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Thermal simulation of process formation composite layer on model casting

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Materials

ABSTRACT

Purpose: In article the results of thermal simulation of formation composite layer on model cast steel casting process have been presented. The aim of researches was determination of technological parameters of formation composite layer process for which is possible to obtain good quality reinforcement layer with desirable thickness.
Design/methodology/approach: For assumed changes of chose technological parameters, distribution of temperature in model casting as well as course of temperature changes in characteristic point of composite insert have been determined. Simulations have been carried out for two different materials of compositing element (insert) and three different pouring temperatures with software NovaFlow&Solid 2.9 r81.
Findings: Obtaining good quality and with desirable thickness composite layer depends on process and level of heating during casting process.
Research limitations/implications: Researches made possible to determination which technological parameters directly influent on this process and how criterions should be meet by casting technology of this kind of casting.
Originality/value: Obtained results and their experimental verification will make possibility to form a basis for work out guidelines and principles for design technology of casting with composite layer on choose surfaces productions
Keywords: Casting; Surfacing alloy layer; Computer simulation; Technology design

1. Introduction

In present advanced technology world to parts of any kind of devices and machines are put bigger and bigger demands with, in the same time, pressure on falling costs of production and on reducing emission of damaging to environment substances. Characteristic examples are parts of machines with some surfaces open to hard abrasive and, in the same time, open to impact load. It requires high hardness (surface) and high yield point from material of which the part is made [1-4]. Joining of such different properties, high abrasive resistance and good plasticity requires application of elements made of plastic material with reinforced these surfaces which are opening on abrasion. Such reinforcement may be realized on many manners e.g. surfacing by welding alloy layer, bonding of abrasive resistant part with plastic body, hard soldering, etc. [4,7] All of these technologies have many advantages but also have many disadvantages, first of all is that all of them are expensive. Technology of casting made reinforced layer (composite) on chose casting surfaces with, in same time, cast shaping process are deprive of these disadvantages.

2. Researches

The aim of researches was working out constructional assumptions for model casting and working out optimal pouring technology – right construction of pouring system assured as slowly as possible pouring of mould cavity and at uniform rate heating compositing elements. First of all is determination, for worked out constructional and technological assumptions, optimal pouring temperature for tested materials of compositing inserts [3-6]. Optimal in sense of possibility to obtain as thick as possible composite layer on casting with avoiding local dissolve of inserts or its local erosion by flowing metal.

2.1. Researches range

1. Working out constructional assumptions for model casting
2. Working out construction of pouring system and testing it in simulation of pouring process.
3. Simulation of formation composite layer process for the following assumption:
   a. Change of pouring temperature on three level:
      - T_1 = 1510 °C
      - T_2 = 1550 °C
      - T_3 = 1600 °C
   b. Casting material – cast steel AISI-1086
   c. Materials of inserts:
      - ferrochromium FeCr
      - ferrotitanium FeTi
4. Determination of temperature distribution in insert for all levels of variation.
5. Analysis of obtained results and point optimum pouring temperature for tested materials of compositing elements materials.

2.2. Simulation of heat flows during process of formation surface composite

Basis on constructional assumptions three-dimensional geometry of experimental casting has been modeled with SolidWorks software. Next the geometry has been imported to simulation software NovaFlow & Solid v2.9 r81, set the location of virtual thermoelements (fig. 1) and loaded data needed for carrying out simulation (table 1).

Thermophysical data of materials used in thermal calculation:

Materials of comopsiting elements were defined in Flow & Solid 2.9r81 software at group of mould material and inserts were as a kind of chills. It was a result of simulating software limitation.

Thermophysical data of materials are presented in table 1 were: 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} – eutectic heat.

Start data:

- inserts temperature:	20 [°C]
- mould temperature:	20 [°C]
- surroundings temperature:	20 [°C]
- metal temperature:	a) 1510 [°C]
	b) 1550 [°C]
	c) 1600 [°C]

Table 1.
Thermophysical data of materials used in calculation

T [°C]	λ [W/m/°C]	Cp [J/kg/°C]	P [kg/m^3]
Ferrochromium FeCr			
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	-
Ferrotitanium FeTi			
20	40	400	7000
500	30	450	6900
1000	45	500	6800
1500	55	550	6700
Cast steel AISI-1086			
T_{liq} = 1505,53, T_{sol} = 1451, Q_{cr} = 250 [kJ/kg], Q_{eut} = 250 [kJ/kg]			
0	51,8	469	-
20	-	-	7860
100	51	485	-
200	48,6	519	7811,87
300	44,4	552	-
400	42,6	594	-
500	39,3	661	-
600	35,6	745	-
650	-	-	7641,99
700	31,8	845	-
750	28,5	-	-
800	25,9	954	-
850	-	-	7567,31
900	26,4	644	-
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
1700	-	-	6882,23
1800	-	-	6819,49
1900	-	-	6757,99
Sandmix – green sand			
20	0,9	550	1550
500	0,6	600	1500
1000	0,5	800	1490
1500	0,5	900	1450

Location of virtual thermoelements in compositing inserts

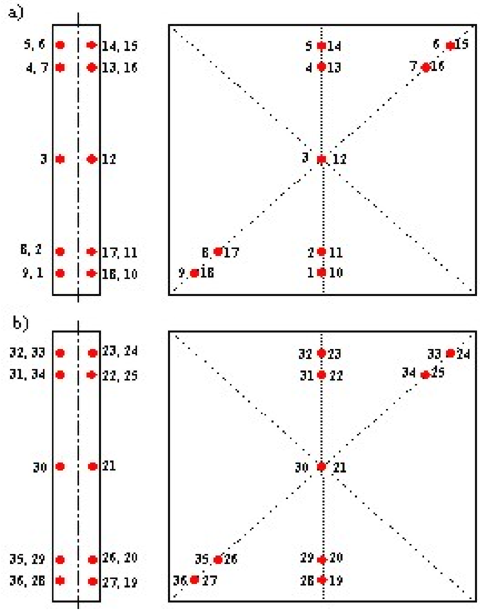

Fig. 1. Location of thermocouple in premould for: a) big cube; b) small cube

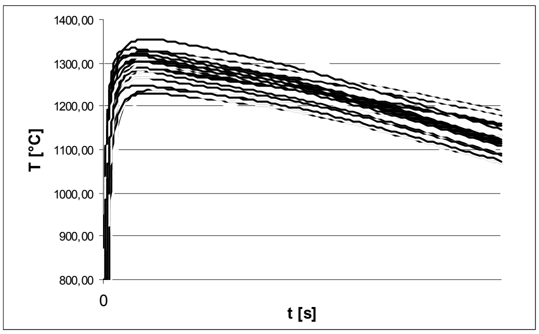

Fig. 2. Temperature – time changes course

Big cube – internal side

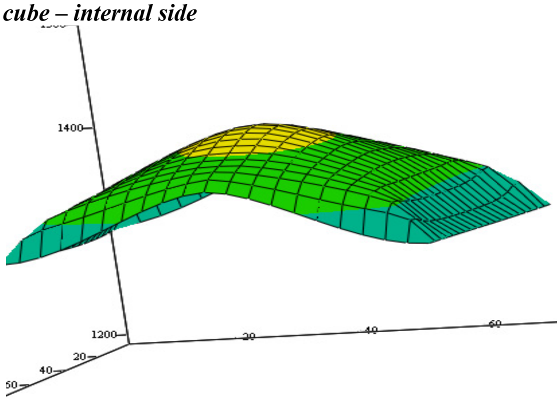

Fig. 3. Insert maximum heating image

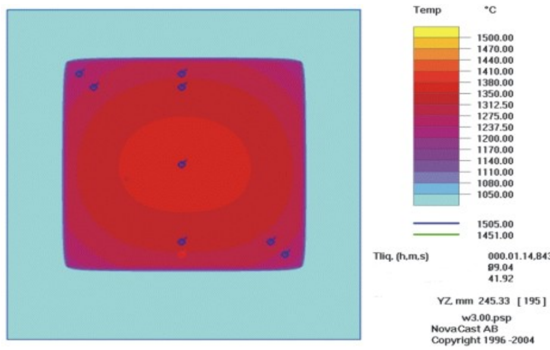

Fig. 4. Temperature distribution after 74,8 s

3. Results

Result of simulation was set of cooling curves one for each virtual point of temperature measure. Example graph for ferrochromium and pouring temperature 1510 °C are presented in figure 2.

Basis on obtained results for all carried out simulation essential data, need for further analysis, have been determined.

T_{max} – maximum temperature in given point of measure,
t_{Tmax} – time after which given point reach maximum temperature,
T_t – temperature at the moment of pouring end,
t_{T-Ts} – time after which given point exceed solidus temperature,
t_{T-TL} – time after which given point exceed liquidus temperature,
t_L – time, during which given point have temperature highest than liquidus temperature,
t_S – time, during which given point have temperature highest than solidus temperature,

Example set of determined values of data in text form are presented in table 2 as well as in graphic form as three-dimension graph of maximum heating of inserts and temperature distribution in insert for given moment at which it was the most advantage are presented in figure 3 and 4.

Temperatures solidus and liquidus for inserts materials were read out from graphs calculated with Thermo-Calc software.
T_{SFeCr} – solidus temperature of FeCr – 1300 °C
T_{LFeCr} – liquidus temperature of FeCr – 1545 °C
T_{SFeTi} – solidus temperature of FeTi – 1390 °C
T_{LFeTi} – liquidus temperature of FeTi – 1460 °C

4. Conclusions

1. For undertook casting construction the most advantages pouring temperature, also for FeCr and FeTi, is 1550 ^{o}C. Its guarantee composite layer formation on whole reinforced surface with low danger of local erosion of insert by flowing metal.
2. In each case more advantages temperature distribution was in compositing element for small cube (smaller mould cavity). Its pointed to advantageous influence of low distance between premould and heat center of casting, not as excepted heat capacity of casting.

Table 2.
Values determined for ferrochromium FeCr and pouring temperature 1550 °C

Pt.	T_{max}	t_{Tmax}	T_t-8,336s	$t_{T-1300(Ts)}$	t_S	$t_{T-1545\ (TL)}$	t_L
1	1375,92	74,35	1187,48	18,43	353,04	-	-
2	1389,12	74,35	1173,63	17,26	393,29	-	-
3	1417,10	74,35	1098,51	17,55	478,28	-	-
4	1380,84	74,35	848,85	24,70	373,16	-	-
5	1364,82	74,35	742,27	29,79	325,50	-	-
6	1305,62	74,35	697,42	63,33	33,14	-	-
7	1343,00	74,35	818,01	33,59	207,24	-	-
8	1347,89	74,35	1129,90	26,56	239,69	-	-
9	1316,13	74,35	1115,20	45,60	83,07	-	-
10	1359,67	74,35	1077,67	27,41	316,61	-	-
11	1374,66	74,35	1062,98	24,29	366,58	-	-
12	1403,72	74,35	867,53	22,91	460,62	-	-
13	1365,41	74,35	378,26	31,98	344,64	-	-
14	1347,20	80,91	232,43	38,97	284,53	-	-
15	1284,18	80,91	218,77	-	-	-	-
16	1326,17	74,35	362,28	45,99	149,44	-	-
17	1332,14	74,35	1018,35	38,56	186,70	-	-
18	1296,81	74,35	1000,32	-	-	-	-
19	1390,37	55,79	1242,25	10,06	345,01	-	-
20	1404,29	55,79	1244,19	9,83	378,60	-	-
21	1421,38	74,35	1097,22	13,75	439,59	-	-
22	1389,35	74,35	802,21	20,13	353,71	-	-
23	1371,83	74,35	733,88	24,05	311,87	-	-
24	1308,20	74,35	685,24	56,28	44,92	-	-
25	1350,07	74,35	783,42	27,14	209,60	-	-
26	1358,24	74,35	1097,83	22,33	247,32	-	-
27	1322,16	74,35	1024,91	39,40	100,54	-	-
28	1415,29	25,30	1372,80	5,95	367,75	-	-
29	1425,37	28,15	1374,72	6,09	395,51	-	-
30	1433,95	74,35	1291,34	8,60	452,42	-	-
31	1404,50	67,96	1133,58	14,43	373,98	-	-
32	1389,17	74,35	1092,06	17,02	340,29	-	-
33	1329,08	74,35	989,67	33,27	113,72	-	-
34	1366,91	67,96	1107,56	18,68	250,64	-	-
35	1374,11	67,96	1200,44	15,31	282,84	-	-
36	1341,20	67,96	1127,89	25,01	158,67	-	-

4. Carried out analysis of results and calculations of probability formation composite layer about particular thickness confirm more advantages conditions of composite layer formation for small cube (thicker and about more regular thickness alloy layer) for low distance between premould and heat center of casting.
3. Obtained results and its analysis make possible to determine basic guidelines for designing technology and construction of surface reinforced casting, but whole experiment was carried out as a virtual experiment and obtained results should be verified in real experiment.

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