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The attempt of determination of parameters for the alloy layer forming process based on the empirical examination

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Abstract

In this work the results of research connected with the problem of determination of the temperature at the beginning of the alloy layer forming process on the steel cast were presented. It was shown that diffusion of chromium, carbon and iron, between the material of the premould made of grainy, high – carbon ferrochromium and the cast steel, has an influence on the surface alloy layer forming process. There was an attempt to determine the liquidus and solidus temperatures for ferrochromium. Additionally, the researches were carried out with the purpose of determination of the time of alloy layer forming process.

Keywords: Layer cast, Surface alloy layer, Ferrochromium, Diffusion, Composite premould

1. Introduction

The research connected with the layer and composite cast have been carried out in Foundry Department of Silesian University of Technology for several years [1-8]. Recently, the layer casts have become the most interesting because of great industry demand for the parts of machines resistant to abrasive wear. The steel casts need to be subject to heat treatment or chemical constitution modification in order to gain high resistance to abrasive wear. It is not economical. The foundry technology of surface alloy layers on the steel cast forming satisfies the needs of contemporary industry: high hardness, strength, resistance to abrasive wear and concurrently high plasticity of the core. The process of forming such layers is possible thanks to foundry technology of forming the element with required properties not for all cast but only for chosen parts. Specially prepared premould is fixed on the chosen surfaces of the mould cavity and poured with the liquid metal.

At the beginning, researches were carried out with the use of cast iron [1-2]. Nowadays, low – carbon cast steel is used in the researches [3-8]. 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 all composite premould and solidification as the layer connected with the cast lastingly [3]. The second one says that composite layer forms by the diffusion of components (Fe) from metal to premould and inversely (Cr, C) [4]. It is assumed that diffusion process proceeds mainly in the solid state from the moment of the contact between liquid alloy and premould. The layer of the alloy freezes to the premould as result of large temperature difference. The higher temperature is 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 constitution different from both alloy of the cast and grainy material of the composite premould.

2. The researches aim and range

The first aim of the researches was to determine the temperature when the alloy layer forming process starts. The second aim was to confirm a hypothesis that surface alloy layer starts to form at the temperature lower then T_S for premould material and the cast. At the beginning, the liquidus and solidus temperatures for high – carbon ferrochromium FeCr800 should have been determined.

The following stages of researches were done:

1. Finding the temperatures T_L and T_S for ferrochromium FeCr800 with the use of results obtained during ATD analysis.
2. Finding the characteristic temperatures T_L and T_S with the use of program Thermo-Calc.
3. Conducting the test casts in order to determine the characteristic parameters of alloy layer forming process.

The structure of the alloy layer obtained from high – carbon ferrochromium and cast steel is presented on the figure 1. cast low – carbon steel (0,28%C) was used in the researches. Grainy high – carbon ferrochromium FeCr800 (tab. 1) with the size of the grain 0,2 ÷0,3 mm was used to make the premould. The solution of polystyrene in etyl acetale was used as the binder. The pouring temperature was 1600^0C.

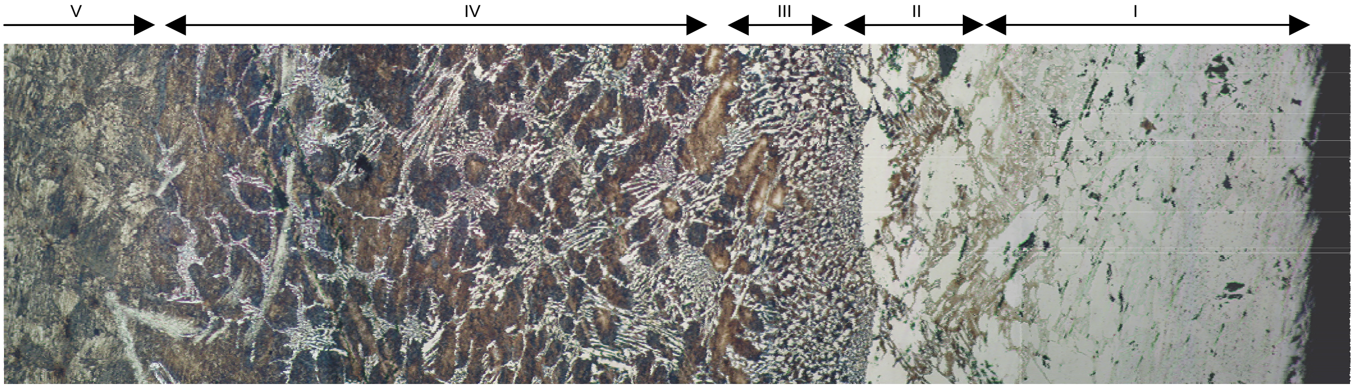


Fig. 1. Microstructure of the layer cast - magnification 100x

On the figure 1, there is the area of:
I – alloy layer,
II – the layer of party melted grains FeCr joined by eutectic mixture,
III.- eutectic mixture,
IV – hypoeutectic mixture,
V – cast steel.
The thickness of surface alloy layer averages 3,68 mm for the premould 5 mm.

2.1. The determination of the liquidus and solidus temperature for high – carbon ferrochromium

The ralation between liquidus and solidus temperatures of premould material land Basic alloy is one of the most important requirement for surface alloy layer forming. The first theory of alloy layer forming would be more justified at the lower temperatures T_L and T_S. So, one of the aims of this work was to determine liquidus and solidus temperatures for ferrochromium with the use of ATD method.

High – carbon ferrochromium FeCr800 was used during the researches. Its chemical constitution is the following (tab.1).

Table 1.
Chemical constitution of ferrochromium

Material	Fe%	Cr%	C%
FeCr800	26	65	9

Ferrochromium was being melted in the inductive crucible furnace of average frequency (in graphidoidal crucible). Three melts were conducted, each with ATD attempt.
Figure 2 shows the example of ATD result. The characteristic points were found on the basis of solidification and crystallization curves. The liquidus and solidus temperatures were determined for each attempt. The average temperatures are the following: T_L = 1600 ^{o}C and T_S = 1489 ^{o}C.

Moreover, the liquidus and solidus temperatures for ferrochromium were found from the diagram of Thermo-Calc program (fig.3).
T_L – liquidus temperature for FeCr800 – 1627^{o}C,
T_S – solidus temperature for FeCr800 – 1547^{o}C.
The temperatures determined by the program Thermo-Calc are different then the temperatures determined by ATD method, the

difference was 27°C for liquidus temperature and 58°C for solidus temperature.

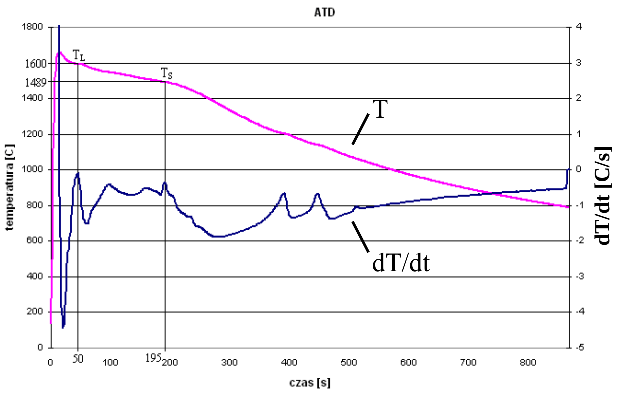


Fig. 2. The process of solidification and crystallization of ferrochromium

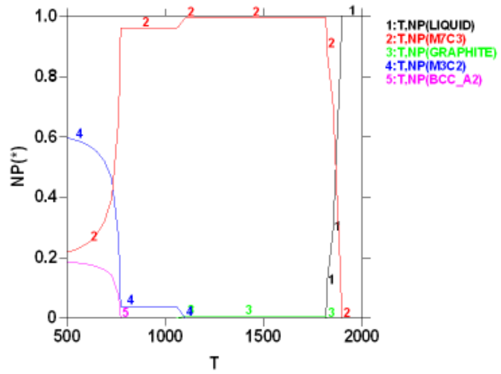


Fig. 3. The process of FeCr800 crystallization

The difference between the temperatures may be caused by the different speed of cooling down of the alloy; the approximate speed for real researches was 1,1 [K/s], the speed of program Thermo-Calc was determined for equilibrium conditions.

2.2. Run of main researches

Three attempts were conducted in order to determine the initial temperature for alloy layer forming process. It was assumed to create the same conditions during alloy layer forming process on cast steel as in the foundry mould.

During the first attempt, high – carbon ferrochromium at the grain coarseness from 0,2 to 0,3 mm mixed with low – carbon cast steel (0,28% C) 1:1 were placed in the quartz pipe. The samples took the shape of cylinder with 5mm diameter and 30mm height (tab. 2 – sample 1). They were dipped in liquid cast steel at the temperature 1300, 1350 and 1400 °C for two minutes. The problem considered for the attempt 1 concerns the question if grains of FeCr and cast steel will be joined as a result of diffusion at the temperature 1300 ÷1400°C. In this case the effect of diffusion is observed for the samples 1_2 i 1_3 heated at the temperature 1350° and 1400°C.

During the second attempt, cast steel bar with 5mm diameter hole was placed in the quartz pipe. There was placed high – carbon ferrochromium in the hole. The sample 2_1 was dipped in liquid cast steel at the temperature 1300 °C for two minutes. The sample 2_2 was dipped in liquid cast steel at the temperature 1350°C for two minutes. The sample 2_3 was dipped in liquid cast steel at the temperature 1350°C for four minutes. The problem considered for the attempt 2 concerns the question if it is possible to obtain alloy layer at the temperature lower then T_S of FeCr800 and cast steel.

The alloy layer was obtained in all cases in spite of enlarged heat capacity. The original carbides MC were not fully dissolved by parameters of the process. They stayed in the layers as the small, ball – shaped phases (sample 2_2). The fragmentary joint of ferrochromium with cast steel is observed for the samples heated at the temperature 1300 °C and 1350 °C for two minutes. Surface alloy layer with the transition zone is observed for the sample heated at the temperature 1350 °C for four minutes.

During the third attempt, cast steel bar and high – carbon ferrochromium were placed in the quartz pipe (tab. 2 – attempt 3). The bar (ϕ5 mm) was in contact with grainy FeCr800 with the use of only one frontal surface. The samples were dipped in liquid cast steel at the temperature 1300, 1350 and 1400 °C for two minutes.

The components were fully mixed in the sample 3_3 heated at the temperature 1400 °C. Surface alloy layer with the transition zone is observed for the samples heated at the lower temperatures.

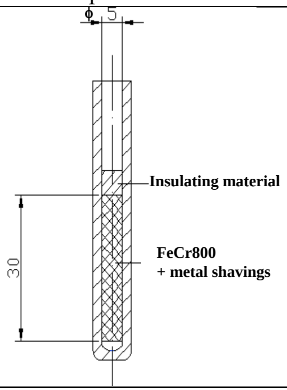
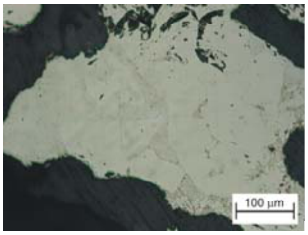
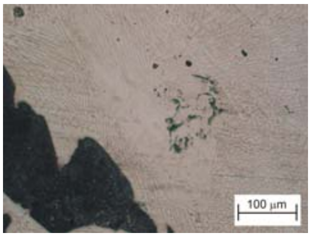
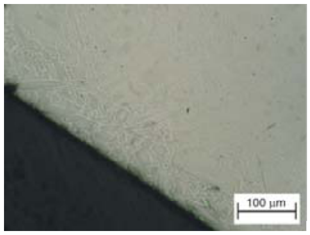
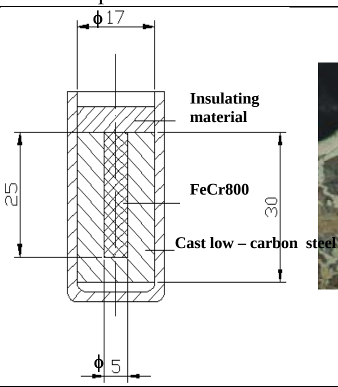
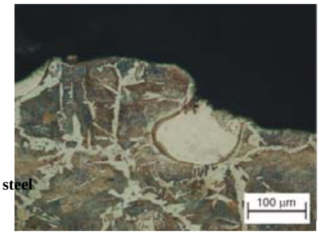
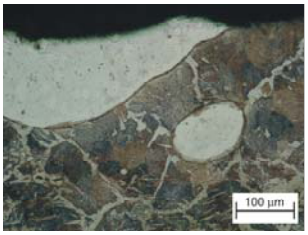
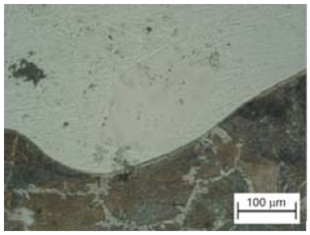
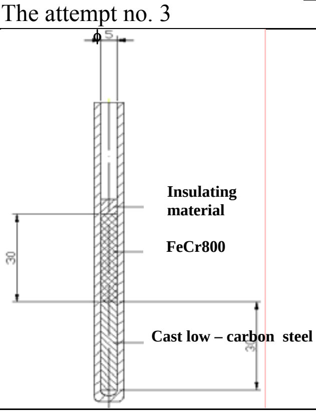
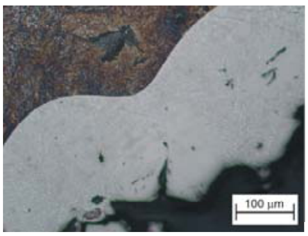
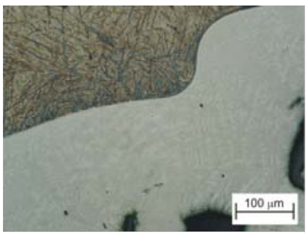
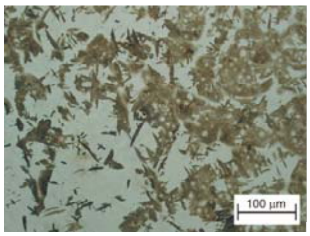
3. Conclusions

There are some premises, based on the comparison between temperaatures T_L and T_S of Febr (fig.2,3) and low – carbon cast steel (0,28%C), to say that surface alloy layer forming proceeds from the solid state. Thre diffusion of Cr and C from ferrochromium to cast steel and Fe from cast steel to FeCr is the reason of surfach alloy layer forming process. It is possible to assume that the diffusion takes place till the moment when the concentration of these elements is similar in both the transition zone and chromic eutectic cast iron. Then, the melting, crystallization and layer forming process will take place.

The following conclusions were obtained on the basis of researches:

- the temperature and the time of joined materials staying at this temperature have influence on the surface alloy layer forming,
- the temperature, which is needful for the beginning of the alloy layer forming process on the contact surface between FeCr and cast steel, is lower then solidus temperature for both cast steel and ferrochromium,
- the mechanism of the alloy layer forming process on the contact surface between premould and steel cast comes from the diffusion in liquid state; as a result of this phenomenon, the alloy, with melting temperature lower then T_S of both FeCr and cast steel, is obtained; the alloy forms (after solidification) surface alloy layer lastingly fixed to the cast.

Table 2.
The kind of conducted researches

No. of the attempt	magnification 200x for temperature		
	1300°C	1350°C	1400°C
The attempt no. 1	1_1	1_2	1_3
	 Time – 2 [min]	 Time – 2 [min]	 Time – 2 [min]
	1300°C	1350°C	1350°C
The attempt no. 2	2_1	2_2	2_3
	 Time – 2 [min]	 Time – 2 [min]	 Time – 4 [min]
	1300°C	1350°C	1400°C
The attempt no. 3	3_1	3_2	3_3
	 Time – 2 [min]	 Time – 2 [min]	 Time – 2 [min]

Acknowledgements

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