HEAT FLOW KINETCS IN THE MOULDING SAND

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Abstract

Attempt to determine the heat flow kinetics in insulating moulding sand with aluminosilicate microspheres matrix in order to identify and modify its properties. Destination of moulding sand is pouring thin-walled skeletal casting 3D, characterized by strongly developed surface of heat dissipation and 1,5÷3 mm predicted connector thickness. Shows the results of computer simulation of temperature field in the mould. For the implementation of the research uses about eutectic aluminium alloy with silicon (AlSi12). Shows the results of the heat flow in the cast-mould system using experimental casting typically for thermal derivative gradient analysis (TDGA). The method was developed in the Department of Foundry of Silesian University of Technology. For the purpose of the own research the methodology has been modified by location most of the thermocouple not in the cast, but in the moulding sand. Thermocouple were placed in established and variable distances in the range of 0 to 8 mm from the surface of the casting. One of the thermocouple was placed in the geometric centre of the casting. Simulation study were performer, which aim was precision analysis of heat flow in the mould. This analysis is the basis for the designation of thermophysical and technological parameters of mould or core sand. The aim is to estimate the thermophysical of technology quantity in actual industrial environments. Application of the concept of TDGA methods in the assumption should allow to quickly obtain the information about thermal properties of mould without uses of complex thermal laboratory research. Assumed that the analysis of the temperature field gives a qualitatively comparable results to the standard determining of thermal properties in a function of temperature. Despite the simplifications, the importance of technological methods may prove to be attractive in the production conditions of a typical foundry.

Keywords: Aluminosilicate microspheres, moulding sand, heat flow, TDGA

1. INTRODUCTION

Control of crystallization parameters, in particular the rate of heat removal, has a fundamental role in the production of castings. Proper design of the mould is not easy, moreover, is difficult and expensive process. An important tool for engineers, which significantly facilitates the process of developing technology, is a specialized computer software. It allows to perform simulations of complex thermal processes occurring during casting and, despite needs of considerable computing power, greatly shortens the implementation process technology [1].

2. SIMULATION PROGRAMS

Simulation programs, both in the foundry and broadly defined other branches of industry, have an important role. On the one hand allow to fine-tune manufacturing processes without the need for laborious technical tests, on the other to visualize a series of phenomena occurring during the process proceed. The examples of practical use of computer simulation in foundry can be found at:

a) conduct metal place control and pouring system,

b) evaluation of the functioning of risers, optimize their size, shape and location of the casting,

c) check the connections methods of risers with cast and insulation materials activities,

d) the search for alternative ways of eliminating porosity, e.g. through the use of external chill or cooling fins,

e) depict the crystallization process and the designation of time after which the cast reaches the right temperature for knocking out,

f) determining the stress field in casting and sites vulnerable to breakage,

g) casting structure prediction and appearance e.g. hard spots in cast iron etc.,

h) estimating the kinetics of phase transformations that occur in the solid cast during its cooling down and during the various thermal treatment.

Simulations of all these phenomena can be successfully used in the analysis of the tests described in literature [2÷9]. A series of information concerning the description in foundry simulation processes and results of research related to heat flow, predicting the microstructure or description of the process included among other things in items [10÷14].

3. RANGE OF STUDIES

The aim of the study is presenting and analyzing the results of computer simulation of heat flow in a cast-mould system using experimental casting typically for thermal derivative gradient analysis (TDGA) [15]. Experimental casting has a cone shape.

In the framework of the research casting model and mould were made in the SOLID EDGE programme. In programme NOVAFLOW&SOLID desirable materials both parts were assigned, then 6 sensors in the mould at dirfferent position of high were located (similarly in the TDGA method). Sensors were placed on the rising spiral of the curve. 1 sensor were placed in the geometric centre of the casting. Thermocouples were located at the mould-casting contact and in the mould in 2, 4, 6 or 8 mm distance from the casting. Localisation of thermocouple shown in fig. 1. In subsequent simulations sensors distance from casting surface were edited.

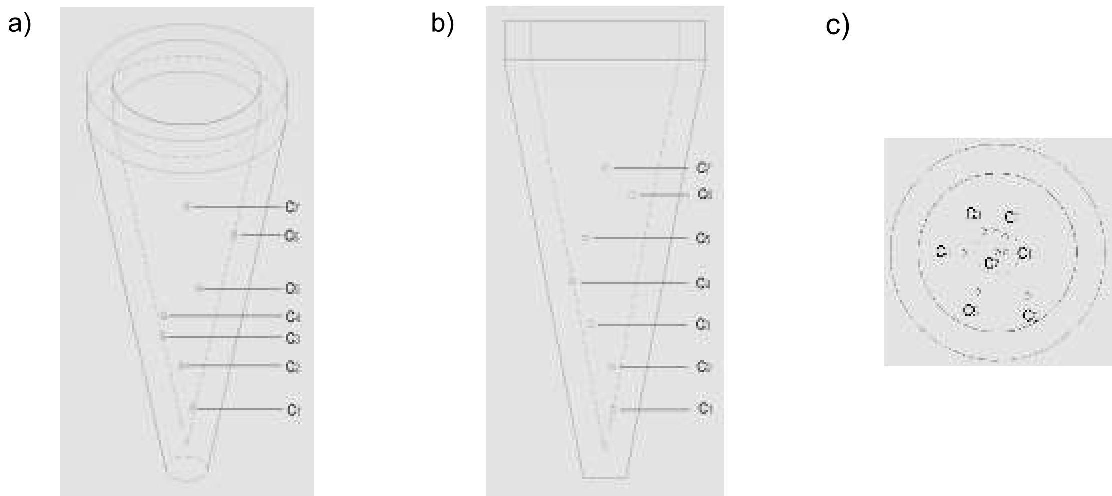

Fig. 1. Examples of arrangement of sensors C1÷C6 in the mould enclosing cone experimental casting. C7 sensor in the geometric centre of the experimental casting

4. RESULTS OF STUDIES

The results of the maximum temperature value and the corresponding time shown in tables 1,3,5,7,9. Temperature measurement at intervals of 100 seconds shown in the tables 2,4,6,8,10. In figure 2÷6 presented the cooling curves obtained by simulation. Pouring temperature is assumed to be equal to the 680 [°C].

4.1. SENSORS PLACED AT THE MOULD-CASTING CONTACT

Table 1. Maximum temperature and the duration of its occurence reported at the mould-casting contact

Sensor no	C1	C2	C3	C4	C5	C6	C7
Max temp. [°C]	653	680	595	608	648	678	681
Time [s]	1	1	8	8	6	4	3

Table 2. Temperature measurement at intervals of 100 seconds at the mould-casting contact

Time [s]	C1	C2	C3	C4	C5	C6	C7
	Temp. [°C]						
100	552	572	556	556	548	573	574
200	387	390	381	371	363	377	379
300	240	246	241	234	226	230	234
400	156	163	161	157	152	154	156
500	106	113	113	111	109	112	111
600	84	91	91	91	90	93	91

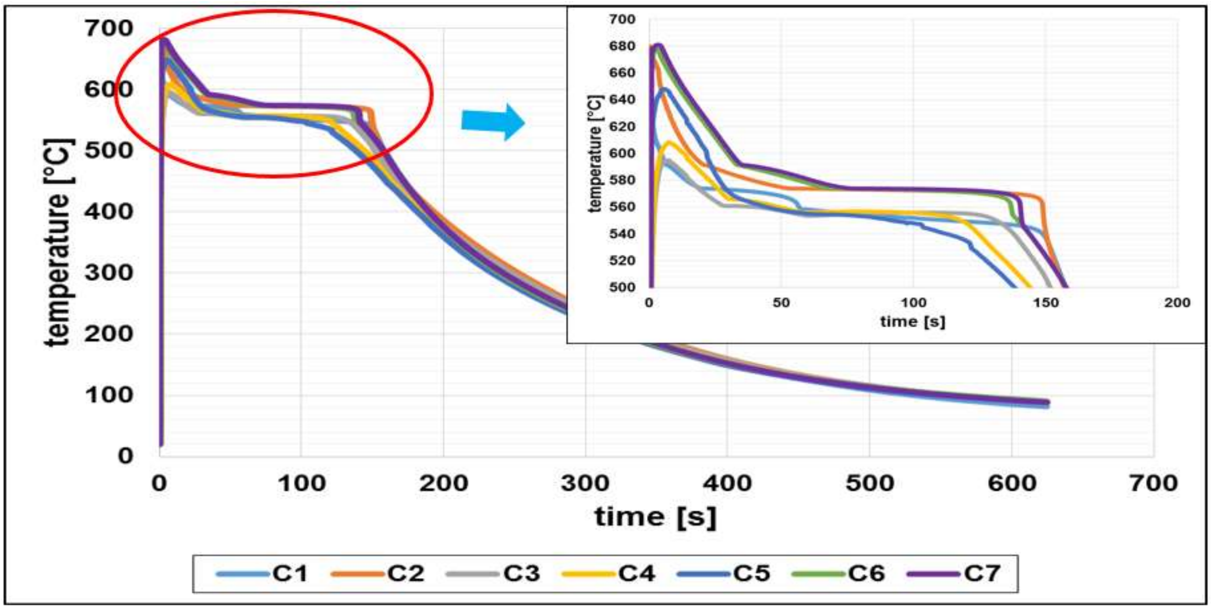

Fig. 2. Temperature change at the mould-casting contact

4.2. SENSORS PLACED IN 2 MM FROM CASTING SURFACE DISTANCE

Table 3. Maximum temperature and the duration of its occurence reported in 2 [mm] from casting surface distance

Sensor no	C8	C9	C10	C11	C12	C13	C14
Max temp. [°C]	435	446	391	439	405	499	681
Time [s]	142	143	136	120	104	127	3

Table 4. Temperature measurement at intervals of 100 seconds in 2 [mm] from casting surface distance

Time [s]	C8	C9	C10	C11	C12	C13	C14
	Temp. [°C]						
100	428	434	375	433	405	496	574
200	329	345	320	339	296	362	379
300	206	223	214	220	192	221	234
400	137	150	148	150	130	148	156
500	93	102	103	105	93	105	111
600	74	81	82	85	78	86	91

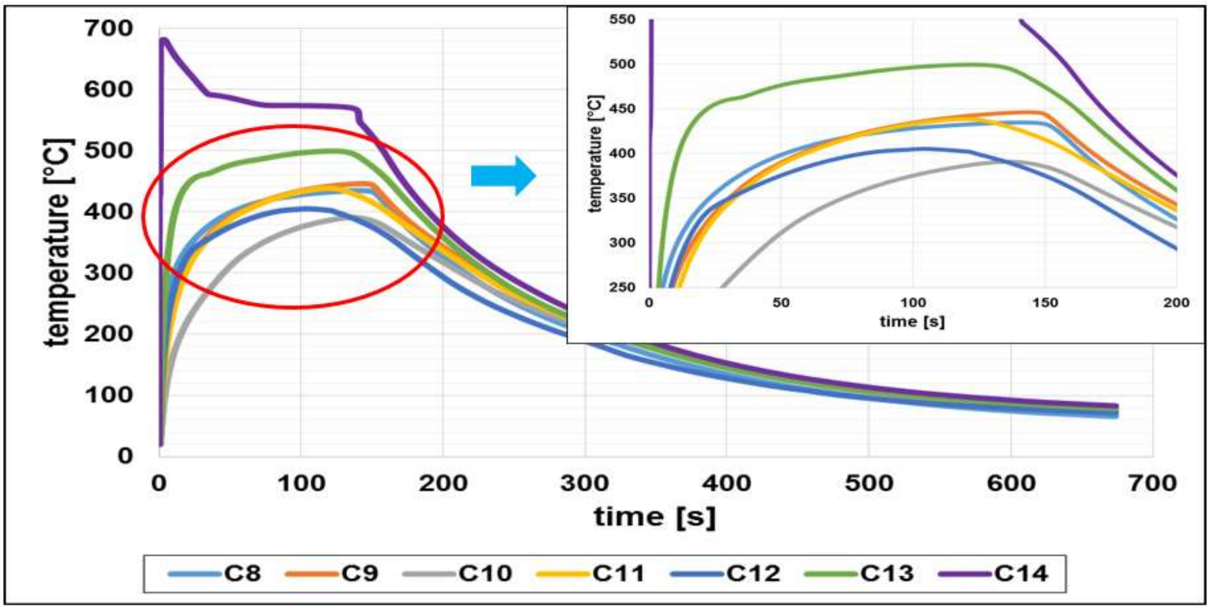

Fig. 3. Temperature change in 2 [mm] from casting surface distance

Among the sensors located inside the walls of the mould the highest maximum temperature recorded thermocouple C13 located at the altitude of 102 [mm], which indicated temperature nearly 500 [°C]. It can be presumed that the lowest maximum temperature should be noted by sensor, which is the lowest because of the smallest volume of liquid metal in the place of its location, what is connected with the fastest heat loss from the beginning of the pouring process. The lowest temperature (391 [°C]) were pointed by sensor C10, which is positioned at height of 51 [mm]. It can be the result of a small mesh concentration, which preclude accurately arrangement of the sensors, the consequences the thermocouple C10 could be much more remote from the outside surface of casting than the other thermocouple.

4.3. SENSORS PLACED IN 4 MM FROM CASTING SURFACE DISTANCE

Table 5. Maximum temperature and the duration of its occurence reported in 4 [mm] from casting surface distance

Sensor no	C15	C16	C17	C18	C19	C20	C21
Max temp. [°C]	308	322	323	343	310	380	681
Time [s]	152	152	145	133	127	139	3

Table 6. Temperature measurement at intervals of 100 seconds in 4 [mm] from casting surface distance

Time [s]	C15	C16	C17	C18	C19	C20	C21
	Temp. [°C]						
100	288	296	300	327	303	363	574
200	261	279	280	291	261	317	377
300	174	189	192	193	174	193	222
400	119	131	133	133	121	131	148
500	86	95	98	99	92	97	111
600	68	75	78	80	76	80	91

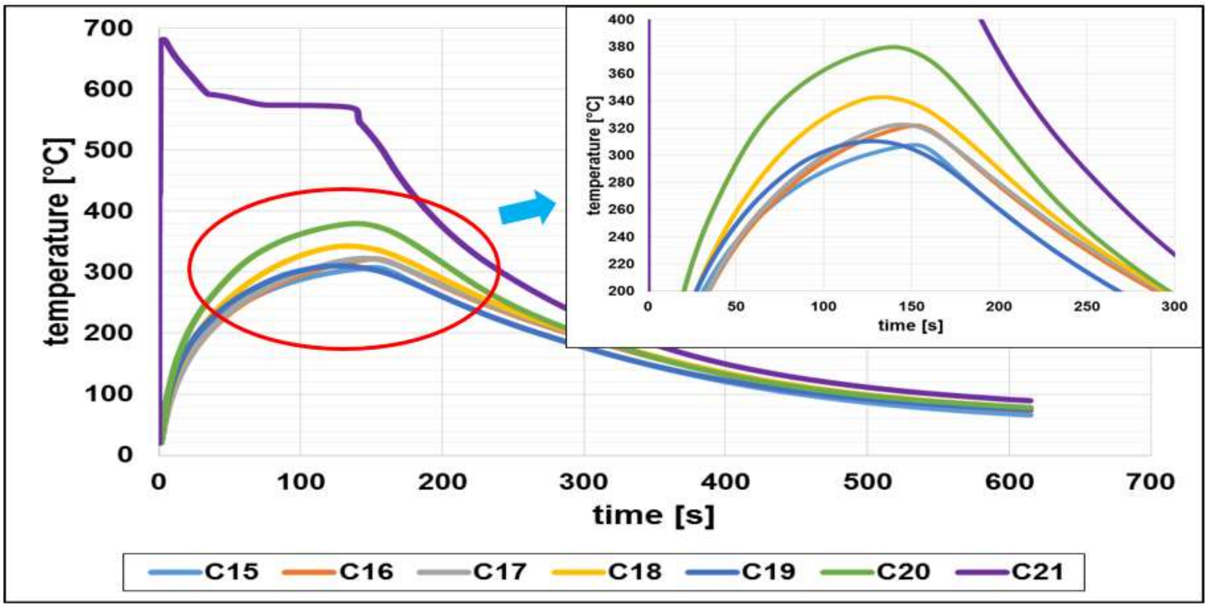

Fig. 4. Temperature change in 4 [mm] from casting surface distance

It can be noted a significant decrease of the maximum value of temperature relative to the sensors placed 2 [mm] from the casting. The highest temperature in 4 [mm] distance from the inner surface of the mould again indicate the sensor embedded the highest, i.e. C20 with a score of 380 [°C]. The second highest maximum temperature of thermocouple indicated C18, which is located at an altitude of 68 [mm]. It may be the result of termal centre of cast effect. At the same height the tendency to create the shrinkage has been observed.

4.4. SENSORS PLACED IN 6 MM FROM CASTING SURFACE DISTANCE

Table 7. Maximum temperature and the duration of its occurence reported in 6 [mm] from casting surface distance

Sensor no	C22	C23	C24	C25	C26	C27	C28
Max temp. [°C]	255	285	269	291	255	296	681
Time [s]	157	155	153	143	141	152	3

Table 8. Temperature measurement at intervals of 100 seconds in 6 [mm] from casting surface distance

Time [s]	C22	C23	C24	C25	C26	C27	C28
	Temp. [°C]						
100	237	261	249	273	245	273	574
200	233	258	249	262	234	270	379
300	167	186	184	187	168	184	234
400	117	132	132	133	120	128	155
500	81	91	93	94	87	91	110
600	64	73	74	76	72	75	91

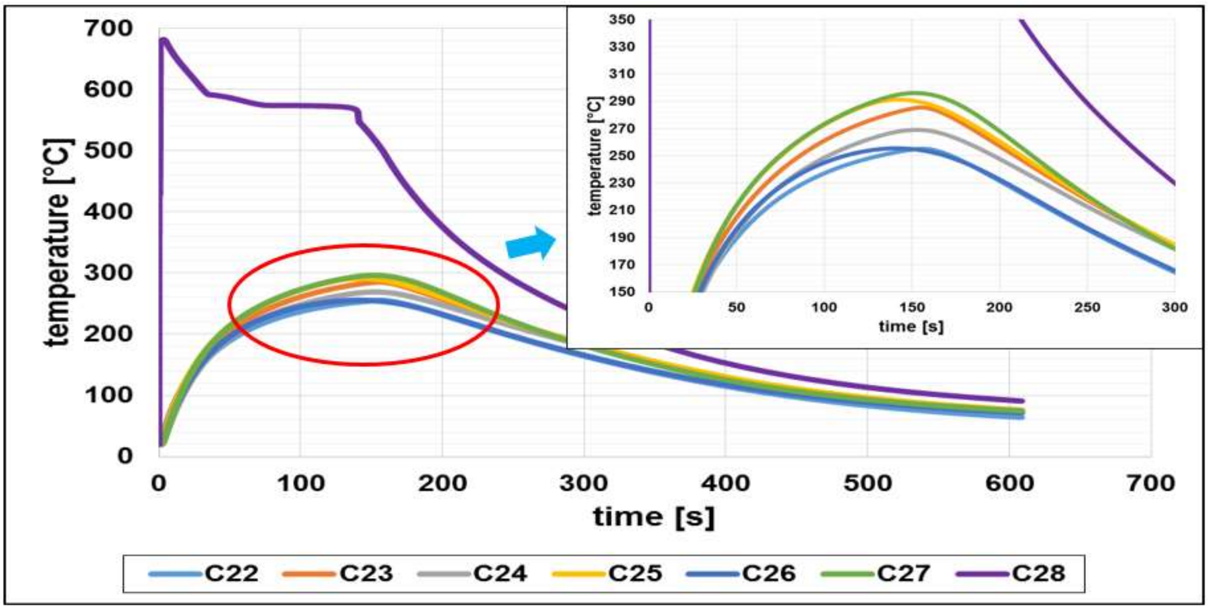

Fig. 5. Temperature change in 6 [mm] from casting surface distance

As in previous simulations, the highest temperature at the highest arranged sensor were observed. The order of the individual measurement of the maximum temperatures is the same as for simulation No. 3.

Recorded the highest results consistently fall down in relation to measurements the sensors located closer to the outer surface of casting.

4.5. SENSORS PLACED IN 8 MM FROM CASTING SURFACE DISTANCE

Table 9. Maximum temperature and the duration of its occurence reported in 8 [mm] from casting surface distance

Sensor no	C29	C30	C31	C32	C33	C34	C35
Max temp. [°C]	210	225	216	239	216	268	681
Time [s]	163	164	164	152	150	156	3

Table 10. Temperature measurement at intervals of 100 seconds in 8 [mm] from casting surface distance

Time [s]	C29	C30	C31	C32	C33	C34	C35
	Temp. [°C]						
100	194	206	200	224	206	248	574
200	200	215	208	225	205	251	379
300	150	164	160	168	153	177	234
400	108	120	118	122	111	124	155
500	76	84	85	87	81	88	110
600	60	67	68	71	67	73	91

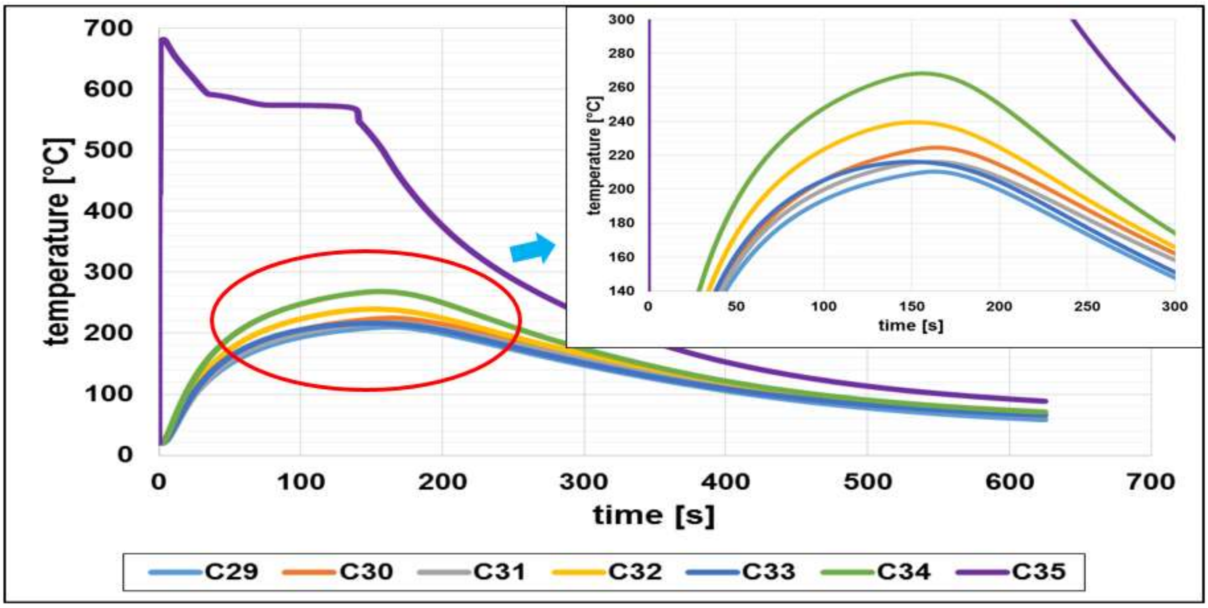

Fig. 6. Temperature change in 8 [mm] from casting surface distance

It was observed that the drop of temperature in 8 [mm] distance from the outer surface of casting in comparision to previous simulation is much smaller. The difference between the highest maximum temperature and the lowest is less than 70 [°C], while in the case of simulation, where thermocouple were placed just 2 [mm] from the outer surface of casting, this difference amounted more than 108 [°C].

5. CONSLUSIONS

Based on conducted studies following conclusions have been formulated:

a) due to the possibility of accommodate of measurement sensor, simulation program allows to check the temperature distribution during the pouring and self-cooling process any place of moulds and cast; it gives the chance to check how intensively is heat removal from casting to mould,

b) presented concept allows to estimate the thermal properties of the moulding sand for casting with varying thickness,

c) simulations results require practical experimental verification.

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