ARCHIVES
of
FOUNDRY ENGINEERING
Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 10
Issue 1/2010

191 – 198

33/1

The influence of the size of ferrochromium grain on the surface composite layer forming process

J. Szajnar, C. Baron*, A. Walasek
Foundry Department, Faculty of Mechanical Engineering, Silesian University of Technology
ul. Towarowa 7, 44-100 Gliwice POLAND
*Corresponding author. E-mail address: czeslaw.baron@polsl.pl

Received 03.08.2009; accepted in revised form 03.09.2009

Abstract

The aim of the researches was to determine the influence of the size of high - carbon ferrochromium grain (which was used to make the pad) on the quality of the composite layer on the steel cast. This kind of cast was obtain by pouring the mould with the pad placed on the chosen surface with liquid metal. As thick as possible composite layer without any defects and discontinuity was required. Both good quality and required thickness of surface composite layer depend on many factors. The pouring temperature, module of cast solidification, size and shape of the cast are the most important ones. The suitable graininess of pad material is also significant parameter. The conducted researches allowed to take the suitable graininess of the pad material which improved the quality of the surface composite layer.

Keywords: Composite, Cast, Surface composite layer, Ferrochromium, Graininess

1. Introduction

Composite materials seems to be a good answer for demand of industry for materials with better constructional and exploitation properties. They also make it possible to obtain desired properties in particular place. This kind of composite material is obtained by foundry method. The technology of composite layer forming process make it possible to obtain in a chosen place many desired properties:

- great hardness, much bigger then the one of basic cast,
- great wear resistance, much bigger then the one of basic cast,
- great thickness of the alloy composite layer depending on the work conditions of the cast wall,
- two – stage heat treatment is not necessary.

The foundry method of alloy layer forming process on the cast is the following. First, the mould is prepared by drift of alloy layer (FeCr800) to proper cavity. Next, it is poured by liquied metal [1,2,3]. Composite alloy layer is obtained as a result of cooperation between cast steel poured to the mould and alloy coat [4,5].

Surface layer forming process depends on many chemical and physical factors. First of all, the obtain properties depend on cooling conditions and the reaction on the surface metal/pad (it means the kind of interaction between the pad material and surface cast layer). The size of the composite pad grain also influences the quality of composite layer. The pad should characterize the following properties [6,7]:

- the suitable graininess of the dispersion material,
- cooling temperature lower then basic material's,
- non gascreative binder,
- exactly determined thickness.

2. The aim and the range of researches

The aim of the researches was to determine the influence of the pad grain size on the quality of composite layer on the steel cast. This kind of cast was obtained by pouring the mould with the composite pad placed on chosen surface by liquid metal. As thick as possible composite layer without any defects and discontinuity was required.

3. Researches

The casts from the low – carbon cast steel (0,28% C) with the composite pad placed in chosen inner part of the mould were conducted. Grainy high – carbon ferrochromium FeCr800 was used as the material of the pad (Table 1). Ferrochromium was composed of the grains at different sizes and shapes. Screen analysis was done to determine particular fraction and to estimate homogeneity of the grainy constitution of ferrochromium [8,9,10]. The graininess of ferrochromium was variable and it was the following:

- The pad 1 – grain at the size 1,6 - 0,8 mm,
- The pad 2 - grain at the size 0,8 – 0,63 mm,
- The pad 3 - grain at the size 0,63 – 0,32 mm,
- The pad 4 - grain at the size 0,32 – 0,16 mm,
- The pad 5 - z grain at the size less then 0,16 mm.

The surfaceactive fluxing compounds were used as the binding material. The 15 % solution of polystyrene in ethyl acetate $C_4H_8O_2$ was used as the binder.

Table 1.
Chemical constitution of ferrochromium

Material	Fe%	Cr%	C%
FeCr800	26	65	9

The sizes of the grains with pads were presented on figures 1-5. The composite pads were done in frame matrix 80x80x5 mm.

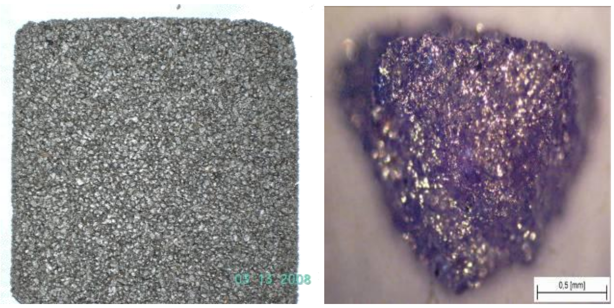


Fig. 1. Pad 1, Grain (1,6 - 0,8 mm) - Magnification x 50

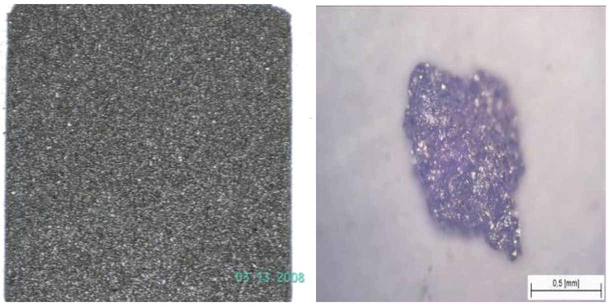


Fig. 2. Pad 2, Grain (0,8 – 0,63 mm) - Magnification x50

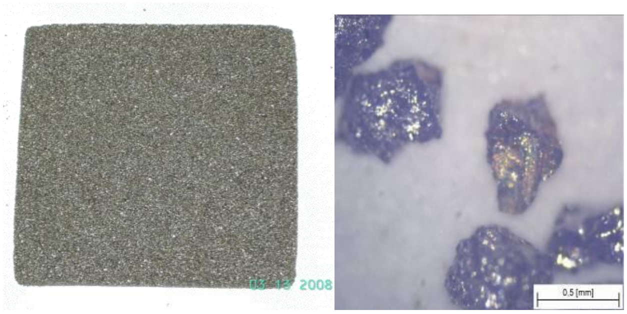


Fig. 3. Pad 3, Grain (0,63 – 0,32 mm) – Magnification x 50

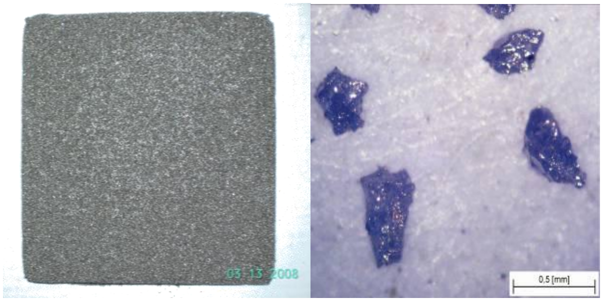


Fig. 4. Pad 4, Grain (0,32 – 0,16) – Magnification x 50

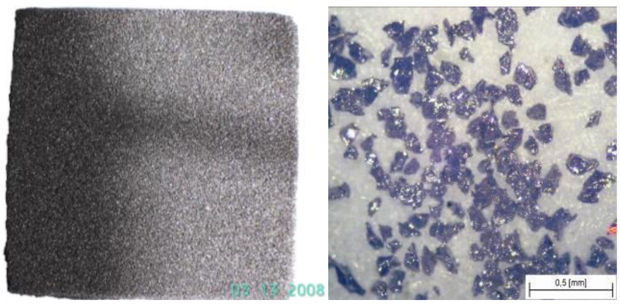


Fig. 5. Pad 5, Grain (poniżej 0,16 mm) – Magnification x 50

Some test, cubicoid shape casts with the composite pad placed on the one of inner surface of the mould were conducted The pouring temperature was 1550°C. The shape of the cast was presented on the figure 6. The dimension of the cubicoid nr 1 was the following 80x80x60 [mm] and nr 2 – 80x80x100 [mm].

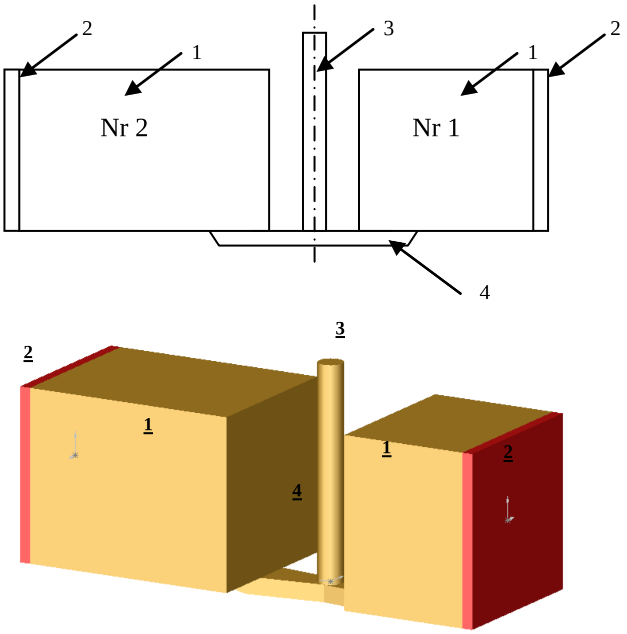


Fig. 6. The scheme of the cast – pad system construction;
1 – model (cast), 2 – pad, 3 – top gate, 4 – running gate

The position of the measurement points for the cubicoids from the side of the contact of the pad with the cast steel (inner side) and from the side of the contact of the pad with the mould (outer side) were presented on the figure 7. The changes of the temperature in time (for the pads with the lowest graininess) were presented on the figurek 8 – 10. The frequency of the measurements was 1 second.

It is possible to read the time of being of the composite pad material over 1300°C (forecast temperature necessary for composite layer forming process) and maximal temperature (table 2) from the presented results of researches.

The measurement of the thickness and hardness (by Rockwell method with the universal hardness testing machine in scale C – obtained averages are presented in table 3) of surface cast steel layer were also conducted during the researches. The distributions of the layer thickness on the cast section were presented on figures 11 – 15.

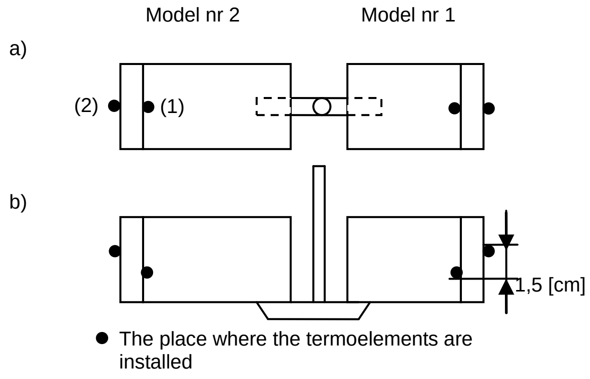


Fig. 7. Arrangement of the thermoelements
a) top view; b) view from the side

Table 2.
Data obtained from the measurement points; maximal obtained temperature and the time of being of the pad in the temperature over 1300°C

	Temperature [°C]		Time [s]	
Graininess 0,63 – 0,32 mm				
	Measurement point		**Measurement point**	
	(1)	(2)	(1)	(2)
Cubicoid 80x80x100	1333	994	191	-
Cubicoid 80x80x60	1356	973	308	-
Graininess 0,32 – 0,16 mm				
	Measurement point		**Measurement point**	
	(1)	(2)	(1)	(2)
Cubicoid 80x80x100	1333	1124	191	-
Cubicoid 80x80x60	1373	888	284	-
Graininess less then 0,16 mm				
	Measurement point		**Measurement point**	
	(1)	(2)	(1)	(2)
Cubicoid 80x80x100	1166	1290	-	-
Cubicoid 80x80x60	1006	994	-	-

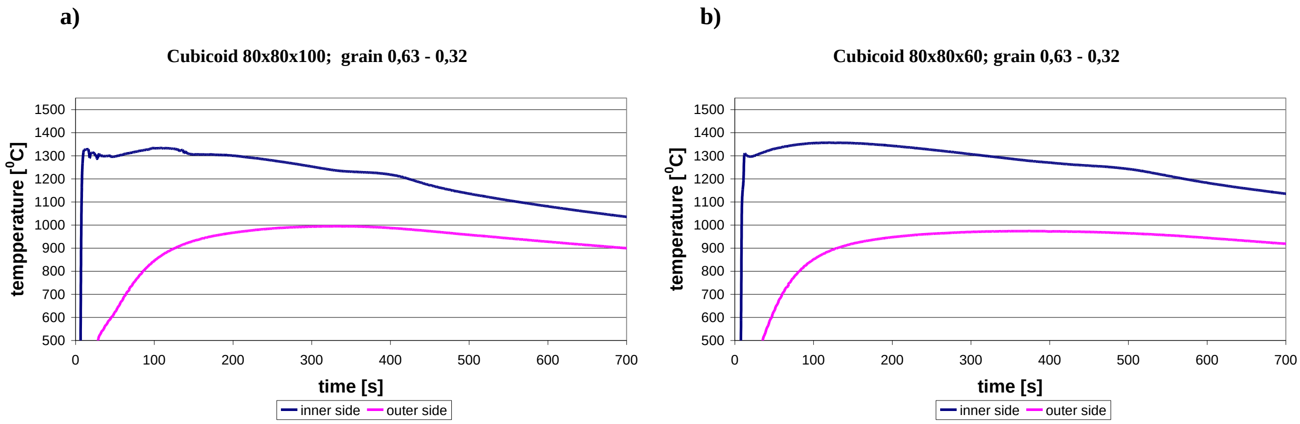


Fig. 8. The process of temperature changes in time T=f(t) – the pad with the grain at the size 1,6 - 0,8 mm; a) cubicoid 80x80x100; b) cubicoid 80x80x60

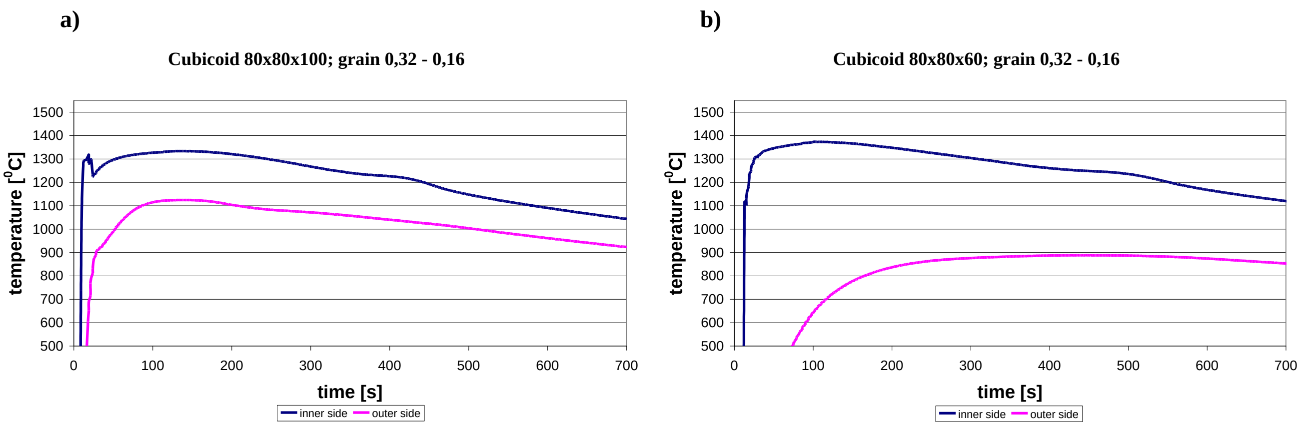


Fig. 9. The process of temperature changes in time T=f(t) – the pad with the grain at the size 0,32 - 1,6 mm; a) cubicoid 80x80x100; b) cubicoid 80x80x60

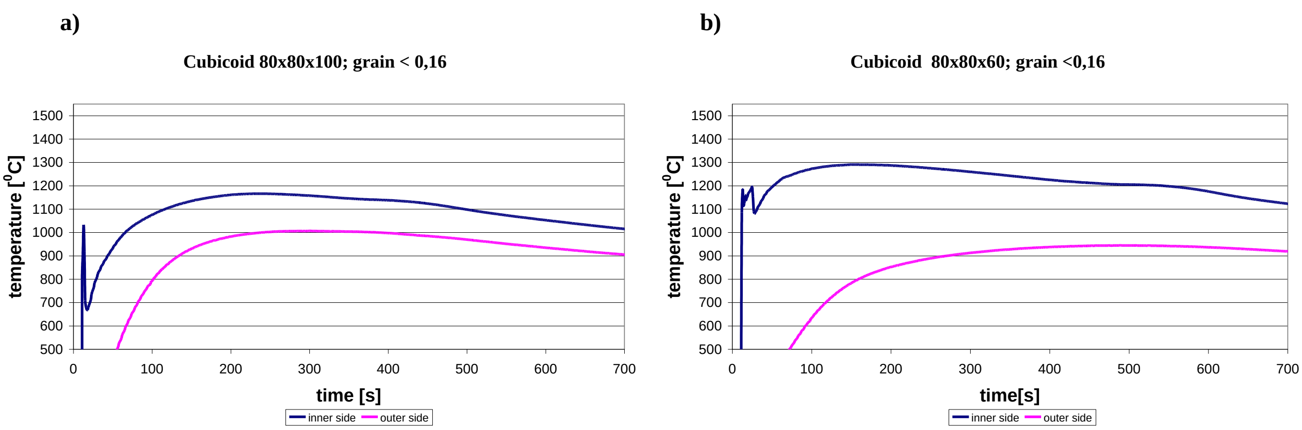


Fig. 10. The process of temperature changes in time T=f(t) – the pad with the grain at the size less then 1,6 mm; a) cubicoid 80x80x100; b) cubicoid 80x80x60

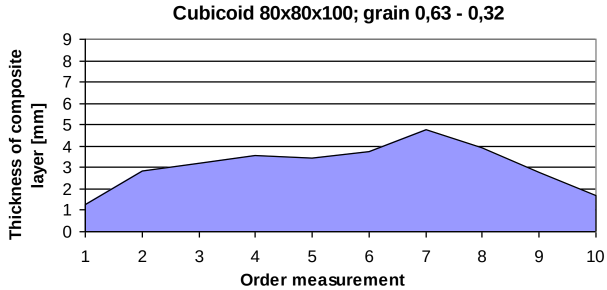


Fig. 11. The measurement of the composite layer thickness on the cast section with the graininess 0,63 – 0,32; 80x80x100

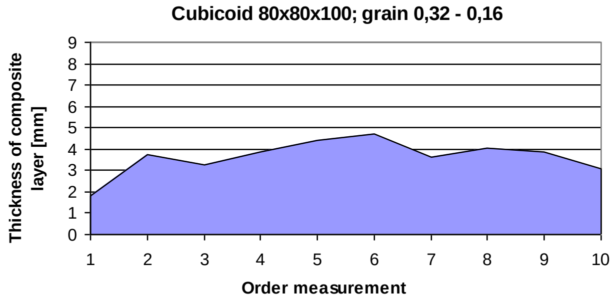


Fig. 12. The measurement of the composite layer thickness on the cast section with the graininess 0,32 – 0,16; 80x80x100

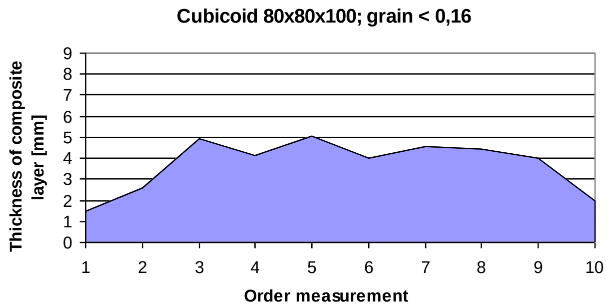


Fig. 13. The measurement of the composite layer thickness on the cast section with the graininess < 0,16; 80x80x100

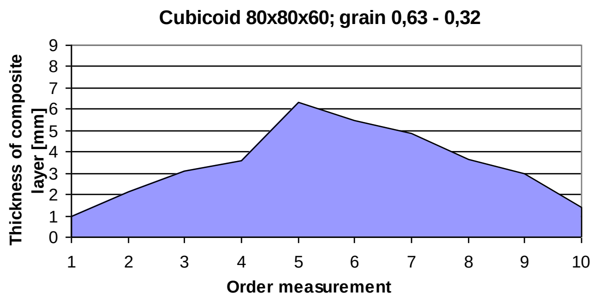


Fig. 14. The measurement of the composite layer thickness on the cast section with the graininess 0,63 – 0,32; 80x80x60

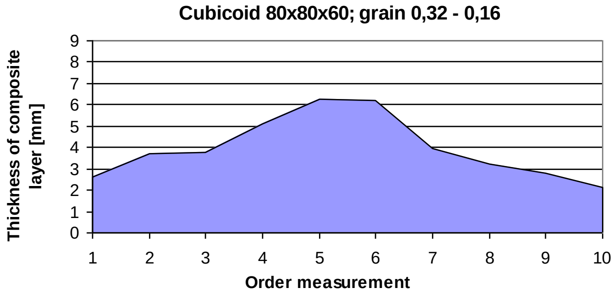


Fig. 15. The measurement of the composite layer thickness on the cast section with the graininess 0,32 – 0,16; 80x80x60

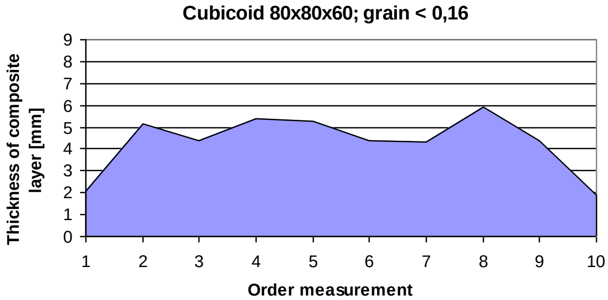


Fig. 16. The measurement of the composite layer thickness on the cast section with the graininess < 0,16; 80x80x60

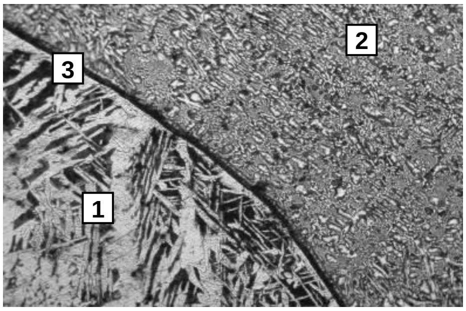
The structures of the obtained composite layers (Fig. 17 – 21) were also observed, for characteristic places:

- transition zone between composite layer and cast steel,
- cast steel layer,
- composite layer,
- surface layer.

Table 3.
The measurement of the thickness and hardness of the composite layer depending on the pad graininess

	Thickness of the layer [mm]	Hardness Scale HRC	
		Composite layer	Cast steel
Graininess 1,6 - 0,8 mm			
Cubicoid 80x80x100	4,972	40	less 20
Cubicoid 80x80x60	5,366		
Graininess 0,8 – 0,63 mm			
Cubicoid 80x80x100	3,107	41,3	35.3
Cubicoid 80x80x60	3,43		
Graininess 0,63 – 0,32 mm			
Cubicoid 80x80x100	3,092	42,7	30,7
Cubicoid 80x80x60	3,458		
Graininess 0,32 – 0,16 mm			
Cubicoid 80x80x100	3,623	43,2	23,2
Cubicoid 80x80x60	4,018		
Graininess less then 0,16 mm			
Cubicoid 80x80x100	3,719	40,2	22,3
Cubicoid 80x80x60	4,316		

a)



b)

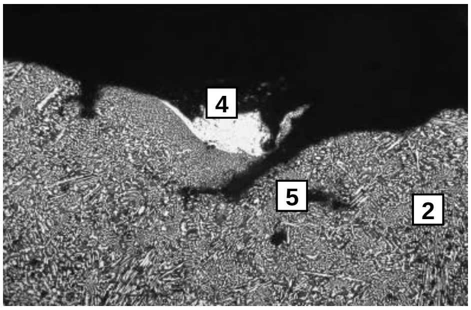
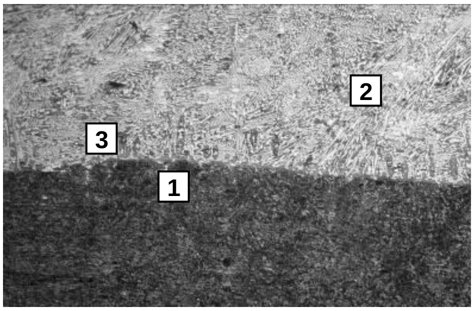


Fig. 17. The structure of the sample – the graininess of the pad 1,6 - 0,8 mm; a) transition zone cast steel - composite; b) surface zone of the composite layer; 1 – cast steel, 2 – composite; 3 – transition zone between cast steel and composite, 4 – no diffused FeCr, 5 –cracks piping

a)



b)

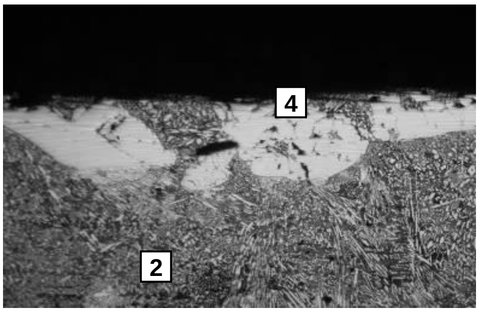
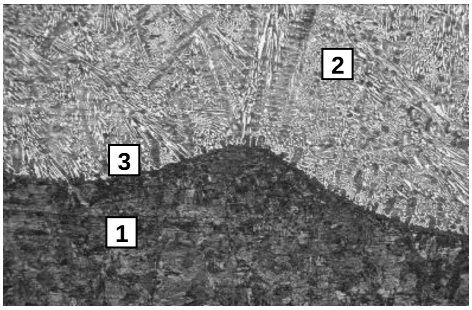


Fig. 18. The structure of the sample – the graininess of the pad 0,8 – 0,63; a) transition zone cast steel - composite; b) surface zone of the composite layer; 1 – cast steel, 2 – composite; 3 – transition zone between cast steel and composite, 4 – no diffused FeCr

a)



b)

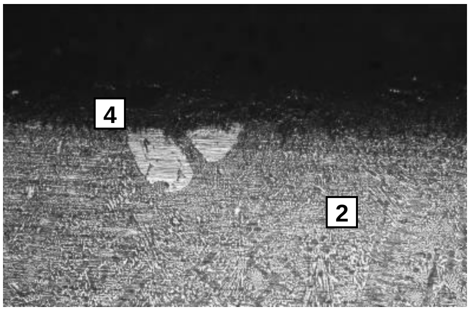
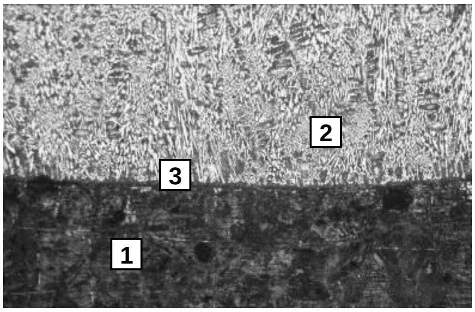


Fig. 19. The structure of the sample – the graininess of the pad 0,63 – 0,32 mm; a) transition zone cast steel - composite; b) surface zone of the composite layer; 1 – cast steel, 2 – composite; 3 – transition zone between cast steel and composite, 4 – no diffused FeCr

a)



b)

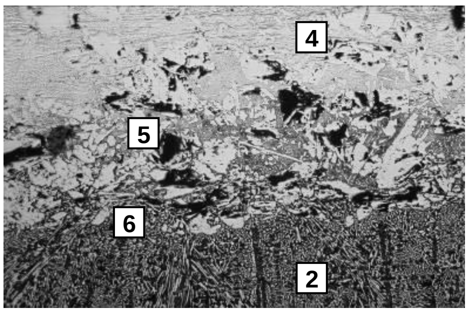
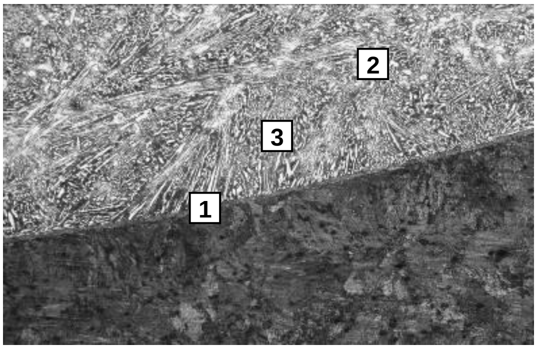


Fig. 20. The structure of the sample – the graininess of the pad 0,32 – 0,16 mm; a) transition zone cast steel - composite; b) surface zone of the composite layer; 1 – cast steel, 2 – composite; 3 – transition zone between cast steel and composite, 4 – no diffused FeCr, 5 –cracks piping, 6 – transition zone between composite and surface layer

a)



b)

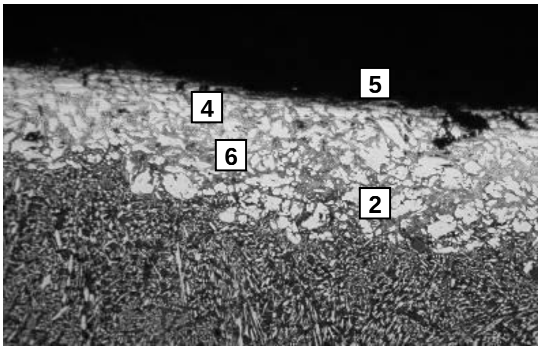


Fig. 21. The structure of the sample – the graininess of the pad less then 0,16 mm; a) a) transition zone cast steel - composite; b) surface zone of the composite layer; 1 – cast steel, 2 – composite; 3 – transition zone between cast steel and composite, 4 – no diffused FeCr, 5 –cracks piping, 6 – transition zone between composite and surface layer

4. Analysis of researches

The aim of the work was to obtain the layer as thick as possible and concurrently with as good properties as possible. The variable parameters: the size of cast, the size of the grain of ferrochromium used to form the composite pad were use In researches.

It was shown that the biggest layer was obtained with the use of the cubicoid 80x80x60 [mm]. The average difference in the thickness of the layers between cubicoid 80x80x60 and 80x80x100 was 0,5 [mm].

The thickness measurements and microscope observation showed that the biggest and the most homogeneous layer was obtained on the cast 80x80x60 with the pad at graininess 0,63 – 0,32 [mm]. The average thickness was 3,45 [mm] (table 3). Microscope observation didn't show any cracks and pipings In the layer. Only little quantity of no diffused ferrochromium was observed (fig.12). Maximal temperature obtained during the layer forming process was 1356^{o}C and the time of being the pad in the temperature 1300^{o}C was 308 [s] (table 4).

Inhomogeneous layer was obtained on the cast where the pad at the graininess 1,6 – 0,8, and 0,32 – 0,16, and lower then 0,16 was used; in spite of the fact that the surface alloy layer was the thickest. Great number of cracks and pipings was observed on the first kind of the cast. Second one was characterized by delamination of obtained composite layer. The last one was characterized by inhomogeneous structure and some cracks.
Hardness measurement showed that the hardness of composite layer changes from 35 till 45 HRC.

The thin layer of solidified cast steel is formed near the composite pad during pouring the mould by the liquid metal. It is a result of the contact with composite pad which works as a chill. The solidified thin layer of cast steel gives its solidification warmth to composite pad. It heats the pad quickly to some temperature and melts itself thanks to much bigger heat capacity of the cast then the heat capacity of th layer of alloy material. The pad which basic material consists of small grains (graininess 0,32 – 0,16; and lower then 0,16) is characterized by great conductivity and concurrently small heat capacity. It means that the cast steel didn't dissolve completely in composite material. However, dynamic cristalization took place and the zone of no diffused ferrochromium was formed on the surface of composite layer. The layer 4 (fig. 21) is a little bit harder (50,5 HRC) then the layer 2 (fig.21) - 45 HRC. It is also observed that too big grain which is characterized by small conductivity and concurrently great heat capacity influences negatively the composite layer forming process (graininess 1,6 – 0,8 mm).

5. Conclusions

1. The method of composite layer forming process is easy. However, obtaining the desired thickness depends on many factors, for example: module of cast solidification, pouring temperature, the size and shape of the cast.
2. The obtained composite layer was characterized by great hardness in relation to cast steel, for example for the cast at the graininess 0,63 – 0,32 the obtained composite layer had 42,7 HRC, and the cast steel 30,7 HRC.
3. The size of the grain of ferroalloy which was used to do the pad, influences the quality and the size of composite layer. The hardest layer without any cermets, cracks and pipings was obtained by the graininess of ferrochromium (used as the basic material of the pad of FeCr) 0,63 – 0,32 mm.
4. The size of the cast influence the thickness of the composite layer. The composite layer was thicker in smaller casts (at the average 0,5mm). The position of the thermal centre also influence the thickness of the composite. The closer to the composite pad the thermal centre is situated, the higher maximal temperature is and the thicker composite layer is. Shorter time of the process of pouring the mould by metal and distant thermal centre caused smaller thickness of the composite layer on the bigger cast.
5. Heating temperature of compost pad is also important. The diffusion of the elements (and alloy surface layer forming) takes place when the temperature is higher then the critical level (about 1300^{o}C) and the time of being in this temperature is enough long.

References

[1] Baron C., Szajnar J.: The determination of the thickness of composite layer, Archives of Materials Science and Engineering, Vol. 30, Issue 1, March 2008, pp. 45-48.

[2] Baron C., Bartocha D., Szajnar J.: The determination of the composite layer thickness with the use of software NovaFlow&Solid and Preforma 1.1, Archives of Foundry Enginering, Vol.8, Issue 1, January-March 2008, pp.5-12.

[3] Szajnar J., Bartocha D.,Baron C., Walasek A.: The attempt of determination of parameters for the alloy layer forming process based on the empirical examination Archives of Foundry Enginering, Vol.8, Special Issue 3, 2008, pp.139-143.

[4] Walasek A, Baron C., Szajnar J.: Simulation of composite layer production on a steel cast, Slevarenstivi 2008, No ¾ and on the CD Supplement of Conference Proceedings.

[5] Baron C., Szajnar J.: The thickness of surface composite layers in a stochastic expressions, Quality of materials and products - Monography, Saint – Petersburg 2008, pp.51-58.

[6] Szajnar J., Baron C., Walasek A.: The influence of the temperature and heating time of ferrochromium premould on surface composite layer forming process, Effectiveness of the machines maintenance and processes, Novosibirsk, 2009, pp.79-88.

[7] Walasek A., Baron C., Bartocha D., Szajnar J.: The analysis of solidification process of high carbon FeCr in the aspect of the alloy layer forming process, Inernational PhD Foundry Conference, 3 June 2009, pp.2-8.

[8] Więckowski A., Stręk F.: Porowatość mieszanin ciał sypkich, Chemia stosowana, 1966 pp. 95-128.

[9] Więckowski A., Stręk F.: Porowatość ciał sypkich, Chemia stosowana, 1966 pp. 431-447.

[10] Lu L., Soda H., McLean A.: Microstructure and material properties of Fe Cr-C eutectic composites, Materials Science and Engineering, 2003, pp.214-222.