The procedure of choosing an optimal offer for a conical pick as an element of realizing the sustainable development concept in mining enterprises

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The contemporary market requires something more from the manufacturer than merely a good quality product. What matters nowadays for the consumer and co-operator is the fulfillment of certain ethical standards by an enterprise, such as, for example, the ones proposed by the sustainable development concept. This is particularly important for companies in the mining branch, which are frequently classified as "3D" - dirty, dangerous and difficult. Sustainable development should be realized in three areas: social, environmental, and economical. In the article, the authors present an engineering solution involving an optimal choice of conical picks, which realizes the sustainable development concept in the economic and social context. This allows saving the financial resources of a mining enterprise while choosing a high-quality product, which improves the working conditions. The article contains a description of a comprehensive procedure for selecting the most favorable offer of a conical pick, taking the geometry, material, durability, and the price into consideration. The procedure optimizes the choice of a conical pick while taking into account the technical requirements as well as allowing the price share to be tailored according to the current needs and financial possibilities of the user, which has been illustrated with an example of a mining plant where the procedure has been used.

***Keywords:** conical pick, mine, procedure, choice of an offer, sustainable development.*

Introduction

In today's world, the sustainable development of enterprises has attracted the interest of managers and investors all over the world. The financial success of a company is no longer the only measure of economic activity; now, it is also viewed through the prism of high ethical standards. Contemporary Europe, in particular, the European Union, has decided that its strategic goal by the year 2020 will among others be intelligent development, which allows investing in the economy based on knowledge and innovation, therefore, an activity that enables increasing effectiveness while realizing the sustainable development concept in the mining branch. Realization of sustainable development in an enterprise is based on activities in three areas: social, ecological, and economical. Each of these areas needs the use of several tools. In this article, the authors present a tool that enables the most optimal choice of an offer of a conical pick, which, in line with the sustainable development idea, allows saving the company's resources and their rational managing in the future.

Conical picks, known in Poland as tangential-rotary picks, are typical tools used in underground mining. Depending on the working conditions, their consumption ranges from a few to several dozen a day for one mining shearer, and the unit cost of a pick ranges from PLN 60 to PLN 200. The mine's costs resulting from the purchase of conical picks are estimated to reach several million PLN annually, which for underground mining means a total of several dozen million. The users want to use the best accessible picks, but the choice of the most favorable offer is complicated, as many factors determine the quality of a pick. First of all, an important thing is resistance to abrasive wear as well as geometric and material parameters. Picks offered for coal mines vary considerably in their price, which is often not adequate to durability. For this reason, a parametric methodology for evaluating conical picks, allowing for the choice of an optimal offer, has been developed and implemented in three Polish coal mines. The procedure utilizes the method of measurements and laboratory tests. The methodology also involves control tests, which allow verifying the delivered picks' quality, and, in consequence, enable maintaining a good quality of deliveries. Conical picks are also used to mine rocks (underground mines of ores and salt as well as open-pit mines), concrete and asphalt (road building and maintenance, building works), so the procedure in question has a significant application potential.

Sustainable development of enterprises

At the turn of the 20th and 21st century, the notion of sustainable development grew in popularity. The concept began to be defined in the 1960s, when so-called Club of Rome, established in 1968, published four reports:" Limits of Growth", "Mankind at the Turning Point", "Future in Our Hands" and "The Barefooted Revolution", which was a pioneer attempt to forecast many global phenomena and problems as well as a serious warning. In the report-manifest entitled "Limits of Growth", a team of researchers headed by Dennis Meadows questioned the previous view that the development of humankind was not limited by anything, and the

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advancement of science and technology would break the environmental barrier. Further research conducted by independent institutions in subsequent years confirmed the mutual relationships between demographic phenomena, production, and natural environment. All that influenced the way of thinking and undertaken activities. The increasing knowledge of highly developed countries about the consequences of a continuing economy based solely on economic growth contributed to the concept of sustainable development. Global events which played the most significant role in propagating the sustainable development idea include UN Conference in Stockholm in 1972, UN Conference "Environment and Development" in Rio de Janeiro in 1992 and UN Conference in Johannesburg in 2002. These conferences caused that highly developed countries, in particular, UE states, started undertaking several activities to protect the environment and change the model of economic development (Midor and Tarasiński, 2010).

Initially, the sustainable development concept referred mainly to the development of the world and civilization. However, since Agenda 21 was published during the conference in Rio de Janeiro in 1992, sustainable development has been applied to towns, communes, and other local units as well as enterprises. Agenda 21 defines sustainable development as social and economic development which aims to meet the needs of contemporary societies without affecting the possibility of satisfying the needs by future generations (Midor, 2014). Since the time of Agenda publication, there have been many proposals specifying the way such development might be effected in the activity of companies. Currently sustainable development of enterprises is associated with such concepts as: social responsibility of business (Hąbek, 2015), business ethics (Hąbek and Brodny, 2017), triple bottom line or management of relationships with stakeholders (Zasadzień and Midor, 2015), design for manufacturing (DFM) strategies help companies to develop new products that are feasible to manufacture (Jakubowski, 2014) and (Božek, 2014).

On mature markets, the question about business style is asked more and more frequently. This question began to determine the choice of a particular brand, product, or even an institution. As a result, the focus has changed from moralizing arguments and social criticism of enterprise behavior to searches for the most effective instruments of management (Midor and Tarasiński, 2012), (Brodny and Tutak, 2016), (Biały, 2014). The most important challenge for creating a new way of enterprise management, based on the sustainable development concept is to introduce an appropriate channel for obtaining information about and from the environment. Organizations which want to increase their profitability in the future should focus their activities on four entities simultaneously: shareholders, society, natural environment, and finances. Devoting too much attention to one of the entities mentioned above at the cost of the remaining ones may prevent companies from achieving long-term success. The best method for implementing this multi-direction strategy is sustainable development. It allows introducing innovative solutions, making proper distinctions, and achieving long-term success.

In Poland, the necessity of undertaking innovative activity should be aimed first of all at mining enterprises, as hard coal mining is still a strategic branch of Polish industry. In coal mining, Poland has a 10th position in the world and ranks 1st in the European Union. For Poland, coal is a guarantee of energy security and is currently the primary source of electric energy production (Midor and Biały, 2016), (Biały, 2014). As the mining industry is often classified as "3D" – dirty, dangerous and challenging due to the difficulties and constant changes in the realization of the sustainable development idea (Gunarathe et al., 2016), solutions that will bring coal mines closer to the sustainable development concept have to be searched for on many levels. In the article the authors present a solution for an optimal choice of conical picks, which effects the idea of sustainable development in the economic and social aspect, allowing the financial resources of a mining company to be saved while choosing a high-quality product, thus improving the working conditions.

Conical picks

The exploitation of longwalls and galleries in global underground mining is mainly mechanical. Mechanical mining involves direct using an extraction tool on rock mass. The most common is rock mining by milling with a cutter loader and planning with cutting tools (Bołoz and Krauze, 2018), (Bołoz, 2018), (Krauze and Bołoz, 2018), (Bołoz, Krauze and Kubin, 2018). Currently, the global standard is to use conical picks in the mining elements of heading machines and longwall cutter-loaders. Milling elements are crucial parts of mining machines, and the durability of picks is essential from the point of view of operational costs, the time of machine work and the energy efficiency of the process. Users' expectations, as well as increasingly hard conditions, cause that mining machines have to meet increasingly strict requirements regarding their efficiency, safety reliability, and staff comfort. Fulfilling these requirements largely depends on the proper selection of cutting tools with handles and a mining element. This selection results from the milling process theoretical framework and is known from the literature (Bołoz and Kruze, 2018), (Krauze, Bołoz and Wydro, 2015), (Bołoz and Midor, 2018), (Bołoz and Leonel, 2018).

During exploitation, the conical pick contacts the excavated rock mass. It is the pick that is directly responsible for the mining process. The shape and appropriate manner of fixing the pick in the handle allows its free turn, which results in the blade's uniform wear. Due to the working conditions and the specific character of the mining machine, picks can differ in geometry (shape, size, manner of mounting), materials and the way of protecting the body against abrasive wear. It is therefore crucial that the selected picks meet the requirements which guarantee a proper milling process for a particular machine and working conditions.

The problem of conical picks' durability is the subject of many investigations carried out in research centers around the world. Due to the construction of the pick, durability research is conducted in a few variants. The standard conical pick, presented in Fig. 1, is built of an operational part in a conical shape, a cylindrical pin, which is the holding part, and a blade in the form of an insert made of sintered carbide.

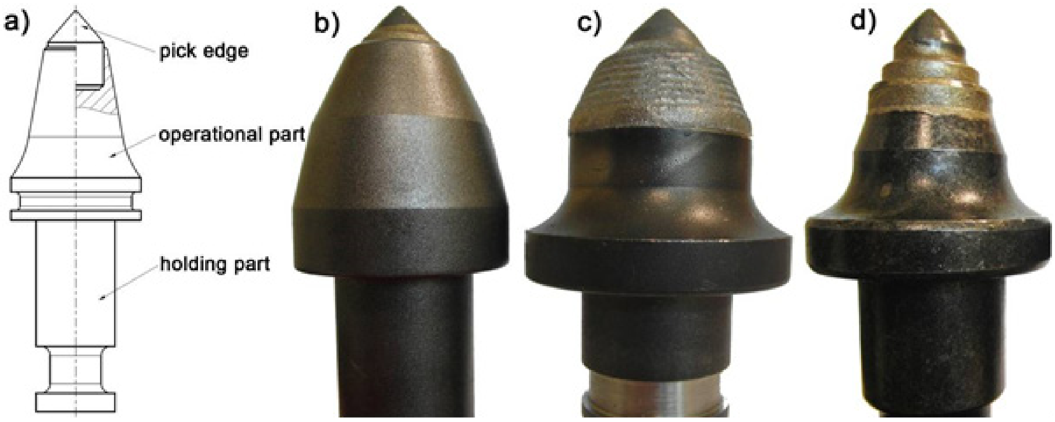

Fig. 1. Construction and example solutions for conical picks a. construction of pick, b. typical pick, c. pick with an abrasion-resistant coating,d. pick with a ring made of sintered carbide

The body can be additionally protected against abrasive wear with abrasion-resistant coatings, by weld surfacing or with rings made from sintered carbides (Krauze, Bołoz, Wydro and Mucha, 2017), (Chang et al., 2017). These investigations are aimed at finding a solution characterized by the highest abrasive resistance. Works are carried out to explore the mechanism of picks' abrasive wear (Dewangan et al., 2015), to predict the wear (Gajewski et al., 2013), or a possibility to support the mining process (Kotwica, 2011). Investigations are conducted for the material – sintered carbide (Nahak et al., 2015), (O'guigley et al., 1997), for a complete pick (Dewangan et al., 2015), (Songyong et al., 2017) or picks which form a mining element (Kotwica and Krauze, 2007). As a result, we obtain information about the mass loss in materials subjected to testing. Importantly, this research usually consists of searching for new solutions or are conducted for advertising purposes and are only marginally useful for picks users. The only way forward is the possibility of coating (Hornik, 2015).

Various producers can provide a particular selected pick. However, producers do not specify the quality or durability of picks in a way allowing their comparison before purchase.

A mining enterprise, which is obliged to follow the procedure of public tenders, use the prices as the only criterion when choosing an offer of picks. Therefore, bearing in mind the public procurement law that state-owned mining companies have to comply with, the testing of picks had to be developed in a way which would enable choosing the best offer while maintaining the lowest possible price. Therefore, the issue in question is essential from the point of view of sustainable development, as it allows saving the financial resources of an enterprise and improving the working conditions.

The methodology of the conducted investigations aimed at evaluating the quality of conical picks

Correct and extended operation of properly selected conical picks depends on the following elements:

- geometrical parameters of the whole pick and sintered carbide itself,
- material parameters of the body and blade,
- the hardness of the body and blade,
- the hardness of the pick.

The durability of picks is the most critical element of their quality description, but in practice checking the geometric and material parameters of the body and insert is also recommended and applied (Krauze, Bołoz and Wydro, 2015).

Determining the quality of picks requires measuring the above elements in a way that enables a comparison of their quality so that an optimal solution can be chosen. Moreover, the user must have the possibility of controlling the quality of picks provided by the producer.

Bearing the above in mind, investigations in three stages have been proposed (Krauze, Bołoz and Wydro, 2015) :

- measurement of conical picks' geometrical picks,

- testing of conical picks' material parameters,
- testing of conical picks' wear rate.

Measurement of geometric parameters

The testing of a conical pick is aimed at determining its selected linear and angular dimensions. The obtained results should be compared with the user's requirements and the producer's documentation. The pick must comply with both requirements.

Major linear and angular dimensions of the conical pick are (Fig. 2a):

- operational part length L_n,
- total length L_c,
- the diameter of diameters of the holding part d_u
- of the stopper ring collar d_k,
- the angle of the insert blade $2\beta_u$,
- height of sintered carbide insert h_w,
- the diameter of sintered carbide insert d_w,
- marking on the holding part z /d_w/$2\beta_u$ /L_n, where z is the producer's trademark

Measurement of shaped parts can be efficiently performed by 3D reverse engineering methods (Buransky and Peterka, 2013). Linear measurements were taken with an Insize altimeter (max. error ±30 μm), the angle measurement was taken with a Mitutoyo Digimatic protractor (max. error ±2'). The tests were conducted on a special measuring stand (Fig. 2b).

Material parameters testing

Determining the quality and properties of materials that the conical pick is made of requires separating the steel body from the blade, which is made of sintered carbide. Tests were carried out for the pick body material to determine the chemical composition of steel, the hardness of the holding and operational part as well as thermal treatment of the sintered carbide insert to determine the composition, density and hardness (Fig. 3).

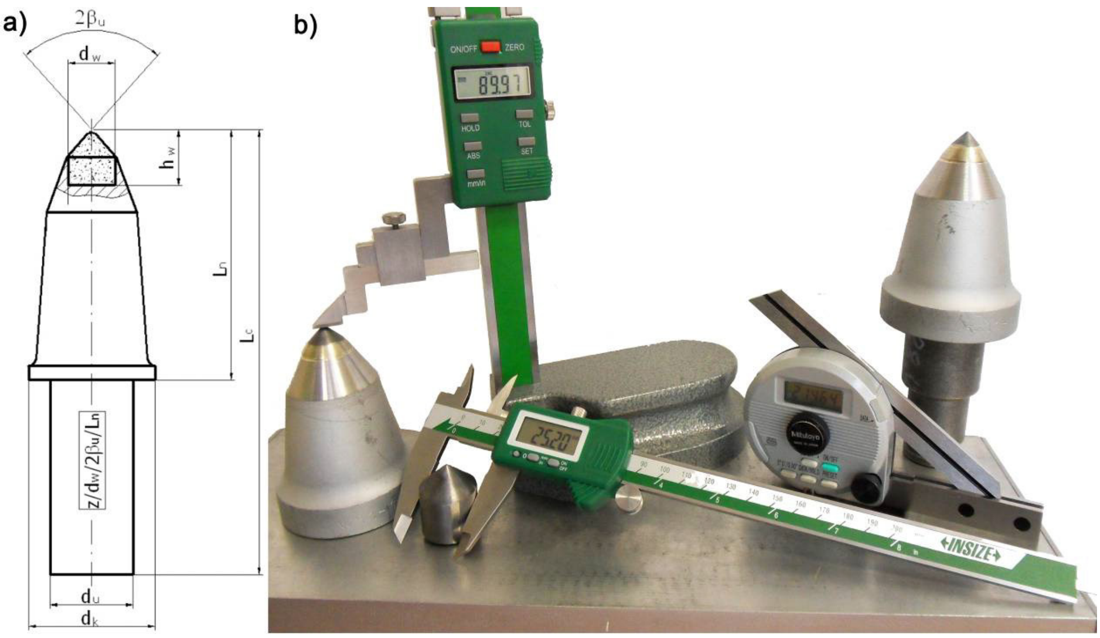

Fig. 2. Measurement of the pick's geometric values:
a. pick parameters subjected to measurement, b. measuring stand with measuring equipment

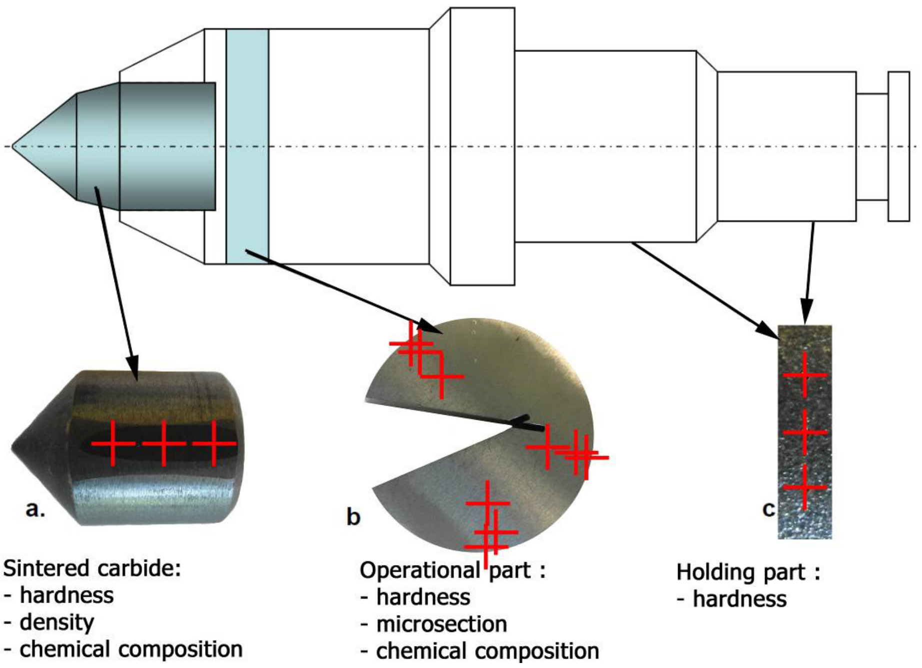

Fig. 3. Measurement of the pick's geometric values: a. pick parameters subjected to measurement, b. measuring stand with measuring equipment

The chemical composition of the pick body material was conducted by the spark testing method, with a Foundry Master device, whereas the hardness measurement was taken by the Rockwell method – it is carried out on a sample taken from the area near the insert in accordance with Polish standards. The composition, density and hardness of sintered carbide were proposed to be determined by the Vickers method in line with Polish standards.

Wear rate tests

In industrial conditions the hardness of cutting picks is usually determined as a ratio of the number of replaced (used) picks to the amount of material mined. Therefore, determining the hardness of picks required developing a plan and methodology of research, enabling determining their wear rate. A wear rate measurement must always be performed in the same controlled conditions so that the results can be reproducible and comparable. Such an approach allows indirectly determining the picks' durability, using a number index, and enables producers to compare various solutions and choose the best ones.

The methodology of conical picks' wear rate involves milling a rock sample with four picks of the same kind. To determine the wear rate, it is necessary to determine a mass loss of the examined picks as well as the volume of a sample mined by them. After testing the index characterizing, their wear rate can be calculated. The picks' wear rate, which describes durability, should be determined to utilize the following formula (Krauze, Bołoz and Wydro, 2015):

$$X1 = \frac{\Delta m}{m} \cdot \frac{V_w}{V_u}, \ [-] \tag{1}$$

where:

$X1$ – wear rate [-],
Δm - pick's mass loss during testing (body with the blade) [g],
m - pick's mass before test [g],
V_W – standard/reference volume of sample [m^3],
V_u – volume of sample mined by picks during testing [m^3].

Testing of all types of picks is performed in accordance with the prescribed methodology and research plan. Laboratory tests have to be carried out on a special stand (Fig. 4). Conical pick tests presented in the further part of the chapter were performed on a laboratory stand for testing the mining process by milling or rotary drilling with single cutting tools or elements, the description and possibilities of which have been quoted in literature (Krauze, Bołoz and Wydro, 2015), (Bołoz, 2018).

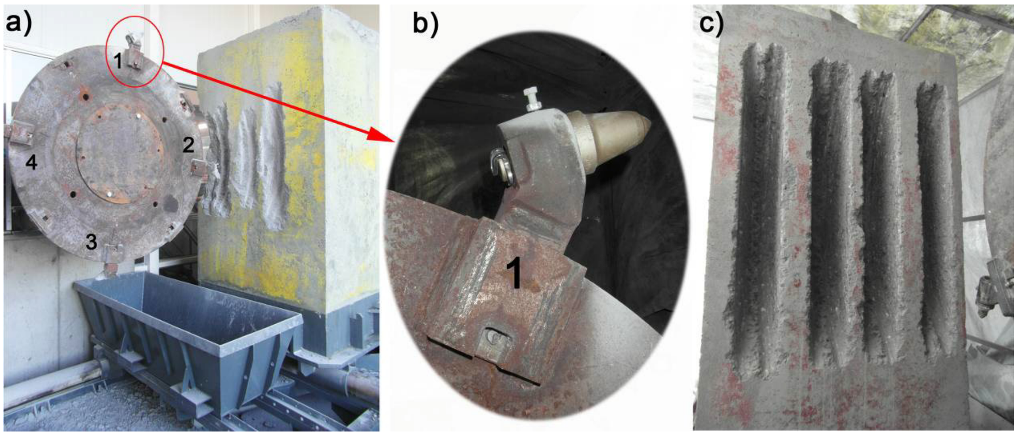

Fig. 4. Wear rate laboratory tests. a. stand with a testing disc, b. pick number 1 mounted on the disc, c. mined sample

Choosing an optimal offer of the conical pick

From the point of view of the user looking for the best pick characterized by good value for money, clear criteria which allow making an optimal choice are essential. When searching for the best offer, one should use multi-criteria optimization. An evaluation of the picks' quality must take into account two essential criteria – price and durability. The choice is made difficult by the mutual influence of criteria. i.e., the occurrence of Pareto optimality. Despite a lack of unambiguous correlation, in general, increasing the durability of picks involves the necessity of using more sophisticated technical means, which translates into an increased price. The weighed criteria method, which is a typical multi-criteria optimization method, was applied so that the user could decide about the influence of price and durability on the choice. Therefore, the procedure enables establishing the influence of the share of price criterion and durability criterion in the offer price. Knowing the pick's price K [PLN] and the determined wear rate $X1$ [-], the number of points P [-] is calculated according to formula 4.2. This formula provides the number of points P depending on the adopted weight W [-] of pick's quality within the range $W = 0 \div 100$. In practice, the quality criterion weight is in the range $W = 35 \div 70$. In the case of low-quality weight (for example, $W < 20$) there is a risk of choosing a pick characterized by a low price and, at the same time, low quality. In the case of high values (for example, $W > 80$), there is a risk of choosing the most expensive offer, in which the pick's durability can be slightly higher than in a much cheaper offer. Weight W can also be established by determining the maximum acceptable price of a single pick.

In results, a number value P, not higher than 100, is obtained. The higher the P-value, the more favorable the offer is.

$$P = \frac{\min\left(X1_n\right)}{X1_n} \cdot W + \frac{\min\left(K_n\right)}{K_n} \cdot \left(100 - W\right),\ [\text{-}] \tag{2}$$

where:

P – number of points awarded to a particular offer, $P \leq 100$ [-],

n – number of the subsequent offer [-],

W – quality weight in the final evaluation of the pick , $W = 0 \div 100$ [-],

$X1$ – wear rate of picks [-],

K – pick unit cost [PLN],

$X1_n$, K_n – index $X1$ and price K for offer i ,

$\min(X1_n)$, $\min(K_n)$ – minimum values of $X1$ and K among all the analyzed offers.

How to maintain a good quality of conical picks?

The proposed research methodology allows choosing picks of the best quality, but it is necessary to control deliveries to maintain the assumed quality. In the event, the user reports reservations regarding the quality of the picks, control testing is carried out. The control involves doing geometric and material tests of the picks delivered for checking. The results of tests can be quantitatively compared with the results of standard picks. To check the wear rate, comparative testing of the controlled and standard picks on the same rock sample must be conducted. Only then can one unequivocally determine whether the wear rate has changed.

This factor is comparable for various coal beds, and the bigger value it has, the more difficult is the bed mining capacity. In order to determine coal compactness (compact/weakly-cohesive), in parallel with the measurement of the mining capacity factor, the angle of side crushing is determined.

Example of applying the procedure of an optimal offer choice

The presented procedure was implemented in three Polish coal mining companies. The tendering procedure was applied for a total of ten underground mines. Each tender consisted of many tasks, and each task concerned one type of pick. The said procedure was used in four tenders:

- tender 1 – 5 mines, 9 types of picks, a total of 240 500 pcs, delivery time 2 years,
- tender 2 – 6 mines, 14 types of picks, a total of 371 640 pcs, delivery time 2 years,
- tender 3 – 2 mines, 12 types of picks, a total of 47 210 pcs, delivery time 1 year,
- tender 4 – 4 mines, 6 types of picks, a total of 66 677 pcs, delivery time 1 year.

Assuming the average value of a pick as PLN 110, we obtain big amounts (PLN 26.5 million, PLN 40.9 million, PLN 5.2 million, PLN 7.3 million, respectively). Due to their quantity, a minimal advantage in the price or durability of picks translates into considerable savings in the scale of the whole mine or company. In particular tenders, the ordering parties established a different weight W of the quality criterion. Subsequently, they used values W = {70, 40, 35, 40}.

In practice, each of the bidders in the tender for deliveries of picks of one particular type provided a representative sample consisting of 22 pcs of the product. In accordance with the procedure, 3 picks were sent for geometric tests, another 3 for material tests and 4 for wear rate tests. The remaining 12 picks were standards for quality control. In case of a complaint, the mine delivered 10 picks, which were checked for geometric parameters (4 pcs) by comparing them with standard picks (4 picks). Based on the test results, conclusions were formulated to confirm or reject the mine's claims. The complaint procedure was applied only eight times, which proves the fact that producers maintain the quality of picks.

Below have been presented the results of tests for one selected task, in which 5 producers, marked P1 to P5 respectively, took part. The subject or research was a pick for heading machine z/25/90/70 having the following dimensions (markings according to Fig. 2a):

- L_n,= 70 mm, admissible value range: 69.0 mm ÷ 71.0 mm,
- L_c, = 147 mm, admissible value range: 146.0 mm ÷ 148.0 mm,
- d_u = 38 mm, admissible value range: 37.8 mm ÷ 38.0 mm,
- d_k = 58 mm, admissible value range: 57.0 mm ÷ 59.0 mm,
- $2\beta_u$= 93°, admissible value range: 92.0° ÷ 93.0°,,
- h_w= 35 mm, admissible value range: 34 mm ÷ 36 mm,
- d_w = 25 mm, admissible value range: 24.5 mm ÷ 25.5 mm,

As a result of the conducted geometric parameters tests, check charts for 3 picks for each producer were obtained. The results for the first pick manufactured by each of the producers have been given in Table 1. Despite a wide tolerance field, the required dimensions were not fulfilled by all the producers (item 5). As a result, producer P5 was rejected; the remaining offered picks complied with the requirements. Values given in red font mean failure to meet the user's requirements or the manufacturer's declaration.

Tab. 1. Results of geometric parameters' measurements

No.	Pick No.	Geometrical parameters of the pick								
		L_c [mm]	L_n [mm]	L_u [mm]	h_k [mm]	$2\beta_u$ [°]	d_k [mm]	d_u [mm]	d_w [mm]	h_w [mm]
1.	P1/1	147.12	70.11	77.01	15.98	92.87	58.16	38.00	24.85	35.08
2.	P2/1	146.73	69.76	76.97	15.54	93.00	58.07	37.98	25.00	35.06
3.	P3/1	146.66	69.62	77.04	16.22	93.00	57.88	38.00	24.75	35.11
4.	P4/1	146.95	69.98	76.97	16.22	93.00	58.09	37.95	25.48	34.89
5.	P5/1	148.31	71.40	76.91	16.20	93.68	58.04	37.97	24.96	34.55

Metallographic tests consist of many elements. The results of tests for the pick produced by each manufacturer have been presented in example tables. The hardness of the body operational part is quoted in Tab.

2, the hardness of the body holding part – in Tab. 3, the chemical composition of the body steel – in Tab. 4, sintered carbide hardness – in Tab. 5, density and chemical composition of sintered carbide – in Tab. 6.

Tab. 2. Results of HRC hardness tests for the pick operational part

No.	Pick No.	HRC 1mm	HRC 3 mm	HRC 10 mm	Requirements
1.	P1/1	53	53	52	≥ 45
2.	P2/1	51	53	52	
3.	P3/1	54	55	53	
4.	P4/1	52	52	52	
5.	P5/1	35	41	40	

Tab. 3. Results of HRC hardness of the pick holding part (for 3 picks)

No.	Pick No.	pick 1	pick 2	pick 3	Requirements
1.	P1	32	31	33	25 ÷ 35
2.	P2	32	32	34	
3.	P3	35	37	34	
4.	P4	33	36	34	
5.	P5	48	47	47	

Tab. 4. Results of chemical composition analysis for the body material

No.	Pick No.	C %	Mn %	Si %	S %	P %	Cr %	Ni %	Mo %	V %	Grade
1.	P1	0.336	0.899	1.18	0.009	0.009	1.13	0.077	0.005	0.002	35HGS
2.	P2	0.326	0.901	1.33	0.021	0.009	1.10	0.08	0.016	0.002	35HGS
3.	P3	0.372	0.667	0.294	0.020	0.012	0.98	0.227	0.140	0.010	42CrMo4
4.	P4	0.343	0.840	1.24	0.006	0.010	1.12	0.056	0.008	0.002	35HGS
5.	P5	0.444	0.719	0.272	0.006	0.005	1.14	0.128	0.170	0.007	42CrMo4

Tab. 5. Results of sintered carbide HV30 hardness (for 3 picks)

No.	Pick No.	pick 1	pick 1	pick 1	Requirements
1.	P1	1171	1160	1156	≥ 1050
2.	P2	1141	1129	1136	
3.	P3	1306	1294	1274	
4.	P4	1163	1153	1176	
5.	P5	1148	1158	1151	

Tab. 6. Results of sintered carbide density and composition analysis

No.	Pick No.	Density g/cm^3	Co %	W %	Grade
1.	P1	14.634	7.9	92.1	B2
2.	P2	14.549	9.6	90.4	B23
3.	P3	14.665	7.5	92.5	B2
4.	P4	14.560	9.4	90.6	B23
5.	P5	14.423	10.8	89.2	B40

The last element of testing was determining the wear rate. Tests for all the picks were conducted on a sand-cement sample with basalt aggregate characterized by the grain size 2 mm ÷ 8 mm, resistance to single-axis compression R_c = 11.49 MPa and density ρ = 2.095 kg/m^3. The results of tests were juxtaposed – selected picks produced by all the manufacturers after testing have been presented in Fig. 5.
The lower the value of the calculated *XI* index, the better the durability of the pick. In the presented table the best pick is P2, whereas the least durable one is P5. Selected picks of all the producers after testing have been presented in Fig. 4.

Tab. 7. Results of pick wear rate tests (average value for 4 picks)

No.	Producer	Mass before g	Mass after g	Loss G	Volume mined m^3	Index X1 -
1.	P1	157.,30	1568.66	8.64	0.0260	1.055
2.	P2	1579.24	1572.63	6.61	0.0261	0.801
3.	P3	1581.78	1574.04	7.74	0.0267	0.916
4.	P4	1590.69	1583.59	7.10	0.0245	0.910
5.	P5	1497.03	1488.81	8.22	0.0255	1.076

The values of index *XI*, after taking the picks' price into account, allow choosing an optimal offer. The results of geometric and material parameters measurements enable excluding the offers which do not fulfill the requirements. Table 8 contains the results of score evaluation *P* of the offers, taking into account the producers' average prices and various levels of weight *W*. the influence of weight *W* on offer evaluation is clearly visible, hence, its value should be determined with caution. The optimal values for a given level of significance of quality have been marked in green. It is worth noting that there are disproportions in prices and durability; the durability of picks P3 and P4 is similar despite a considerable difference in the price. Determining weight *W* at the stage of issuing a call for tenders allows an objective, unambiguous, and indisputable choice of an optimal offer.

Tab. 8. The juxtaposition of an optimal choice results for three values of weight W

No.	Producer	X1 -	price PLN	P - W = 90	P - W = 70	P - W = 40	P - W = 35	P - W = 10
1.	P1	1.055	90	77.78	81.48	87.04	87.96	92.59
2.	P2	0.801	100	**98.50**	**95.50**	**91.00**	90.25	86.50
3.	P3	0.916	160	84.01	77.15	66.85	65.14	56.56
4.	P4	0.910	130	85.76	81.23	74.44	73.31	67.65
5.	P5	1.076	85	77.00	82.11	89.78	**91.05**	**97.44**

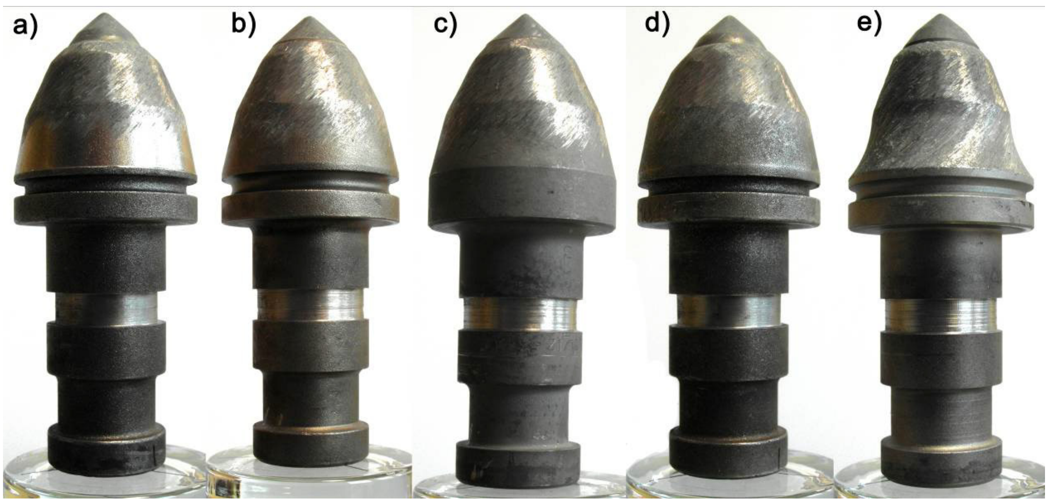

Fig. 5. Conical picks number 1 after tests (number according to Fig. 3) a. P1, b. P2, c. P3, d. P4, e. P5

Conclusions

Contemporary enterprises in the mining branch are facing the necessity of improving their image in society. They can do this by implementing the idea of sustainable development, which is based on ethical behavior. In the issue presented in this article, the ethical behavior consists in applying an engineering solution aimed at eliminating waste in an enterprise as well as improving the working conditions by using a high-quality product.

The correct operation of conical picks guarantees high durability of tools and milling elements as well as the low energy efficiency of the process, low level of dust and sparking. Achieving such a result depends on a proper selection of kinematic and geometric parameters of the element with the whole mining machine as well as geometric and material parameters of picks with handles. To achieve the set goal, it is necessary to ensure compliance of the above-mentioned parameters with the ones assumed at the stage of design, i.e., the highest possible quality and durability of the product must be achieved. Technically, the producer has no possibility to specify the durability of his product in a way enabling a comparison of offers. Therefore, an appropriate research methodology for the needs of Polish mining companies has been developed. Based on a three-stage analysis of research results, it is possible to choose an optimal offer while taking the price into account. However, it should be noted that despite the significance of the research in question, in the future testing should also include the milling elements and pick handles to maintain the highest possible durability of machine operational parts.

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