Dariusz BARTKOWSKI[1*], Bartłomiej DUDZIAK[2], Adam PIASECKI[1], Waldemar MATYSIAK[1]
[1] Poznan University of Technology
Pl. Marii Skłodowskiej-Curie 5, Poznan, Poland
e-mail: dariusz.bartkowski@put.poznan.pl
[2] Industrial Institute of Agricultural Engineering
ul. Starołęcka 31, 60-963 Poznan, Poland

POSSIBILITIES OF PRODUCTION OF THE COMPOSITE COATINGS REINFORCED BY HARD CERAMIC PARTICLES BY LASER CLADDING

Summary

The paper presents research results of metal matrix composite coatings produced on S355 steel using laser cladding. Two powder mixtures Stellite-6/30% B_4C and Stellite-6/30% SiC were used. The aim of this study was to determine the applicability of these materials in the production of composite coatings having a microstructure similar to sintered carbides. Applied carbides were characterized by very high hardness (B_4C – 3800 HV, SiC – 2500 HV) and a high melting point (B_4C – 2763°C, SiO – 2730°C). Such parameters are conducive to formation of coatings with composite microstructure. The purpose of analyzed process consisted in complete melting of matrix material, partial melting of reinforcing particles and minimal melting of substrate material. This effect has been achieved to a limited extent.
***Key words**: laser cladding, microstructure, EDS microanalysis, tungsten carbides, cobalt based alloys*

MOŻLIWOŚCI WYTWARZANIA KOMPOZYTOWYCH WARSTW POWIERZCHNIOWYCH WZMACNIANYCH TWARDYMI CZĄSTKAMI CERAMICZNYMI PRZY UŻYCIU NAPAWANIA LASEROWEGO

Streszczenie

Przedstawiono wyniki badań kompozytowych warstw powierzchniowych wytwarzanych na stali S355 przy użyciu proszkowego napawania laserowego. Zastosowano dwie mieszaniny proszkowe Stellite-6/30%B_4C oraz Stellite-6/30%SiC. Celem badań było określenie możliwości zastosowania tego rodzaju materiałów do wytwarzania kompozytowych warstw powierzchniowych o mikrostrukturze zbliżonej do węglików spiekanych. Zastosowane węgliki charakteryzowały się bardzo dużą twardością (B_4C – 3800 HV, SiC – 2500 HV) oraz wysoką temperaturą topnienia (B_4C – 2763°C, SiC – 2730°C). Takie parametry sprzyjają wytworzeniu warstwy o budowie kompozytowej. Celem badanego w pracy procesu było całkowite przetopienie materiału osnowy, częściowe cząstek fazy wzmacniającej oraz minimalne materiału podłoża. Efekt ten został osiągnięty w ograniczonym zakresie.
***Słowa kluczowe**: napawanie laserowe, mikrostruktura, mikroanaliza EDS, węgliki wolframu B_4C, stopy kobaltu*

1. Introduction

There are a limited number of publications related to manufacture of coatings reinforced with particles of boron carbide B_4C. Most often, ongoing research were related to combining these particles with other carbides, eg. tungsten or silicon [1]. X. Niu i M.J. Chao et al. have applied a method of laser cladding to produce coating based on Ni-Cr-Fe matrix [2, 3]. They made an attempt to strengthen the matrix by B_4C particles. They observed a very good metallurgical connection between coating and substrate, and microstructure of coating consisted of a dendritic matrix, wherein the B_4C phase was identified. It was also found that the microstructure of the bottom, middle and upper region of the coating has a different character. In the bottom area researchers found coniferous dendrites scattered in a matrix which was built from solid solution γ (NiFe). In the middle area and the surface area, beyond the coniferous dendrites, interdendritic, eutectic separation in the form of white tiles has also been observed. The authors showed that the addition of the interstitial phase of B_4C twice increased the wear resistance as compared to the coatings formed from pure Ni-Cr-Fe.

Only a few researchers have taken steps to increase the durability of the coatings by laser cladding using powder mixtures containing hard particles of SiC. Q. Li and his team [4] have conducted studies on the microstructure and wear resistance under dry friction conditions of coating with nickel matrix reinforced with particles of silicon carbide SiC. For this purpose, authors applied the powder mixture in proportions: 70% of nickel and 30% of SiC and cladded it on steel substrate. SiC particles completely fell away from the produced coating and consequently, the microstructure consisted of dendrites solid solution, dendritic carbides $M_{23}C_6$ and interdendritic eutectic. In the subsurface zone of layer, there was a small amount of spherical graphite precipitates. These phases acted as a self lubricating phase, thus reducing wear.

Surface treatment processes using hard ceramic phase allow to increase resistance to wear by friction [5-9] in different environments of tools operation. Therefore, the problems of strengthening the Stellite-6 coatings by carbides SiC and B4C are discussed in this paper. An analysis of the macro and microscopic being a prelude to further research.

2. Aim and Scope of Research

The aim of this study was to determine selected properties of metal matrix composite coatings in the system of Stellite-6 as matrix – boron carbides, silicon carbides and tungsten carbides as a reinforced phase. Macro- and microstructure were investigated.

2.1 Production Conditions of MMC Coatings

Metal matrix composite coating were produced on S355 low-carbon steel in order to improve properties of its surface. Chemical composition of S355 steel is shown in Table 1. The powder mixtures consisting of 70% of Stellite-6 and 30% of silicon or boron carbide were applied as a material to produce MMC coatings. Morphology of powders is shown in Figure 1.

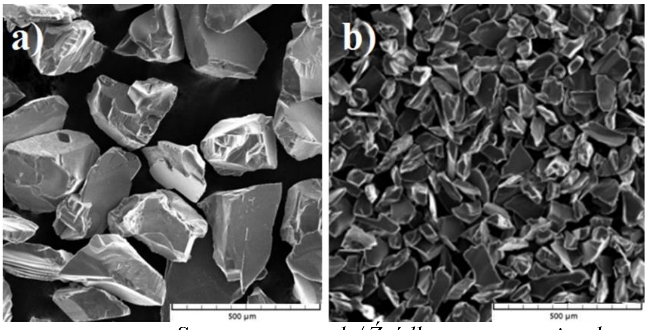

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Fig. 1. Morphology of powder: a) SiC, b) B_4C

Rys. 1. Morfologia proszku: a) SiC, b) B_4C

Laser cladding was carried out using different powers of laser beam: 400, 550 and 700 W and the same scanning speed which was equal to 340 mm/min. During laser cladding process, laser beam diameter 1,64 mm; 40% overlapping; powder feed rate of 2,75 g/min for SiC and 2,67 g/min for B_4C were applied. The schema of production of MMC coating using laser cladding technologyis is shown in Figure 2.

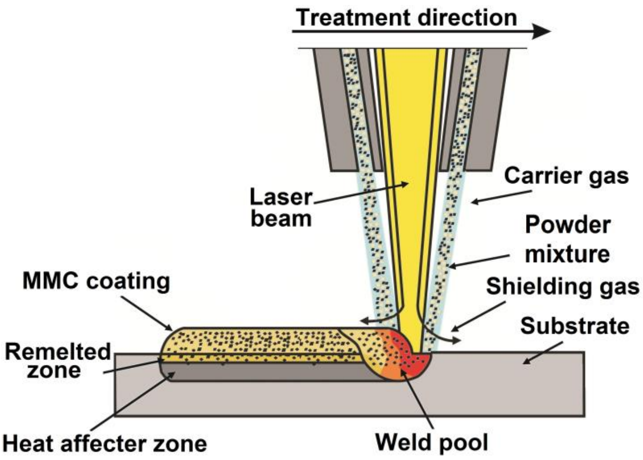

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Fig. 2. Schema of production of MMC coating using laser cladding technology

Rys. 2. Schemat wytwarzania kompozytowej warstwy powierzchniowej przy użyciu napawania laserowego

2.2. Macro- and microstructure

Macroscopic observations were performed using a Neophot 2 microscope. Metallographic cross-sections were etched using solution consisting of 25% HCl and 75% HNO3 and next were observed using VEGA TESCAN 5135 scanning electron microscope (SEM).

3. Results of Research

3.1. Stellite-6/30%SiC MMC coatings

Stellite-6/30% SiC coatings produced using laser beam power equal to 400 W and 550 W were characterized by a plurality of pores and gas bubbles (Fig. 3). Increasing the laser beam power to 700 W reduced the amount of blisters. The elimination of defects was caused by the delivery of a greater amount of heat to the material and hence its greater remelting.

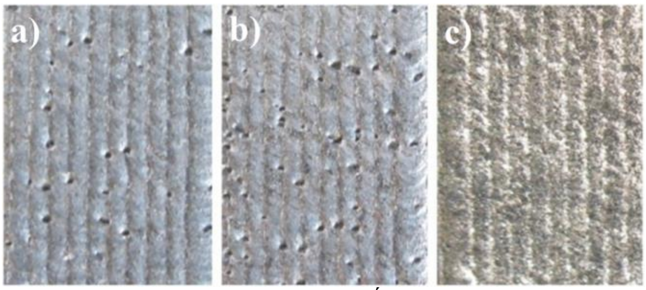

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Fig. 3 Stellite-6/30% SiC coatings produced using laser beam power: a) 400 b) 550 c) 700 W

Rys. 3. Warstwy powierzchniowe Stellite-6/30%SiC wytwarzane przy mocy wiązki lasera: a) 400 W, b) 550 W, c) 700 W

Figure 4 shows microstructure of Stellite-6/30% SiC coating formed using laser beam power equal to 700 W and a scan speed of 340 mm/min, resulting from digestion by nital. It was found the presence of porosity and numerous cracks over the entire cross of coating. Although not remelted primary carbides of silicon SiC are visible, and thus it is possible to form a composite coating, its quality is not satisfactory. Silicon carbide is mainly arranged in the surface zone, not evenly throughout the layer. It is associated with a large difference in the densities of the individual components of the powder mixture. The density of silicon carbide is equal to 3.22 g/cm³, while Stellite-6 8.44 g/cm³. More than 2.5 times lighter carbides during the deposition process float on the molten material, and after, form the subsurface carbides zone. By the presence of interstitial phases, this zone has a high hardness, but it is inappropriate to produce a coating having a thickness of about 1 mm, in which only the subsurface zone having a thickness of several tens of micrometers meets the criteria of the composite coating.

Table 1. Chemical composition of steels used for study

Tab. 1. Skład chemiczny użytych stali

	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	B	Ti	Fe
S355	0,185	0,128	1,180	0,016	0,002	0,282	0,070	0,135	0,335	0,000	0,015	Base

Source: own work / Źródło: opracowanie własne microstructure around silicon carbides occurred. Microstructure around the silicon carbide is shown in Figure 6. In addition, on the border of silicon carbide - metal matrix, plate separations of new interstitial phase were observed. Therefore, it was concluded that the connection between silicon carbide and Stellite-6 matrix, have diffusion character.

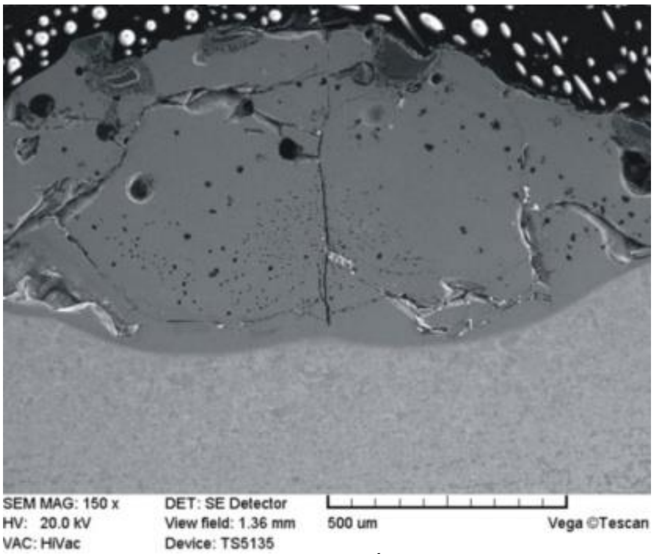

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Fig. 4. Microstructure of Stellite-6/30%SiC coating produced using laser beam power 700 W
Rys. 4. Mikrostruktura warstwy Stellite-6/30%SiC wytworzona przy mocy wiązki lasera 700 W

In addition, in composite zone of Stellite-6/30%SiC coating found lack of connection between silicon carbide and metal matrix. The wettability of silicon carbide by Stellite-6 alloy was so small that they are clearly separated from metal matrix. This resulted in formation of porosity and cracks in the zone on the border of carbide-matrix (Fig. 5). In addition, intensive heat dissipation through the steel substrate made impossible to slightly melt the surface layer of carbides, and hence their metallurgical connection with Stellite-6 matrix.

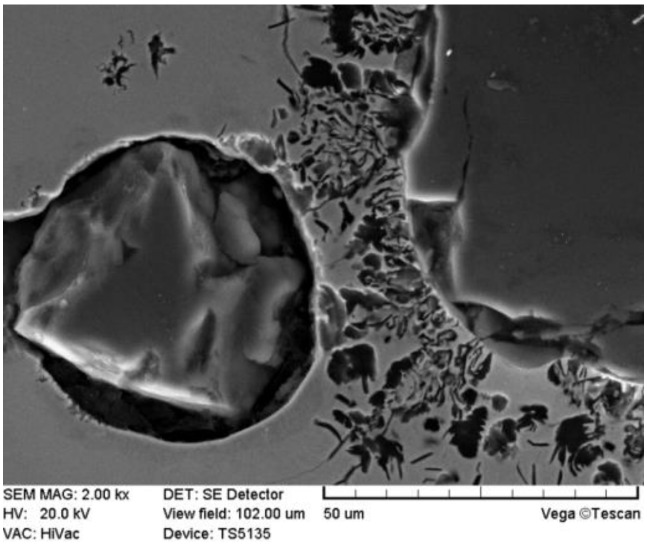

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Fig. 5. Lack of connection between silicon carbide SiC and Stellite-6 alloy matrix
Rys. 5. Brak połączenia między węglikiem krzemu SiC, a osnową ze stopu Stellite-6

In the superficial zone, where the heat dissipation by the substrate was less, and the interaction of the laser beam on the material more intense, melting of silicon carbide particles was observed. Effect of this, enriching of the matrix in carbon and silicon and formation of the eutectic

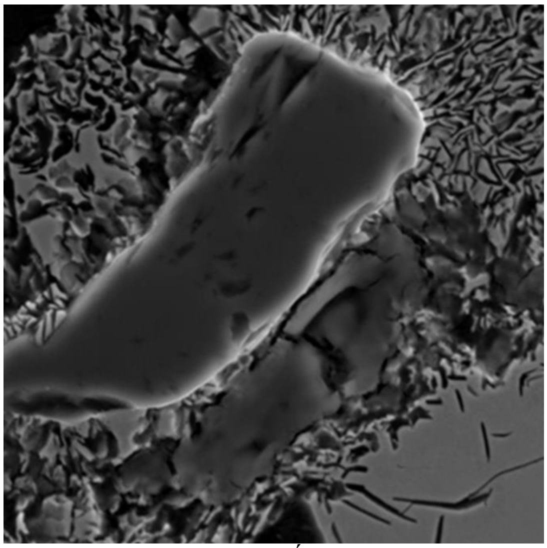

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Fig. 6. Microstructure around SiC carbide
Rys. 6. Mikrostruktura w obrębie węglika SiC

3.2. Stellite-6/30%B_4C MMC coatings

Macroscopic image of Stellite-6/30%B_4C coating was shown in Figure 7. This coating is not porous and does not crack. However, it has been found that with the increase in laser beam power the tendency to crack goes up. The resultant cracks are often invisible by naked eye, but they can be observed using scanning electron microscopy.

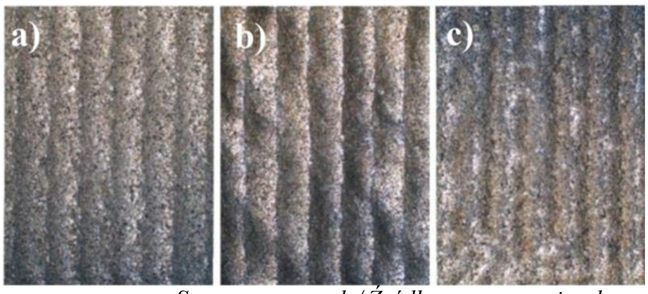

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Fig. 7. Stellite-6/30%B_4C coatings produced using laser beam power: a) 400 b) 550 c) 700 W.
Rys. 7. Warstwy powierzchniowe Stellite-6/30%B_4C wytwarzane przy mocy wiązki lasera: a) 400 W, b) 550 W, c) 700 W

Just like Stellite-6/SiC coatings, therefore coatings reinforced by boron carbide were characterized by a distribution of reinforcing particles only in the surface zone (Fig. 8a). It is also related to low density of interstitial phase. Boron carbide has a lower density than silicon carbide equal to 2,52 g/cm^3 and during the deposition process comes to surface of molten material. Boron carbides are better wettable by molten Stellite-6 alloy and in the area around them there is no porosity (Fig. 8b).

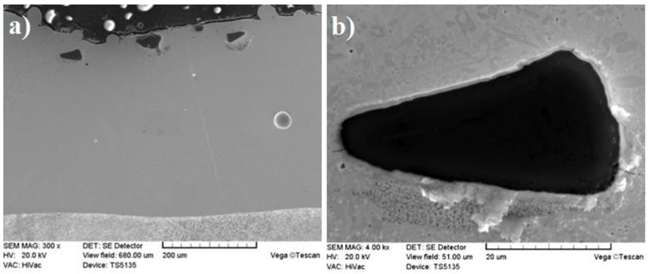

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Fig. 8. Stellite-6/30% B4C coating: a) microstructure, b) phase particle of B_4C
Rys. 8. Warstwa powierzchniowa Stellite-6/30%B_4C: a) mikrostruktura warstwy, b) cząstka fazy B_4C

Due to the use of boron carbide particles of a small size in the range from 25 to 50 µm, a lot of them were melted enriching the matrix with boron and carbon. Boron carbide with sharp and irregular shapes during the deposition process changed to an oval shape.

4. Conclusions

Addition of boron carbides and silicon carbides to Stellite-6 matrix did not produce positive results. The particles of these phases due to the low density compared to the Stellite-6 alloy, floated on the surface of molten material during the cladding process, making it difficult to establish itself in coating. These types of carbides were localized exclusively in subsurface area of produced coating.

5. References

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