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Dominika GRYGIER*

EVALUATION OF THE OPERATIONAL WEAR OF THE SANDVIK CV117 CENTRIFUGAL CRUSHER

OCENA ZUŻYCIA EKSPLOATACYJNEGO ELEMENTÓW ROBOCZYCH KRUSZARKI ODŚRODKOWEJ SANDVIK CV117

Key words: centrifugal crusher, microstructure, operation.

Abstract: The purpose of the study described in the work was to evaluate the operating wear of the SANDVIK CV117 centrifugal crusher working in the Melaphyre mine in Grzędy. The research was carried out on work elements, such as the lining assembly, rotor tips, shredder hammers, the directional bushing, and the distributor divider. All components had direct contact with the aggregate, and their operating time was about 1150 hours. The studies included a mine full scale observation, macroscopic analysis of the elements, and an assessment of the impact of exploitation on selected structural properties of the elements material. On the basis of the carried out analyses, it was concluded that the major problem faced by all the tested components is the simultaneous interaction of high friction and impact forces resulting from the kinetic energy of the accelerated grains of the material acquired from the rotor during operation of the crusher.

Słowa kluczowe: kruszarka odśrodkowa, mikrostruktura, eksploatacja.

Streszczenie: Celem badań opisywanych w pracy była ocena zużycia eksploatacyjnego kruszarki odśrodkowej typu SANDVIK CV117 pracującej w kopalni melafiru w Grzędach. Przedmiotem realizowanych badań były elementy robocze takie, jak: zespół okładzin, końcówki wirnika, młotki rozdrabniające, tuleja kierunkowa oraz przegroda dystrybutora. Wszystkie elementy miały bezpośredni kontakt z kruszywem, a czas ich eksploatacji wynosił ok 1150 motogodzin. Przeprowadzone badania obejmowały wizję lokalną z kopalni, analizy makroskopowe elementów, jak również ocenę wpływu eksploatacji na wybrane właściwości strukturalne materiału elementów. Na podstawie przeprowadzonych analiz stwierdzono, że poważnym problemem, na który narażone są wszystkie badane elementy, jest jednoczesne oddziaływanie wysokich sił tarcia oraz udarności, wynikających z energii kinetycznej rozpędzonych ziaren nadawy, nadanej za pomocą wirnika podczas pracy kruszarki.

INTRODUCTION

In recent years, due to the rapid economic development, expansion, and modernization of road and rail infrastructure, the demand for mineral ore mining has increased significantly **[L. 1]**. Types of deposit mining technologies in surface mining are diverse. Specific varieties can be characterized and classified based on the method of extraction and the machines and devices used. The onshore aggregate mining technologies are the most diverse due to the size of resources and the possibility of their extraction. Onshore construction, and filling sands, ceramic and refractory clays, gravels, and compact rocks are most often exploited. In the case of aggregate exploitation from under water, deep mining produces mainly sands and gravels. It is also possible to combine both mining methods by using land and floating excavators simultaneously **[L. 3, 6]**. Most often, metamorphic, igneous, and sedimentary rocks exhibiting adequate resistance to climatic factors as well as abrasion and compression strength are used as construction and road stones **[L. 1, 4]**.

* ORCID: 0000-0001-7062-6357. Wrocław University of Science and Technology, Department of Materials Science, Strength and Welding Technology, Smoluchowskiego 25 Street, 50-372 Wrocław, Poland.

Mineral Polska is a brand belonging to the European construction company STRABAG SE. It produces aggregates, mainly intended for road and rail construction. It is the owner of the melafir mine in Grzędy (Czarny Bór commune). Melafir is a volcanic, alkaline, effusive rock with an afanite structure (crystals cannot be macroscopically seen), characterized by very good physico-mechanical parameters (i.e. frost resistance, resistance to crushing, abrasion, very good compressive strength), which caused that it is often used as a building stone **[L. 4, 6]**.

The process of crushing melafir takes place in a three-stage node **[L. 3, 9]**. The first stage, preliminary crushing, takes place on a jaw crusher, which crushes the ore large stones using jaws. Then the raw material is transported by belt conveyors to the production buffer, where the batch (sand) with the size of 0–2 mm is separated from the larger fraction. The second stage of crushing takes place on a cone crusher, then the screen separates the winning into such fractions as: 0/63 mm, 0/31.5 mm. The remaining winning goes to the buffer, where the 31 mm and 63 mm input is separated from the rest. The third and final stage takes place on centrifugal crushers, after which the right fractions 0/4 mm, 4/8 mm, 8/11 mm, 11/16 mm, and 16/25 mm are formed.

In centrifugal crushers, the feed is crushed due to the centrifugal force that is applied to the aggregate grains through the rotating impeller (**Fig. 1**) **[L. 6, 10]**. The force transmitted to the grains gives them a linear speed, and thus also kinetic energy. The energy is used to crush the grains of the material during collision of the accelerated grains with the liner located inside the rotor, which remains motionless. The condition for the proper course of the grinding process is the fact that the energy must be greater than the value of work necessary for grain decohesion. The lining with which the material collides can take the following forms: a smooth surface with a conical shape, segments of baffle plates (anvils), or possibly a set of grains of crushed material placed in pockets.

The diverse construction of centrifugal crushers is caused by construction of their crushing zone, i.e. the rotor-crumbling liner assembly, which is determined according to the type of processed material, technological capabilities of the machine, and patent rights **[L. 6, 8–10]**. Classic construction variants include the following:

- Crushers with a smooth conical liner, in which aggregate is crushed primarily on this liner;
- Crushers with segment lining and baffle plates (anvils), where the grains are mainly crushed;
- Crushers with lining, formed from grains of crushed aggregate, retained on a concentric shelf with a rotor or in the so-called pockets;
- Crushers with lining, made of grains of crushed aggregate stopped on the shelf, on which both the grains thrown by the rotor and those placed on the shelf crumble bypassing it; and,
- Crushers with a profile liner, where the aggregate grains leave the rotor and are crushed by free working elements, located on the rotor lugs and pressed against the liner by centrifugal force caused by the rotor **[L. 9]**.

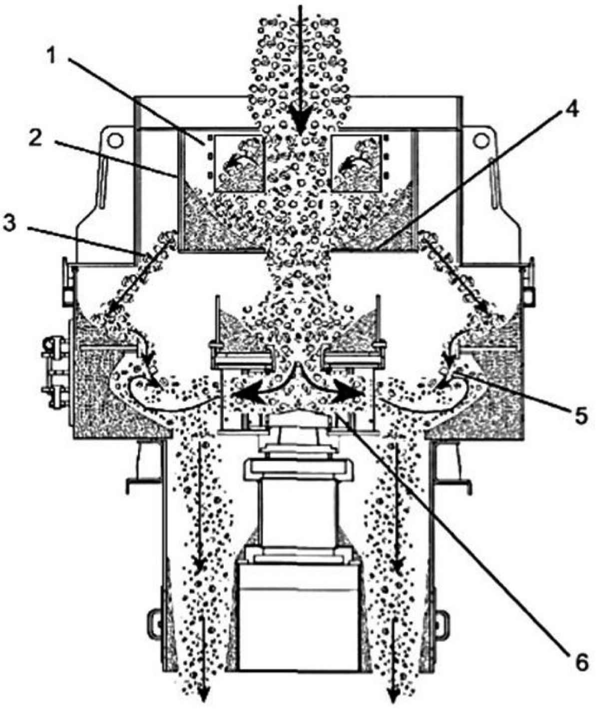

Fig. 1. Diagram of the feed flow through the SANDVIK CV crusher: 1 – feed inlet, 2 – adjusting gates, 3 – position of the adjusting gate (regulates the feed flow to the rotor, its excess, which has not been fed to the rotor, is drained through external inlets), 4 – feed inlet, 5 – feeds from the rotor and from the outside combine again (a constant cloud of atomized particles moves around the crushing chamber, the particles stay in dust for 5–20 seconds before they lose energy and fall out of the crushing chamber), 6 – the rotor accelerates the feed and forces its continuous discharge into the crushing chamber [L. 2]

Rys. 1. Schemat przepływu nadawy przez kruszarkę serii CV firmy SANDVIK: 1– wlot nadawy, 2 – bramy nastawcze, 3 – pozycja bramy nastawczej (reguluje przepływ nadawy na wirnik, jej nadmiar, który nie został doprowadzony do wirnika, jest odprowadzany przez zewnętrzne wloty), 4 – wlot nadawy, 5 – nadawy z wirnika i z zewnątrz łączą się ponownie (dookoła komory kruszenia przemieszcza się stała chmura rozpylonych cząsteczek, cząsteczki utrzymują się w pyle przez 5–20 sekund zanim utracą energię i wypadną z komory kruszenia), 6 – wirnik przyspiesza nadawę i wymusza jej nieprzerwany zrzut do komory kruszenia **[L. 2]**

PURPOSE AND SUBJECT OF THE STUDY

The purpose of the research described in this work was to assess the wear and tear of the SANDVIK CV117 centrifugal crusher operating at the melafir mine in Grzędy. The subjects of the conducted research were working elements, such as the following: the cladding assembly of the rotor end, crushing hammers, the directional sleeve, and the distributor baffle (**Figs. 2–5**). All components had direct contact with the aggregate, and their operating time was about 1150 hours.

Fig. 2. Macroscopic image of the tested directional sleeve (feed inlet) of the SANDVIK CV117 centrifugal crusher

Rys. 2. Obraz makroskopowy badanej tulei kierunkowej (wlotu nadawy) kruszarki odśrodkowej typu SANDVIK CV117

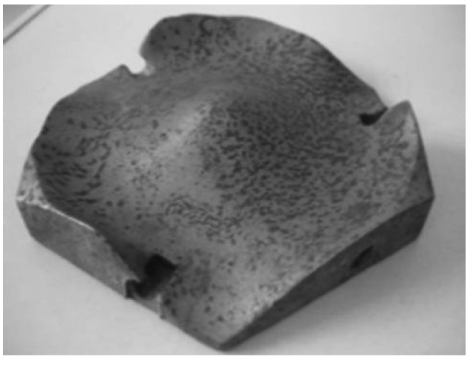

Fig. 3. Macroscopic image of the tested partition of a SANDVIK CV117 centrifugal crusher distributor

Rys. 3. Obraz makroskopowy badanej przegrody dystrybutora kruszarki odśrodkowej typu SANDVIK CV117

Fig. 4. Macroscopic image of the tested lining of the of the rotor ends in the SANDVIK CV117 centrifuge crusher

Rys. 4. Obraz makroskopowy badanej okładziny końcówek wirnika kruszarki odśrodkowej typu SANDVIK CV117

Fig. 5. Macroscopic image of the examined hammer assembly of the SANDVIK CV117 centrifugal crusher

Rys. 5. Obraz makroskopowy badanego zespołu młotków kruszarki odśrodkowej typu SANDVIK CV117

The performed research included full scale observation in the mine, macroscopic analysis of the elements, as well as the assessment of the impact of operation on selected structural properties of the material of the elements.

Macroscopic studies were based on observations with the unaided eye of the surface of post-operational elements and a comparison of dimensions and masses of tested elements with the non-utilized elements.

A NIKON ECLIPSE MA200 light microscope was used to assess the impact of operation on selected structural properties of the material of the components. Observations were made in a non-etched and etched condition, with magnifications in the range of 100x to 1000x. Image recording was made with a Visitron Systems digital camera coupled with a microscope using Spot Advanced and NIS Elements BR software. Metallographic specimens of subsequent samples were prepared in the longitudinal and transverse directions to the axis of the element, using the grinding and mechanical polishing process, as well as chemical etching with Mi3Fe.

THE TEST RESULTS

The melafir mine in Czarny Bór is a user of the SANDVIK CV117 automatic crusher with a vertical shaft, a lining of the crushed material, and the side stream of material (**Fig. 6**). The crusher has an open rotor covered with rock layer, which is used to accelerate a continuous stream of rock debris fed into the stone-covered crushing chamber **[L. 2, 7]**.

The feed fed to the top of the machine is accelerated in the rotor, achieving a speed of up to 66 m/s. After reaching high speeds, the grains hit the grains introduced outside the rotor (the "stone against stone" method), the walls of the crushing chamber, and crusher cladding elements. The impeller ensures uninterrupted loading into the crushing chamber. This process refills rock fragments while maintaining a chain reaction of the crushing and grinding process. A second feed stream (Bi-Flow®) can be fed into the chamber in controlled and directed flow. It can further increase the amount of feed circulating in the crushing chamber, improving energy transfer.

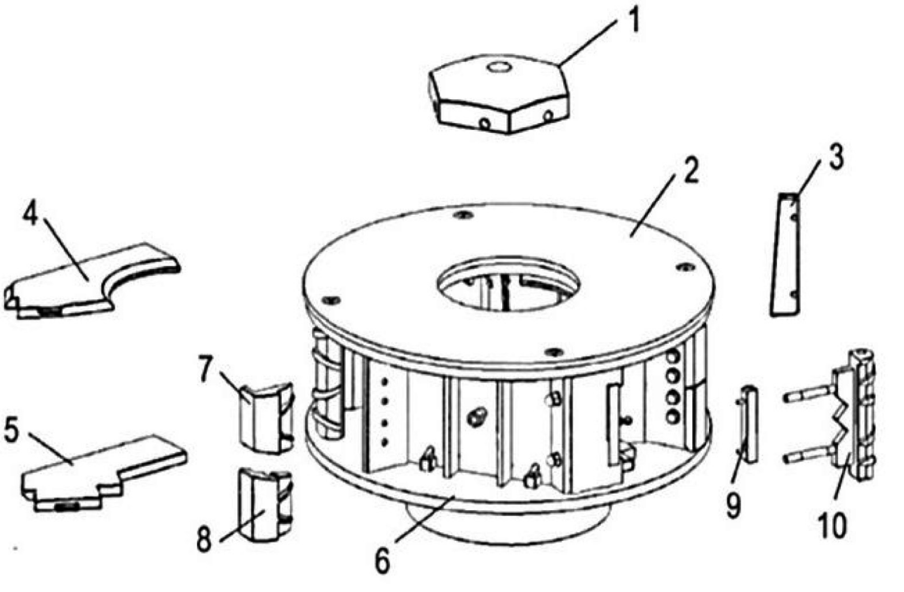

Fig. 6. Construction of the SANDVIK centrifugal crusher rotor CV series [L. 4]: 1 – distributor partition, 2 – rotor body plate, 3 – plate guide, 4 – upper plate, 5 – lower abrasion – resisting plate, 6 – body, 7, 8 – hammer assembly, 9 – spare bit, 10 – rotor bit assembly [L. 2]

Rys. 6. Budowa wirnika kruszarek odśrodkowych SANDVIK serii CV **[L. 4]**: 1 – przegroda dystrybutora, 2 – płyta korpusu wirnika, 3 – prowadnica płytowa, 4 – górna płyta trudnościeralna, 5 – dolna płyta trudnościeralna, 6 – korpus, 7, 8 – zespół młotków, 9 – końcówka zapasowa, 10 – zespół końcówki wirnika **[L. 2]**

The directional sleeve should be replaced when the part facing towards the rotor chamber is worn away to a maximum height of 6mm above the top abrasion-resisting plate. This wear should be even up to the head; therefore, it is important to position the pipe correctly. It also affects the wear of the upper abrasion-resisting plates. Incorrect assembly or use may cause cracks and fractures of the bottom edge.

Macroscopic examinations showed that the reason for the replacement was excessive wear of the part directed towards the chamber (**Figs. 7** and **8**). No visible fractures or cracks in the lower edge were observed. The working surface was used in the range of 20%, and the total weight loss of the element was 22% (**Table 1**).

Table 1. Comparison of dimensions of a directional sleeve before and after operation in a centrifugal crusher type SANDVIK CV117

Tabela 1. Porównanie wymiarów tulei kierunkowej przed i po eksploatacji w kruszarce odśrodkowej typu SANDVIK CV117

	Before operation	After operation	Percentage loss [%]
Inner diameter 4 of the 3 hole [mm]	205	200	2
Outer diameter of the hole [mm]	220	217	1
Thickness (working surface) [mm]	100	80	20
Mass [kg]	13.4	10.5	22

The distributor baffle wears in three areas opposite the impeller inlets. The partition is replaced when around 3–5 mm of material remains in the most-used place. Often, its premature wear is caused by oversize of the grain in feed, the dropping of the feed from the conveyor at high speed and sliding it directly onto the dispenser partition. In the case of the post-operational components from the mine in Grzędy, macroscopic examination showed that the reason for the replacement was wear in places corresponding to the feed inlets to the rotor (**Figures 9** and **10**).

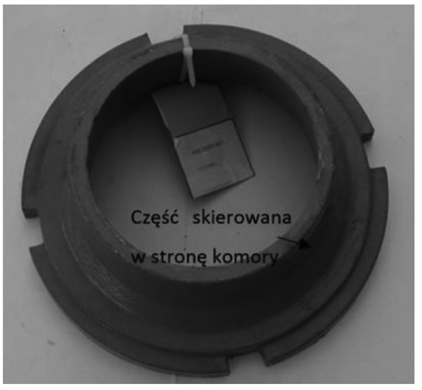

Fig. 7. Macroscopic image of the directional sleeve prior to operation in the crusher
Rys. 7. Obraz makroskopowy tulei kierunkowej przed eksploatacją w kruszarce

Fig. 8. Macroscopic image of the directional sleeve after operation in the crusher
Rys. 8. Obraz makroskopowy tulei kierunkowej po eksploatacji w kruszarce

The partition of the distributor from the mine in Grzędy used up evenly and was replaced accordingly with the manufacturer's recommendation (leaving 3–5 mm of material). The working surface was used in the range of 38%, and the total weight loss of the component was 57% (**Table 2**).

Table 2. Comparison of dimensions of the dispenser partition before and after operation in the SANDVIK CV117 centrifugal crusher
Tabela 2. Porównanie wymiarów przegrody dystrybutora przed i po eksploatacji w kruszarce odśrodkowej typu SANDVIK CV117

	Before operation	After operation	Percentage loss [%]
Width [mm]	265	265	0
Thickness (working surface) [mm]	47	29	38
Mass [kg]	18.5	8.0	57

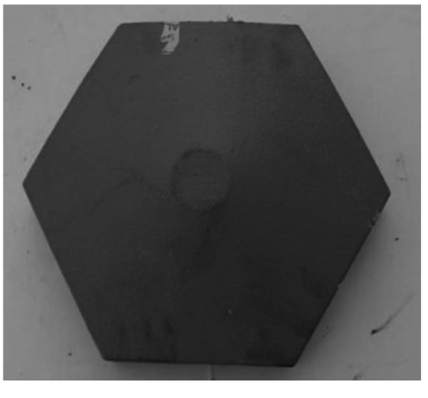

Fig. 9. Macroscopic image of the dispenser partition before operating in the crusher
Rys. 9. Obraz makroskopowy przegrody dystrybutora przed eksploatacją w kruszarce

The standard hammer assembly is replaced before their wear reaches the rotor body. They are replaced in sets, e.g., all top or bottom ones, in order to maintain proper balance of the entire rotor. Macroscopic studies have shown that the reason for the exchange was a large loss of material from a fragment of the hammer directed to the stream space (the place of the feed outlet from the rotor). A much higher wear of the upper element is also visible compared to the lower one (**Figs. 11** and **12**). The exploited surface was worn in the range of 12%, and the total weight loss of the elements was 13% (**Table 3**).

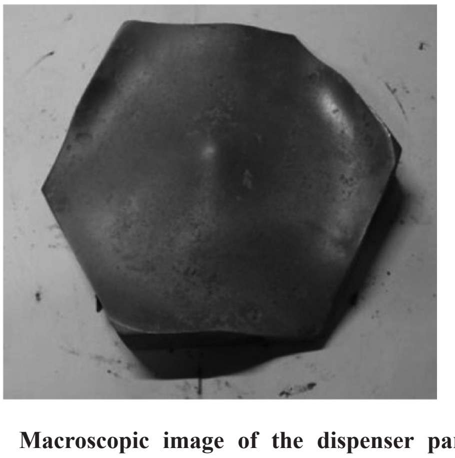

Fig. 10. Macroscopic image of the dispenser partition after operating in the crusher
Rys. 10. Obraz makroskopowy przegrody dystrybutora przed eksploatacji w kruszarce

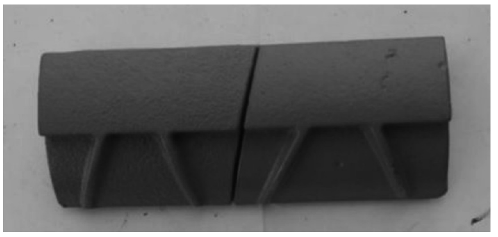

Fig. 11. Macroscopic image of the rotor hammer assembly before operation in the crusher
Rys.11. Obraz makroskopowy zespołu młotków wirnika przed eksploatacją w kruszarce

Fig. 12. Macroscopic image of the rotor hammer assembly after operating in a crusher
Rys.12. Obraz makroskopowy zespołu młotków wirnika po eksploatacji w kruszarce

Table 3. Comparison of dimensions of the rotor hammer assembly before and after operation in the SANDVIK CV117 centrifugal crusher
Tabela 3. Porównanie wymiarów zespołu młotków wirnika przed i po eksploatacji w kruszarce odśrodkowej typu SANDVIK CV117

	Before operation	After operation	Percentage loss [%]
Length [mm]	230	230	0
Width [mm]	92	92	0
Thickness (working surface) [mm]	58	53	12
Mass [kg]	3.0	2.6	13

The assessment of the amount of wear on the impeller tip is carried out by checking the degree of wear on the cartridges, and the tip is replaced before exceeding 95% of the consumption of the middle part of the cartridge. They are also replaced in the event of breakage, cracking, or visible wear of the insert. A signal announcing the need to replace the impeller tip is also the appearance of a large amount of mesh fraction (oversize particles) in the feed, as well as cast steel and cast iron debris.

Macroscopic studies showed that the reason for the exchange was even wear of the elements in the central part and visible fractures in places of material narrowing (**Figs. 13** and **14**). The exploited surface was worn in the range of 8%, and the total weight loss of the element was 17% (**Table 4**).

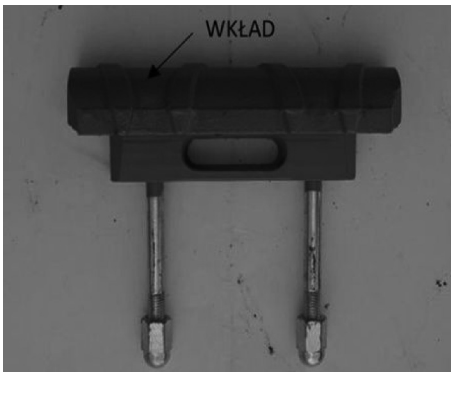

Fig. 13. Macroscopic image of the rotor tip cladding prior to operation in the crusher
Rys.13. Obraz makroskopowy okładziny końcówki wirnika przed eksploatacją w kruszarce

Fig. 14. Macroscopic image of the rotor tip cladding after operating in a crusher
Rys.14. Obraz makroskopowy okładziny końcówki wirnika po eksploatacji w kruszarce

Table 4. Comparison of the rotor tip lining dimensions before and after operation in the SANDVIK CV117 centrifugal crusher
Tabela 4. Porównanie wymiarów okładzin końcówki wirnika przed i po eksploatacji w kruszarce odśrodkowej typu SANDVIK CV117

	Before operation	After operation	Percentage loss [%]
Length [mm]	230	230	0
Width [mm]	63	61	3
Thickness (working surface) [mm]	51	47	8
Mass [kg]	2.4	2.0	17

Microscopic studies have shown diversity in the material used for individual working elements of the SANDVIK CV117 centrifugal crusher. The directional bushes and the distributor's partition are made of Fe-C-Cr alloy resistant to abrasive wear and corrosion **[L. 5, 12–15]**. In both cases, in the microstructure of the tested materials, the primary acicular precipitations of the M7C3 type chromium carbide are visible in the ferritic-austenitic matrix (**Figs. 15–18**). The hammer assembly material is Fe-C-Cr-Si system alloy, and the primary fine precipitations of chromium carbide type M7C3 in the ferritic matrix were observed in its structure (**Figs. 19** and **20**). The rotor tip linings are made of ductile grey cast iron with a pearlitic ferritic matrix (**Figs. 21** and **22**) **[L. 5, 12, 15]**.

At the same time, no structural or phase changes that could indicate a negative impact of exploitation on the structural properties of the materials of the tested elements were observed during microscopic studies (**Figs. 15–22**). Slight observed differences in the amount and size of carbide precipitations depend only on the cooling rate of the alloy during the production process.

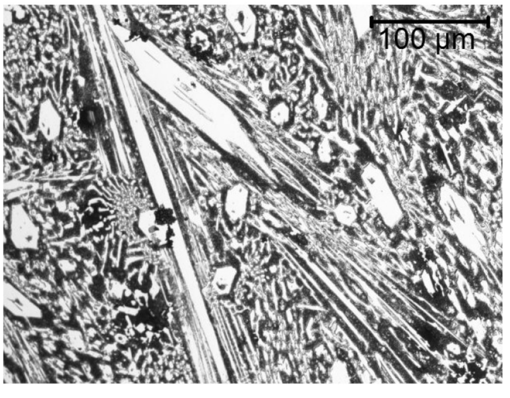

Fig. 15. Microscopic image of the directional sleeve material before operation in the crusher

Rys. 15. Obraz mikroskopowy materiału tulei kierunkowej przed eksploatacją w kruszarce

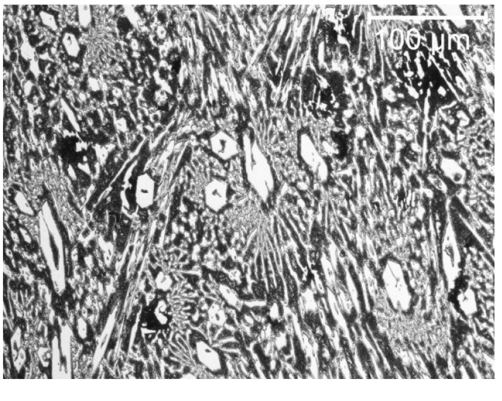

Fig. 16. Microscopic image of the directional sleeve material after operation in the crusher

Rys. 16. Obraz mikroskopowy materiału tulei kierunkowej po eksploatacji w kruszarce

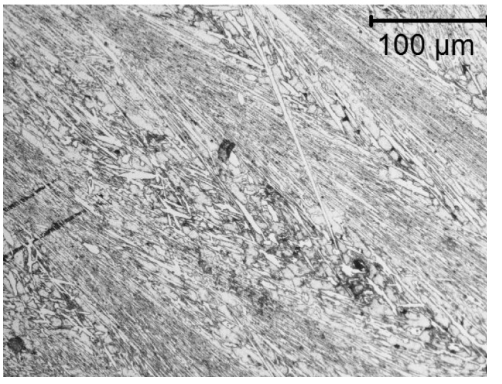

Fig. 17. Microscopic image of the distributor partition material prior to operation in the crusher

Rys. 17. Obraz mikroskopowy materiału przegrody dystrybutora przed eksploatacją w kruszarce

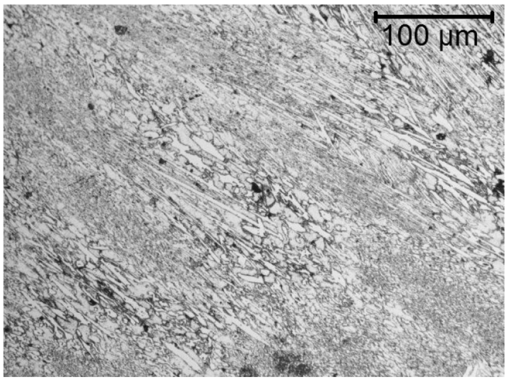

Fig. 18. Microscopic image of the distributor partition material after operation in the crusher

Rys. 18. Obraz mikroskopowy materiału przegrody dystrybutora po eksploatacji w kruszarce

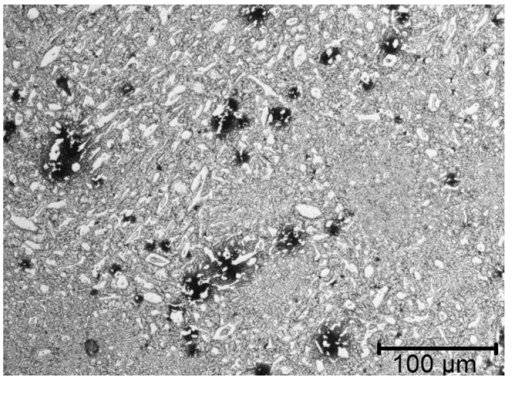

Fig. 19. Microscopic image of the material of the rotor hammer assembly before operation in the crusher

Rys. 19. Obraz mikroskopowy materiału zespołu młotków wirnika przed eksploatacją w kruszarce

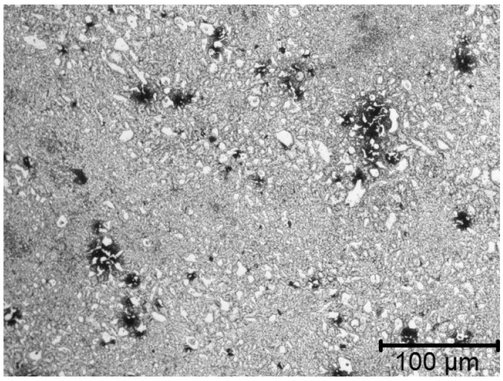

Fig. 20. Microscopic image of the material of the rotor hammer assembly after operation in the crusher

Rys. 20. Obraz mikroskopowy materiału zespołu młotków wirnika po eksploatacji w kruszarce

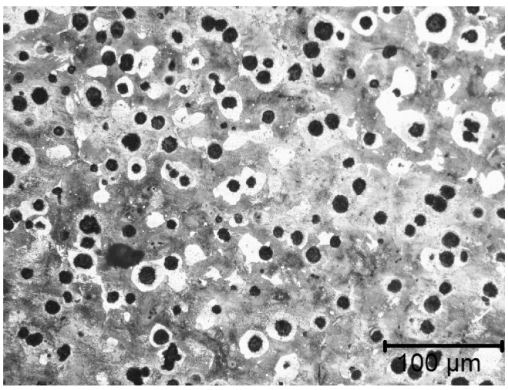

Fig. 21. Microscopic image of the rotor tip cladding material prior to operation in the crusher

Rys. 21. Obraz mikroskopowy materiału okładziny końcówki wirnika przed eksploatacją w kruszarce

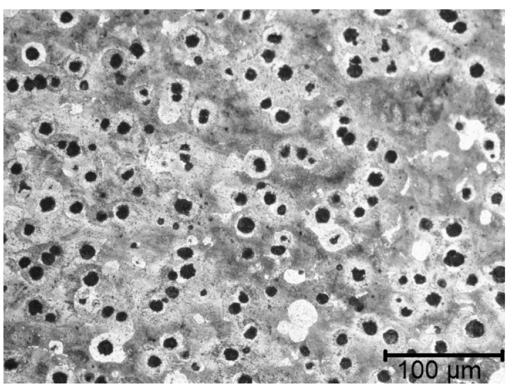

Fig. 22. Microscopic image of the rotor tip cladding material after operation in the crusher

Rys. 22. Obraz mikroskopowy materiału okładziny końcówki wirnika po eksploatacji w kruszarce

SUMMARY AND CONCLUSIONS

The aim of the research presented in the work was the macroscopic and microstructural analysis of the rotor crusher components of the SANDVIK CV117 centrifugal crusher working in the melafir mine in Czarny Bór. A local inspection at the melafir mine has shown that all crusher components are replaced by hand. The record of the wear of replaceable parts during daily work of the crusher is made only macroscopically. If the case of noticing excessive wear, damage or lack of any component all subassemblies in the rotor must be replaced immediately.

The detailed macroscopic results showed that the largest defects occur on the surfaces of working details. The directional bushing reduced its thickness by 20%, the distributor baffle by as much as 38%, the rotor tips by 12%, and the hammer assembly by 8%. The most important is, however, the mass loss of elements, especially in the case of the partition of the distributor, where it reaches as much as 57%. Based on the analyses carried out, it was found that a serious problem to which all the tested elements are exposed is the simultaneous impact of high friction forces and impact load resulting from the kinetic energy of the accelerated feed grains, imparted by the rotor during the crusher operation.

Microscopic studies have shown diversity in the material used for individual working elements of the crusher rotor. The directional bushing and the baffle of the distributor are made of the Fe-C-Cr alloy resistant to abrasion and corrosion, the material of the hammer assembly is the wear-resistant alloy of the Fe-C-Cr-Si system, while the rotor tip linings are made of ductile grey pearlitic-ferritic cast iron.

Such a significant difference in materials causes a disproportion of properties that the tested elements exhibit. The result of the research may be surprising, because, despite the very similar nature of the work, the materials from which the tested components are made differ radically from each other. However, after analysing the whole case and taking into account the work performed by individual components, resulting from the direction of rotation of the rotor, the reason for this difference can be determined. The part of the rotor that grinds the aggregate to the greatest extent is protected on both sides against direct contact with the aggregate by the tested components. However, the directional bushing, crushing hammer assembly, and distributor baffle are located in the rotor face and consequently collide with the aggregate with the greatest strength and intensity. These components were made of alloys with increased resistance to abrasive wear. The rotor tip lining, as the name implies, is located at the back of its grinding part, i.e. it is somewhat protected against the largest feed stream, and thus the dynamic loads it is subjected to are much smaller; therefore, it was made of a material with lower hardness and abrasion resistance, the grey cast iron.

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