina and Rakwic, 2019; Božek and Pokorný, 2014). The testing procedure was developed by the paper authors – Fig. 4.

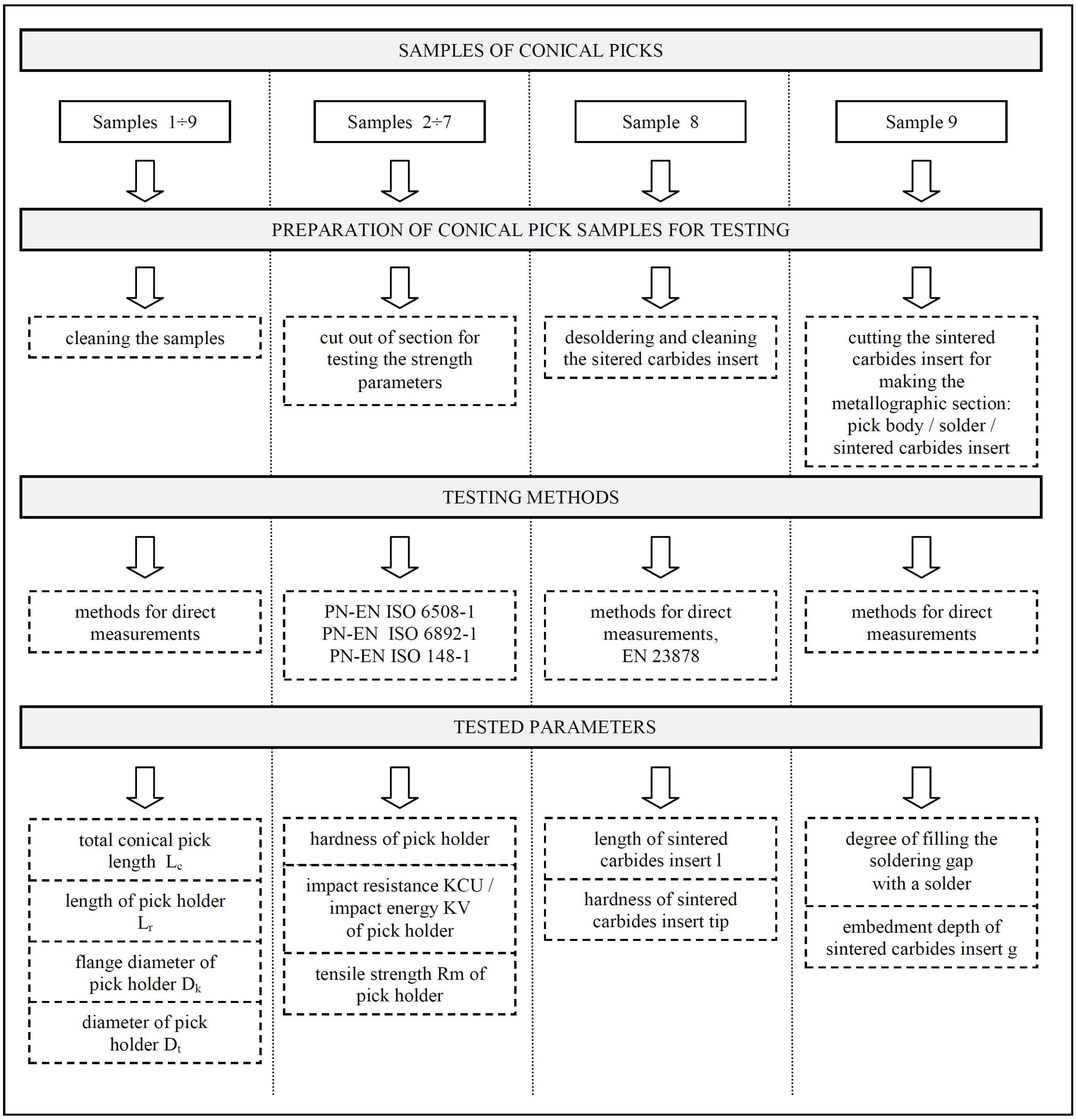

Fig. 4. Algorithm of the testing procedure of conical picks used in longwall shearers and roadheaders

Quality tests of each type of cutting tool were carried out on nine cutting tool samples marked by numbers from 1 to 9. Before taking measurements of the geometrical parameters of the tool's body, the samples were cleaned with petroleum ether. A 10 mm thick disc was cut from the working part of the sample No. 2. Then the sample was ground to obtain two parallel cross-section planes for measuring the hardness of the body material. For the tensile strength tests, two sections of dimensions according to the PN-EN ISO 6892-2 Standard were cut off from the working part of samples No. 3 and 4, and three sections with a notch U or V were cut off according to the PN-EN 148-1 Standard from the samples 5÷7 for impact resistance/energy of impact tests. For measurements of geometrical parameters (length and diameter) and hardness, the sintered carbide was desoldered from the sample No. 8 and cleaned from the solder.

For testing the degree of filling the soldering gap with solder and the embedment depth of sintered carbide from the edge of the working part of the cutting tool's body, a metallographic section of the cutting tool, solder and sintered carbide connection, obtained after cutting the sample No. 9 along its axis, were prepared.

The measurements of geometrical parameters of the bodies of conical picks and sintered carbides were taken using the direct methods. The degree of filling the solder gap was determined as the percentage share of the solder surface area in the solder gap surface area, subtracting the surface of the technological void. The surface area of the solder, voids and solder gap were calculated based on their edge length and their width, obtained from the stereoscopic microscope measurements. Measurement results for metallographic microsections of connection between the pick holder, solder and sintered carbides inserts made on two perpendicular cross-sections of the sample No. 9 along the symmetry axis, were averaged.

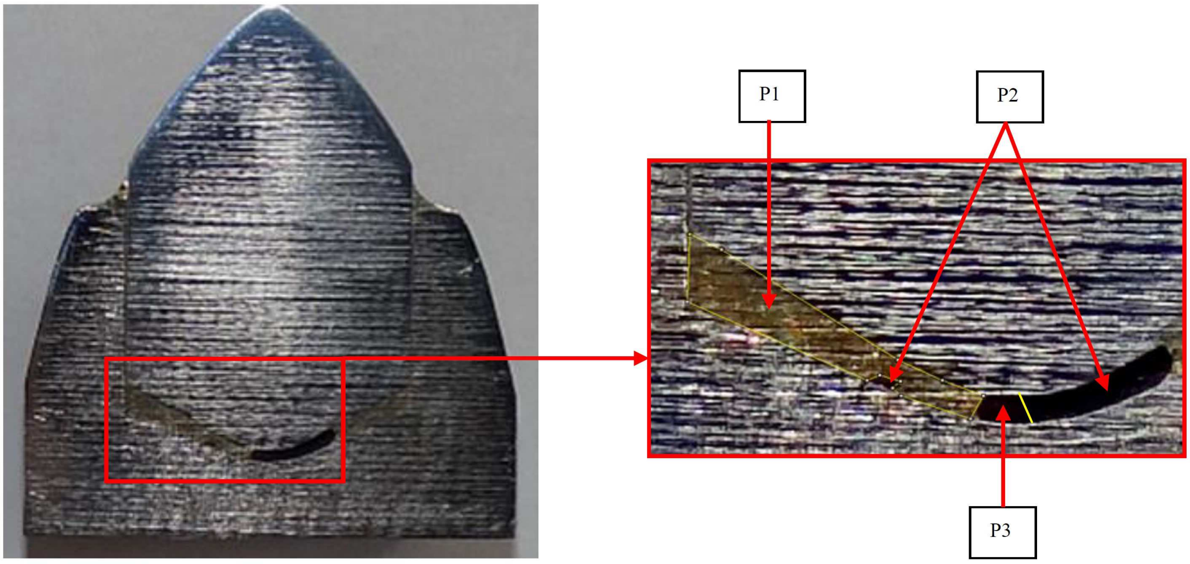

Fig. 5. Sample cross-section of roadheader's cutting tool used for determination of the degree of filling the solder gap symbols: P1 – solder, P2 – lack of solder, P3 – technological void

Tests of material properties of the conical picks holders and sintered carbides were conducted using the standardized methods. Hardness of the holder's material was measured according to the PN-EN ISO 6508-1 Standard using the Rockwell method, hardness of the sintered carbide was determined according to the EN 23878 Standard using the Vickers method, the tensile test was carried out according to the PN-EN ISO 6892-1 Standard, and the *KCU* impact test or the *KV* energy of impact test was conducted according to the PN-EN ISO 148-1 Standard.

The test results were assessed in Stage 4 according to the criteria set out in Stage 2. Based on the analysis of the results, the parameters of conical picks, which require a correction were pointed out.

Results and discussion

The tests showed that geometric parameters in the majority of samples of conical picks holders did not differ from the criteria specified in stage 2. Single cases which did not meet the accepted deviation in the total length of a cutting tool and in its working part as well as in the flange diameter and holding part for the manufacturers A and C, were reported.

Individual cases of failure to meet the above criteria were also found for the depth of sintered carbide embedment from the working edge. Two reported cases concerned the F cutting tool manufacturer.

The detailed results of testing the strength parameters of pick holders, hardness and length of sintered carbides and the degree of solder filling of the solder gap are presented in Table 2.

Tab. 2. Results of testing the strength parameters of conical picks, their hardness and length of combined carbides as well as the degree of solder filling of the solder gap

Markings of the conical picks				Results of testing the pick holders				Results of testing the sintered carbides inserts		
				strength to the tensile force R_m	impact resistance *KCU*	impact energy *KV*	hardness	hardness	length	degree of solder gap-filling of the solder gap
				[MPa]	[J/cm^2]	[J]	[HRC]	[HV30]	[mm]	[%]
Ø22 146/70/58/38/1	X	I	A	**1099.5**	-	**17.2**	45.0	1190	35.0	-
Ø22 146/70/58/38/2	X	I	A	**1046.5**	-	**17.5**	44.5	1240	35.0	-

Ø22 140/65/48/38/30/1	X	II	B	1435.5	-	45.0	44.0	1010	35.0	92.6
Ø18 169/89/48/30 /1	Y	I	B	1358.0	-	**14.0**	40.4	1010	27.7	90.2
Ø18 169/89/48/30 /2	Y	I	B	1310.5	-	28.7	43.6	1020	**25.4**	**83.3**
Ø25 147/70/58/38 /1	X	I	A	1260.0	39.7	-	47.6	1020	-	-
Ø22 144/64/48/30/1	X	I	C	**1119.5**	29.7	-	**38.0**	**950**	**32.0**	**39.1**
Ø22 189/92/59/38/1	X	I	C	**688.0**	40.4	-	**21.8**	**940**	**29.2**	**60.5**
Ø22 186/92/59/38/1	X	I	C	**1211.0**	32.7	-	**37.6**	**980**	**27.5**	**77.9**
Ø22 186/92/59/38/2	X	I	C	**1195.5**	-	**22.0**	**35.1**	1170	**25.6**	100.0
Ø22 144/64/48/30/2	X	I	B	1477.0	**25.8**	-	**46.6**	1200	35.1	99.0
Ø20 165/89/65/38/30/1	Y	II	A	**1161.5**	36.7	-	43.4	1120	-	99.5
Ø25 146/70/58/38/1	X	I	D	**1007.5**	37.5	-	**32.6**	1200	-	99.2
Ø18 195/102/55/35/1	Y	I	E	1695.5	39.8	-	44.0	1040	**24.0**	99.1
Ø22 189/92/59/38/2	X	I	A	1389.5	35.1	-	**51.2**	1230	34.3	93.4
Ø18 195/102/55/35/2	Y	I	F	1408.5	48.2	-	44.0	1030	27.1	98.5
Ø20 165/89/65/38/30/2	Y	II	A	**1224.0**	40.7	-	**38.6**	1000	-	92.1
Ø22 144/64/48/30/3	X	I	B	1300.5	50.8	-	42.6	1180	35.4	93.7
Ø22 189/92/59/38/3	X	I	A	1324.0	36.6	-	41.8	1130	35.3	91.9
Ø22 189/92/59/38/4	X	I	F	1544.5	**22.7**	-	46.5	1120	34.2	95.2
Ø22 189/92/59/38/5	X	I	F	**1143.0**	46.1	-	**33.5**	1110	**31.1**	98.7
Ø22 189/92/59/38/6	X	I	F	**1140.0**	**23.5**	-	**35.5**	1150	**31.1**	97.4
Ø22 189/92/59/38/7	X	I	F	**1068.5**	53.3	-	**34.1**	1150	34.3	**74.2**

Symbols: X – conical picks for roadheaders, Y – conical picks for shearers, I – one-step conical picks, II – two-step conical picks, A÷F – manufacturers.

The tests showed that:

- materials for conical picks had high tensile strength from 688.0 MPa to 1695.5 MPa, impact resistance from 22.7 to 50.8 J/cm^2, the energy of impact test from 14 to 45 J and hardness from 21.8 to 51.2 HRC,
- the hardness of sintered carbides varied from 940 to 1240 HV,
- length of sintered carbides varied from 24.0 to 35.4 mm,
- degree of solder filling of the solder gap varied from 39.1 to 100.0%.

The analysis of the test results showed that:

- materials for pick holders in 52% of the tested conical picks did not meet the required tensile strength, in 18% - impact resistance, in 67% – energy of impact test,
- 39% of tested pick holders had hardness below the required one and 9% above it,
- 13% of tested sintered carbides did not meet the criteria regarding the hardness, 44% regarding the length and 25% regarding the degree of solder filling of the solder gap.

The inconsistencies mentioned above concerned the conical picks of all manufacturers.

Conclusions

Technical parameters of conical picks, including the geometric ones as well as types and properties of materials used for their manufacture, specified at the cutting drums designing stage, have a decisive impact on their life during rocks cutting.

Excessive and uneven abrasion as well as falling out of sintered carbides are the most frequent mechanical damages to conical picks. These disadvantages can be caused by the insufficient hardness of the pick holder material, improper length of sintered carbides and their embedment depth from the working edge as well as by the insufficient degree of solder filling of the solder gap. The authors' test results confirm (Bołoz, 2018; Kalentev et al., 2017) that the manufacturers control geometric parameters of pick holders. However, the problem is with meeting the requirements concerning the properties of the materials used for the manufacture of conical picks, especially their hardness. Thus, it is indispensable to extend the scope of controlling the quality of conical picks manufacture by the control of materials, delivered by steel and sintered carbides manufacturers, in the independent laboratories and to avoid assessing them based only on the materials attestation approvals.

The authors show that the procedures for assessing the quality of conical picks, implemented in the mining plants, including the method developed at the AGH University of Science and Technology, should be complemented by an assessment of the parameters of the connection between sintered carbide and pick holder. Especially the solder filling degree of the solder gap should be assessed. For that purpose, the method, suggested by the authors in their testing procedure, can be implemented.

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