Rebounding process of moulding sands-thermal degradation of bentonite binding qualities

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Abstract

Problems related to a gradual degradation of binding qualities of montmorillonite, the main component of foundry bentonites, are presented in the paper. This degradation is caused by high temperatures originated from liquid metal influencing moulding sands. Laboratory measurements of an active binding agent content in classic moulding sands prepared with two types of bentonite and subjected to a controlled heating to high temperatures – were performed. These laboratory examinations were compared to industrial tests, in which a temperature distribution was being determined in several places in the thickness of the casting ingot mould for 24 hours from the moment of pouring liquid metal. On the basis of the performed examinations, the method allowing to determine optimal additions in the rebounding process of the tested bentonites was developed.

Keywords: mould production, bentonite sand, green sand, rebounding process

1. Introduction

In the case of casting moulds made of classic moulding sands with bentonite, a successive influence of a high temperature originated from liquid casting alloy has a negative influence on sands properties. Another use of the same sand requires its rebounding during preparation in mixers. Specially important in the rebounding process is the type of a binding agent used, since each agent is characterized by a different thermal resistance. This part, which due to a thermal degradation of montmorillonite completely loses its binding abilities, should be substituted by a fresh material. The significant lowering of binding qualities of main components of bentonite, it means materials from the montmorillonite group, usually starts at a temperature range of 400 – 500ºC [1, 2]. The effect of a binder loosing its ability to bind matrix grains is different for various types of bentonite. The knowledge of the range of this effect for the given bentonite is very important for the proper realisation of the rebounding process, joining problems of a technological and economic nature.

2. Laboratory examinations of a thermal degradation of binding abilities of bentonite

An influence of a heating temperature of moulding sand samples, on the amount of adsorbed methylene blue was tested.
After heating, the amount of active bentonite in samples was determined by the methylene blue adsorption method.

In order to estimate the amount of active montmorillonite in sands, which were subjected to high temperature influence, the reference diagrams were drawn in Figure 1. To be able to draw these reference diagrams the moulding sands with fractions of the bentonite under testing being: 3%, 5% and 7%, were prepared and then titrated with a methylene blue solution. These diagrams constituted the basis for the determination of active bentonite in the samples heated at the given temperature. The obtained results are presented graphically in Figure 2.

![Fig. 1. Reference diagrams of the methylene blue adsorption for Geko S bentonite and Special bentonite.](image1)

![Fig. 2. Comparison of the active bentonite content in moulding sands with Geko S bentonite and Special bentonite in dependence of the heating temperature of roll samples Φ 50 x 50 mm.](image2)

The obtained data indicate a different thermal resistance of the tested bentonites. The comparison of thermal resistances of both bentonites indicates that Special bentonite has a better resistance to a long-term thermal influence. However, for both bentonites 500°C is a limiting temperature, above which the thermal degradation of binding abilities becomes much faster.

Using the data presented in Figures 1 and 2, the method of determining the relative degree of the thermal degradation of bentonite $D_{\text{bent}}$, can be proposed, thus allowing to calculate the decrease of a binding ability from the following equation:

$$D_{\text{bent}}(T) = (1 - \frac{V_{\text{metyl}}(T)}{V_{\text{metyl}}(\text{ini})}) \cdot 100\%$$

where:

- $V_{\text{metyl}}(T)$ – methylene blue volume used for titration of sand samples, after holding at the determined temperature; cm$^3$,
- $V_{\text{metyl}}(\text{ini})$ – methylene blue volume used for titration of sand samples of a nominal bentonite content, which were not heated (initial sand - fresh); cm$^3$.

The calculated values of the relative degree of the thermal degradation $D_{\text{bent}}(T)$ and thermal resistance $O_{\text{bent}}(T)$ of the tested bentonites, in sand samples after being heated in the temperature range 0-900°C, are shown in Table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Heating temp. of sand samples $T$ °C</th>
<th>Volume $V_{\text{metyl}}(\text{ini})$ [cm$^3$]</th>
<th>Volume $V_{\text{metyl}}(T)$ [cm$^3$]</th>
<th>Degradation degree $D_{\text{bent}}$ [%]</th>
<th>Thermal resistance $O_{\text{bent}}$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>28.0</td>
<td>28.0</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>27.6</td>
<td>28.0</td>
<td>1.4</td>
<td>98.6</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>27.0</td>
<td>28.0</td>
<td>3.6</td>
<td>96.4</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>25.3</td>
<td>28.0</td>
<td>9.3</td>
<td>90.6</td>
</tr>
<tr>
<td>5</td>
<td>400</td>
<td>24.5</td>
<td>28.0</td>
<td>12.2</td>
<td>87.8</td>
</tr>
<tr>
<td>6</td>
<td>500</td>
<td>23.3</td>
<td>28.0</td>
<td>16.5</td>
<td>83.5</td>
</tr>
<tr>
<td>7</td>
<td>600</td>
<td>16.1</td>
<td>28.0</td>
<td>42.4</td>
<td>57.6</td>
</tr>
<tr>
<td>8</td>
<td>700</td>
<td>9.8</td>
<td>28.0</td>
<td>64.7</td>
<td>35.3</td>
</tr>
<tr>
<td>9</td>
<td>800</td>
<td>4.2</td>
<td>28.0</td>
<td>84.9</td>
<td>15.1</td>
</tr>
<tr>
<td>10</td>
<td>900</td>
<td>2.8</td>
<td>28.0</td>
<td>89.9</td>
<td>10.1</td>
</tr>
</tbody>
</table>

The presented method of relative estimation is very useful in assessing the thermal resistance of the given moulding sand with bentonite, however is burdened with a serious inconvenience. The same percentage value $D_{\text{bent}}$ obtained for two different bentonites does not mean that the loss of real binding qualities is identical. In this case the assessment based on measuring and comparing $V_{\text{metyl}}(T)$ value separately for each material is more reliable.

### 3. Influence of the applied bentonite type on the sand rebounding process

The obtained information concerning the actual thermal degradation state $D_{\text{bent}}$ of the tested bentonite type in moulding sand samples, which underwent heating, can be used for
determination of optimal parameters of the sand rebounding process in the case of the casting made in casting moulds prepared of classic sands and the tested bentonites.

Implementations of these studies into an industrial practice were done within the Research Project [3], which included among others a diagnostics of a thermal state of spent moulding sand used for casting steel ingot mould W – 61 of a mass 18 Mg. (Fig. 3).

This is an example of a casting mould of a heavy thermal load, illustrated by given below data. Volume of overall dimensions of a mass block in a casting box is app. 10.5 m$^3$, including: volume of a mass outside an ingot mould app. 4.3 m$^3$, volume of an inner mass 3.20 m$^3$, metal volume app. 3.0 m$^3$. Thermal load expressed as a ratio of a casting mass to moulding sand mass: $m_{odl} : m_{masy} = 1 : 0.6$. It should be mentioned that in the inner mass, constituting the ingot mould core, more than 50% of volume is taken by a steel core carcass.

Synthetic moulding sand was prepared on the basis of used sand rebounded by an addition of 3% of bentonite and water to a wet content of 3.6%. After a sand compaction, the same in both cases, a core-paint was placed on working surfaces of moulds and cores. Set systems were dried in a drying chamber according to a procedure used in foundry plants. When systems were dried and transferred to the pouring region the sensors for measuring temperature, connected with the computer recording system, were installed in the external layer of moulding sand of a thickness app. 240 mm. The measuring system for both types of moulds was the same. The portable system, based on computer Pentium III with a prototype 16-channel measuring box for measuring physical values, was used. The measuring system is presented in Figure 4.

![Fig. 3. Schematic presentation of the mould for casting the steel ingot mould W-61](image)

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![Fig. 4. Instrumentation for measuring sands temperatures in the casting mould and in the ingot mould core W-61: a) - Recording system, b) - Placement of thermocouples](image)

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Sand temperatures in a mould were recorded during a continuous measurement for over 20 hours. In the upper part of the mould, where an access was easier, 6 thermocouples were placed. Their distances from the outside surface of the casting were: 70, 135, 170, 205 and 240 mm. The last thermocouple was placed in the core approximately 100 mm from its contact with metal.

The temperatures recorded in the mould of a classic sand with Geko S bentonite are shown in Figure 5.

![Fig. 5. Changes of the sand temperature in the ingot mould W-61, made of a classic sand with Geko S bentonite](image)

Fig. 5. Changes of the sand temperature in the ingot mould W-61, made of a classic sand with Geko S bentonite [4].

On the basis of the temperatures measured in various thermocouple pockets in the sand the maximum temperatures - to which the moulding sand is heated at the determined distance from the casting surface – were found. The obtained data are shown in Figure 6 together with the graphical dependence used for the sand volume fraction determination in the mould (in relation to the total sand volume), corresponding to the thickness of the sand layer calculated as the distance from the casting surface to the measuring point.

The experimental results presented in Figure 6 can be approximated by the logarithmic dependence allowing to calculate a temperature $T$ in the determined place at a thickness of the external layer of the mould, marked by „d“. This dependence is as follows:

$$T = 1224.1 \cdot e^{0.0068 \cdot d}; [°C]$$  \hspace{1cm} (3)

On the other hand it is possible to calculate a thickness $d$, which corresponds to the distance of the thermocouple pocket, which temperature is equal to $T$. This is useful for the determination of the relative degree of the thermal degradation $D_{bent}(T)$ of the sand, according to data given in Table 1.

For the calculation the analysed value of $d$ [mm], equation (3) rearranged to the following form is used:

$$d = \frac{\ln T - \ln 1224.1}{0.0068}; [\text{mm}]$$  \hspace{1cm} (4)

Taking into account a dependence between $d$ (distance from the casting surface) and a moulding sand fraction (calculated in the
Thus, the calculated rebounding additions are equal to:
- bentonite Geko S – 2.48 %
- bentonite Special – 1.96 %

4. Conclusions

The presented examinations constitute an introduction for further studies aimed at the optimisation of the rebounding process of moulding sands. The bentonite type applied in foundry plant has a significant influence on the rebounding process and due to that, the knowledge of the thermal degradation relative degree of bentonite $D_{bent}$ as well as of the thermal resistance of sands $O_{bent}$ at the given load with liquid metal – is essential.

However, neither an influence of a casting mould drying before being poured with liquid metal nor a time of heating on an activity of bentonite were taken into consideration in the presented paper. The knowledge of those factors is important for running the process under optimal conditions, taking into account a broad spectrum of technological and organizational elements, especially in the situation when the rebounding process can be computer aided by simulation programs used in foundry engineering. With their help, after considering the data analogical to the presented in this paper, it will be possible to determine the temperature distribution in the casting mould and the fraction of the moulding sand heated to the given temperature. A mathematic description of the investigated dependences is necessary for an effective implementation of the computer aided rebounding processes of classic moulding sands with bentonite.

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References

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