ARCHIVES of FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 8
Issue 3/2008

105 – 110

19/3

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Model castings with composite surface layer - application

J. Szajnar, P. Wróbel*, T. Wróbel
Silesian University of Technology, Foundry Division, Towarowa 7, 44-100 Gliwice, Poland
* Corresponding author. E-mail address: piotr.wrobel@polsl.pl

Received 18.04.2008; accepted in revised form 29.04.2008

Abstract

The paper presents a method of usable properties of surface layers improvement of cast carbon steel 200–450, by put directly in founding process a composite surface layer on the basis of Fe-Cr-C alloy. Technology of composite surface layer guarantee mainly increase in hardness and aberasive wear resistance of cast steel castings on machine elements. This technology can be competition for generally applied welding technology (surfacing by welding and thermal spraying). In range of studies was made cast steel test castings with composite surface layer, which usability for industrial applications was estimated by criterion of hardness and aberasive wear resistance of type metal-mineral and quality of joint cast steel – (Fe-Cr-C). Based on conducted studies a thesis, that composite surface layer arise from liquid state, was formulated. Moreover, possible is control of composite layer thickness and its hardness by suitable selection of parameters i.e. thickness of insert, pouring temperature and solidification modulus of casting. Possibility of technology application of composite surface layer in manufacture of cast steel slide bush for combined cutter loader is presented.

Keywords: Composites; Composite surface layer; Cast steel

1. Introduction

In the last years in machine-building industry is required a large number of castings with special properties, for example high aberasive wear resistance and heat-resisting. These elements are produced from expensive and difficult to available materials. However in many cases high properties are necessary for surface layers of castings. Therefore unprofitable is founding of complete element with expensive alloy additions i.e. Ni, Cr, Mo or Ti [1÷11].

In methods of composites production on special attention deserves founding method. This technology by put directly in founding process a composite surface layer is the most economic methods of enrichment of casting surface [1, 2].

Modern technologies of surface engineering are connected with manufacturing of composite surface layer on casting surface sectors, where are very difficult conditions of working. These surfaces perform technical and useful requirements and moreover increase life of casting. In case of strengthening of complete surface, favourable is founding of complete casting from highly alloyed material. Then parameters of founding technology of composite surface layer are nearly identical with manufacturing of usual casting. Properties of surface layer of casting depend mainly from self-cooling conditions and reaction on surface of metal-mould, that is on type of influence of mould material on surface layer of casting in time of pouring and self-cooling of casting [1÷11].

2. Range of studies

The main aim of studies was improvement of usable properties i.e. hardness and aberasive wear resistance of type metal-mineral of surface layer of cast carbon steel 200-450

(Tab.1) casting, by put directly in founding process a composite surface layer on the basis of Fe-Cr-C alloy (Tab.2).

Table 1.
Chemical composition of cast carbon steel 200-450

Mass contents in %				
C	Mn	Si	P	S
0,60	1,25	0,60	0,03	0,03

Table 2.
Chemical composition of Fe-Cr-C alloy

Mass contents in %				
C	Cr	Si	P	S
8,65	66,50	0,75	0,02	0,01

In range of experimental plan was made 18 test castings in shape of spheres with diameter 100, 80 and 60 mm. Metal was poured into the shell mould, which contains a inserts with thickness 2, 3 i 4 mm (Fig.1). On the basis on values of liquidus temperature T_L = 1525°C and solidus temperature T_S = 1490°C of investigated cast steel, pouring temperature was set to 1550 and 1600°C.

a) b)

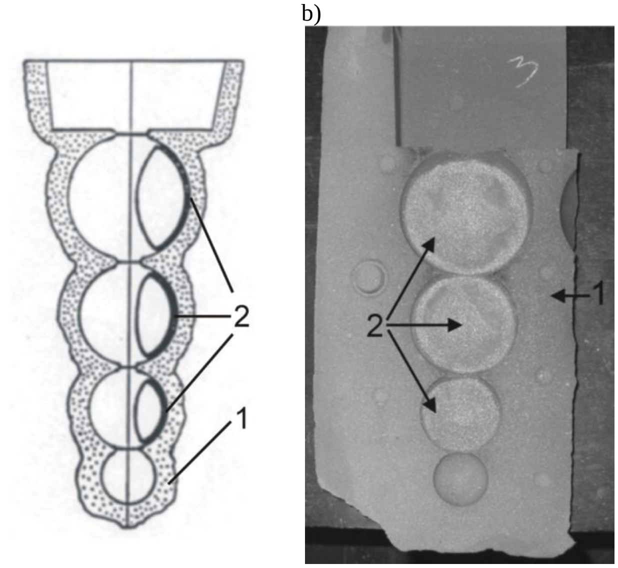


Fig. 1. Scheme (a) and view (b) of shell mould (1) with composite insert (2)

In aim of determination of solidification process course were registered a cooling curves in geometric centre of sphere, on border of composite insert – cast steel and on surface of mould. To registration of cooling curves 24 channels Cristaldigraph M24 and computer program M1lab was used.

In aim of assessment of quality of joint between cast steel and composite surface layer was made metallografic examinations with use of light microscopy Nikon EPIPHOT-TME with magnification from 100x to 600x. Surfaces of samples which were prepared for microstructure analysis were etched with use of Nital.

Thickness of composite layers were measured on cross-section of castings with use for thickness to 5 mm of magnifying glass with magnification 10x and scale 0,1 mm and for thickness above 5 mm with use of slide caliper.

Hardness examinations of composite layer, transition zone and cast steel (Fig.2) were made on ultrasound MIC2 hardness tester with load 49N.

Wear resistance investigations were measured on the basis of ASTM G 65 - 00 standard (Fig.3).

Fig. 2. Scheme of hardness measurement on cross-section of test casting of sphere

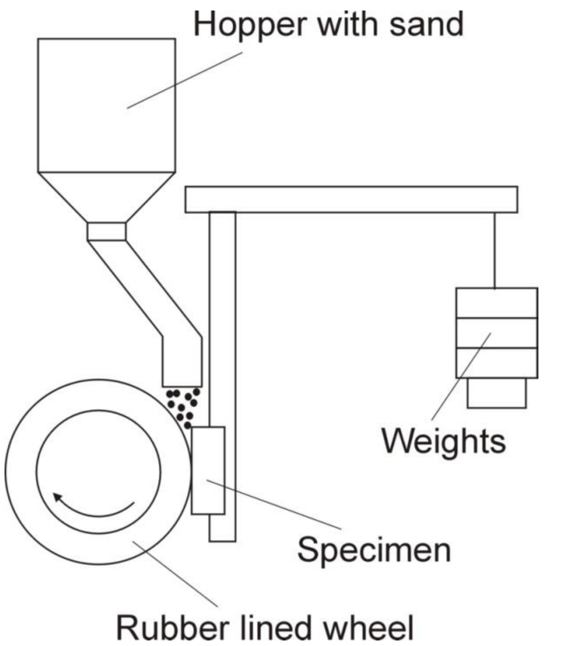


Fig. 3. Schematic diagram of test apparatus to wear resistance investigation [12]

3. Results and analysis

On the basis of studies in result of which was obtained of cast steel casting with composite surface layer, was formulated, that at pouring temperature 1550 °C and inserts with thickness 2 mm in sphere ϕ100, in selected points on border of composite insert – cast steel and composite insert – shell mould, temperature considerably exceed T_L = 1281°C and T_S = 1220°C of composite material Fe-Cr-C (Fig.4). In result of large heat capacity and high pouring temperature, composite insert was totally melted and does not create a composite layer. Likewise composite insert was melted in sphere ϕ80 as was shown on Figure 4 (lines 2.1÷2.3). After as maximal value was achieved, temperature decreases and next increases. This confirmed a thesis, that after contact with composite insert on surface of lquid metal was created a thin layer of cast steel, which returns heat to the insert and next this layer was melted again in result of large heat capacity of casting. In this case composite insert is external chill for cast steel casting.

Analogous to this phenomenon is process, which was proceeded in sphere ϕ60, but decreases and next increases of temperature is smaller.

In second test for insert thickness 3 mm, only in sphere ϕ60 on border of composite insert – shell mould, the insert was not heated to T_S and T_L of the insert basic material (Fig. 5). It result from larger thickness of the insert and smaller modulus of sphere. In result of these studies was achieved conditions of composite surface layer creation after totally melted of the insert, which allow to foresee a maximal thickness of composite insert at apply pouring temperature and solidification modulus of casting in aim of obtain of correctly enriched cast steel casting. The cooling curves for spheres with diameter ϕ80 and ϕ100 (Fig. 5, lines 1.1÷1.3 and 2.1÷2.3) shown, that on border of composite insert – cast steel and composite insert – shell mould, temperature achieves T_S and T_L of the insert basic material. This testify about melting of composite insert.

In third test for insert thickness 4 mm, only in sphere ϕ100 were temperatures higher than T_S and T_L of the insert basic material. Whereas in spheres ϕ80 and ϕ60 temperature does not achieve only T_L of the insert basic material (Fig.6).

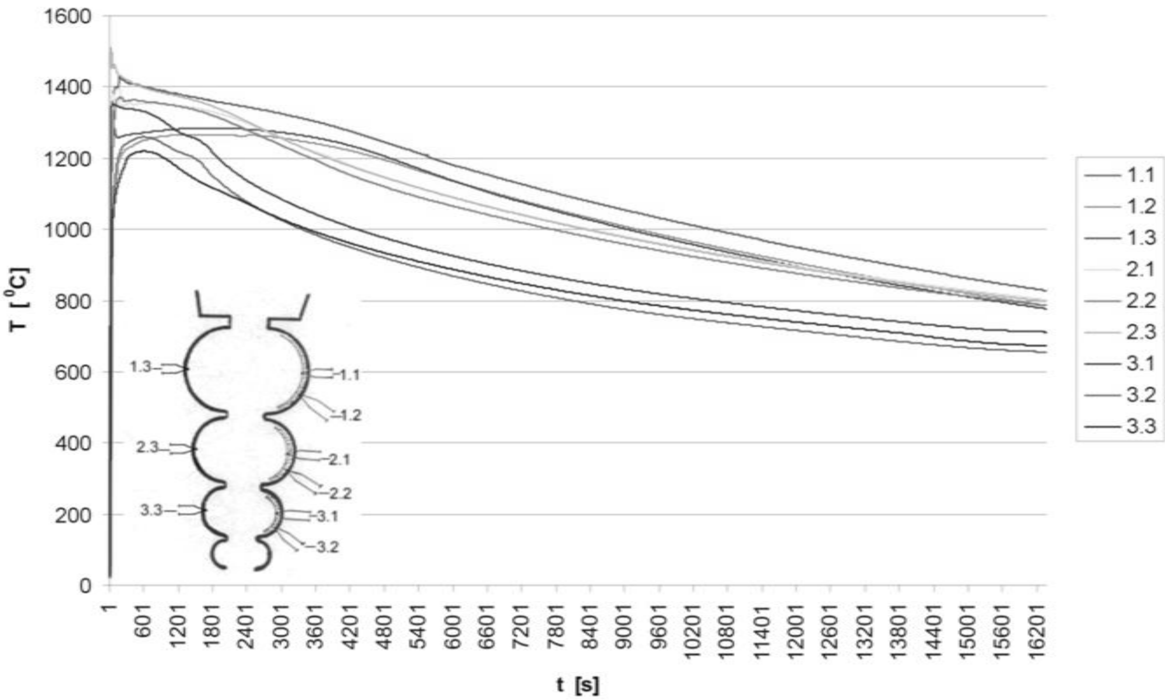


Fig. 4. The cooling curves for test casting with pouring temperature $T_{zal} = 1550^0$C and thickness of insert 2 mm

The results of hardness and thickness measurements of composite surface layers are presented in Table 3. Thickness of composite surface layers is larger than thickness of composite insert. Moreover thicker layers have smaller hardness than thin layers. It result from larger diluting of alloying constituents after long time of diffusion. Average of measurements of hardness for sphere ϕ100 with thickness of composite insert 4 mm was 469HV and for sphere ϕ60 with the same thickness of composite insert was 490HV. Probably it result from smaller content of carbides in sphere, which has larger diameter. However confirmation of this thesis demands to make a quantitative research of carbides distribution in composite layer. Hardness of transition zone has value between hardness of composite surface layer and hardness of cast steel. Likewise as for hardness of composite surface layers, hardness of transition zone is smaller for larger spheres. In accurate correlation with results of hardness are results of research of aberasive wear resistance of type metal-mineral. Composite surface layers have about quadruple higher aberasive wear resistance than cast steel 200-450 (Fig.7).

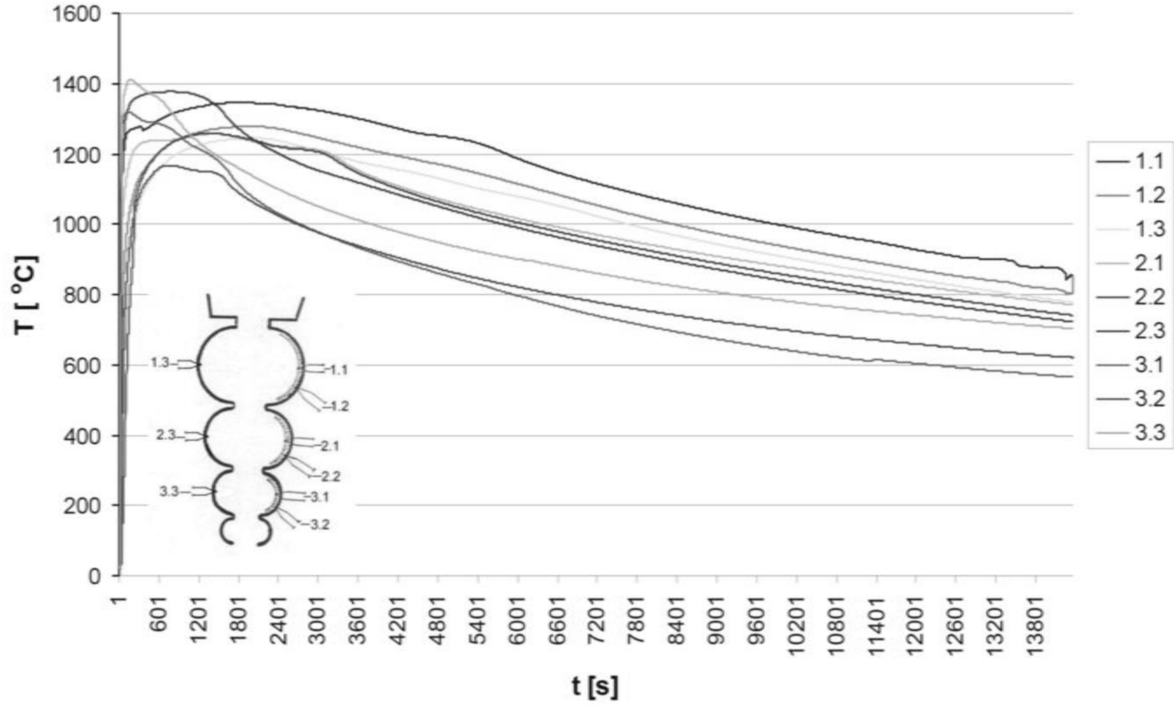


Fig. 5. The cooling curves for test casting with pouring temperature T_{zal} = 1550^{0}C and thickness of insert 3 mm

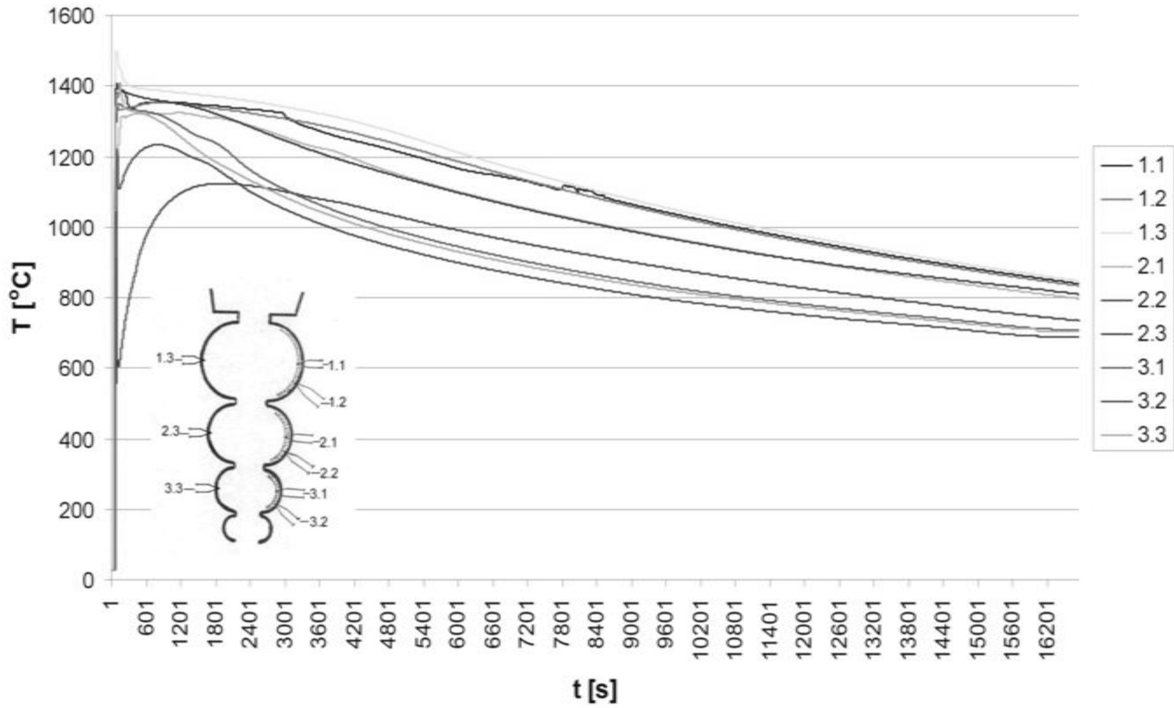


Fig. 6. The cooling curves for test casting with pouring temperature T_{zal} = 1550^{0}C and thickness of insert 4 mm

Table 3.
Results of measurements of hardness and thickness of composite surface layers on cast steel castings

No.	T_{ZAL} [°C]	Diameter of sphere [mm]	Thickness of insert [mm]	Thickness of composite layer [mm]	$\overline{HV}$ Area*		
					I	II	III
1	1550	60	2	3,4	475	353	360
2		80		2,5	480	382	
3		100		0,1	–	370	
4	1600	60	2	3,7	444	347	350
5		80		3,0	468	365	
6		100		3,3	450	351	
7	1550	60	3	4,0	428	312	360
8		80		3,8	452	344	
9		100		3,5	478	333	
10	1600	60	3	4,0	493	382	365
11		80		4,9	426	321	
12		100		5,0	430	334	
13	1550	60	4	4,3	480	326	353
14		80		5,1	473	312	
15		100		5,1	460	302	
16	1600	60	4	3,1	490	481	361
17		80		5,6	430	287	
18		100		5,3	469	400	

* - Area I – composite layer, II – transition zone, III – cast steel.

On the basis of metallographic examinations it was affirmed, that high quality of joint between composite insert – cast steel was obtained. Transition zone is very uniform and has not in its a acute boundary of distribution (Fig. 8 and 9).

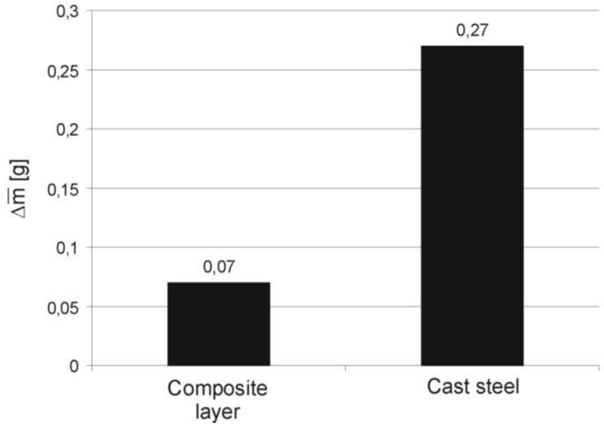


Fig. 7. Aberasive wear resistance of type metal-mineral, $\overline{\Delta m}$ - mass loss

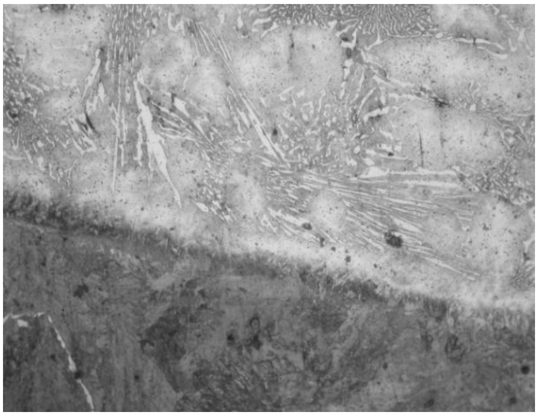


Fig. 8. Structure of transition zone composite layer (ferrite and carbide eutectic) – cast steel (pearlite), magnification: 200x, etching: Nital

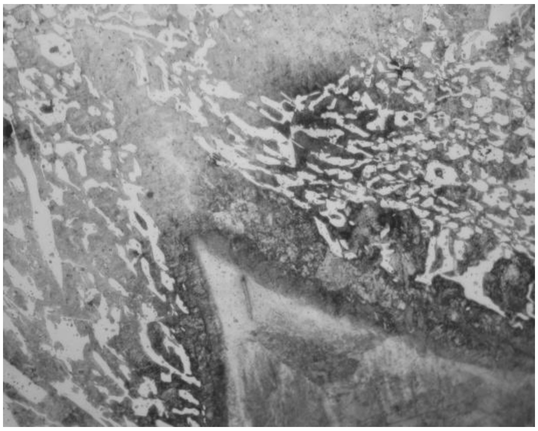
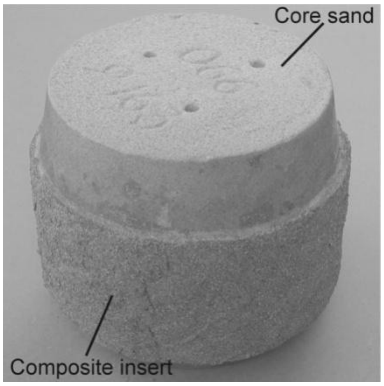


Fig. 9. Structure of transition zone composite layer (ferrite and carbide eutectic) – cast steel (pearlite), magnification: 400x, etching: Nital

4. Industrial application

On the basis of conducted studies analysis, industrial application of composite surface layers technology was made. This application take in founding of cast steel slide bush for combined cutter loader, in which move a arm of head to mining of hard coal. On Figure 10 was presented view of core with composite insert and of slide bush with composite layers on internal surface, which cooperates with shaft.

a)



b)

Fig.10. Core with composite insert (a) and casting of slide bush ($\phi_{wew.}$= 160 mm) for combined cutter loader (b)

5. Conclusions

Based on conducted studies following conclusions have been formulated:

1. Composite surface layers arise from liquid state.
2. Possibility have been shown of control of thickness, hardness and aberasive wear resistance of type metal-mineral of composite surface layer by suitable selection of parameters i.e. thickness of composite insert, pouring temperature and solidification modulus of casting. Composite layers with large thickness are results from use of larger thickness of composite insert, higher pouring temperature and larger thickness of casting wall i.e. larger solidification modulus.
3. Thicker layers have smaller hardness than thin layers. It result from larger diluting of alloying constituents after long time of diffusion. But confirmation of this thesis demands to make a further research.
4. Obtained thickness of composite layers are proper for assurance of suitable time of castings exploitation.
5. High quality of joint between composite surface layer and cast steel guarantee suitable life of investigated castings in exploitation conditions.

References

[1] J. Gawroński, J. Szajnar, P. Wróbel, Surface composite layers cast iron – ceramics particles, Archives of Foundry, vol. 5, No. 17 (2005) (in Polish).

[2] J. Gawroński, J. Szajnar, P. Wróbel, Technology of surface composite layers on castings, Archives of Foundry, vol. 6, No. 19 (2006) (in Polish).

[3] M. Ashby, Criteria for selecting the components of composites, Acta Metallurgica, No. 41 (1993).

[4] M. Cholewa, Simulation of solidification process for composite micro-region with incomplete wetting of reinforcing particle, Journal of Materials Processing Technogy, No. 15 (2005).

[5] J. Sobczak, Modern tendency of practical application of metal composite, Composite, No. 3 (2002) (in Polish).

[6] I. Sidorin, V. Silaeva, T. Soloveva, V. Solton, G. Eskin, Cast composite alloy for perforator parts, Material Science and Heat Treatment, vol. 13, No. 8 (1971).

[7] S. Tomczyński, Quality of centrifugal composite castings after composite remelting, Solidification of Metals and Alloys, vol. 2, No. 43 (2000) (in Polish).

[8] R. Zhou, Y. Jiang, D. Lu, The effect of volume fraction of WC particles on erosion resistance of WC reinforced iron matrix surface composites, Wear, No. 255 (2003).

[9] R. Asthana, Processing effects on the engineering properties of cast metal-matrix composites, Advanced Performance Materials, No. 5 (1998).

[10] C. Li, F. Ellgin, S. Koh, S. Oh, Influence of porosity on fatigue resistance of cast SiC particulate-reinforced Al-Si alloy composite, Materials Science and Engineering, No. A276 (2000).

[11] J. Szajnar, P. Wróbel, T. Wróbel, Enrichment of casting surface in founding process, Archives of Foundry Engineering, vol. 7, No. 3 (2007).

[12] Standard ASTM G 65 – 00.