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COMPOSITES THEORY AND PRACTICE

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MATERIALS SCIENCE CHARACTERISTICS OF SEGMENT OF CIRCULAR SAW USED FOR CONCRETE CUTTING

The paper presents the results of studies on a segment of acircular saw used for cutting concrete. Usually, such products are manufactured by powder metallurgy methods with an addition of diamond particles. This manufacturing technology of such materials is aimed at obtaining a 'self-sharpening' effect. The effects consist in matrix abrasion during operation and in exposing the cutting diamonds, then their falling out and the following matrix abrasion. In the process of manufacturing such materials, such a matrix composition should be chosen so as to ensure that the diamond particles feature good adhesion. Because of that, the studies were aimed at determining uniformity of the diamond particles arrangement in a fracture of the studied segment, and determining the element distributions in the material matrix. Chemical composition point analyses were performed using the EDS method as well as element distribution maps in the product matrix. An X-ray phase analysis was carried out to evaluate the possibility of forming intermetallic compounds between the matrix components which could have formed during sintering.

Keywords: **powder metallurgy, diamond particles, circular saw segment**

CHARAKTERYSTYKA MATERIAŁOZNAWCZA SEGMENTU PIŁY TARCZOWEJ STOSOWANEJ DO CIĘCIA BETONU

Przedstawiono wyniki badań dotyczące segmentu piły tarczowej stosowanej do cięcia betonu. Zwykle takie wyroby są wytwarzane metodami metalurgii proszków z dodawaniem cząstek diamentu. Zadaniem tej technologii wytwarzania tego typu materiałów jest otrzymanie efektu „samoostrzenia". Efekt ten polega na ścieraniu w trakcie pracy osnowy i odsłonięcia tnących diamentów, następnego ich wypadnięcia i kolejnego ścierania osnowy. W procesie wytwarzania takich materiałów należy dobrać taki skład osnowy, żeby zapewnić cząsteczkom diamentu dobrą przyczepność. Z tego względu celem badań było określenie równomierności rozmieszczenia cząstek diamentu w przełomie badanego segmentu, określenie rozkładu pierwiastków w osnowie materiału. Wykonano analizy punktowe składu chemicznego metodą EDS oraz mapy rozkładu pierwiastków w osnowie wyrobu. W celu oceny możliwości utworzenia związków międzymetalicznych pomiędzy składnikami osnowy, które mogły utworzyć się w czasie spiekania, przeprowadzono rentgenowską analizę fazową.

Słowa kluczowe: **metalurgia proszków, cząstki diamentu, segment piły tarczowej**

INTRODUCTION

Metallic sinters containing fine diamonds (synthetic or natural) are materials most often used for cutting and dressing stones (building materials). Usually they are in the form of metal segments containing randomly arranged diamond particles [1]. Diamonds are the cutting elements in the segments, while the metallic matrix keeps them in a working position till their abrasion wear and falling out. Then the matrix wears off resulting in exposure of the next diamonds capable of cutting (self-sharpening effect). Therefore, the properties of the matrix are as important as that of the diamonds.

The process of manufacturing metallic-diamond sinters consists in mixing the powder, being the metallic matrix, with a natural or synthetic diamond powder, in pressing the shapes and then their sintering or in hot pressing [2]. These operations result in obtaining a sinter, commonly known as a metallic-diamond segment, which is then soldered to steel discs. The use of diamonds imposes certain limitations on the sintering process parameters, e.g. a synthetic diamond loses its strength above 800°C, while a natural much above 1000°C [3].

An important feature of the matrix material is the capability of retaining the diamond particles during a saw operation. The matrix must ensure that the diamond particles are retained in such a way as to prevent their falling out, forcing in or rotating during cutting [4].

In such materials, the matrix material may consist of tungsten carbide, W, Co, Fe, Ni, Cu and bronzes or various combinations of the aforementioned elements [4-6]. Carbide-forming elements are frequently added to a powder mixture [3, 5, 6] to cause cohesion through carbides formation on the separation surface of the diamond and binder. The components combination decides whether the matrix is plastic or not, affects its hardness and Young's modulus, impact strength and abrasion resistance. A too soft matrix causes diamonds to fall out prematurely and the tool wears too fast. On the other hand, a too hard matrix causes the tool to blunt and there is no self-sharpening effect [3, 7].

MATERIAL AND EXPERIMENTAL METHODS

A circular saw segment of metallic-diamond sintered material was used for the studies. Fracture studies and chemical composition analyses were performed on a JEOL JSM-5400 electron scanning microscope working with an EDS type electron microprobe X-ray analyser. Additionally phase analysis on a SEIFFERT 3003/T X-ray diffractometer was carried out using a cobalt tube with a wavelength of $\lambda = 0.17902$ nm.

The segment surface was analysed in the initial state as well as after grinding and polishing. Computer software and the DHN PDS crystallographic database were used for phase identification.

RESULTS OF STUDIES

Studies on the segment fracture have shown that the diamonds are arranged non-uniformly, the places of their dense location are visible (Fig. 1a) as well as places with no diamonds (Fig. 1b). Diamonds of an angular shape occur, in places pits are visible - places after particles which fell out or diamonds spalled from the fracture (Fig. 1).

The places where elements analysis was carried out are marked in Figure 2, while the results of the analysis are presented in Table 1.

TABLE 1. **Results of chemical composition analysis at individual points**

TABELA 1. **Wyniki analizy składu chemicznego w poszczególnych punktach**

Point	Element content [% weight]				
	Fe	Co	Cu	Sn	W
1	12.82	43.83	2.96	2.89	37.49
2	12.33	39.06	7.43	6.59	34.58
3	15.42	41.68	2.95	2.87	37.08
4	13.34	36.60	8.41	7.57	34.08
5	0.54	8.45	52.24	38.08	0.70
6	12.90	45.39	10.63	10.7	20.35
7	10.68	43.24	3.96	4.27	37.85
8	9.32	39.27	7.25	4.61	37.76

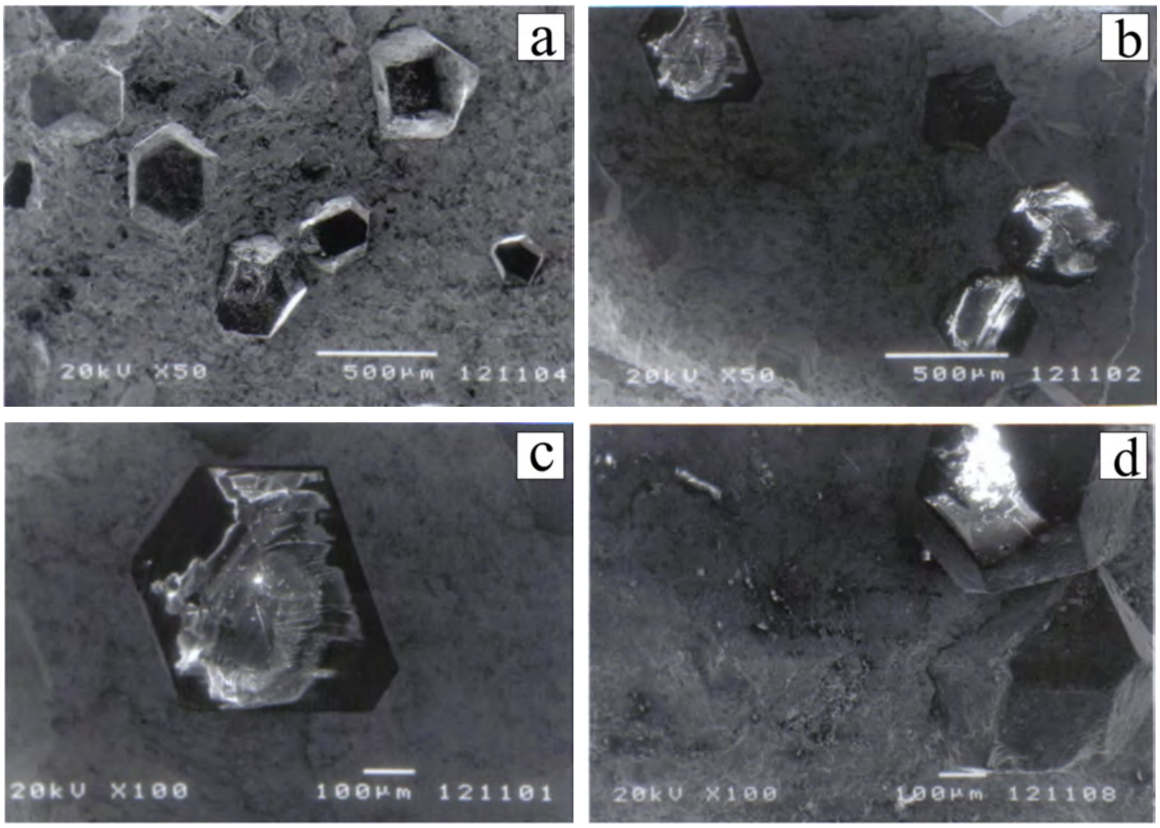

Fig. 1. Fracture of circular saw segment

Rys. 1. Przełom segmentu piły tarczowej

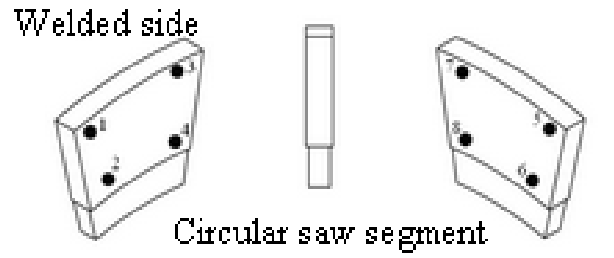

Fig. 2. Places, where scanning analysis was performed

Rys. 2. Miejsca, z których została wykonana analiza skaningowa

The results of the studies have shown that the chemical composition of individual areas of the studied material on the welded side is comparable. In contrast on the opposite side, element distribution is non-uniform. The chemical composition differs substantially at point 5. The iron content is 0.54%, cobalt - 8.45%, while copper makes more than 50%. This can result from non-uniform powder mixing before sintering. Element distribution Mapswere additionally made for points 1 and 2. In these places, the maps of element distribution maps (Fig. 3) have shown a slight segregation of cobalt and tungsten.

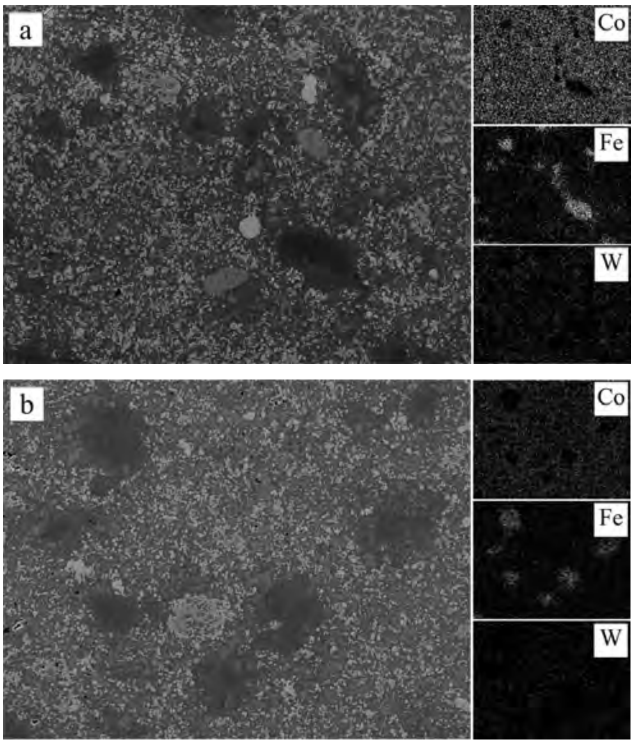

Fig. 3. Element distribution maps at points 1 (a) and 2 (b), magnification 500x

Rys. 3. Mapy rozkładu pierwiastków w punktach 1 (a) i 2 (b), pow. 500x

In both cases (Figs. 3a, b), there is local enrichment of the matrix with iron at the cost of cobalt and tungsten.

X-ray phase analysis (Fig. 4, Table 2) has shown a number of compounds formed during material sintering.

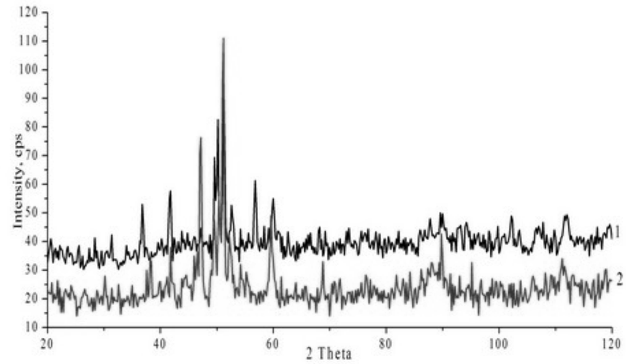

Fig. 4. X-ray diffraction patterns of studied segment surface: 1 - initial surface, 2 - polished surface

Rys. 4. Dyfraktogramy rentgenowskie powierzchni badanego segmentu: 1 - powierzchnia wyjściowa, 2 - powierzchnia polerowana

TABLE 2. **Phases and compounds obtained as result of X-ray phase analysis**

TABELA 2. **Fazy i związki otrzymane po przeprowadzeniu rentgenowskiej analizy fazowej**

	Phase contain
Initial surface	FeSn, Fe_3Sn, Fe_3Sn_2, CoSn, $CoSn_2$, Co_3Sn_2, Cu_3Sn, (Cu, Sn), FeC, WC, Fe, W, Co, C
Polished surface	FeSn, Fe_3Sn, Fe_5Sn_2, $FeSn_2$, Fe_3Sn_2, $Fe_{1,3}Sn$, CoSn, $CoSn_2$, Co_3Sn_2, Cu_3Sn, Cu_6Sn_5, FeC, Fe_5C_3, WC, Fe, W, C

X-ray phase analysis (Table 2) has shown that certain compounds have formed in the studied sinter, like: FeSn, Fe_3Sn, Fe_3Sn_2, CoSn, $CoSn_2$, Co_3Sn_2 and Cu_3Sn. In addition, tungsten (WC) and iron (FeC and Fe_3C) carbides also exist. Peaks originating from pure carbon (diamond) are visible, as well. However, not all the elements entered into mutual reactions during sintering, which is proven by the peaks originating from tungsten and iron.

SUMMARY

Studies performed on a circular saw segment made of a metallic-diamond sinter have shown the existence of diamond particles protruding on the surface of a finished segment. These particles share in the material fracture is not uniform because there are places of a dense presence and places containing little diamond. Analysis of the chemical composition at various segment points has shown five elements - components of the matrix: cobalt, tungsten, iron, copper and tin. These components have different melting points. Because of the presence of diamond particles, the sintering point did not exceed 800°C [3]. The presence of tin (T_m = 232°C) has improved consolidation and intensified the whole sintering process. It has been shown that in the studied saw segment, the content of such components as cobalt (~35%) and tungsten (32%) was the highest.

In places, the distribution of matrix material components was non-uniform. The element distribution maps have shown iron-rich areas at the cost of a lack of cobalt and tungsten in these places. X-ray phase analysis has shown the formation,, of such compounds as: FeSn, Fe_3Sn, Fe_3Sn_2, CoSn, $CoSn_2$, Co_3Sn_2, Cu_3Sn, WC, FeC and Fe_3C during the sintering process. Apart from these compounds, carbon exists in the material in the form of diamond, as well as Fe and W, which have not created compounds. The non-uniformity of diamond particles distribution may result in an improper course of the self-sharpening process, causing excessive wear of the sinter matrix material, which is scarce in diamond particles. Instead, areas of a too high concentration of diamond particles are exposed to spalling during operation.

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