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Cutting edges with high hardness made of nanocrystalline cemented carbides

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ABSTRACT

This article presents comparative results of investigations of cutting edges made of nanocrystalline and standard cemented carbides. The cutting edges made of nanocrystalline cemented carbides were sintered by the PPS method at various values of temperature (1320–1560 K) for 500 s in a vacuum of 0.05 Pa and under a load of 60 MPa. The results of investigations showed considerable variation in the structure of the nanocrystalline cemented carbides depending on the applied sintering parameters. The nanocrystalline cemented carbides obtained by the PPS method were characterized by considerably higher hardness than the standard cemented carbides with similar chemical composition. The PPS is a new method of producing sintered materials elaborated at Warsaw University of Technology.

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1. Introduction

Fine-grained tool materials often have better mechanical properties (hardness, bending strength, fracture toughness) than standard tool materials with a coarse-grained structure. For that reason more and more investigations of nanocrystalline tool materials have been carried out lately [1–12].

The paper presents selected results concerning the influence of the sintering parameters on the structure and hardness of the WC–5 wt.% Co nanocrystalline cemented carbides with 2.5 wt.% (TaC–NbC) growth inhibitor and without it. The cutting edges made of nanocrystalline cemented carbides were sintered by the Pulse Plasma Sintering method [6,7]. During the manufacturing process of cutting edges, various values of both sintering temperature and sintering time were applied [7]. Due to the pulse character and the phenomena accompanying the pulse process (Fig. 1), pulse sintering allows for more efficient production of sintered tool material than conventional methods [6,7].

In the PPS apparatus, the WC–Co powder is placed between two graphite punches in the graphite die. A capacitor battery is the energy source which delivers high-current electric pulses. Thanks to the short duration of the electric pulses (500 μs) compared to the interval between them (0.5–5 s) the average temperature of the sintered powders is lower than the temperature during the electric impulse. The high instantaneous value of temperature during electric pulse ensures a high rate of the diffusion between the individual particles [6,7].

The temperature variation during the Pulse Plasma Sintering process is presented in Fig. 2.

Thanks to high energy delivered in a pulse (of the order of 50 kA · 10 kV · 0.005 s = 2.5 MW·s) the Pulse Plasma Sintering process is much more intensive than that achieved in other techniques (PAS, SPS, FAST) [13–16].

2. Material and method

The paper presents the results of comparative investigations of structure and hardness of the standard and the nanocrystalline WC–55 wt.% Co and the WC–55 wt.% Co + 2.55 wt.% (TaC–NbC) cemented carbides.

Cutting edges made of the standard cemented carbides (type: the H20 (WC–5 wt.% Co) and the H20S (WC–5 wt.% Co + TaC–NbC)) were produced by Baildonit using Hot Pressing (HP) method.

The nanocrystalline carbides powder were applied in the production of the cutting edges by using the Pulse Plasma Sintering (PPS) method [6–8]. Prior to the sintering, the gas from the chamber was pumped out to a pressure of 0.05 Pa. In the first stage, the samples were heated under a load of 60 MPa at a temperature of 870 K for 60 s [7]. During this process, the organic compounds and the gases absorbed on the powder surface were evaporated. In the second stage, the obtained samples (cutting edges: 9.52 × 9.52 × 3.18 mm) made of nanocrystalline cemented carbides were sintered at various values of temperature (1320 K, 1370 K, 1420 K, 1470 K, 1520 K, 1560 K) for 500 s in a vacuum of 0.05 Pa and under a load of 60 MPa. The temperature and the pressure variation during the Pulse Plasma Sintering process are presented in Fig. 3.

In the production of nanophase cemented carbides, the nanocrystalline WC–5 wt.% Co powder of the purity of 99.9% and with the TaC–NbC growth inhibitor was applied. Both WC and Co powder grains were

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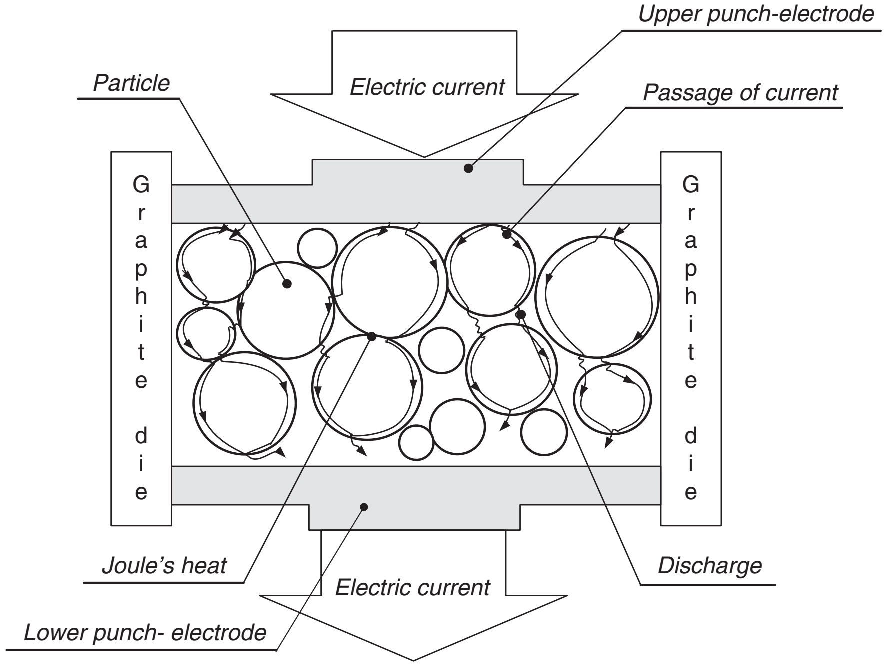

Fig. 1. Phenomena occurring in the Pulse Plasma Sintering process (elaborated on the basis of [6–8]).

from 40 to 80 nm in diameter. The WC–Co and TaC–NbC powders were delivered by the Inframat Co., USA. Fig. 4 presents SE images of the WC–Co powder agglomerates.

Measurements of grain size of powder were carried out on the Atomic Force Microscope (AFM-2D and 3D: Quesant Q-Scope 250). The mean value of diameter of powder particle from 10 measurements is 46 nm. The measurements confirm data obtained from the producer of powder.

The hardness of the samples was then measured using the Vickers hardness tester. The hardness was determined under a load of 294 N (HV30). The densities of sintered samples were determined using the Archimedes method in water immersion [7]. The microstructure of cutting edges was observed using scanning electron microscopy images formed in both the secondary electrons (SE) and the backscattered electrons (BSE) contrasts. Measurements of grain size in cemented carbides were carried out using SEM – Vega TS 5135 (magnification: 20–500 000 times; resolution: 4 nm) and the Atomic Force Microscope (AFM-2D and 3D: Quesant Q-Scope 250).

The PPS is a new method of producing sintered materials, elaborated at the Department of Materials Science, Warsaw University of Technology [6,7]. The most important advantage of the PPS method, in relation to other methods, which were used for sintering of the tool materials, is very short sintering time. Before modification, the Pulse-Plasma Sintering (PPS) method was used at first for production of hard coatings as the Pulse-Plasma Deposition method (PPD) [17–19].

3. Results and discussion

Nonocrystalline cemented carbides were compared with standard cemented carbides. Fig. 5 presents the microsections of nanocrystalline cemented carbides obtained by the PPS method.

Fig. 6 presents images of the microsections of the standard cemented carbides of similar chemical composition as the nanocrystalline cemented carbides from Fig. 5. The standard cemented carbides were produced using the Hot Pressing (HP) method. Fig. 6a shows the backscattered electrons images of the microsections of the H20 (WC–Co) standard cemented carbides with grain size 2000–3000 nm, and Fig. 6b presents BSE images of the H20S (WC–Co + (TaC–NbC)) standard cemented carbides with grain size 1500–2000 nm.

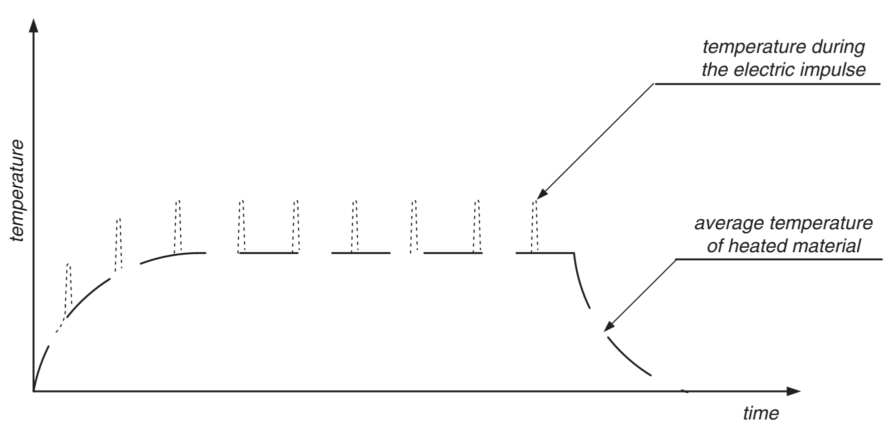

Fig. 2. The temperature variation during the Pulse Plasma Sintering process (elaborated on the basis of [6,7]).

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