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The morphology of TiC carbides produced in surface layers of carbon steel castings

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Abstract

The study presents the results of investigations of the process of in situ fabrication of TiC carbides in a surface layer of carbon steel casting. Carbides were produced by SHS reaction taking place between the substrates deposited on mould surface and cast molten alloy. The thickness of the obtained layer was up to 700 μm, and the size of carbides was comprised in a range of 1-10μm. During alloy solidification in mould, a thermal analysis was carried out; its results were used in evaluation of the morphology of the obtained titanium carbides. It has been found that, at the moment of reaction, the temperature of the reaction layer and the temperature of the central part of casting differed by 93 K. This difference has changed the morphology of the obtained carbides. In the region of reaction layer, where the temperature amounted to 1955 K, the crystals assumed an oval and coagulated shape, while at the layer-casting interface, TiC carbides in the form of cuboids were formed.

Keywords: Composite layers, Composite in situ, SHS process, Morphology, Solidification, Superficial layer, Cast steel, Carbides of TiC

1. Introduction

Manufacture of cast structural components locally reinforced with hard phases resistant to tribological wear is an interesting and economically justified research area. Special attention deserve ferroalloys, mainly because of a relatively low manufacturing cost and good mechanical properties, hardness and abrasive wear resistance. Currently, for the manufacture of hard and wear-resistant composite layers, among others, the following methods are used: powder [1,2], laser including LISHS (laser ignited self-propagating high-temperature synthesis) [3], plasma LPPS (low pressure plasma spraying) [5] and casting [6]. One of the methods used in fabrication of composite layers reinforced with TiC, NbC and TaC carbides is the SHS synthesis (self-propagating high-temperature synthesis) [7-8]. This study presents the results of investigations involving fabrication on steel castings of a composite layer reinforced with titanium carbides and examination of the casting solidification process in foundry mould as having an impact on the morphology of TiC carbides obtained by SHS reaction.

2. Methods of investigation

The mixture of substrates necessary for titanium carbide synthesis was prepared by SHS technique according to equation 1.

$$Ti + C = TiC \quad (1)$$

To perform this task, commercial products (Aldrich), titanium powder of 99,98% purity and 44 μm granulation, and graphite rods (150 x φ6 mm) of 99,99% purity were used. The graphite rods were ground in a ring-type eccentric mill, obtaining powders of 30 μm granulation. The powders were next mixed together in appropriate ratios for 24h. After the lapse of this time, 20g of powder was compacted on the bottom of the previously prepared mould.

Table 1 gives chemical composition of the investigated cast steel.

Table 1

Materials	Chemical compositions (mass%)										
Base metal	C	Si	Mn	Cr	Cu	Ni	V	Al	Mo	S	P
	0,24	0,52	0,71	0,25	0,16	0,058	0,05	0,04	0,025	0,03	0,02

The mould was made from a mixture of molochite and sodium silicate, blown with CO_2, a schematic representation of which is shown in Figure 1.At the next stage of the process, moulds with the applied layer of reagents were dried at a temperature of 773 K for 10min to be placed later in the chamber of a Balzers furnace. To perform the thermal analysis of the alloy solidification process in mould, two Pt10Rh-Pt thermocouples (S type) were mounted, one in the layer of the reaction substrates and the other in the central part of mould (Fig. 1c). The furnace crucible was filled with charge of a composition corresponding to the composition of carbon steel in Table 1; melting was carried out in the atmosphere of protective gas (argon). When metal reached the temperature of 1823 K, it was poured into a mould placed in the furnace chamber. The ready casting was cut into pieces and specimens were taken for the scanning microscopy (SEM), X-ray microanalysis (EDX/EDS) and phase analysis (XRD).

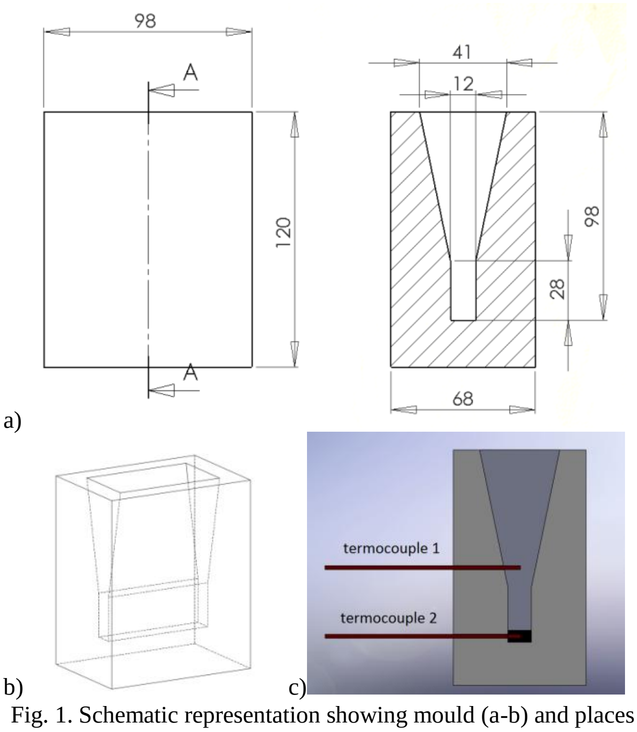

Fig. 1. Schematic representation showing mould (a-b) and places where thermocouples were placed (c)

3. The results

Figure 2 shows SEM image of composite layer produced by SHS synthesis in alloy melt. It consists of dispersive and locally coagulated hard titanium carbides distributed in alloy matrix; the thickness is approximately700 μm.

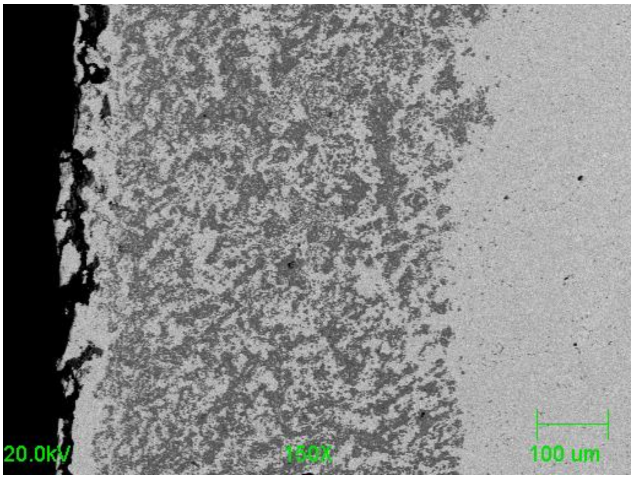

Fig. 2. Composite layer produced on carbon steel casting

Figure 3 shows phase composition of composite layer fabricated on carbon steel casting. In terms of structure, the matrix of the composite layer is alpha iron; the reinforcing phase is titanium carbide. This result confirms the correct course of the SHS synthesis in molten alloy.

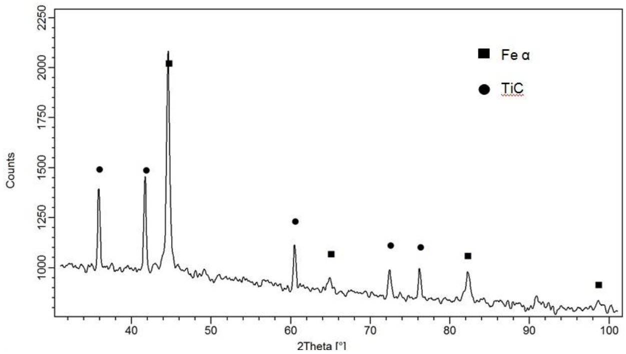

Fig. 3. Phase analysis of composite layer produced on carbon steel casting

Figure 4 shows the results of thermal analysis carried out in mould (Fig. 1c). From the run of the cooling curves it follows that the difference between molten alloy temperature in the reaction layer and in the central part of mould is 93 K. The thermal analysis also indicates different run of the alloy solidification process in the region of thermocouples 1 and 2. The curve plotted by thermocouple 1 placed outside the substrate reaction layer shows absence of a typical arrest corresponding to the peritectic transformation occurring in hypoeutectoid cast steel. The said arrest appears on the curve plotted by thermocouple 2, placed in a layer of the Ti and C powders mixture.

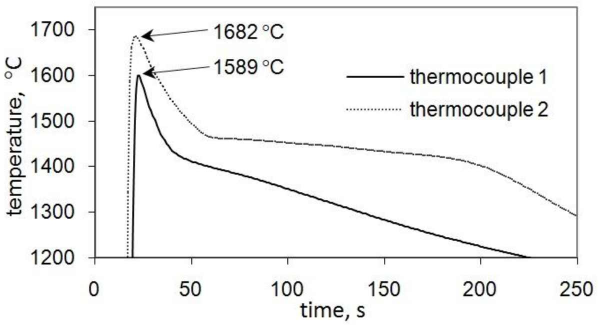

Fig. 4. Thermal analysis of the process as recorded in a layer of reaction substrates (thermocouple 2) and in the central part of casting (thermocouple 1)

Figures 5 and 6 shows morphologies of titanium carbides obtained in the casting composite layer; the size of the carbides is 1-10μm. The first morphology includes oval and coagulated crystals visible in Figure 5. This is the morphology found in a substrate reaction layer (the zone of thermocouple 2). The second morphology includes typical faceted crystals shown in Figure 6, which grow at the layer-casting interface (the zone between thermocouples 1 and 2).

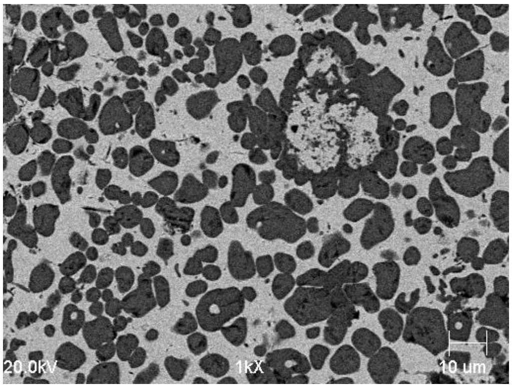

Fig. 5. The region of composite layer with well-visible precipitates of TiC carbides in coagulated form

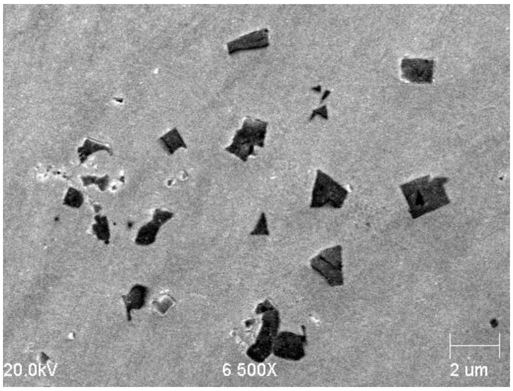

Fig. 6. The region of composite layer with well-visible precipitates of TiC carbides in faceted form

To reveal the spatial form of TiC carbides, the specimen was subjected to deep etching. The topographic images shown in Figures 7 and 8 confirm the oval and faceted character of TiC carbides obtained by synthesis.

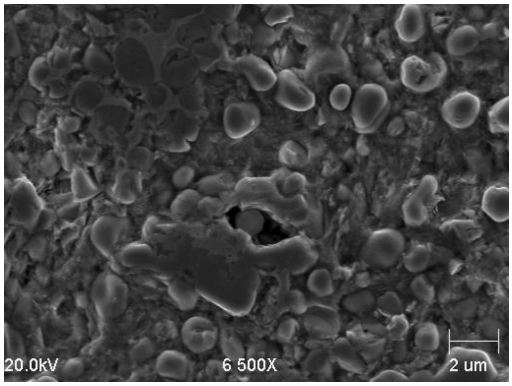

Fig. 7. SEM image of composite layer with oval coagulated forms of TiC crystals

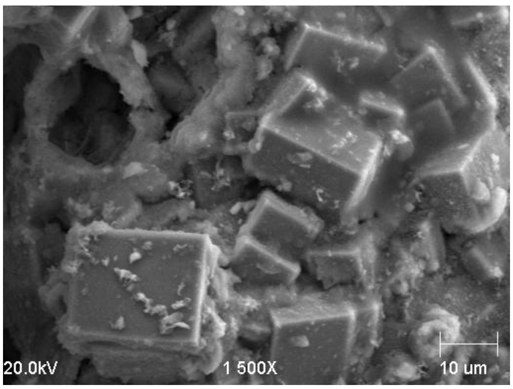

Fig. 8. SEM image of composite layer with faceted forms of TiC crystals

4. Conclusions

The study includes the results of investigations relating to the fabrication of composite layer in carbon steel castings. The layer was produced by introducing into mould cavity the reaction substrates of SHS reaction which under the influence of the heat supplied by liquid alloy have undergone the process of synthesis. As a result of this reaction, on the surface of casting, a composite layer of 700 μm thickness (Fig. 2), composed of alpha iron matrix and titanium carbides distributed in this matrix, was formed (Fig. 3). In the layer, two forms of TiC crystals were identified – the first form was oval and coagulated (Fig. 5 and 7), the second form was of a faceted character (Fig. 6 and 8). The results of the thermal analysis of the solidification process (Fig. 4) indicate that alloy temperature in the area of thermocouple 2 is by 93 K higher than the temperature in the area of thermocouple 1. Hence a conclusion follows that the process of TiC crystal growth within the zone of reaction has assumed a course different than at the casting boundary. The locally increased temperature of SHS reaction resulted in surface melting of crystals which, due to both their number as well as a turbulent character of the SHS reaction, were coagulating. As regards crystals placed outside the reaction zone or at its boundary, their growth was unrestrained making them assume the shape of cuboids (Fig. 8).

Acknowledgements

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References

[1] W. Yisan, D. Yichao, W. Jing, Ch. Fengjun, S. Jianguo, In situ production of vanadium carbide particulates reinforced iron matrix surface composite by cast-sintering, Materials and Design, 28 (2007) 2202-2206.

[2] Kieback, A. Neubrand, H. Riedel, Processing Techniques for Functionally Graded Materials, Materials Science and Engineering A, 362A (2003) 81-105.

[3] Y.X. Li, J.D. Hu, H.Y. Wang, Z.X. Guo, Study of TiC/Ni_3Al Composites by Laser Ignited Self-propagating High-temperature Synthesis (LISHS), Chemical Engineering Journal, 140 (2008) 621-625.

[4] K. Khor, Y.W. Gu, Z.L. Dong, Plasma Spraying of Functionally Graded Yttria Stabilized Zirconia/NiCoCrAlY Coating System Using Composite Powders, Journal of Thermal Spray Technology, 9 (2000) 245-249.

[5] H. Park, K. Nakata, S. Tomida, In Situ Formation of TiC Particulate Composite Layer on Cast Iron by Laser Alloying of Thermal Sprayed Titanium Coating, Journal of Materials Science 35 (2000) 747-755.

[6] K. Asano, H. Yoneda, Formation of In Situ Composite Layer on Magnesium Alloy Surface by Casting Process, Materials Transactions, 49 (2008) 10, 2394-2398.

[7] E. Fraś, A. Janas, A. Kolbus, E. Olejnik, Matrix- Particle Interphase Boundaries of the Selected In Situ and Ex Situ Composites MMCs ,Archives of Foundry, 6 (18) 2006, 297-304 (in Polish).

[8] E. Fraś, A. Janas, A. Kolbus, E. Olejnik, Cast Ni_3Al/MeC (Me-W,Zr) Composites In Situ, Archives of Foundry, 6 (18) (2006), 317-324 (in Polish).