ARCHIVES
of
FOUNDRY ENGINEERING

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

ISSN (1897-3310)
Volume 11
Issue 1/2011

99 – 104

21/1

Influence of insert granularity and pouring temperature on the thickness of surface alloy layer

J. Szajnar, D. Bartocha, C. Baron, A. Walasek*
[a] Faculty of Mechanical Engineering, Foundry Department, Silesian University of Technology,
Towarowa 7, 44-100 Gliwice, Poland
*Corresponding author. E-mail address: agnieszka.walasek@polsl.pl

Received 01.03.2011; accepted in revised form 01.03.2011

Abstract

In the paper the characteristic of the surface alloy layers on cast steel castings is presented. The assumptions for the simulation with the use of FLUENT software were worked out on the basis of the mechanisms known from the previous researches. The contact geometry (of preform and cast steel) and boundary conditions similar to the technological conditions were determined. The simulation was carried out for three pouring temperatures. The results of the simulations and the conclusions were presented. The real examinations for the same technological parameters were carried out to verify the calculations. The obtained results were compared.

Keywords: Composites; Alloy layers; Ferrochromium; Cast steel; Simulation - Fluent

1. Introduction

The steel cast are used as the elements of machines where high mechanical properties are desired (Rm, Re), concurrently providing relatively good plasticity (A5, Z%, KU, KV). Working elements are also desired to be resistant to abrasion in the industry (for example in extractive industry, mineral processing, power engineering) [1,2]. Unfortunately, it is impossible to obtain all these properties in one material. There are many materials – for example high tough and abrasion resistant steel such as Hardox and Weldox (SSAB), american military kinds H-80 and H-100, american T1 produced by Thyssen Stahl and home equivalents as steel. However, their abrasion resistance is unsatisfactory. Therefore, the surfaces of working elements of machines are strengthened by surface treatment (for example carbonizing or nitriding which gives hard layers till) in difficult conditions. However, electrode padding weld is used more frequently. Electrodes contains mainly chromium (20-30%) and (3-6%) carbon. The obtained abrasion resistant layer is and its composition and structure is similar to chromium cast iron. [3].

Many components of machines are produced by cast technology. Therefore, the method of creating the alloy layer on such casts based on concurrent pouring the mould and creating the alloy layer on chosen parts seems to be simplest and cheapest one [4, 5].

The alloy layers produced with the use of this kind of the method are characterized by:

- easy technology,
- the thickness of the layer possible to be regulated,
- obtaining the layers on any surface of the cast.

The technology of obtaining surface alloy layers on the chosen part of the cast allows to get some properties:

- hardness – repeatedly higher then the hardness of the alloy of basic cast,

- abrasion resistance - repeatedly higher then the resistance of the of basic cast,
- the thickness of the surface alloy layer adapted to the conditions of work and the thickness of cast wall,
- the possibility of thermal treatment in one cycle, for example normalization – obtaining different properties of the cast and alloy layer (the cast is characterized by high mechanical properties and the alloy layer by high hardness and abrasion resistance).

The researches connected with the casts with the surface alloy layers are conducted in the Foundry Department of Technical University in Gliwice. First, the cast iron was used [1]. Nowadays, low - carbon cast steel is used during the researches [6– 9].

The foundry method worked out in the Department consists in preparing the mould by fixing the properly prepared preform on chosen parts of cavity and pouring it by the liquid metal. The grainy material (which includes Cr and C) placed on the surface of the cavity fills the niches of the mould by the diffusion process (to the cast steel). Carbides and the alloy layer are created during the diffusion process.

The surface layer creation process depends on many physical and chemical factors. First of all, the obtained properties depends on self – cooling conditions and physical and chemical processes on the surface of metal/premould (the kind of influence of premould material on the surface layer during the process of cast pouring and self – cooling). The size of the grain of alloy premould also influences the quality of the obtained layer.

However, the choice of proper parameters of the process to obtain the layer with desired properties makes common application of the surface alloy layers in the production difficult. In this work, the attempts of modeling the process of the surface alloy layer creation on the cast steel were made and the influence of geometry plane on this process was examined. The results of physical experiments were also presented to verify the obtained results from the simulation.

2. Materials for researches

The grainy low – carbon ferrochromium (FeCr800) was used to build the premould. Chemical constitution of ferrochromium is presented in Table 1. The graininess of material was the following: 0,8 – 0,63 mm, 0,63 – 0,32 mm, 0,32 – 0,16 mm. The average values from these ranges (0,75, 0,5 and 0,25 mm) were used during the simulation. The process of cubicoid premould (30x30x5) forming (for physical experiments) was conducted at the room temperature in a stiff matrix, whereas all cast was realized from the low – carbon cast steel at the carbon percentage 0,2 %.

Table 1.
Chemical constitution of ferrochromium

Cr %	C %	Si %	P %	S %
62,53	7,92	0,75	0,026	0,02

The pouring temperature was: 1550°C, 1600°C and 1650°C both for physical experiment sand the simulation. The selected temperature allowed to examine the influence of overheating the liquid metal on the process of alloy layer forming.

3. Run of researches and the results

The first part of the researches was to conduct the simulation of the surface alloy layer forming process [10] with the use of CFD Fluent software. According to the assumptions, the simulation was conducted for three levels of premould graininess. The geometry of the surface of the contact between the premould and cast steel was modeled with the use of Gambit software. It also made the use of MES net possible. The representation of the edge of the contact was presented on Fig. 1. The calculations were conducted with the use of the geometry presented on Fig. 1 a, b, c. Because of the in homogeneity of the surface of the contact between the material and the cast, the modification of the parting plane was conducted to reflect exactly its real shape (fig. 1 d, e, f). However, the results were not substantially changed.
The aim of the researches was to conduct the simulation of the alloy layer forming process and examine the influence of surface segmentation geometry on it.

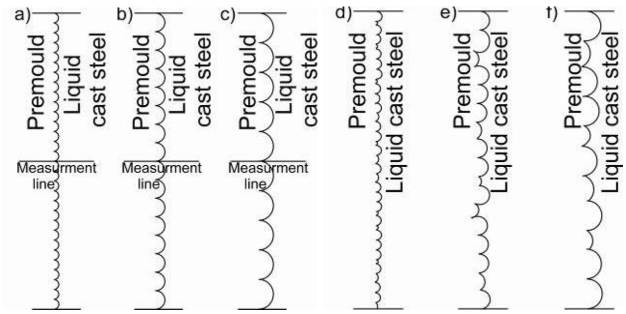

Fig. 1. The edge of the FeCr insert modeled in Gambit software for granularity: 0,25 (a; d), 0,5 (b; e), 0,75 (c; f)

The examples of the diagrams presenting the temperature distribution along the measurement line are shown on Fig. 2-4 for the specific time step equal 0,5 s. The placement of the measuring line is shown on fig. 1 a – c.

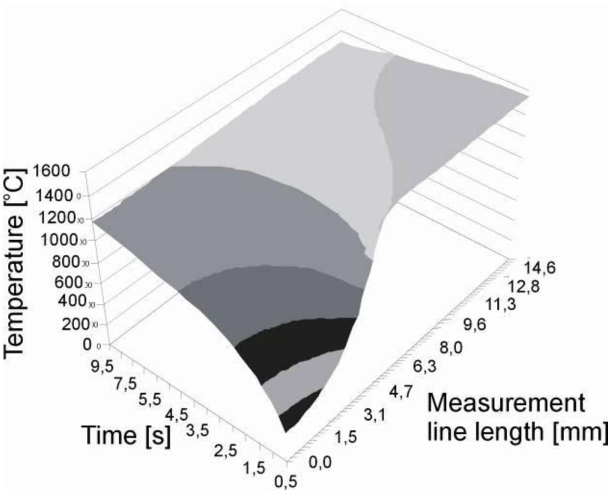

Fig. 2. Diagram change of the temperature of time along the measurement line as in fig. 1: $T_{pouring}$ = 1550°C, granularity premould 0,5 mm

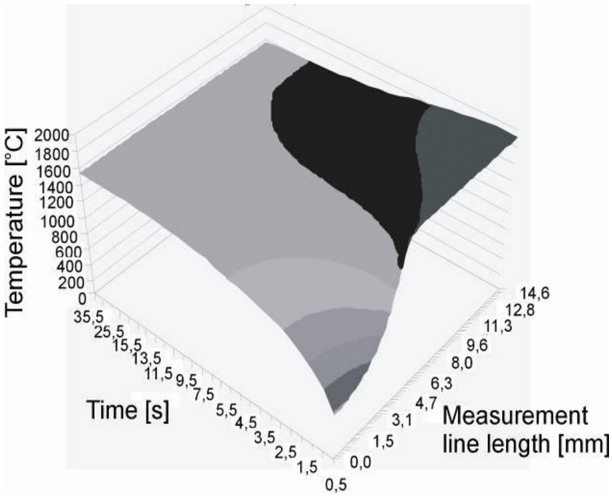

Fig. 4. Diagram change of the temperature of time along the measurement line as in fig. 1: $T_{pouring}$ = 1650°C, granularity premould 0,5 mm

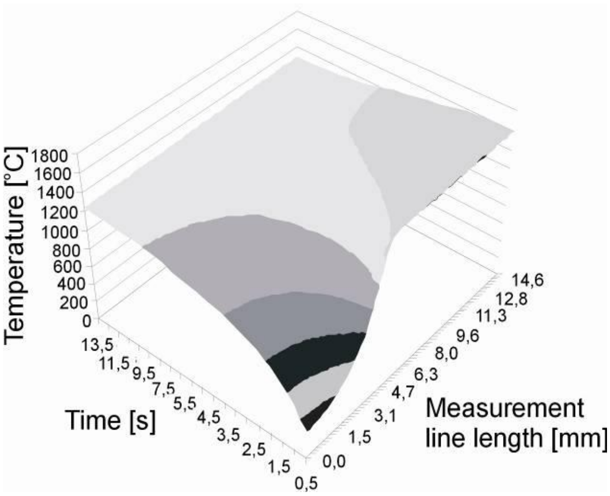

Fig. 3. Diagram change of the temperature of time along the measurement line as in fig. 1: $T_{pouring}$ = 1600°C, granularity premould 0,5 mm

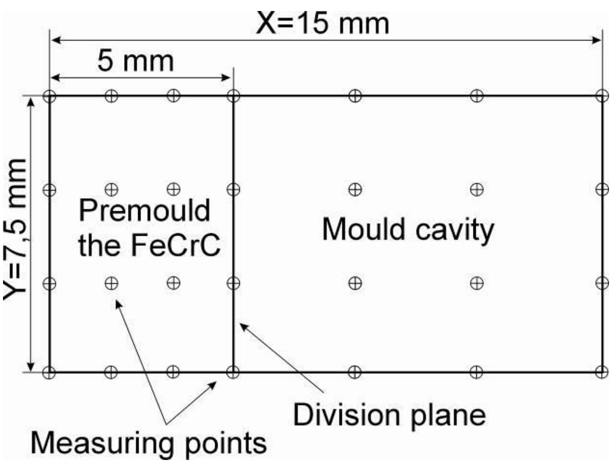

Fig. 5. Schematic subdivision of the moulds along with the location of measurement points

The materials used during the calculation were defined as the mixture of iron, chromium, carbon and silicon in proper proportions (the preliminary assumptions were changed). The net of measurement points was put on the geometrical model to measure the temperature and the distribution of elements concentration in each step of calculation. The scheme of the considered in simulation pad – mould cavity layout (cast steel) with the recording points layout were presented on fig. 5. The examples of the results are shown on Fig. 6.

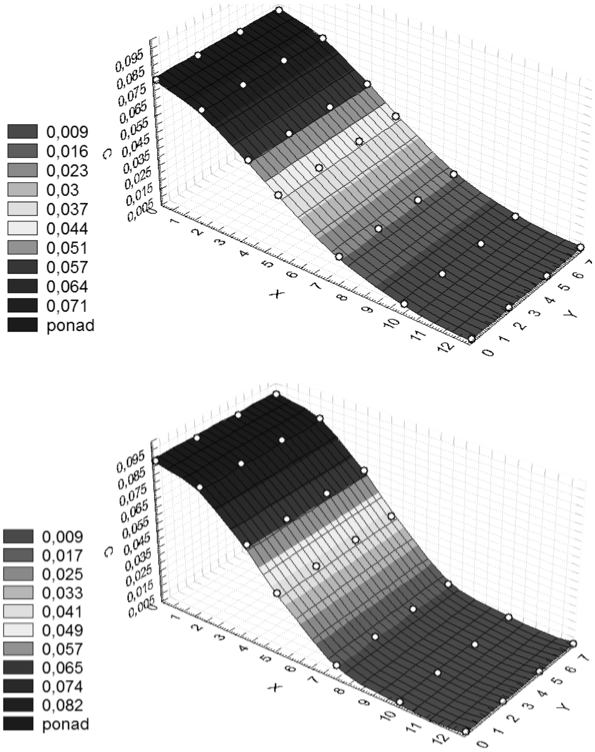

Fig. 6. Distribution of carbon concentration in the model area; a) granularity 0,75 mm; b) granularity 0,5 mm; $T_{pouring}$ = 1550°C; where: C - carbon concentration [%] x10^2, X i Y – dimensions used in the simulation model [mm]

The times (from simulation) of being the premould at the temperature over 1300°C (after exceeding it, the profitable conditions are reached) are shown on Fig. 7.

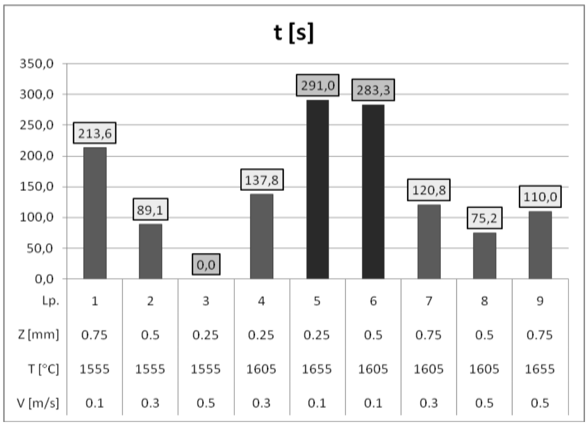

Fig. 7. Statement of the duration of each simulation: Z – granularity the ferrochromium [mm], T – pouring temperature [°C], V – rising velocity of liquid steel mirror [m/ s]

On the simulations no. 5 and 6 basis it may be assumed, that the alloy layer will not be created. The conclusion can be made after the numerous experiments carried out under real casting conditions. That suggest that the layer is created inside the temperature range1300 – 1500°C. When 1500°C is exceeded the pad washes out as a result of overheat and smelting occurs [8, 9, 11]. For the simulation (no. 5 and 6) the maximum temperature was 1570 and 1549°C. However, for the simulation no. 3 the maximum temperature was 1277°C what suggests that the proper temperature conditions for the alloy layer did not occur.

Thicknesses of the layer for chosen examples are presented on Fig. 8.

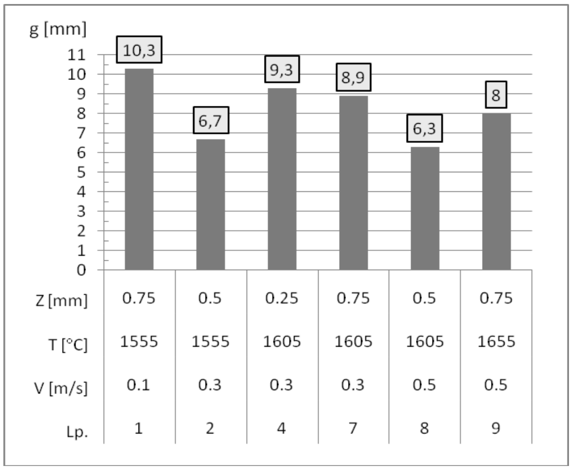

Fig. 8. Alloy layer thickness obtained from the simulation: Z – granularity the ferrochromium [mm], T – pouring temperature [°C], V – rising velocity of liquid steel mirror [m/ s]

The casting real experiments were conducted to verify the results obtained from the simulation. First, the temperature recording was done in the place of the contact between premould material and cast steel. Next, the observation of obtained structure was done and the thickness of each layer was measured. The obtained results are shown in Table 2. The example of microstructure picture was presented on Fig. 9.

Table 2.
Selected parameters of obtained cast steel castings with surface alloy layer

The average maximum temperature [°C]	The average time of being the pad over 1300°C [s]	The average thickness of the layer [mm]
	T_{zal}=1550°	
1428	364	6,83
	T_{zal}=1600°	
1437	415	9,36
	T_{zal}=1650°	
1500	778	Layer did not form – mixing of components
	T_{zal}=1600°	
(graininess **0,8 – 0,63 mm**) 1430	400	8,2
(graininess **0,63 – 0,32 mm**) 1433	407	8,5
(graininess**0,32 – 0,16 mm**) 1448	438	11,4

The transition zone and alloy layer which You can divide into external (prime) and inner (secondary) part were obtained as a result of the joining two materials (fig. 9). The external alloy layer (prime) is an area of incompletely melted grains of ferrochromium jointed by eutectic mixture. This area consists of big grains with high chromium content. The inner area (secondary) is a fundamental part of alloy layer formed as a result of the diffusion of basic elements. It is mainly built from carbon emitting.

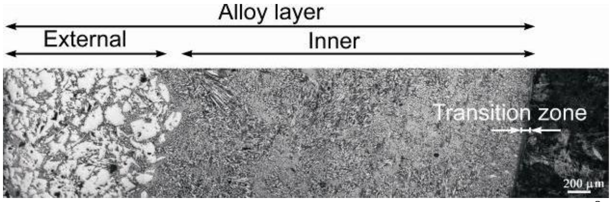

Fig. 9. The structure of alloy layer - pouring temperature 1550^{o}C magnification 50x

The cast steel has a structure composing from pearlite and ferrite. Alloy layer has a structure of alloy ferrite and eutectic mixture ferrite + carbides (mainly M_7C_3). There is also the transition zone different in the respect of the structure in comparison with cast steel and obtained alloy layer (fig. 9).

a) b) c)

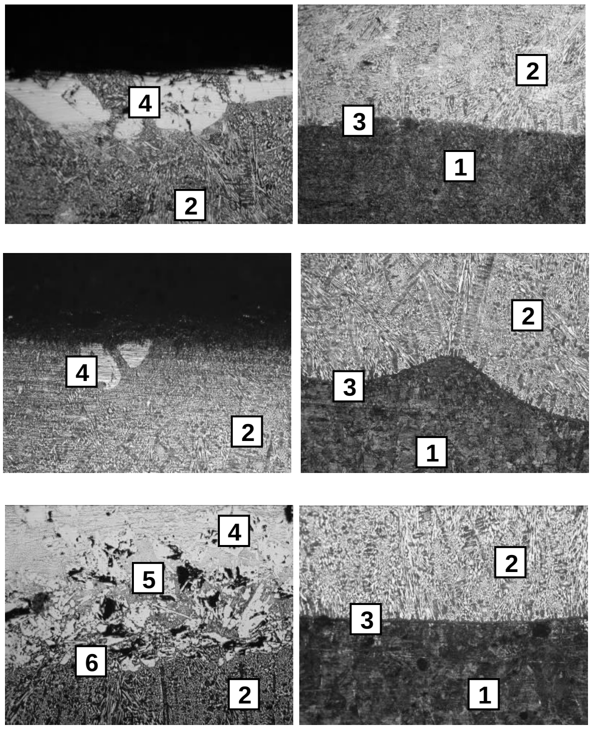

Fig. 10. The structure of the sample; a) the graininess of the pad 0,8 – 0,63, b) the graininess of the pad 0,63 – 0,32 mm, c) the graininess of the pad 0,32 – 0,16 mm; 1 – cast steel, 2 – alloy layer; 3 – transition zone between cast steel and alloy layer, 4 – no diffused FeCr, 5 – cracks piping, 6 – transition zone between alloy layer and surface layer

The structures of the obtained composite layers (fig. 10) were also observed, for characteristic places:

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

4. The conclusions

The conducted simulations show that the greatest influence on the parameters of the obtained layer have: pouring temperature and the time when the surface of the diffusion stay in the area of increased temperature.

Simulations point out small influence of the division boundary geometry (graininess of premould) on the alloy layer forming process on the cast steel. It is not confirmed by physical experiments. The physical experiments show that the graininess of premould influences the both quality and the thickness of obtained surface. The smaller the grain size of the resulting thickness of the alloy layer is greater.

The pouring temperature influences the thickness of the obtained layer with the utmost degree. The higher pouring temperature, the higher temperature on the boundary of the contact between the material of premould and the cast. It profitable influences the process of the layer forming. But you must remember that too high temperature can cause joinit penetration and mixing of both materials (or cast steel and FeCrC).

When compare the experiments carried out it could be stated that the simulations do not completely reflect the real layer creation conditions.

Acknowledgements

This research project was financed from support funds for science during 2010-2012.

References

[1] W. Sakwa, S. Jura, J. Marcinkowska, B. Kusznik, Theoretical foundations of alloy layer forming process on the cast iron, Solidification of Metals andi Alloys nr 1, 1979

[2] J. Gawroński, J. Szajnar, P. Wróbel, Surface layers of composite technology and its application (Technologia powierzchniowych warstw kompozytowych i przykłady jej zastosowania), Archiwum Odlewnictwa 2006,

[3] A. Klimpel, K. Luksa, J. Wacławik, Influence of technological conditions of robotised arc pad welding by self-shielding powder wire on properties of pad welds carried out by zigzag-type motion of the burner, "Przegląd Spawalnictwa" nr 11, 2007

[4] S. Jura, J. Suchoń, Layer steel castings and cast iron (Odlewy warstwowe stal i żeliwo), Krzepnięcie Metali i Stopów, nr 24, PAN Katowice

[5] J. Gawroński, J. Szajnar, M. Cholewa, P. Wróbel, Solidification and crystallization of the particles containing composites and surface composites, Kompozyty 5(2005)4a
[6] J. Szajnar, D. Bartocha, C. Baron, A. Walasek, The attempt of determination of parameters for the alloy layer forming process based on the empirical examination, Archives of Foundry vol. 8, No. 21 (2008)
[7] A. Walasek, C. Baron, D. Bartocha, J. Szajnar, 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] C. Baron, The surface composite layer on the steel cast, Doctor`s thesis, Silesian University of Technology, Gliwice, 2007
[9] P. Wróbel, Improvement of the cast steel castings surface by creating the alloy composite layer in casting process, Doctor's thesis, Silesian University of Technology, Gliwice, 2004
[10] R. Lubojański, D. Bartocha, J. Szajnar, Alloyed surface layer - computer simulation of the formation (Powierzchniowa warstwa stopowa – komputerowa symulacja powstawania), Stal Metale & Nowe Technologie