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THE MICROSTRUCTURE AND PROPERTIES FORMING SINTERED M35 HSS BASE CERMETS

In this paper the manufacturing process and properties of sintered M35 high speed steel with addition of tungsten carbide WC cermets have been studied. The chemical composition of M35 steel is presented in Table 1. Morphology of powder particles M35 steel and tungsten carbide WC are shown in Figure 1. The raw powders were mixed together in a ceramic mortar for 60 minutes. The following composition was investigated: M35+10 wt.% WC. Cold compacting in a rigid, rectangular die at 800 MPa was followed by sintering in vacuum furnace at six different temperatures in the range 1150÷1220°C under vacuum pressure below 10^{-2} Pa. The sintering process assembled with three stages: annealing at 950°C for 30 minutes, isothermal sintering for 60 minutes and cooling with furnace.

The as-sintered specimens were subjected to density and microhardness measurements. Density was measured on the base of Archimedes' law. Figure 2 shows the results of density of sintered M35+10 wt.% WC cermets. For the microhardness measurement Hanemann harness testing machine was used. For microstructure examination light and SEM microscopy techniques were employed. Diffractometer TUR M62 with HZG4 goniometer was employed for X-ray diffraction analysis. On the base of results and microstructure observation it may be concluded that the processing parameters and tungsten carbide content simultaneously affect the as-sintered properties of the investigated cermets.

Key words: cermet, high speed steel, tungsten carbide, pressing, sintering

SPIEKANE WĘGLIKOSTALE NA OSNOWIE STALI SZYBKOTNĄCEJ M35 - KSZTAŁTOWANIE MIKROSTRUKTURY I WŁAŚCIWOŚCI

Przedstawiono wyniki badań spiekanych węglikostali na osnowie stali szybkotnącej typu M35 z dodatkiem węglika wolframu WC. Skład chemiczny stali M35 przedstawiono w tabeli 1. Morfologię cząstek proszku stali M35 i węglika wolframu WC pokazano na rysunku 1. W wyniku ucierania proszków w ceramicznym ścieraku moździerzowym przez 60 minut wytworzono mieszanki o składzie M35+10% WC. Mieszanki proszków prasowano w prostopadłościennej matrycy stemplem od góry pod ciśnieniem 800 MPa. Kształtki spiekano w próżni poniżej 10^{-2} Pa w temperaturze od 1150 do 1220°C. Proces spiekania składał się z trzech etapów: wyżarzania w 950°C przez 30 minut, izotermicznego spiekania przez 60 minut oraz chłodzenia z piecem.

Przeprowadzono badania gęstości, mikrotwardości oraz składu fazowego spiekanych węglikostali. Pomiar gęstości spiekanych węglikostali wykonano metodą wykorzystującą prawo Archimedesa, a wyniki przedstawiono na rysunku 2. Badanie mikrotwardości przeprowadzono za pomocą mikrotwardościomierza Hanemanna. Obserwacje mikrostruktury wykonano za pomocą mikroskopów świetlnego oraz skaningowego. Rentgenowską analizę fazową spiekanych węglikostali wykonano z pomocą dyfraktometru TUR M62 z goniometrem HZG4. Na podstawie analizy otrzymanych wyników stwierdzono, że dodatek węglika wolframu WC oraz zmiana parametrów wytwarzania pozwalają na kształtowanie w szerokim zakresie właściwości oraz mikrostruktury spiekanych węglikostali.

Słowa kluczowe: węglikostal, stal szybkotnąca, węglik wolframu, prasowanie, spiekanie

INTRODUCTION

Cermets are the materials fulfilling high requirements like high mechanical strength, abrasion resistance. The main objective of present investigations is decrease of manufacturing process costs. Decrease of manufacturing process costs will be achieved trough reduction of number of production stages, manufacturing parameters modification, contents components modification and reduction of finishing treatment operation.

Manufacturing parameters modification, leads primarily to decrease of sintering temperature. Optimal sintering temperature let us get fully density in short time like a few minutes.

At lower temperatures even during long sintering period will not achieve density above 90% [1]. To avoid matrix and carbides grain growth, the sintering time should be reduced to minimum. The temperature range required for suitable realization of sintering process is extremely small. The „sintering window", approximately a few degrees, mainly depends on powder grade degree [2]. Decreasing sintering temperature and getting suitable microstructure can be achieved after modification of chemical composition of sintered steel. The influence of tungsten carbide addition was presented in other publication [3-9].

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MATERIALS AND RESEARCH

Base materials

As raw materials M35 high speed steel powder and tungsten carbide were employed. Chemical composition of M35 was shown in Table 1. Figure 1a presents morphology of M35 steel powder, Figure 1b - tungsten carbide WC.

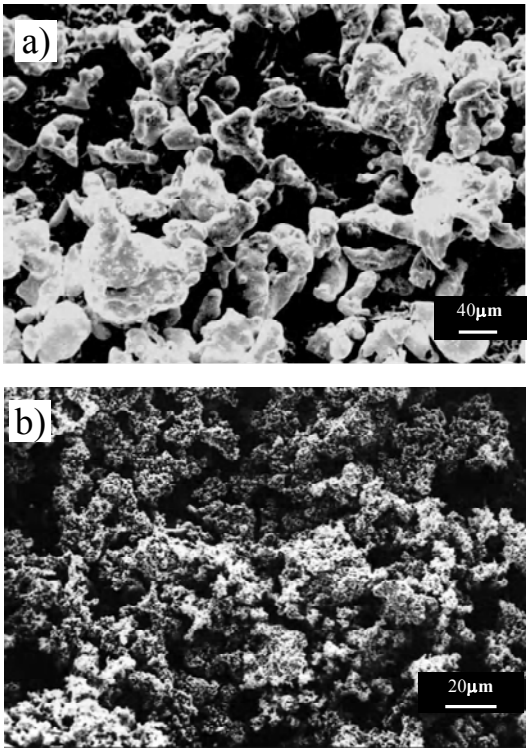

Fig. 1. Morphology of powder particles, SEM: a) high speed steel M35, b) tungsten carbide WC

Rys. 1. Morfologia cząstek proszków, SEM: a) stal szybkotnąca typu M35, b) węglik wolframu WC

TABLE 1. **Chemical composition of M35 high speed steel**
TABELA 1. **Skład chemiczny stali szybkotnącej typu M35**

Chemical composition, wt.%													
C	Cr	Co	Cu	Mn	Mo	Ni	P	S	Si	V	W	Fe	O
0.94	4.30	4.83	0.17	0.19	5.02	0.35	0.022	0.029	0.17	1.79	6.35	75.8	1293 ppm

Experimental details

The high speed steel powder was mixed with tungsten carbide in ceramic mortar for 30 minutes. The powders were uniaxially cold compacted in a cuboid die at 800 MPa. The sintering process was divided into three stages:

- annealing at 950°C for 30 minutes,
- isothermal sintering in vacuum at temperatures: 1150, 1170, 1180, 1190, 1200 and 1220°C for 60 minutes,
- cooling with furnace.

RESULTS

As-sintered density of cermet

Density was measured on the base of Archimedes' law. Figure 2 shows the results of density of sintered M35+10 wt.% WC cermets.

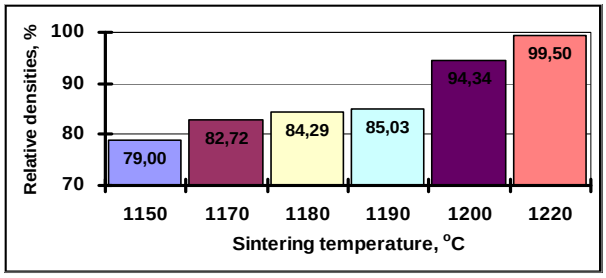

Fig. 2. Relative densities of sintered cermet M35+10 wt.% WC as function of sintering temperature

Rys. 2. Wpływ temperatury spiekania na gęstość względną spiekanej węglikostali M35+10% wag. WC

X-ray diffraction analysis

Diffractometr TUR M62 with HZG4 goniometer was employed for X-ray diffraction analysis. Lamp with iron anode was used. Steps' counting was $\Delta 2\theta = 0.02°$, in the range $2\theta = 30 \div 115°$. Time counting was $\tau = 5$ s. In order to demonstrate changes in phase composition of sintered cermets, the diffraction patterns of sintered M35+10 wt.% WC cermets were compared. The results are shown in Figure 3.

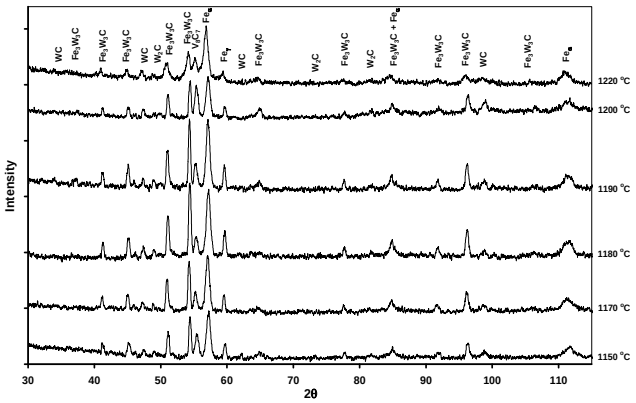

Fig. 3. X-ray diffraction of M35+10 wt.% WC cermet as a function of sintering temperature

Rys. 3. Wpływ temperatury spiekania na skład fazowy węglikostali M35+10% wag. WC

Microstructure investigations

Two microscopes LEICA DM 4000 and SEM microscope type Hitachi 3500N were employed for microstructure investigations. Polished sections were etched for visualisation of carbide phases existing in sintered material. Carbides type M_2C and M_6C differ

from each other in gray scale are presented in Figures 4 to 10. Additionally distribution of elements analysis was made in order to identify carbides type.

Microstructure observation with the aid of light microscope

Microstructure observation with the aid of SEM microscope

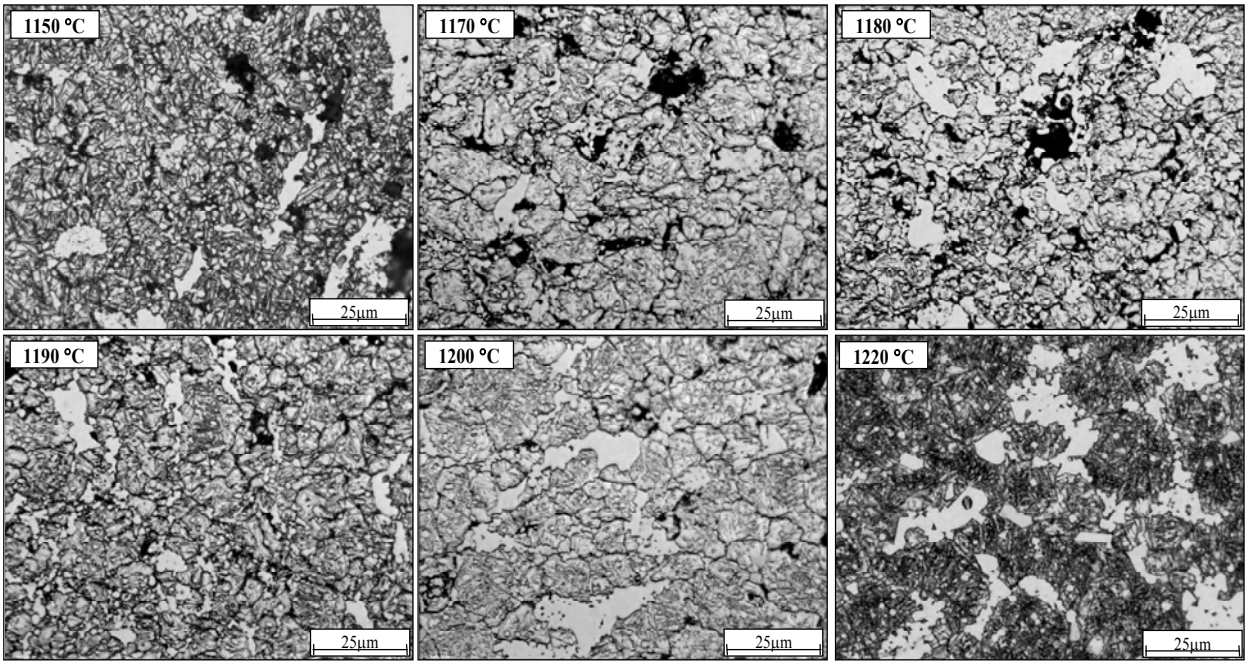

Fig. 4. Light micrographs of M35+10 wt.% WC cermets sintered at 1150, 1170, 1180, 1190, 1200 and 1220°C

Rys. 4. Mikrostruktury węglikostali M35+10% wag. WC spiekanych w temperaturze 1150, 1170, 1180, 1190, 1200 i 1220°C, mikroskop świetlny

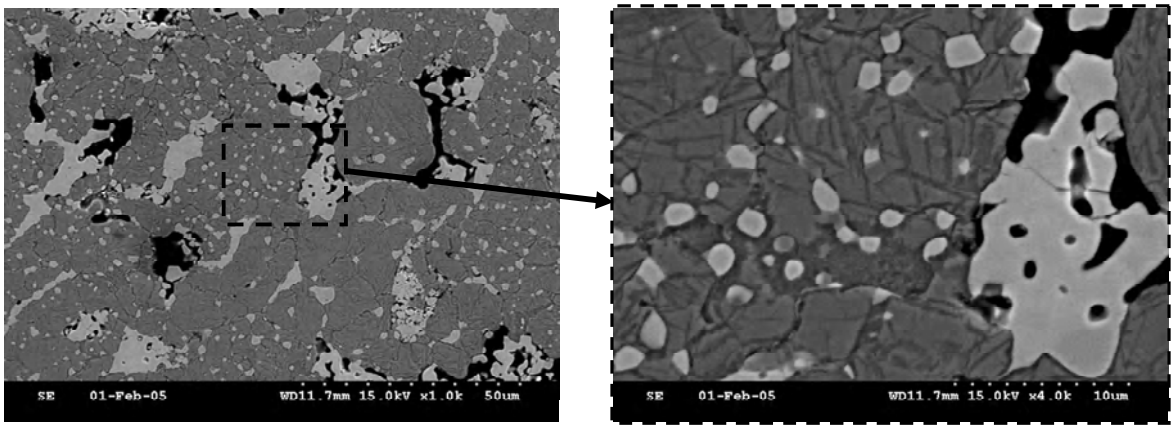

Fig. 5. SEM micrographs of M35+10 wt.% WC cermet sintered at 1150°C

Rys. 5. Mikrostruktura węglikostali M35+10% wag. WC spiekanej w temperaturze 1150°C, SEM

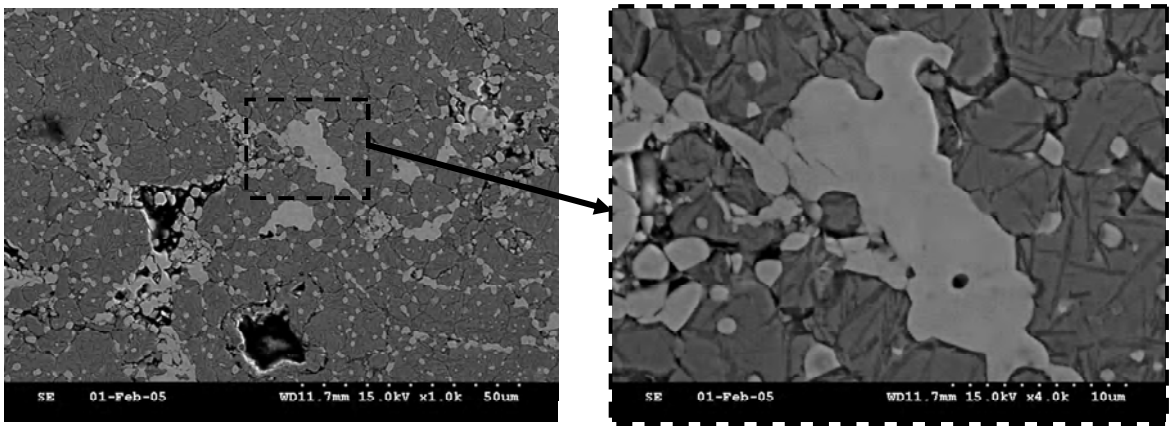

Fig. 6. SEM micrographs of M35+10 wt.% WC cermet sintered at 1170°C

Rys. 6. Mikrostruktura węglikostali M35+10% wag. WC spiekanej w temperaturze 1170°C, SEM

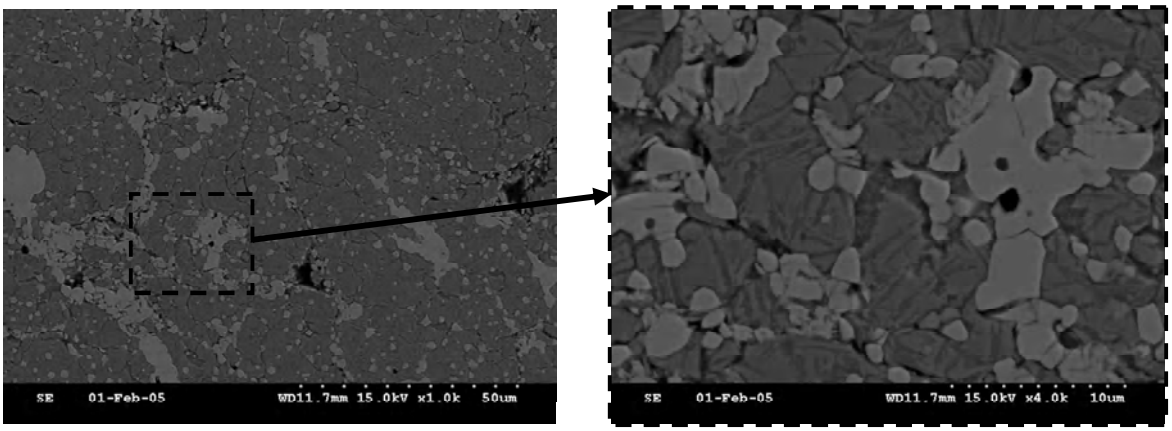

Fig. 7. SEM micrographs of M35+10 wt.% WC cermet sintered at 1180°C

Rys. 7. Mikrostruktura węglikostali M35+10% wag. WC spiekanej w temperaturze 1180°C, SEM

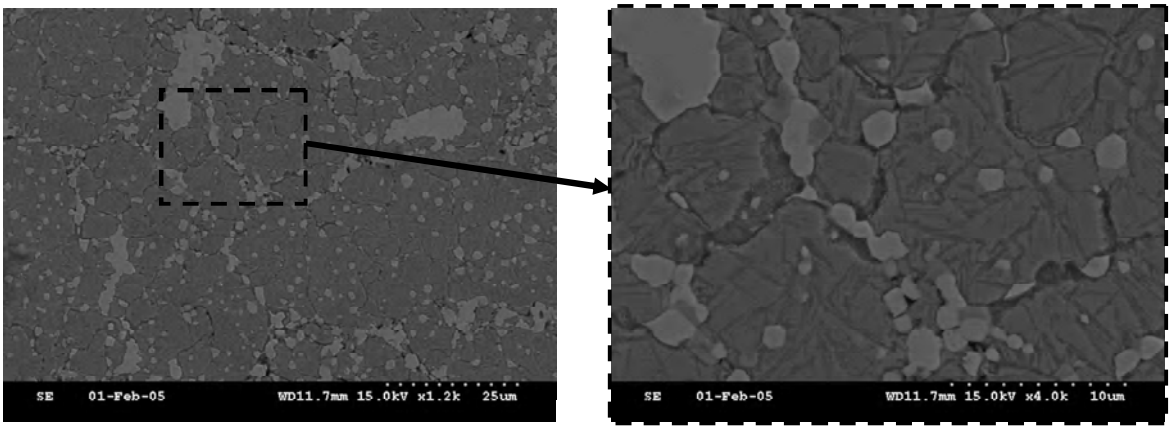

Fig. 8. SEM micrographs of M35+10 wt.% WC cermet sintered at 1190°C

Rys. 8. Mikrostruktura węglikostali M35+10% wag. WC spiekanej w temperaturze 1190°C, SEM

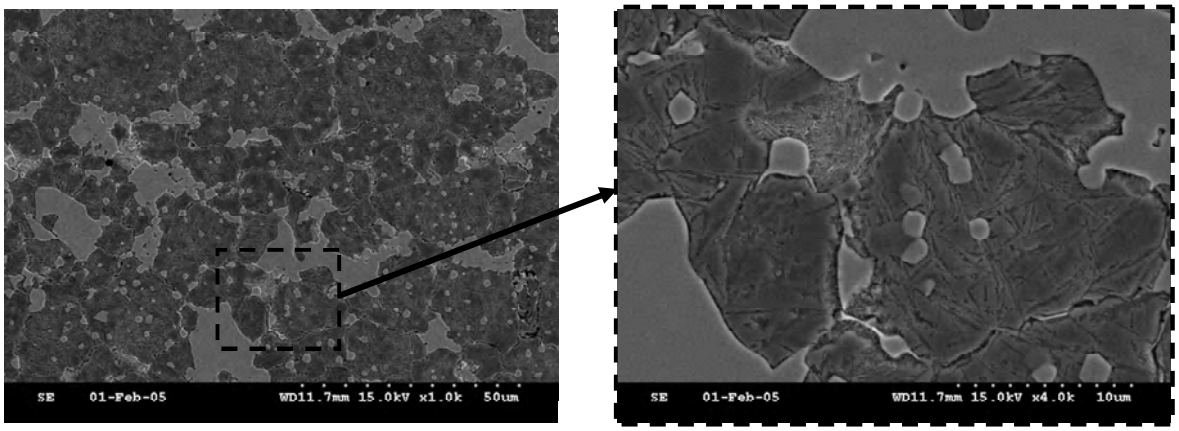

Fig. 9. SEM micrographs of M35+10 wt.% WC cermet sintered at 1200°C

Rys. 9. Mikrostruktura węglikostali M35+10% wag. WC spiekanej w temperaturze 1200°C, SEM

DISCUSSION

The addition of 10 wt.% tungsten carbide to M35 high speed steel allows achieving density about 99.5%. On the base of previous investigations [13-17], elements such as Co, Fe, W, Cr, Ni, Mo as well as sintering temperature [4-7] influenced tungsten carbide WC decomposition. During cermet sintering the structure consist of carbides type M_2C and M_6C (Fig. 4-10).

The results of X-ray diffraction analysis (Fig. 3) showed that cermet M35+10 wt.% WC matrix consist of

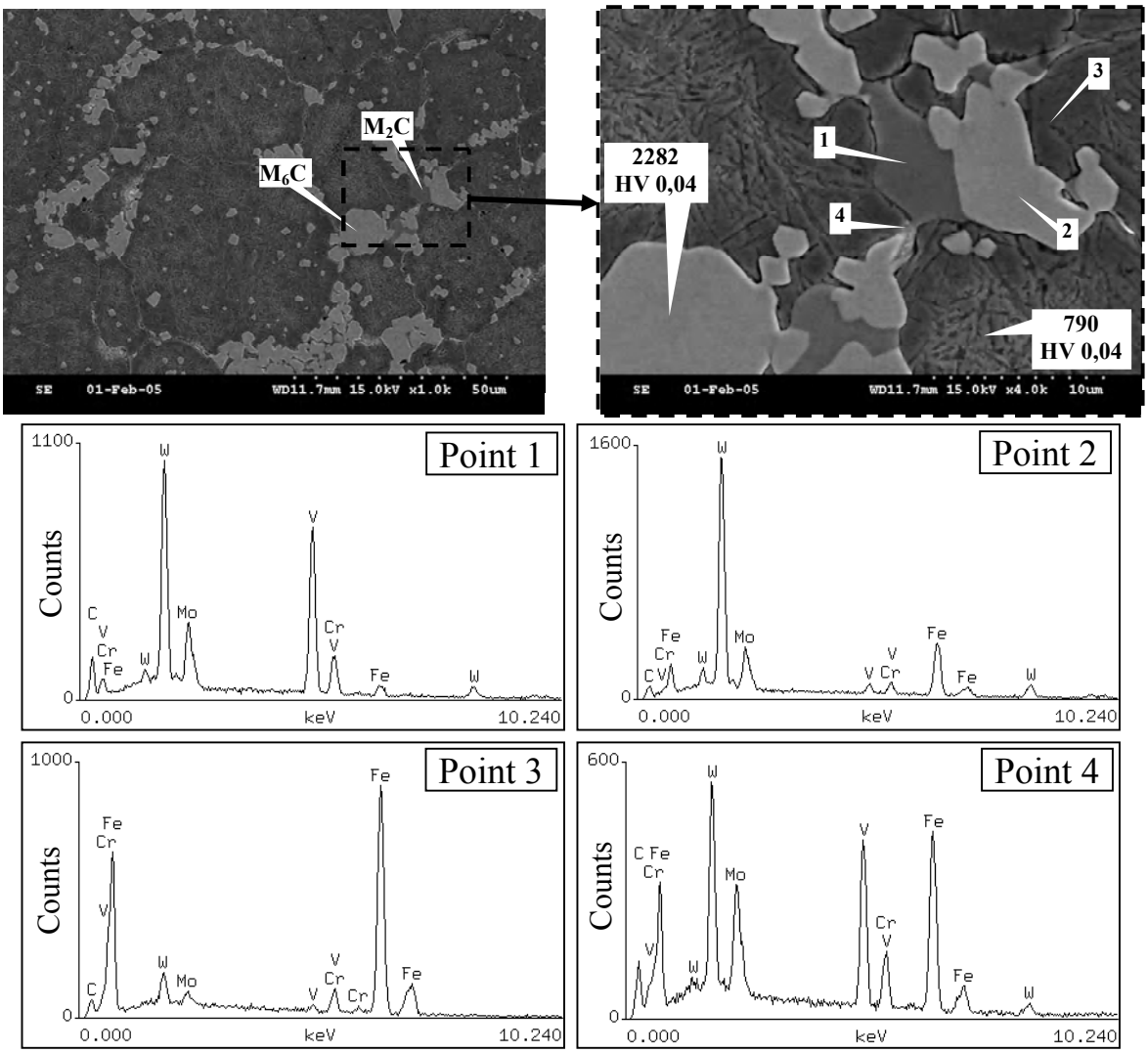

Fig. 10. SEM micrographs and distribution of elements (points 1, 2, 3 and 4) in M35+10 wt.% WC cermet sintered at 1220°C

Rys. 10.Mikrostruktury oraz analiza półilościowa (punkty 1, 2, 3 i 4) węglikostali M35+10% wag. WC spiekanej w 1200°C, SEM

austenite diffusionless transformation products and results of microhardness investigation shows that it is probably bainite (Fig. 10), while precipitations existing in the matrix are V_8C_7, Fe_3W_3C, WC, W_2C carbides. Increasing the sintering temperature causes growth of the content of carbide type Fe_3W_3C but decreasing tungsten carbide type WC contents. Microstructure observation (light microscopy) shows clear influence of sintering temperature on density process, location and type of carbide phases. After sintering at 1200 and 1220°C it was found decreasing content of primary carbide phase inside high speed steel grains and the tendency for carbide localization on matrix grain boundaries (Figs 4 and 10). That effect was strongly visible during SEM investigations (Figs 9 and 10). Tungsten carbide W_2C content in cermet sintered at temperature 1220°C is larger than in cermets sintered at lower temperatures.

The low stability of tungsten carbide WC at high sintering temperature (1220°C) is the main reason for its decomposition. As a consequence of this, on phase boundary (high speed steel and tungsten carbide WC) free carbon was appeared. Small quantity of free carbon is advantageous because let us to decrease sintering temperature - as activation function of liquid phase result (Figs 5-10) - and obtain full density with simultaneous of reduction production cost.

CONCLUSIONS

1. Increasing sintering temperature increase density of M35+10 wt.% WC cermet.
2. Sintering temperature influences fundamentally the spacing and type of carbide phase in investigated cermet.
3. The addition of tungsten carbide activates the sintering process and let achieve almost full density of sintered materials.

4. Evolved precipitations in cermet are MC, M_6C carbides. Also it was found that tungsten carbide type W_2C was formed, which is a result of chemical reaction between high speed steel and tungsten carbide type WC.

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