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SINTERED HIGH SPEED STEEL-BASE COMPOSITES FOR WEAR AND SLIDING APPLICATIONS

PM route has been chosen to fabricate M3/2 HSS-base wear resistant composite materials with WC and Cu additions of 0÷30 wt.-% and 7.5÷45 wt.-% respectively. The effects of the mixed powder composition on its cold compressibility and sintering behaviour have been investigated. The kinetics of sintering was monitored by means of dilatometry. The as-sintered specimens were subjected to density measurements, hardness and wear resistance tests, micro-structural examinations as well as X-ray diffraction analysis. It has been found that WC reinforced material shows superior resistance to wear while higher Cu content markedly improves sliding properties thus creating prospects of new applications.

SPIEKANE MATERIAŁY KOMPOZYTOWE NA OSNOWIE STALI SZYBKOTNĄCEJ, CHARAKTERYZUJĄCE SIĘ DUŻĄ ODPORNOŚCIĄ NA ŚCIERANIE ORAZ DOBRYMI WŁASNOŚCIAMI ŚLIZGOWYMI

Wykorzystując klasyczną metodę metalurgii proszków, wyprodukowano partię odpornych na ścieranie, kompozytowych spieków na osnowie stali szybkotnącej z gatunku M3/2, z dodatkiem do 30% węglika wolframu oraz od 7,5 do 45% miedzi. Badano wpływ wyjściowego składu mieszanek proszków na ich zgęszczalność oraz, stosując metodę dylatometryczną (rys. 1), na kinetykę procesu spiekania. Ponadto, spieki poddano pomiarom gęstości (rys. 2), twardości (rys. 3), odporności na zużycie ślizgowe (rys. 4), jakościowej analizie rentgenowskiej (rys. 5) oraz obserwacji struktury z użyciem mikroskopu skaningowego (rys. 6). W wyniku badań stwierdzono, że odporność spieków na zużycie ślizgowe rośnie wraz ze wzrostem zawartości węglika wolframu, podczas gdy zwiększanie zawartości miedzi do 45% wyraźnie poprawia własności ślizgowe materiału, co stwarza nowe możliwości zastosowania badanych materiałów w węzłach tarcia.

INTRODUCTION

It has been well documented that high speed steels offer a unique combination of high hardness and mechanical strength as well as excellent resistance to heat and wear. These properties render high speed steels suitable for manufacture of various wear resistant constructional parts, automotive components etc. Good sintering behaviour of HSS powders combined with cost effectiveness of powder metallurgy technology initiated a comprehensive research towards developing an economic PM process for the manufacture of wear resistant materials at sintering temperatures possibly restricted to 1150°C. So far, the efforts have mainly been concentrated on:

- decreasing the densification temperature by means of a liquid phase formation at low temperatures due to additions of copper, phosphorus and carbon [1-11],
- improving wear resistance by adding refractory carbides and/or other hard phases [12-18],
- infiltrating HSS porous skeletons with copper alloys [19-21].

EXPERIMENTAL

The main characteristics of powders used in this study are given in Table 1.

Twelve M3/2 HSS powder-based mixtures with varying additions of WC and Cu were prepared by milling in a laboratory mortar-grinder for 2 hours. The powders were cold pressed in a rigid die at a pressure of 800 MPa. The green compacts were subsequently sintered over the temperature range between 1150 and 1250°C for 1 hour in vacuum better than 10^{-3} torr.

Concurrently with furnace sintering, dilatometry was used to monitor the compacts' shrinkage and to estimate the characteristic temperatures being of importance to the sintering process of specific powder compositions. Figure 1 shows typical dilatometric measurement taken on heating a green compact at 1°C/min in vacuum better than 10^{-3} torr. The differential curve, which represents an absolute shrinkage rate, has been plotted in addition to the relative shrinkage curve to assist in estimation of the sintering window of a specific powder composition [22].

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TABLE 1. **Selected properties of powders**
TABELA 1. **Wybrane własności proszków**

Powder Proszek	Particle size Wielkość cząstek µm	Apparent density Gęstość nasypowa g/cm^3	Tap density Gęstość nasypowa z usadem g/cm^3
M3/2 HSS	0÷160	2.26	3.13
WC	2÷3	2.70	4.55
Cu (electrolytic)	0÷40	1.60	2.08

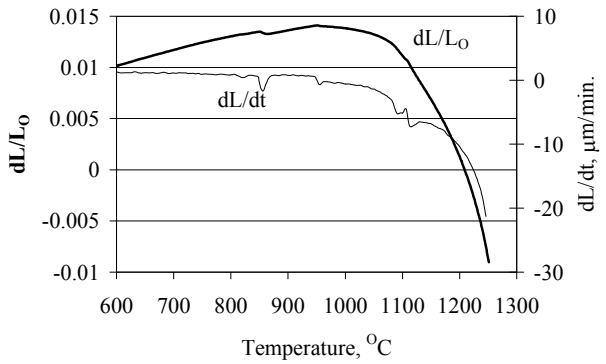

Fig. 1. Dilatometric evaluation of M3/2+30%Cu material
Rys. 1. Krzywe dylatometryczne dla spieku M3/2+30%Cu

The as-sintered specimens were subjected to density measurements, tested for hardness and resistance to the sliding wear as well as subjected to microstructural examinations and X-ray diffraction analysis.

The wear measurements were carried out using a fully computerised Block-on-Ring Wear Tester capable of simultaneous evaluation of friction coefficients. Steel 55, heat treated to 55 HRC, was used as the backing ring. The applied procedures complied with the ASTM D2714, G77, D2981 and D3704 standards.

RESULTS

The sintered densities, Brinell hardness numbers and sliding wear resistance data are summarised in Figures 2-4 respectively.

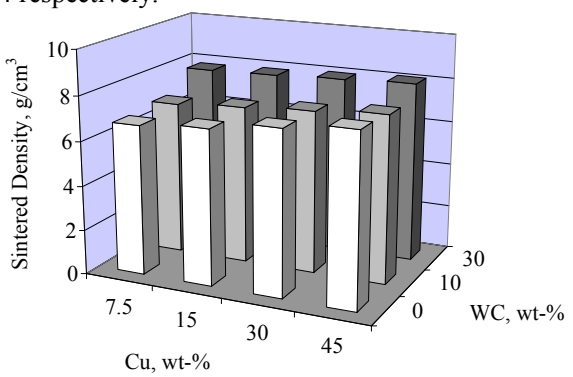

Fig. 2. Sintered density
Rys. 2. Gęstość spieków

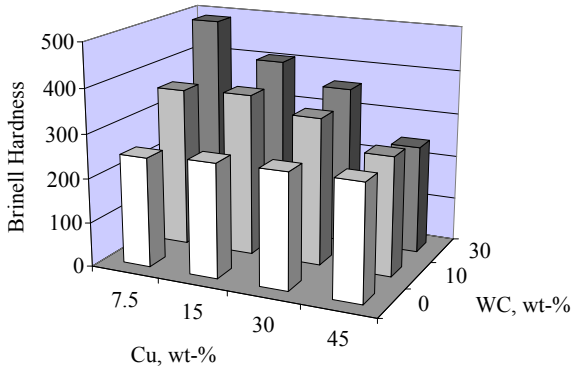

Fig. 3. Sintered hardness
Rys. 3. Twardość spieków

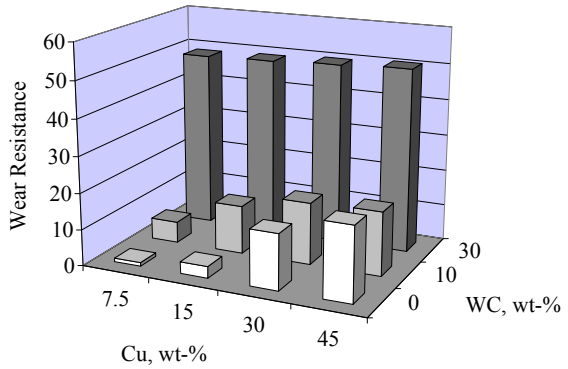

Fig. 4. Resistance to sliding wear
Rys. 4. Odporność na zużycie ślizgowe

The wear resistance of the test material has been expressed as the ratio of the volume wear of a reference material (M3/2+7.5%Cu) to the volume wear of the test material, under identical conditions.

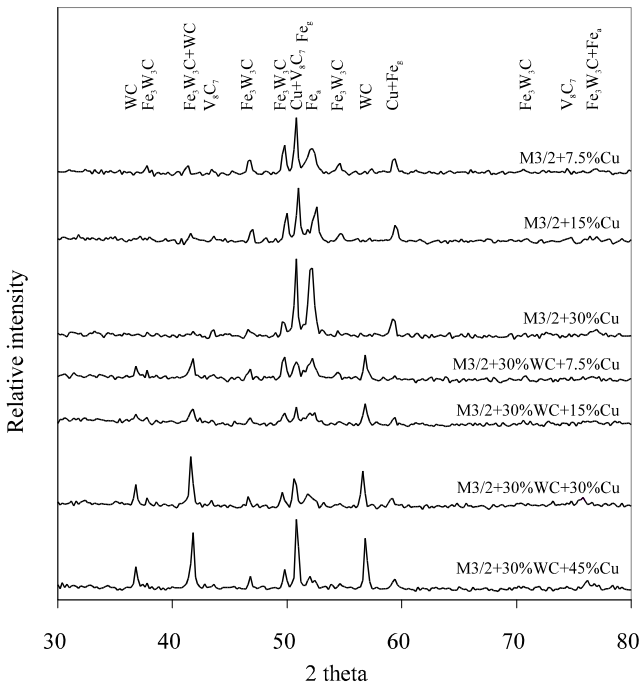

Fig. 5. X-ray diffractograms of the investigated materials

Rys. 5. Zapisy dyfraktograficzne dla badanych spieków

The lowest sliding coefficient values, ranging between 0.28 and 0.32, have been recorded for materials containing 45% Cu, which may render them effective in sliding applications.

The X-ray diffraction analysis has revealed complexity of the microstructure of the investigated composites (Fig. 5). Copper has not been fully dissolved in the HSS matrix during sintering, even in alloys containing 7.5% Cu, and forms copper rich regions with certain amount of iron dissolved.

A microstructure typical to HSS-WC-Cu composites is s

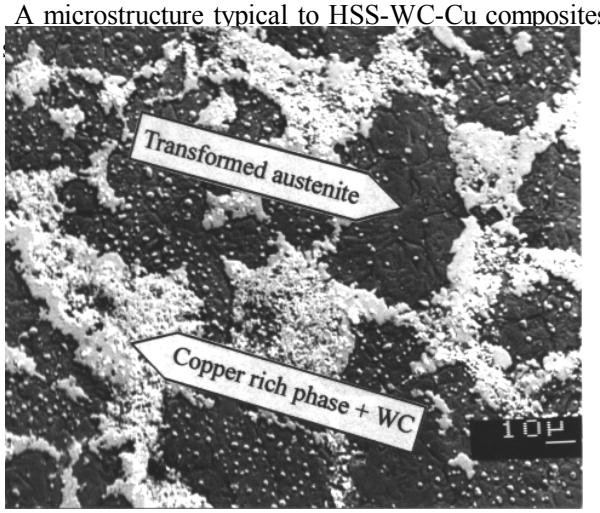

Fig. 6. SEM micrograph of M3/2+30%WC+7.5%Cu material
Rys. 6. Mikrostruktura spieku M3/2+30%WC+7.5%Cu

CONCLUSIONS

In view of the results described above the main conclusions may be described as follows:

- copper aids densification of both HSS-Cu and HSS-WC-Cu composites, whereas tungsten carbide additions have the opposite effect,
- additions of tungsten carbide increase hardness of HSS-WC-Cu composites except for materials containing 45% Cu; it has been found that the lower is the copper content the more profoundly is the hardness affected by tungsten carbide additions,
- tungsten carbide markedly increases resistance of HSS-WC-Cu composites to the sliding wear,
- copper effectively decreases friction coefficient of HSS-(WC)-Cu composites,
- microstructure of HSS-(WC)-Cu composites comprises two microstructural constituents i.e.: transformed austenite regions, with primary and secondary carbides, and copper rich, tungsten carbide impregnated (where added) regions,
- simplicity and flexibility of dilatometry render it useful as a complementary technique for the estimation of characteristic temperatures in HSS compositions.

The results presented above constitute the first part of the research project. Experimental work involving prealloyed CuP and graphite additions is still underway.

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REFERENCES

[1] Lezanski J., Dudrova E., Molnar F., Cias A., Hutnik - Wiadomości Hutnicze 1993, 12, 396.
[2] Lezanski J. et. al., Hutnik - Wiadomości Hutnicze 1995, 8, 286.
[3] Hellman P., et. al., Modern Developments in Powder Metallurgy, Plenum Press 1970, 4, 573.
[4] Smart J., Metal Powder Report 1980, 35, 241.
[5] Westerman E.J., Trans. AIME 1962, 224, 159.
[6] Hwang K.S., German R.M., Lenel F.V. Metall. Trans. A. 1987, 18A, 11.
[7] Cambal B., Lund J.A., Int. J. Powder Metall. 1972, 131.
[8] Podob M.T., Harvey R.P., Proceeding and Properties of High Speed Tool Steel, The Metallurgical Society 1980, 181.
[9] German R.M., Powder Metall. 1991, 34, 101.
[10] Bolton J.D., Jeandin M., Jouanny Trésy C., Powder Metall. 1990, 33, 126.
[11] Bolton J.D., Baah H.O., Powder Metall. 1991, 34, 273.
[12] Bolton J.D., Gant A.J., Powder Metall. 1993, 36, 267.
[13] Bolton J.D., Gant A.J., Powder Metall. 1994, 37, 983.
[14] Bolton J.D., Gant A.J., Powder Metall. 1994, 37, 1513.
[15] Oliveira M.M., Bolton J.D., Powder Metall. 1994, 37, 462.
[16] Zapata W.C., da Costa C.E., Torralba J.M., Powder Metall. 1994, 37, 455.
[17] Ashok S., Hariharan M., Krishnanand K.D., Advances in Powder Metallurgy & Particulate Materials 1996, Washington 1996, 5, 17, 213.
[18] Vardavoulias M., Jouanny-Tresy C., Jeandin M., Wear 1993, 165, 141.
[19] Greetham G., Powder Metall. 1990, 33, 112.
[20] Leżański J., Kruczek D., Rudy i Metale Nieżelazne 1993, 38, 254.
[21] Leżański J., Metalurgia i Odlewnictwo 1988, 118.
[22] Konstanty J., Proc. PM World Congress PM'94, Paris, 6-9 June 1994, Vol. II, 1011.

Recenzent
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