

OPTIMISING THE COMPOSITION OF NATURAL MOULDING SANDS INCLUDING THERMAL ASPECTS

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Abstract

The paper discusses the problem of the choice of the moulding sand mixture composition in terms of the sand behaviour in contact with molten metal. Studies of high-temperature phenomena make assessment of the sand composition ability under real operating conditions possible, thus leading to the elimination of sand-originating casting defects. The research was conducted on selected moulding materials included in the composition of traditional moulding sand mixtures without the addition of carbon. The effect of moulding sand composition and moisture content on the linear dilatation and stress-induced allotropic changes of quartz was examined. The analysis of these phenomena was based on 3D charts and maps generated from data collected during the tests.

KEYWORDS: METALCASTING; MOULDING; MOULDING MIXTURE; MOULDING SAND

1. Introduction

Moulding properties mean this state of the moulding sand, in which it has optimal properties as regards its applicability in moulding operations [1]. The vast majority of studies on the sand mouldability, while its behaviour under real conditions, i.e. at elevated temperatures, is checked only when final effects, i.e. the ready castings, are examined. Only then the composition of the sand mixture is corrected, taking into account the defects specific castings and their causes. The sand composition is usually selected after studying a complex of multi-curve diagrams (Fig. 1) [1], which are drawn up as a result of the investigations of the basic mechanical and technological properties.

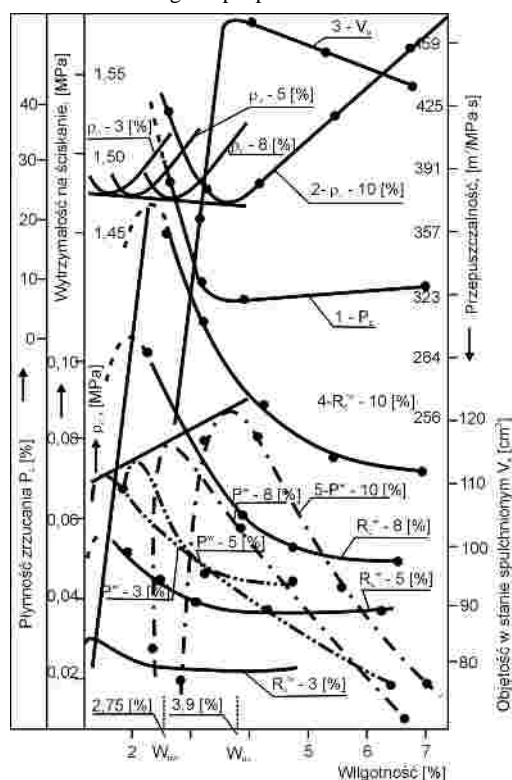


Fig. 1. Effect of moisture content on the sand mouldability
Wytrzymałość na ściskanie – compression strength, Płynność zrzucania – discharge flow, Przepuszczalność – permeability, Wilgotność – moisture content

Sand, on which moulding mixtures are based, is the main and most important component of foundry mould in terms of volume changes taking place in this mould. In the case of the most commonly used sand, its main ingredient is silica (quartz and its varieties), whose polymorphic transformations taking place between the major variations, i.e. quartz, tridymite and cristobalite, decide on volume changes and their derivatives occurring during the process of mould pouring and casting solidification.

The most important transformation in terms of the moulding sand dilatation is the transformation of β -quartz into α -quartz, occurring with high speed at a temperature of 572.4°C. At the point of the transformation one can see a sudden change of density (β -quartz 2.51 [g/cm³], α -quartz 2.655 [g/cm³]) and the change of thermal expansion coefficient. The dilatation changes that occur during this transformation amount to about 1.4 [%] (linear expansion). They are relatively small compared to the dilatation changes that take place during the transformation with restructuring of α -quartz into α -tridymite, amounting to about 14 [%], except that the latter process occurs very slowly due to very strong ionic bonds between Si⁴⁺ and O²⁻.

Using sand as a main component of moulding mixture gave rise to a theory that the behaviour of a foundry moulding mixture is determined by dilatometric changes taking place in the sand alone. However, more detailed investigations enabled combining the effect of dilatation changes originating from the sand and binder (bentonite) [5]. This is particularly important in the case of sand mixtures with high content of binder. Bentonite expands earlier than the sand (lower temperature) and then undergoes sintering. The calculated dilatation curve of moulding sand containing 15 [wt.%] of bentonite is presented in Figure 2.

2. Methods and scope of studies

Studies were conducted on moulding mixtures prepared from moulding materials used most commonly in production of iron and steel castings, i.e. the sand from Krzeszów and Zebiec, and medium-grain size sand from Bukowno, and bentonites - Bentomak and ZGM. The content of binder (bentonite) was 5, 7, 10%, the sand moisture content was 2,3,4 and 5%. The choice of these materials was based on the results of fundamental research determining the following technological properties:

$R_c^w, R_r^w, P^w, S^w, W_{bent}^w, W_{masy}^w$. Specimens for the measurement of free dilatation (FRI method) and dilatation under loading (Dietert furnace) were prepared according to the specification made by H. Dietert and others [3].

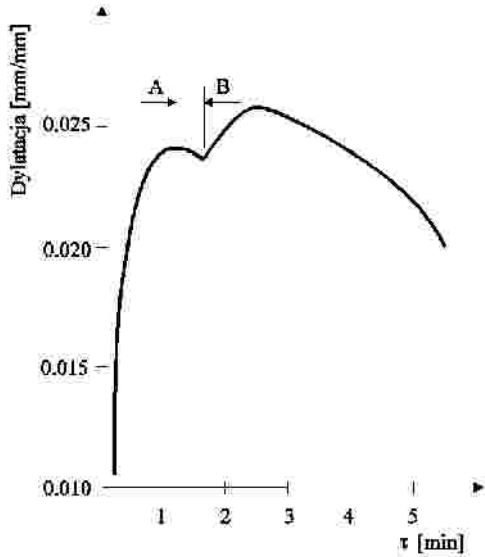


Fig. 2. Theoretical thermal dilatation curve of moulding sand with 15 [%] of Western Bentonite.
 A – bentonite dilatation is predominant, B – sand dilatation is predominant [5].
 Dylatacja – dilatation

For dilatometric tests, 19 most characteristic sand mixtures were selected from the whole set of 72 sand mixture compositions.

On each of the selected sand mixtures the following tests were carried out:

1. Determination of free dilatation (FRI method):
 - a) at a temperature of 500⁰C;
 - b) at a temperature of 600⁰C;
2. Determination of dilatation under preliminary loading (Dietert method)
 - a) at a temperature of 500⁰C;
 - b) at a temperature of 600⁰C.

The test temperatures used in the determination of both free dilatation and dilatation under preliminary loading were selected in accordance with the temperature of the polymorphic transformation of quartz (β -quartz into α -quartz at a temperature of 572.4⁰C).

In the above mentioned methods, standard cylindrical specimens of \varnothing 286x50, 8 [mm] dimensions prepared in an appropriate sleeve-shaped test mould by three blows of the rammer weighing 3.175 [kg], falling from a height of 66.7 [mm] as recommended by H. Dietert, were used. Specimens prior testing of the thermal expansion were dried in a furnace.

The measurement of dilatation under preliminary loading was carried out in a H. Dietert furnace. The specimen was in the furnace chamber heated to appropriate temperature with eight sillite rods mounted on a movable pivot (resistance furnace). The axial pressure on the specimen was exerted by aligning plates. The dilatation was measured with spring-actuated sensor, which every 1 minute recorded changes in the specimen length; the measurement started after the specimen was placed in furnace, preliminary loading of 1 [pound/inch²]/0,0073 [MN/m²] was applied, and sensor recording the increase in length was set to zero.

3. Test results

The test results after graphical processing are shown below. The above presented 3D graph and the respective map have been plotted for one of the several examined moulding sand mixtures. A comparison of test results obtained for sands containing different binders showed that the effect of these binders on the dilatation and stress increase was almost negligible. Therefore, it was decided to depict graphically only the sand effect on the examined parameters (Figs. 4 and 5).

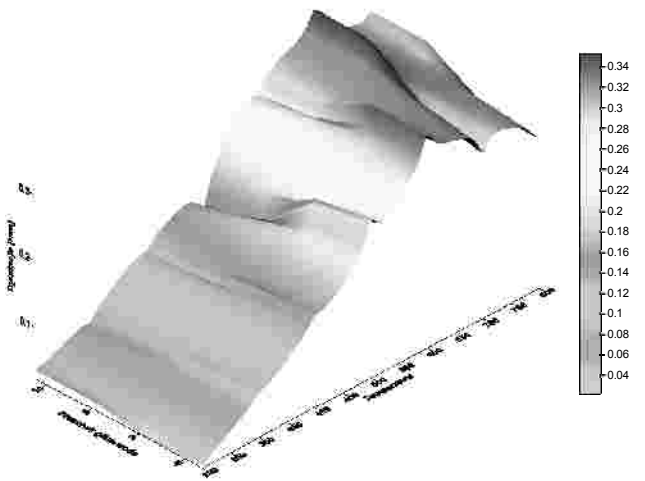


Fig. 3 Graphically illustrated relationship of Δl in function of temperature and clay/water – sand ratio for Krzeszówek sand and ZGM domestic bentonite [7,8,9]
 Dylatacja – dilatation, Temperatura – temperature

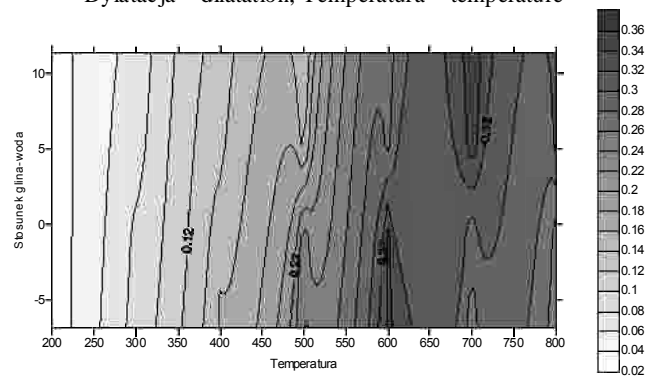


Fig. 3a Graphically illustrated relationship of Δl in function of temperature and clay/water – sand ratio for Krzeszówek sand and ZGM domestic bentonite – a map [7,8,9]
 Stosunek glina-woda - clay-water ratio, Temperatura - temperature

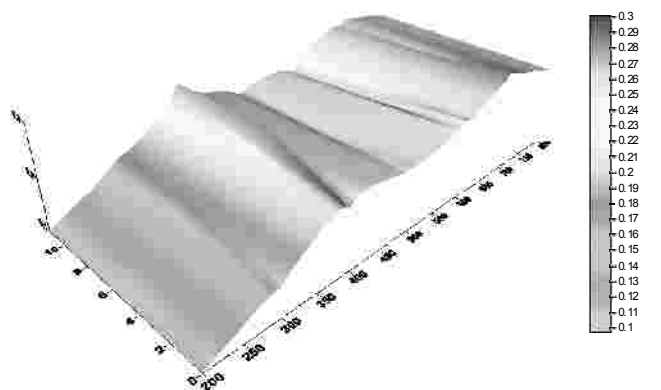


Fig. 4 Graphically illustrated relationship of Δl in function of temperature and clay/water – sand ratio for Krzeszówek sand [7,8,9]

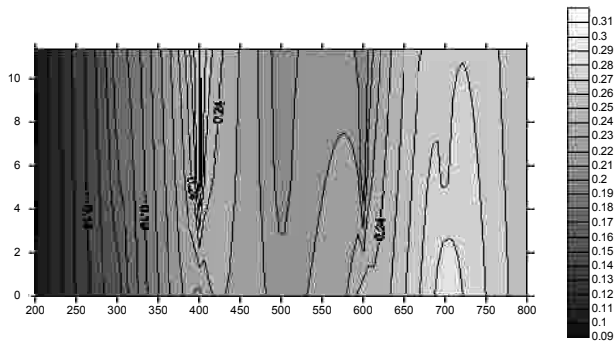


Fig. 5 Graphically illustrated relationship of ΔR_c in function of temperature and clay/water – sand ratio for Krzeszów sand [7,8,9]

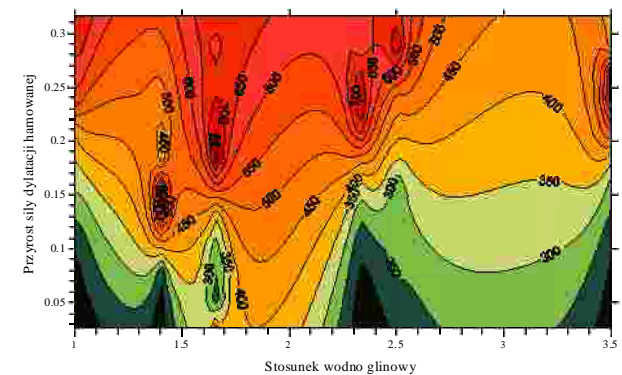
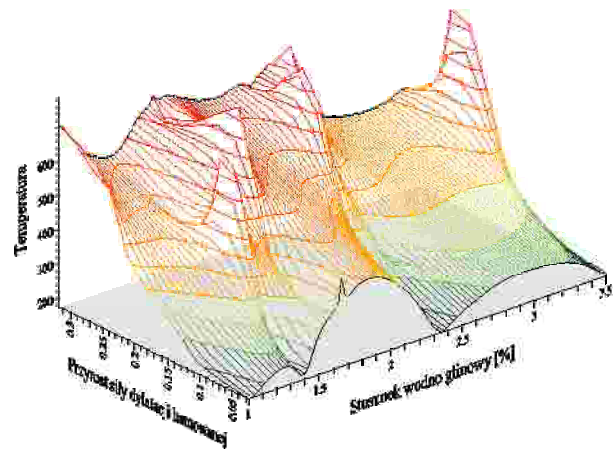


Fig. 4 Relationship between increment in stress $\Delta R'_c$, water/clay ratio and temperature [7,8,9]
 temperatura – temperature
 stosunek wodno-gliniowy – water/clay ratio
 przyrost siły dylatacji hamowanej - increment in force of impeded dilatation

Table 1

Relationship between increment in stress $\Delta R'_c$, water-clay ratio (w/c) and temperature [7,8,9]

temp	c/w	$\Delta R'_c$	temp	c/w	$\Delta R'_c$
200	1,66	0,031	500	3,5	0,201
200	1,4	0,088	500	1	0,231
200	2,33	0,095	500	2,5	0,262
200	3,5	0,097	600	1,66	0,302
200	1	0,102	600	1,4	0,168
200	2,5	0,146	600	2,33	0,277
300	1,66	0,119	600	3,5	0,201
300	1,4	0,089	600	1	0,253
300	2,33	0,153	600	2,5	0,316
300	3,5	0,175	700	1,66	0,311
300	1	0,153	700	1,4	0,136
300	2,5	0,124	700	2,33	0,211
400	1,66	0,139	700	3,5	0,269
400	1,4	0,182	700	1	0,304
400	2,33	0,153	700	2,5	0,263
400	3,5	0,276	800	1,66	0,18
400	1	0,207	800	1,4	0,153
400	2,5	0,194	800	2,33	0,251
500	1,66	0,026	800	3,5	0,251
500	1,4	0,168	800	1	0,252
500	2,33	0,189	800	2,5	0,309

4. Conclusion

The analysis of the results allows drawing the following conclusions:

1. The largest thermal dilatation gives the mixture based on Krzeszów sand. Probably the main role in this case plays not so much the sand granulation as the shape of grains and the content of polymorphic quartz variations.
2. The largest thermal dilatation has the sand mixture, where the water-clay ratio is about 0.2.
3. A characteristic increase in elongation Δl related with the transformation of β - quartz into α -quartz at temperatures around 600 [°C] was observed.
4. The values of the increase in both length and stress reach a very high level of 1% and 0.3 MPa, respectively. Unfortunately, so far, they have been ignored in analysis of the casting producibility.
5. The analysis neglecting different types of bentonite enabled plotting uniform graphs representing relationships between the water-clay ratio and temperature in function of the dilatation changes and stress increase.
6. These types of charts, and maps in particular, can be used in the choice of moulding sand composition allowing for temperature variations.

5. Literature

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