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Determination of the Overheating Degree of Moulding Sand with Bentonite - on the Grounds of Simulation Investigations

S. Żymankowska-Kumon*, M. Holtzer, J. Lelito, R. Dańko
AGH University of Science and Technology, Faculty of Foundry Engineering, Krakow, Poland
* Corresponding author. E-mail address: szk@agh.edu.pl

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Abstract

A determination of the heating degree of the moulding sand with bentonite on the grounds of simulating investigations with the application of the MAGMA program, constitutes the contents of the paper. To this end the numerical simulation of the temperature distribution in the virtual casting mould was performed. It was assumed that the mould cavity was filled with a moulding sand with bentonite of a moisture content 3,2 % and bentonite content 8 %. A computer simulation can be used for predicting the heating degree of moulding sands with bentonite. Thus, prediction of the active bentonite (montmorillonite) content in individual layers of the overheated moulding sand can be done by means of the simulation. An overheating degree of a moulding sand with bentonite, and thus the bentonite deactivation depends on a temperature of a casting alloy, casting mass, ratio of: $mass_{sand}$: $mass_{casting}$, moulding sand amount in the mould and contact area: metal – mould (geometry of the casting shape). Generally it can be stated, that the bentonite deactivation degree depends on two main factors: temperature of moulding sand heating and time of its operation.

Keywords: Green sand, Bentonite, Simulation, Temperature, Degradation of montmorillonite

1. Introduction

Bentonite is one of the basic binding materials used in metal casting for making moulds. Moulding sands with bentonite constitute 70 – 80 % of sands in which castings of ferrous alloys, mainly cast irons, are produced in the world.

One of the most important parameters of casting bentonites is their thermal resistance and strength at high temperatures [1 – 4].

In the rebounding process of sands with bentonite under casting house condition the information concerning the active bentonite content in a sand after casting knocking out, is necessary (the notions: montmorillonite and active bentonite will be used interchangeably in the lecture. Montmorillonite is a bentonite component, which provides binding properties to the sand). This content decides on the amount of a fresh bentonite addition into the sand, and thus influences the sand technological properties and the rebounding process costs. In practice, only a small part of the sand in the moulds, being in a direct contact with the casting or very close, is subjected to the temperature influence causing deactivation of bentonite (montmorillonite decomposition). Whereas the other part of the sand, retains to a high degree its binding properties and does not require rebounding, or only a little, which is an undoubted good point of these sands [5 – 7].

A temperature and time of its operating are factors deciding of the bentonite deactivation process. This is specially important in case of massive castings in which the ratio: moulding sand mass – casting mass, is close to unity. That time, the overheating degree of bentonite is very high and a significant (if not total) addition of fresh bentonite is necessary.

Various heating degrees of a moulding sand with bentonite, and thus various levels of montmorillonite deactivation provides advantageous conditions for the selection of knocked out sands on the grounds of their overheating degree. This would significantly decrease the amount of moulding sands subjected to rebounding, limit the bentonite addition and - in effect - it would lower the process costs [8 – 10].

In the technological process of producing castings in moulding sands with bentonite the determination of the sand volume within which bentonite underwent deactivation (depth of the sand heating to the determined temperature) is important. This decides on the amount of sand which must be rebounded, and thus on the amount of necessary rebounding additions. To this end, the computer simulation of the mould solidification process is very helpful.

2. Simulation assumptions

Simulations were performed for the following conditions: wedge model of a thickness of 20 mm and models of: sphere, cube and plate; – it was assumed that all models were of the same mass, being 6 kg. The assumed moulding sand composition: bentonite – 8 %, moisture content – 3,2 %. The assumed pouring temperature: 1400°C, casting alloy – cast iron. Additional parameters of the simulation: liquidus temperature – 1252°C, solidus temperature – 1152°C, pouring time: 4 s. Calculations were carried out up to the moment, when the inside casting temperature was 25°C. 6 thermocouples were placed in the moulds at a distance from the casting: 5, 10, 15 , 20, 25 and 30 mm. The volume of the green sand with bentonite (in moulding box) was 18 343 cm^3.

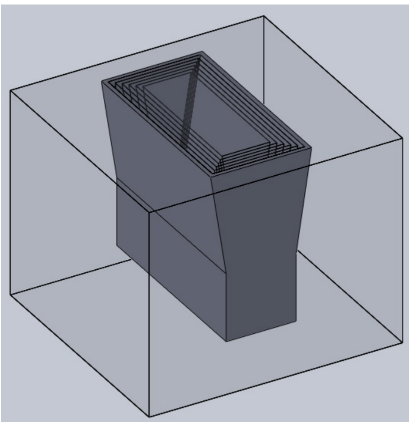


Fig. 1. Mould together with the casting and 6 layers of the moulding sand at a distance from the casting: 5, 10, 15, 20, 25 and 30 mm (figure 3D)

3. Results and discussion

For each moulding sand layer, in the case of the wedge being in between successive thermocouples, the sand volume was calculated (table 1).

Table 1.
Sand volumes calculated for individual moulding sand layers

Sand layer	Sand volume [cm^3]	Temperature [°C]
from casting to 5 mm	345,68	800
from 5 mm to 10 mm	398,64	660
from 10 mm to 15 mm	454,61	550
from 15 mm to 20 mm	513,57	465
from 20 mm to 25 mm	575,54	410
from 25 mm to 30 mm	640,51	370

The temperature field on the surface of the cross-section of the mould perpendicular to the casting length and passing through the virtual thermo-elements is presented in Figure 2.

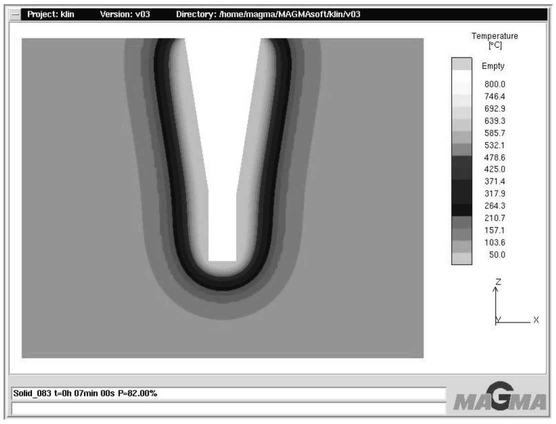


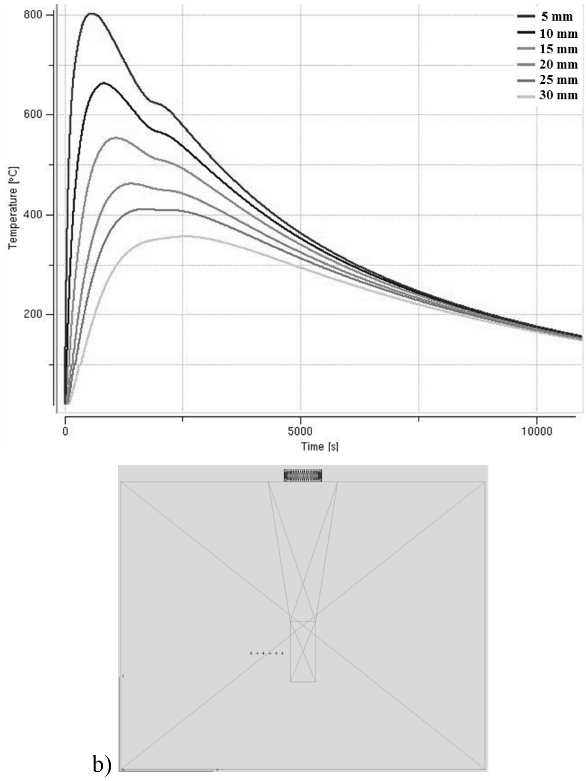
Fig. 2. Temperature field (obtained in the MAGMA program) in the virtual model mould made of the moulding sand with bentonite with the shaped wedge (7 minutes after the mould pouring with liquid alloy)

Cooling curves (obtained by a simulation) recorded for individual thermo-elements placed in the mould with the shaped wedge are presented in Fig. 3a, while their distribution is shown in Fig. 3b.

In order to determine the influence of the surface area of the casting contact with a moulding sand (thereby contact time) on the temperature field distribution, and thus on the bentonite degradation degree, the simulations for the model castings of the same mass (6 kg) but different shapes: sphere (R = 57,6 mm), cube (a = 92,83 mm), plate (200 x 200 x 20 mm) – were performed.

The obtained simulation results are presented in Figures 4 – 9 and in Table 2.

The maximum temperature, of the sand was 800°C (table 1), and the time of operation of this temperature was 14 minutes (Fig. 3a). Moulding sand situated at a distance of 15 mm from the casting wall was heated to temperatures below 500°C, which are not causing any degradation of bentonite. The sand volume (in the case of wedge), which was heated to temperatures causing degradation was approximately 400 cm^3, it means 2,2 % of sands in the whole moulding box. Thus, in practice, only such small amount of sand should be subjected to total rebounding. The remaining part of the moulding sand, after supplementing the moisture content (taking into account the excess of the moisture content in the part which was at the longer distance from the casting – in the overmoistured zone, which contained 7 % of water), could be used again [11].



a)

b)

Fig. 3. Cooling curves: a) Obtained from thermo-elements placed in the model mould at a distance from the casting: 5, 10, 15, 20, 25 and 30 mm, b) Distribution of thermo-elements

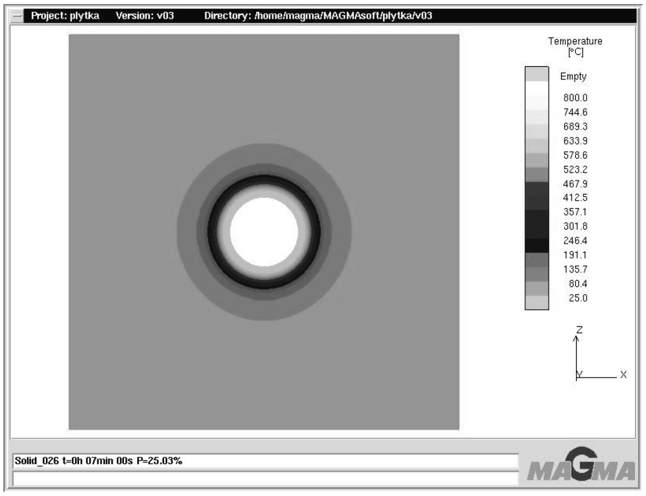


Fig. 4. Temperature map (obtained in the MAGMA program) in the virtual model mould made of the moulding sand with bentonite with the shaped sphere (7 minutes after the mould pouring)

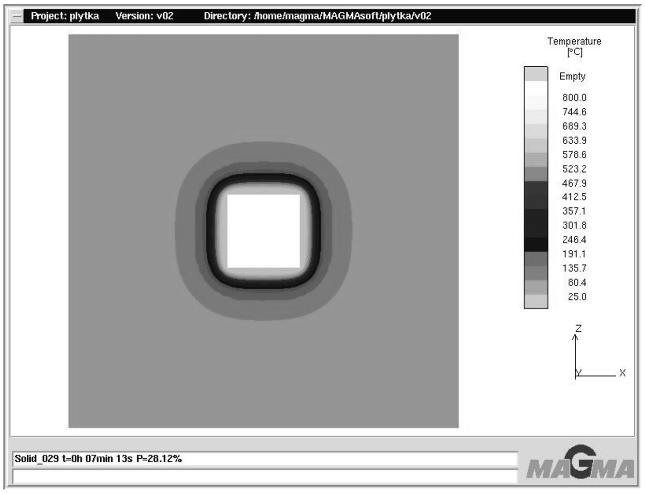


Fig. 5. Temperature map (obtained in the MAGMA program) in the virtual model mould made of the moulding sand with bentonite with the shaped cube (7 minutes after the mould pouring)

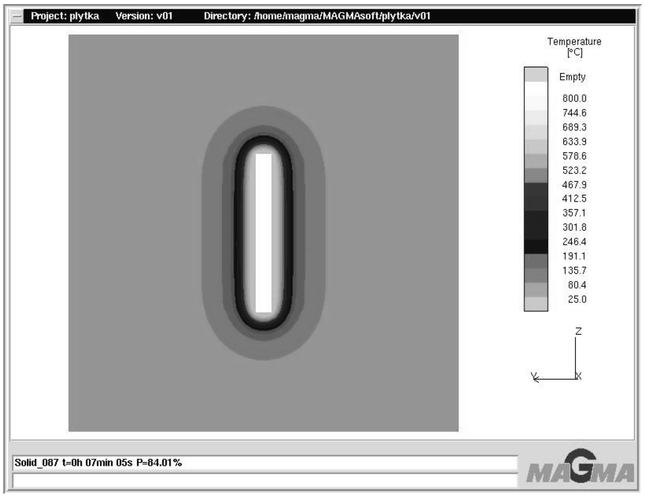
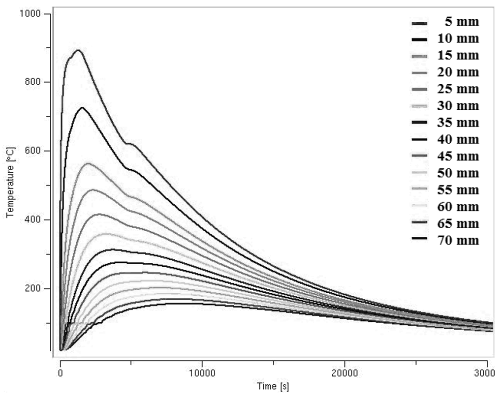
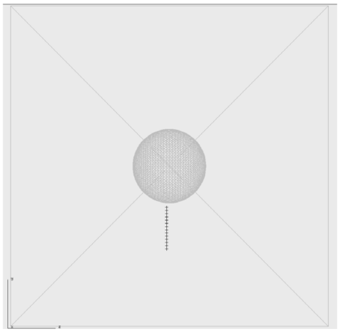


Fig. 6. Temperature map (obtained in the MAGMA program) in the virtual model mould made of the moulding sand with bentonite with the shaped plate (7 minutes after the mould pouring)

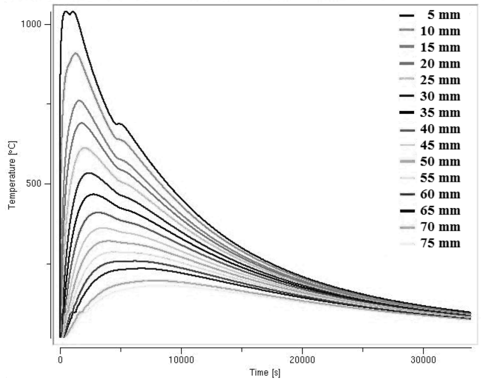


a)

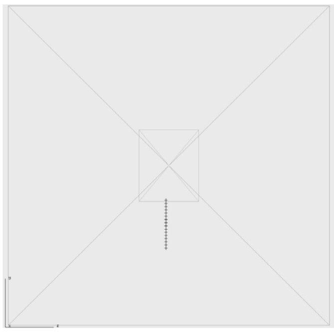


b)

Fig. 7. Cooling curves for the casting of a sphere shape a) Obtained from thermo-elements placed in the model mould at a distance of: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 and 70 mm, distributed as in Fig. b)



a)

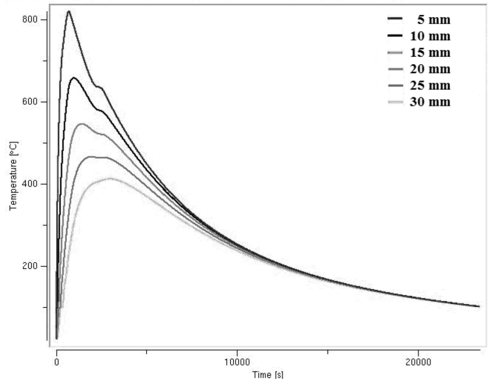


b)

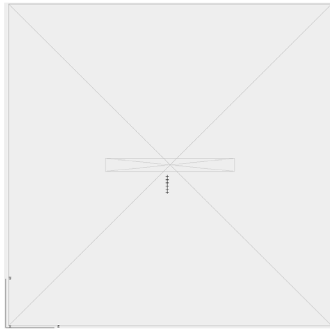
Fig. 8. Cooling curves for the casting of a cube shape a) Obtained from thermo-elements placed in the model mould at a distance of: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70 and 75 mm, distributed as in Fig. b)

For example, for the plate casting the sand volume heated to approximately 600°C was equal 700 cm^3, for the cube casting it was 570 cm^3, and for the sphere casting approximately 300 cm^3 (Table 2). Whereas the casting walls thickness (expressed by its shape) will influence the maximum temperature, which the sand will obtain. For the plate casting (thickness 20 mm) this temperature was 820°C, for the sphere casting (radius 57,6 mm) – 900°C, and for the cube casting (edge 92,83 mm) – 1050°C.

These results are indicative and allow to try amount of overheated sand (related with deactivation of bentonite). Determined by computer simulation the maximum temperature is average (in volume of selected layer).



a)



b)

Fig. 9. Cooling curves for the casting of a plate shape a) Obtained from thermo-elements placed in the model mould at a distance of: 5, 10, 15, 20, 25 and 30 mm, distributed as in Fig. b)

Table 2.
List of the simulation investigations results for various casting models

Sand Layer	Sphere		Cube		Plate	
	T_{max} [°C]	V [cm^3]	T_{max} [°C]	V [cm^3]	T_{max} [°C]	V [cm^3]
from casting to 5 mm	900	226,97	1050	287,37	820	523,00
from 5 mm to 10 mm	730	266,28	910	349,07	660	613,00
from 10 mm to 15 mm	580	308,73	750	416,77	580	709,00
from 15 mm to 20 mm	490	354,32	670	490,47	545	811,00
from 20 mm to 25 mm	415	403,06	610	570,16	470	919,00
from 25 mm to 30 mm	370	454,93	550	655,86	415	1033,00
contact surface: metal – mould	416 cm^2		517 cm^2		960 cm^2	

T_{max} – maximum temperature of green sand, V – sand volume

4. Conclusions

The computer simulation performed for the wedge casting, indicated that only a small fraction of the moulding sand with bentonite underwent heating to temperatures which could cause the montmorillonite degradation at such degree that it would lost its binding properties in moulding sands.

The second simulation series comprising investigating the influence of the size of the contact area of the casting and moulding sand, indicated that this size has an essential influence on the moulding sand heating level and by that on the bentonite degradation degree. The larger contact area, the larger amount of sand is being heated to temperatures which could cause the montmorillonite decomposition.

The presented above results of the computer simulation investigations carried out for castings of the same mass but various shapes (diversified contact surface: metal – mould) revealed that the degree and amount of overheated sand depends significantly on this surface size (casting geometry) [12 – 15].

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