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Castings Dimensions Influence on the Alloyed Layer Thickness

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Abstract

The paper presents the results of simulation of alloy layer formation process on the model casting. The first aim of this study was to determine the influence of the location of the heat center on alloy layer's thickness with the use of computer simulation. The second aim of this study was to predict the thickness of the layer. For changes of technological parameters, the distribution of temperature in the model casting and temperature changes in the characteristic points of the casting were found for established changes of technological parameters. Numerical calculations were performed using programs NovaFlow&Solid. The process of obtaining the alloy layer with good quality and proper thickness depends on: pouring temperature, time of premould hold at the temperature above 1300^{o}C. The obtained results of simulation were loaded to authorial program Preforma 1.1 in order to determine the predicted thickness of the alloy casting.

Keywords: Thermal center, Alloy layer, Ferrochromium, Cast steel

1. Introduction

Nowadays, layer steel casting have become the most interesting subject because of great industry demand for the parts of machines resistant to abrasive wear [1-8]. The steel casts need to be subject of heat treatment or chemical constitution modification in order to gain high resistance to abrasive wear [9]. It is not economical. The foundry technology of surface alloy layers forming on the steel cast 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 only for chosen parts instead of all cast [10]. Specially prepared pad is fixed on the chosen surfaces of the mould cavity and poured with the liquid metal [11,12].

The technology of surface composite layer forming process on the chosen surfaces of the cast also guarantees the following properties [13-15]:

- the hardness much higher than the hardness of the basic cast alloy,
- the abrasion resistance much higher than the abrasion resistance of the basic cast,
- optimal thickness of the surface composite layer depending on the work conditions and the thickness of the cast face,
- the possibility of the heat treatment avoidance – usually one – stage of full annealing or normalization instead of two – stage.

The process of creating a surface layer depends on many physical and chemical factors. Properties mainly depends on the self-colling conditions and the reaction on the surface of the metal / pad (that is the kind of liquid cast steel impact on the pad during pouring and self-colling process) [13-15].

2. The aim of the study

The main aim of this work was to determine the effect of the location of the heat center on the layer's thickness. There were also the attempts of the prediction of the layer's thickness. Tests were conducted with the use of computer programs. There have been changes in the size of the casting, without changing the module casting.

3. The range of studies

To achieve the aims of the work, the following scope of research was taken:

1. working out the constructing assumptions of a model casting
2. simulation of the process of creating alloy layer for the following assumptions:
   a) pouring temperature changes at three levels:
      - $T_1 = 1600^0C$
      - $T_2 = 1550^0C$
      - $T_3 = 1510^0C$
   b) casting material – low-carbon cast steel (Table 1)
   c) material pad:
      - high-carbon ferrochromium FeCr800 (Table 2)

Table 1.
Chemical constitution of low carbon cast steel

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

Table 2.
Chemical constitution of ferrochromium FeCr800

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

3. Casting model design assumption

The shape of the casting was designed so that the construction of the pad and form was not troublesome and time-consuming. Location of the pad and shape of ingate were selected to minimize the erosion of the metal stream (Fig. 1).

The basic model was the cubicoid of dimensions 80x80x100mm (model no 2) and 80x80x60mm (model no 1) – Fig. 1.

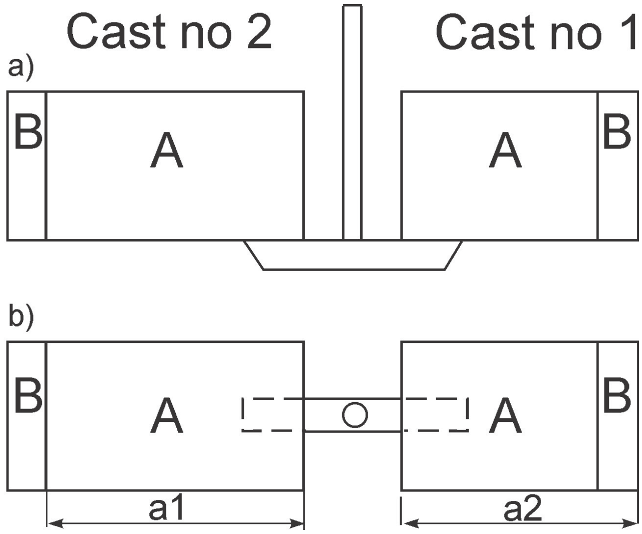

Fig. 1. Construction of model casting; a) top view; b) side view; A – steel casting, B – alloy pad

The dimensions (a1, a2) were reduced or increased to change the position of the heat center (Fig. 2). Dimensions of the cast were changed in such a way that modules of examined casts responded to base cast.

There are presented the changes of dimension with the same module in Table 3.

Table 3.
The size of model casts

Base model nr 2					Base model nr 1				
80	x	80	x	100	80	x	80	x	60
The model changed - by the increasing of the size									
70	x	70	x	150	70	x	70	x	90
70	x	70	x	180	70	x	70	x	100
The model changed – by the reduction of the size									
90	x	90	x	80	150	x	150	x	30
110	x	110	x	55	175	x	175	x	35

4. Simulation

Three-dimensional geometry of the testing casting was made on the basis of construction assumptions in program SolidWorks (Fig.2). Geometry was imported into the simulation program Nova Flow&Solid. It was found the location of virtual thermocouples (Fig. 3) and introduced data for simulation (table 4).

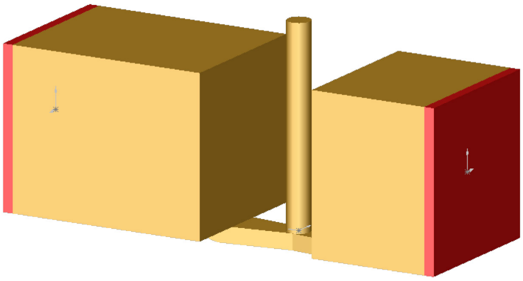

Fig. 2. Schema of model casting

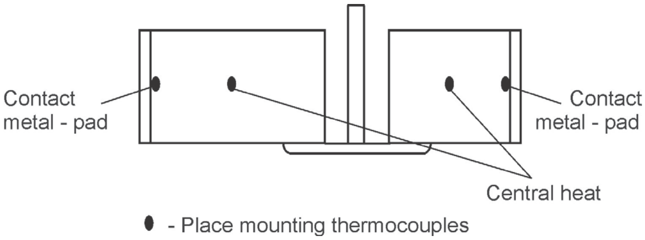

Fig. 3. Arrangement of the thermoelements

Initial temperatures of various materials used in the simulation:

- pad temperature 20 °C
- form temperature 20 °C
- ambient temperature 20 °C
- material temperature:
  - T_1 = 1600 °C
  - T_2 = 1550 °C
  - T_3 = 1510 °C

Computer simulations were carried out for three different pouring temperatures after changes of the cuboids' dimensions (80x80x100mm and 80x80x60mm) and realizing virtual model casting by the program SolidWorks.

Thermophysical data of materials are presented in Table 4, where:

- – T – temperature,
- – λ – thermal conductivity,
- – Cp – specific heat,
- – ρ – density,
- – T_{liq} – liquidus temperature,
- – T_{sol} – solidus temperature,
- – Q_{cr} – heat of crystallization,
- – Q_{eu} – heat of eutectic.

Table 4.
Thermophysical data of materials used in simulation calculation

T [°C]	λ [W/m/°C]	Cp [J/kg/°C]	ρ[kg/m³]
FeCrC			
0	45	450	-
20	-	-	7500
200	-	475	7447
500	30,6	550	7343
700	26,2	600	7270
1100	24	650	-
1200	-	-	7080
1500	-	750	-
Cast steel			
	T_{liq} = 1505,53, Q_{cr} = 250 [kJ/kg],	T_{sol} = 1451, Q_{eut} = 250 [kJ/kg]	
0	51,8	469	-
500	39,3	661	-
1000	27,2	644	-
1100	28,5	644	7431,1
1200	29,7	661	-
1300	29,7	686	-
1400	-	-	7262,6
1525	-	-	6995
1550	-	740	6978,88
1600	30	740	6946,23
Moulding sand			
20	0,9	550	1550
500	0,6	600	1500
1000	0,5	800	1490
1500	0,5	900	1450

5. The results of the simulation.

The results of temperature (at the measurement point) for different cuboids and different pouring temperatures are given in Table 5.

Table 5.
The results of calculations of temperature and time for particular model casts at different pouring temperatures; C_c – central heat, w-m – the place of measurement at the place of the contact pad – cast steel, T_{max} – max temperature, Time – residence time at a temperature above 1300^{0}C, T_{zal} – pouring temperature

	Base model nr 2				**Base model nr 1**			
	80 x 80 x 100				80 x 80 x 60			
T_{zal} [^{o}C]	C_g		w-m		C_g		w-m	
	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]
1600	1591,4	937,8	1565,9	844,8	1591,3	667,4	1503,5	630,4
1550	1543,6	866,7	1513,5	774,4	1542,9	607,9	1502,6	570,4
1510	1506,3	782,3	1504	685,3	1506	462,6	1506	427,2
The model changed - by the increasing of the size								
	70 x 70 x 150				70 x 70 x 90			
T_{zal} [^{o}C]	C_g		w-m		C_g		w-m	
	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]
1600	1590,4	1141,6	1505,3	907,9	1587,8	847,1	1589,9	847,1
1550	1539,4	1035,8	1501,3	788,9	1538,9	762,3	1512,4	681,3
1510	1505,6	929,8	1494,2	656,2	1505,3	625,7	1504	537,7
	70 x 70 x 180				70 x 70 x 100			
T_{zal} [^{o}C]	C_g		w-m		C_g		w-m	
	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]
1600	1589,8	1288	1498	898,4	1587	912,1	1461,7	688,8
1550	1541,7	1170,5	1481,6	789,1	1540,5	817,3	1495,8	706,2
1510	1506	1074,1	1486,5	670	1505,4	683,3	1461,6	573,1
The model changed - by the reduction of the size								
	90 x 90 x 80				150 x 150 x 30			
T_{zal} [^{o}C]	C_c		w-m		C_c		w-m	
	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]
1600	1589,1	929	1505,2	863,6	1594,3	707	1548,6	689,6
1550	1541,3	860,6	1486,8	796	1544,5	644,6	1534,6	629,5
1510	1505,6	725,9	1500,9	660	1506,9	482,8	1504,6	469
	110 x 110 x 55				175 x 175 x 35			
T_{zal} [^{o}C]	C_c		w-m		C_c		w-m	
	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]	T_{max} [^{o}C]	Time [s]	T_{max} [^{o}C]	T_{max} [^{o}C]
1600	1592,4	861,9	1533,5	824,6	1589,9	824,1	1546,7	807,9
1550	1543,5	794,76	1505,4	755	1542,9	743,4	1506,7	722,7
1510	1506,6	636,5	1500,8	602,4	1505,8	539,9	1502,9	532,7

Three models of cast, where the pad holding time above 1300˚C was the longest, were noticed by the analysis of the obtained rezults:

- 70x70x150 (T_{max} = 1505,3; time = 907,9),
- 90x90x80 (T_{max} = 1486,8; time = 796),
- 80x80x100 (T_{max} = 1504; time = 685,3).

The graphs of self - cooling curves for particular virtual measurement points which allow to determine the heating time of pad above the temperature 1300^{0}C are presented on Fig. 4 – 9 . You can specify:

- Hold time at a temperature of 1300^{0}C,
- maximum temperature in the pad.

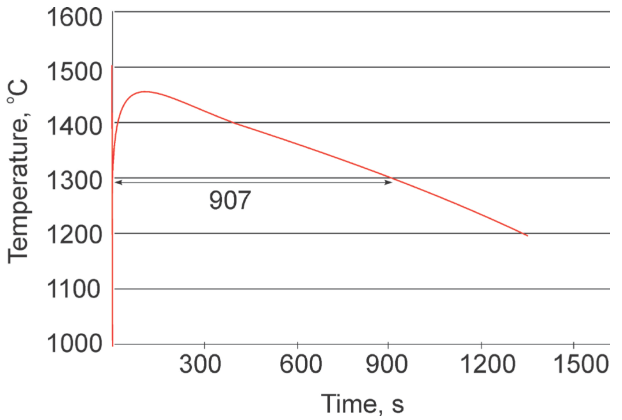

Fig. 4. The courve of temperature changes in time; thermocouple pad; cubicoid 70x70x150mm (pouring temperature 1600^{0}C)

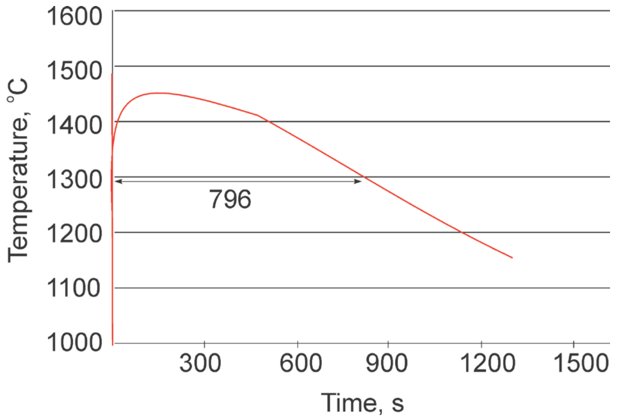

Fig. 5. The courve of temperature changes in time; thermocouple pad; cubicoid 90x90x80mm (pouring temperature 1550^{0}C)

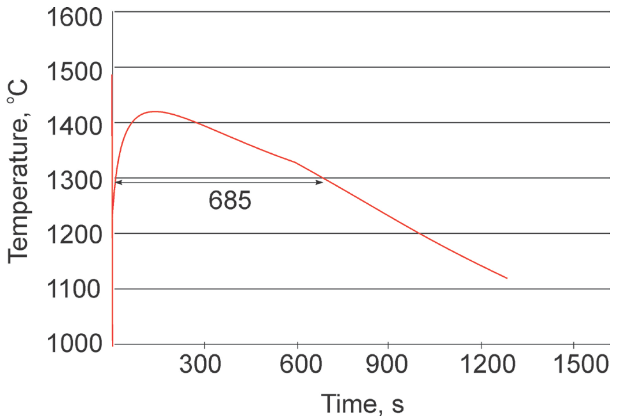

Fig. 6. The courve of temperature changes in time; thermocouple pad; cubicoid 80x80x100mm (pouring temperature 1510^{0}C)

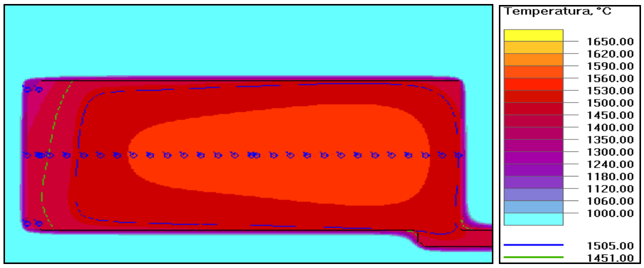

Fig. 7. Temperature distribution after 45 s; cubicoid 70x70x150[mm]; pouring temperature 1600^{0}C

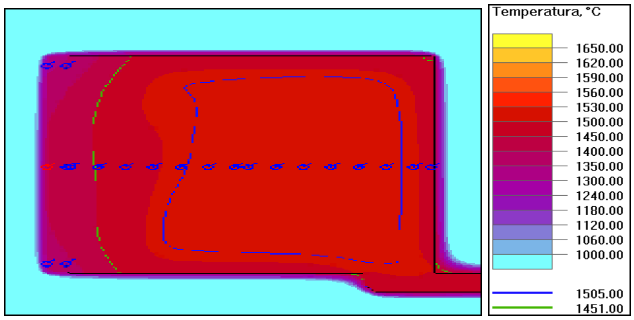

Fig. 8. Temperature distribution after 45 s; cubicoid 90x90x80[mm]; pouring temperature 1550^{0}C

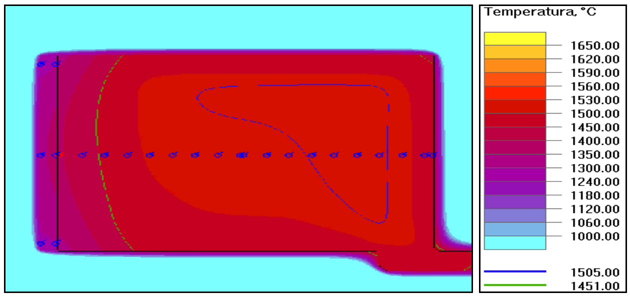

Fig. 9. Temperature distribution after 45 s; cubicoid 80x80x100[mm]; pouring temperature 1510^{0}C

The obtained results (for the three cubicoid castings) were loaded to the program Preforma 1.1 [4]. in order to determine the thickness of alloy layer. The results are shown in Table 5.

Table 5.
The results of alloy layer thickness

Temperature [˚C]	**1600**	**1550**	**1510**
Cuboid cast of dimensions [mm]	70x70x150	90x90x80	80x80x100
Heating time of alloy pad at a temperature above 1300^{0}C [s]	907,9	796	685,3
The average thickness of the alloy pad [mm]	6,4	6,33	5,85

6. Conclusions

It is possible to change the geometry of the casting by changing the location of the heating center in relation to the alloy promould, and to increase the thickness of the layer by the proper choice of pouring temperature.

The greatest thickness of layers was obtained for casting with the dimensions 70x70x150mm and pouring temperature 1600^{0}C.

The thickness of alloy surface layer can be predicted with the use of programs NovaFlow&Solid and Preforma 1.1 (without performing costly trial castings).

The program NovaFlow&Solid calculates the time of pad holding at the temperature above 1300^{0}C. Program Preforma 1.1 calculates the thickness of the alloy casting with the use of obtained data (Table 5).

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