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# The Mechanism of the Surface Alloy Layer Creation for Cast Steel

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## Abstract

The paper presents a detailed description of the process of creation of a surface alloy layer (using high-carbon ferrochromium) on the cast steel casting. The mechanism of the surface alloy layer is based on the known theories [5,6]. The proposed course of formation of the layers has been extended to decarburization stage of steel. The research included proving the presence of carbon-lean zone. The experiment included the analysis of the distribution of elements and microhardness measurement.

**Keywords:** Composites, Composite layer, Ferrochromium, Cast, Mechanism of creation

## 1. Introduction

The research connected with the layer and composite cast have been carried out in Department of Foundry of Silesian University of Technology for several years [1-11]. Recently, the layered castings have become the most interesting because of great industry demand for the parts of machines resistant to abrasive wear. Layered casting are the group of casting, where two different materials are joined into one element (cast). The permanent joint of two different materials can be done with the use of several methods. The cast method (which gives surface composite layers) based on the diffusion joint proceeded directly in the foundry mould was used in the presented research. The foundry method of alloy layer forming process on the cast is as follows. First, the mould is prepared by drift of alloy layer (FeCr800) to proper mould cavity. Next, it is poured by liquid metal. Composite alloy layer is obtained as a result of interaction between cast steel poured to the mould and alloy coat [7,8]. At the beginning, researches were carried out with the use of cast iron [1-4]. Nowadays, low – carbon cast steel is used in the researches [4]. There were also attempts of determination of the forming

conditions and description of the surface alloy layers (sometimes called surface composite layer) forming mechanism. There are two different theories. The first one says that composite layer forms by melting the part or the whole composite insert and solidification as the layer connected with the cast lastingly [5]. The second one says that composite layer forms by the diffusion of components (Fe) from metal to insert and inversely (Cr, C) [6]. It is assumed that diffusion process proceeds mainly in the solid state from the moment of the contact between liquid alloy and insert. The layer of the alloy freezes to the insert as result of large temperature difference. The higher temperature the more intensive diffusion takes place. The proportion of chemical elements on the surface of the contact allows to form the alloy with the temperature  $T_L$  lower then the process temperature. The liquid layer of the alloy solidifies and forms the alloy layer with the chemical composition different from both alloy of the cast and grainy material of the composite insert.

## 2. Materials for researches

The grainy low – carbon ferrochromium (FeCr800) was used to build the insert. Chemical composition of ferrochromium is presented in Table 1. Whereas the whole cast was produced of the low – carbon cast steel (Table 2).

Table 1.

Chemical composition of FeCr800

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

Table 2.

Chemical composition of cast steel

C%	Si%	Mn%	P%	S%	Cr%	Ni%	Mo%	Cu%
0,207	0,18	0,6	0,026	0,015	0,086	0,119	0,073	0,277

Value of pouring temperature was about 1600°C and it was set on the basis of early scientific research [11].

Based on previous studies [11]: it was proved that silicon was very important during the alloy layer forming process. It is shown that the more percentage of silicon in FeCrC, the less liquidus and solidus temperature. It could be the reason for the decrease of the boulder temperature of the moment of the start of alloy layer forming process on the cast steel casting. It causes mixing of the ingredients of both materials.

## 3. The mechanism of alloy layer creation

On the basis of scientific research made in a Department of Foundry Silesian University of Technology as well as on the basis of an observation theoretical model of the surface alloy layer formation was created. During the formation of the surface alloy layer a few stages were specified:

- pouring the mould and insert with liquid metal,
- formation of the thin film cast,
- diffusion in a solid state,
- transition in a liquid state part of transition zone,
- diffusion in a liquid state,
- back diffusion of carbon from cast steel to transition zone,
- crystallization and formation surface alloy layer.

The first stage during the formation of surface alloy layer was pouring the mould with liquid metal (Fig.1). Earlier in the mould was attached insert made from high-carbon ferrochromium. In its place formed the shell characterized by higher properties than cast material.

As a result of contact of the liquid cast steel, which temperature in this stage was about 1550°C and alloy insert material (20°C) was formed thin film cast (Fig. 2). Due to the heat flow from cast steel to mould graduate increase in temperature in a insert of appeared. With temperature increasing in the insert (and difference concentration) mobility of the atoms in the crystal increases lattice which leads to diffusion of elements in a solid state (Fig. 3). Diffusion in the solid state derive from high liquidus

temperature of insert material (1637°C). In this stage mainly carbon (interstitial) and chromium (nodal) diffusion in cast steel direction follows. There is also iron diffusion to insert.

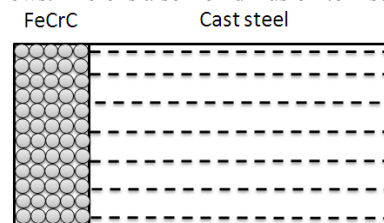


Fig. 1. The first stage of the surface alloy layer formation

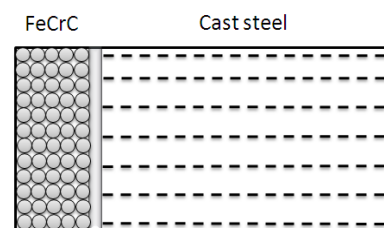


Fig. 2. The second stage of the surface alloy layer formation

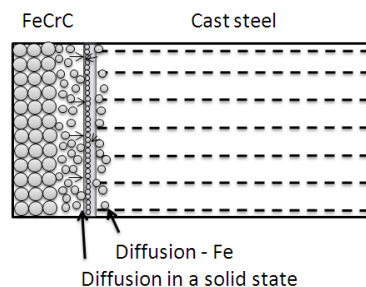


Fig. 3. The third stage of the surface alloy layer formation

When the concentration of particular components was located at the joint of two material is similar to chemical composition of high-chromium cast iron this zone passes in the liquid state (Fig. 4-5). Transition to the liquid state is caused lower of melting point of this material in relation to high-carbon ferrochromium. Then diffusion ingredients in a liquid state (Fig. 6). As a result of diffusion in the liquid state compensation of the concentration of components appears. According to graduate temperature decrease surface alloy layer and solid cast steel is formed. In this stage diffusion does disappear. In connection with chromium diffusion and its high affinity to carbon chromium carbide create. There were also created impoverished/depleted zone in a not carbon because of chromium and carbon joining to gather (Fig. 7). Decarburized zone did not occur in all connection or it was not big (invisible). It was also supposed that at this stage of the layer formation by diffusion of carbon, locally liquid zone may appear.

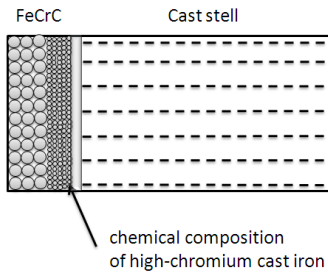


Fig. 4. The fourth stage of the surface alloy layer formation

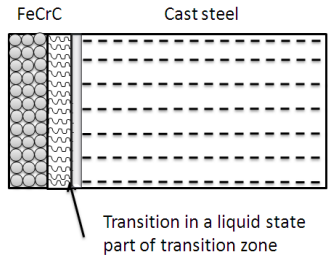


Fig. 5. The fifth stage of the surface alloy layer formation

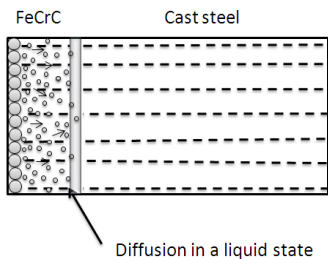


Fig. 6. The sixth stage of the surface alloy layer formation

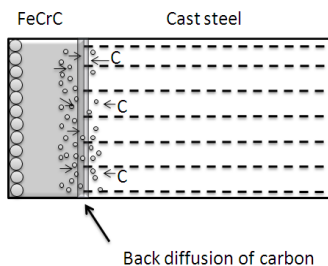


Fig. 7. The seventh stage of the surface alloy layer formation

Because of further processes occurring in the mould among other things like crystallization surface alloy layer is created (Fig. 8).

The present mechanism of the layer is different from that found in the literature [5,6]. The observed difference is due to back diffusion and taking into account the diffusion of iron.

Back diffusion of carbon occurs during the formation of the surface alloy layer. Such a conclusion was drawn from the experiment. Experiments consisted of observation of the structure (Fig. 9) as well as the distribution of individual elements on the casting section of a layer. Decarburised zone is mostly local.

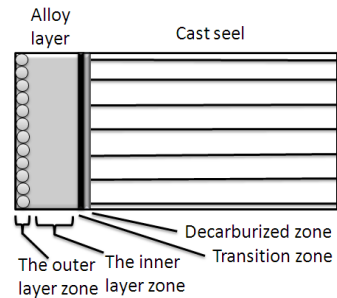


Fig. 8. The eighth stage of the surface alloy layer formation

The analysis of linear distribution of elements in order to verify the chemical composition was conducted. Microhardness measurements were performed on casting cross section. An example of the trend distribution of selected elements is shown in Figure 10. The study shows that there is a significant decrease in carbon content close to of the transition zone were performed. The studies to verify the supposed decarburized zone were occurrence. Microhardness measurements were made on the cut section of casting with surface alloy layer. The materials testing was conducted in a cross-section (Fig. 11) of the layer four time. The measurement results are presented in Table 3 together with their average. Graphical interpretation of average microhardness of the casting sections is presented in Figure 12.

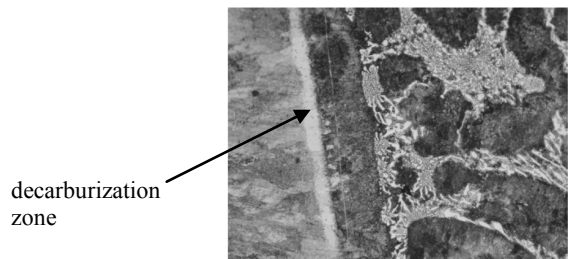


Fig. 9. Microstructure of alloy layers with decarburized zone

The study of microhardness measurements indicates that zone has the lowest hardness. This confirms the supposition founded on the occurrence of decarburization.

Table 3.  
The results of microhardness [ $\mu\text{HV}$ ]

Measurement location	1	2	3	4	Average
A	396,4	343,3	262,6	285,5	322
B	319,8	306,5	269,5	274,8	292,7
C	283,6	272,2	315	248,8	279,9
D	272,5	224,7	196,6	221	228,7
E	493,5	549,8	537	594,4	543,7
F	626,5	556,8	673,9	609,4	616,7
G	737	607,6	537	726,1	651,9

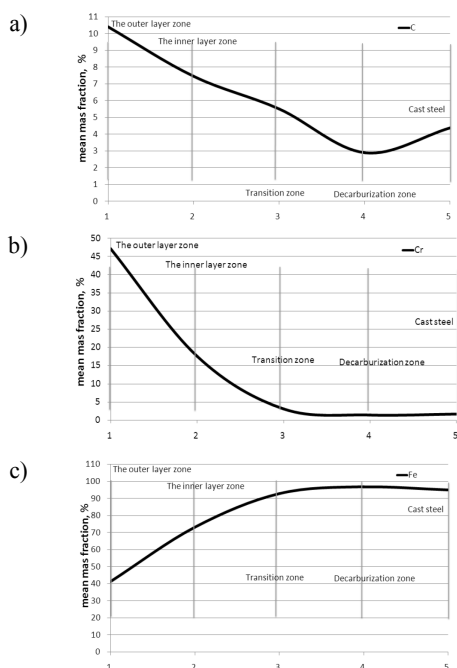


Fig. 10. The average distribution of selected elements; a) carbon, b) chromium, c) iron



Fig. 11. Microhardness measurements location (magnification 400x); A-C) cast steel, D) decarburization zone, E) transition zone, F-G) alloy layer

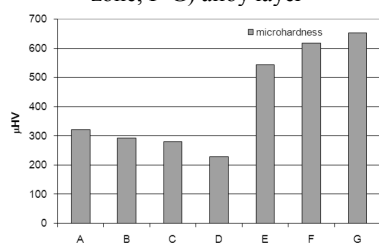


Fig. 12. The distribution of microhardness on the casting cross - section

## 4. The conclusions

The mechanism of the surface alloy layer is based on diffusion processes in both liquid and solid phase. Theories of the formation of the surface alloy layer should be extended to the process of diffusion of carbon from the insert to cast steel. Back diffusion is caused by the formation of chromium carbides.

The propelling force of this diffusion is possibility of carbides creation in transition zone. Cr contributes to the increased diffusion of C and the formation of decarburization zone. These processes may be up to approximately 850 °C. The formation of the alloy layer process is strongly influenced silicon content in insert used [11]. The content of Si effected on temperature of the liquid phase of the transition zone of insert (step 5).

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## References

- [1] Sakwa, W., Jura, S., Marcinkowska, J. & Kusznir B. (1979). Theoretical foundations of alloy layer forming process on the cast iron. *Solidification of Metals and Alloys*. 1, 222-229 (in Polish).
- [2] Marcinkowska, J. & Wróbel, P. (1988). Technology of castings used in case of erosion abrasion by mineral particles. CPBP 02.09. Silesian University of Technology, Gliwice. (unpublished) (in Polish).
- [3] Gawroński, J., Marcinkowska, J., Szajnar, J. & Wróbel, P. (1996). Composite layer on the steel castings. In Proceedings of the V Inter. Scientific Conf. "Achievements in the Mechanical and Materials Engineering", (88-96). Wisła: The Faculty of Mechanical Engineering of the Silesian University of Technology Materials Science Committee of the Polish Academy of Science. (in Polish).
- [4] Wróbel, P. (2004). *Improvement of the cast steel castings surface by creating the alloy composite layer in casting process*. Doctor's thesis, Gliwice Silesian University of Technology. (in Polish)
- [5] Baron, C. (2007). *The surface composite layer on the steel cast*. Doctor's thesis, Silesian University of Technology, Gliwice. (in Polish)
- [6] Szajnar, J., Wróbel, P. & Wróbel, T. Methods of improvement in hardness of composite surface layer on cast steel. *Archives of Foundry Engineering*. 8 (Special Issue 3), 111-116.
- [7] Baron, C., Szajnar, J. (2008). The thickness of surface composite layers in a stochastic expressions. *Quality of materials and products - Monograph* (51-58). Saint-Petersburg.
- [8] Gawroński, J., Szajnar, J. & Wróbel, P. (2006). Surface layers of composite technology and its application. *Archives of Foundry Engineering*. 6 (19), 103-112. (in Polish).
- [9] Szajnar, J., Wróbel, P. & Wróbel, T. (2008). Model castings with composite surface layer – application. *Archives of Foundry Engineering*. 8 (Special Issue 3), 105-110.
- [10] Walasek, A., Baron, C. & Szajnar, J. (2011). The influence of silicon on the process of surface alloy layer forming. In 48<sup>th</sup> Foundry Days and 8<sup>th</sup> International PhD Foundry Conference.