Production of sinters from commercial powder mixtures for a matrix of diamond impregnated tools

Wytwarzanie spieków przeznaczonych na osnowę narzędzi metaliczno-diamentowych z komercyjnych mieszanek proszków

JOANNA BOROWIECKA-JAMROZEK
JAN LACHOWSKI *

DOI: https://doi.org/10.17814/mechanik.2017.1.9

The paper presents the results of analyzing mechanical properties of the sinters obtained from the commercial iron-based powder mixtures. The strength and plastic parameters were determined, as well as the density, hardness and porosity of the produced sinter. The sinters microstructure and the chemical composition analysis were carried out by using the scanning electron microscope. The results were compared with the properties of the sinters obtained from the cobalt SMS (submicron size) powder.
KEYWORDS: cobalt, sinter, diamond impregnated tools

For the last few decades, cobalt has been commonly used as a matrix material in metal-diamond tooling for natural stone cutting. Technologically, cobalt has many advantages [1-4]. It is available in powder forms that vary in chemical purity, particle size and shape. Cobalt powders can be compacted to a density close to theoretical one at temperatures not exceeding 850 °C. During powder consolidation, cobalt moderately affects the graphitization and decreases the mechanical properties of diamond crystals. Sintered cobalt alloys have high durability and good plasticity. The cobalt matrix exhibits very good retention properties, i.e. it holds diamond particles well on the composite work surface [5, 6].

The disadvantage of cobalt is its high and unstable price. Therefore, tool manufacturers are looking for cheaper cobalt-substitute matrix materials [7-9].

Methodology and research results

Sinters obtained by hot-pressing the powder mixtures supplied by the Chinese manufacturer for experimental testing, were used. Powders were labeled with symbols as in the manufacturer's folder [10]: CSA and CSA800 (Figures 1a and b).

Prior to the consolidation process, CSA and CSA800 powders were examined and analyzed using the JSM-7100F scanning electronic microscope integrated into the OINA-AZtec X-ray microanalysis system.

* Dr inż. Joanna Borowiecka-Jamrozek (jamrozek@tu.kielce.pl) – Politechnika Świętokrzyska, Wydział Mechatroniki i Budowy Maszyn; dr Jan Lachowski (jlach@tu.kielce.pl) – Politechnika Świętokrzyska, Wydział Zarządzania i Modelowania Komputerowego

The parameters of the hot pressing process were chosen according to the supplier's suggestion: temperature 850 °C, pressure 35 MPa and time 3 min. The process was carried out using CAR1001 press by ARGA, in a graphite matrix that allows simultaneous execution of 10 samples of nominal size of approximately 7 × 6 × 40 mm.

The sintered specimens were subjected to the following tests: density measurement by weighing in air and water and Vickers hardness measurement using a 10 kG load. Based on the density measurements, the porosity of sintered samples was determined. The results of measurements are presented in Table I.

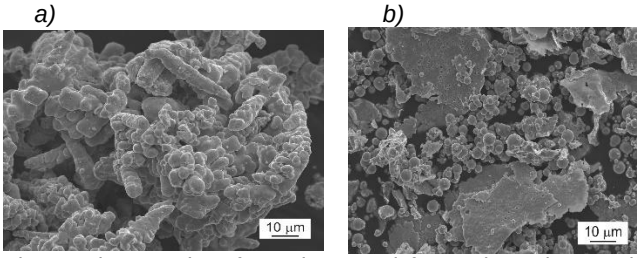

Fig. 1. Photographs of powders used for testing: *a)* CSA, *b)* CSA800

TABLE I. Results of density and hardness measurements

Sinter	Density g/cm^3	Theoretical density, g/cm^3	Porosity, %	Hardness, HV10
CSA	8,06 ± 0,02	8,36	3,60	145,5 ± 9,9
CSA800	8,13 ± 0,01	8,33	2,51	223,1 ± 10,2
Co	8,74 ± 0,04	8,90	1,80	271,0 ± 3,0

Then, the elastic constants of the sintered samples were determined in acoustic test, and on the basis of the static tensile test, the durability and plastic parameters of the samples were estimated (Table II, fig. 2).

Microstructure observations were made using the JSM-7100F scanning electron microscope, integrated with the OINA-AZtec X-ray microscope system. The CSA and CSA800 sinter structures are shown in fig. 3.

TABLE II. Elastic and plastic parameters of sinters

Material	Module of elasticity E, GPa	Poisson's ratio, ν	Offset yield strength $R_{0.2}$, MPa
CSA	163	0,32	251,7 ± 7,6
CSA800	164	0,32	401,7 ± 42,5
Co	205	0,30	404,5 ± 25,4

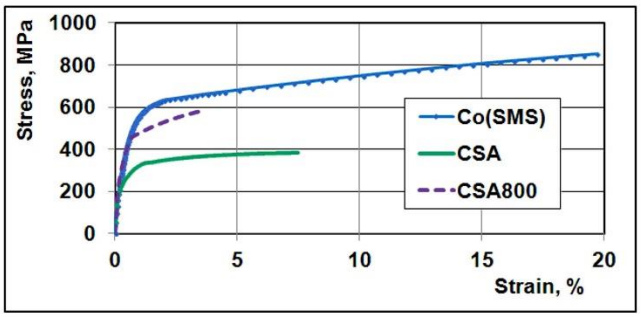

Fig. 2. Stress-strain curves for sinters

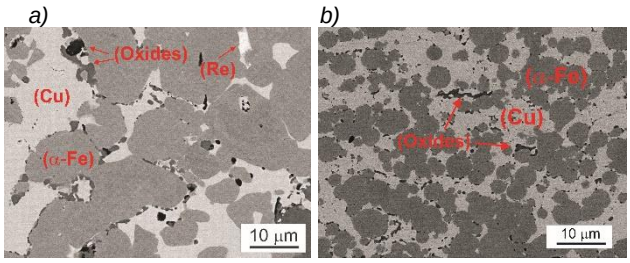

Fig.3. Microstructure of sinters: *a)* CSA, *b)* CSA800

Discussion of results and conclusions

Analysis of the chemical composition of EDS from the surface of individual CSA powder particles showed that the elements of the powder cannot be distinguished, which indicates that it is an alloyed powder. The spectra obtained from the particle surface showed that the powder contained about 45% iron, 50% copper, 3% zinc and 2% tin.

On the other hand, the CSA800 powder, taken from the surface of individual spectral particles, suggests that the powder consists of carbonyl iron particles mixed together with irregular, substantially thicker pre-melted bronze particles. Spectra taken from the surface of individual particles indicate that the powder contained up to 6% zinc, up to 3% tin and up to 1% lead. Probably, it is bronze (B663).

CSA and CSA800 alloys have distinctive combination of mechanical properties. The CSA alloy has low hardness, low yield strength (Table I) and low tensile strength (382.8 MPa), but a large elongation of 8.2% (Figure 2).

The CSA800 alloy has high hardness, high yield strength (Table I) and high tensile strength (591 MPa) with lower maximum deformation of 3.3% (Figure 2).

Analysis of the chemical composition of EDS carried out on CSA and CSA800 metallographic microsections revealed a complex, multiphase microstructure. In the case of CSA, it confirmed the presence of Fe in the amount of 42 ÷ 52% by weight, Cu 48 ÷ 53%, Zn 2 ÷ 3% and Sn 2%, and also showed the presence of rare earth metals such as Ce, La, Sm and Y – at quantities below 3%.

The CSA alloy consists of: a solution (α-Fe) abundant in carbon, a copper (Cu) solution containing Sn and Zn (Figure 3), and dark patches forming a mixture of metal oxides. Rarely isolated white spots are a rare earth metal solution in tin and copper. Analysis of the chemical composition of EDS carried out on metallographic microsections made on CSA800 sinters also showed a complex multiphase microstructure. In the case of CSA, it confirmed the presence of Fe in the amount of 42 ÷ 57% by weight, Cu 35-51%, Zn 3-4%, Sn 3% and Pb<1%, and trace amounts of rare earth metals.

The CSA800 alloy consists of: a solution (α-Fe) abundant in carbon, a solution of copper (Cu), which is a solid solution of Sn and Zn in Cu, and dark patches of a mixture of metal oxides. No isolated Pb inclusions were observed.

Conclusions

- The materials studied are noteworthy because of their affordability, ease of consolidation through hot pressing, the ability to vary in a very wide range of endurance and plastic properties.
- Changing the properties of these materials is possible through the appropriate selection of chemical composition - by introducing additives in the form of chemical elements such as Ni, WC, W or Co.
- The CSA material has a basic chemical composition that can be modified in any way, therefore the strength properties of this material are relatively low. It can be used after the addition of metal additives.
- It is possible to modify the hot ironing temperature. The CSA alloys achieve a density of about 97% of the theoretical density after only a short time (3 min) for pressing at a pressure of 35 MPa in the range of 800 ÷ 880 °C.
- The CSA and CSA800-based matrix has good retention properties for diamond particles during the metal-diamond tool operation, since a mechanical bond between the diamond particles and the matrix is formed during cooling after hot pressing, which depends on the elastic and plastic properties of the matrix material. Analysis of the diamond particle retention in relation to the mechanical properties of the matrix was carried out by the authors in other papers [5, 6].

By analyzing the above conclusions, it can be stated that the CSA and CSA800 materials tested meet the criteria for their use in less demanding general purpose tools [1, 2].

REFERENCES

1. Konstanty J. *"Powder Metallurgy Diamond Tools".* Oxford: Elsevier, 2005.
2. Romański A. *„Rozwój materiałów osnowy w narzędziowych spiekach metaliczno-diamentowych".* Kraków: AGH-UWND, 2015.
3. Borowiecka-Jamrozek J. "Engineering structure and properties of materials used as a matrix in diamond impregnated tools". *Archives of Metallurgy and Materials.* 58, 1 (2013): pages 5–8.
4. Konstanty J. "Sintered diamond tools: trends, challenges and prospects". *Powder Metallurgy.* 56 (2013): pages 184–190.
5. Borowiecka-Jamrozek J., Lachowski J. "Modelling of the mechanical state of a diamond particle in the metallic matrix". *Advanced Materials Research.* 874 (2014): pages 127–132.
6. Borowiecka-Jamrozek J., Lachowski J. "Numerical modelling of stress/strain field arising in diamond-impregnated cobalt". *Archives of Metallurgy and Materials.* 59, 2 (2014): pages 443–446.

7. Mechnik V.A. “Production of diamond-(Fe-Cu-Ni-Sn) composites with high wear resistance”. *Powder Metallurgy and Metal Ceramics.* 52, 9–10 (2014): pages 577–587.
8. Konstanty J., Tyrała D., Radziszewska A. “Iron-base materials manufactured from premixed powders by the hot press process”. *Archives of Metallurgy and Materials.* 54, 4 (2009): pages 1051–1058.
9. Nanbin H., Dianyue G. “The application development of Chinese multi-element pre-alloyed metal powders in diamond tools”. *Diamante, Applicazioni & Technologia*. Diecembre (2013): pages 23–30.
10. “CSA series. Basic Alloy Powder for Diamond Tools”. User's Manual, Henan CUT-Stone Science & Technology, CO., LTD, Zhengzhou 2013.