Microwaves energy in curing process of water glass molding sands

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Abstract
This work presents the results of investigation of microwave heating on hardening process of water glass molding sands. Essential influence of this heating process on basic properties such as: compression, bending and tensile strength as well as permeability and abrasion resistance has been found. It has been proved, that all investigated sorts of sodium water glass with a module between 2.0 and 3.3 can be used as a binder of molding sands in microwave curing process. It has been found during analysis of research results of sands with 2.5 % water glass addition that they are practically the same as in case of identical molding sands dried for 120 minutes at the temperature of 110°C, used for comparative purposes. Application of microwave curing of molding sands with water glass, however, guarantees reduction of hardening time (from 120 to 4 minutes) as well as significant reduction of energy consumption. Attempts of two stage hardening of the investigated water glass molding sands have also been carried out, that is after an initial hardening during a classical CO\textsubscript{2} process (identical sands have also been tested for comparison after CO\textsubscript{2} blowing process) and additional microwave heating. It has been found that application of this kind of treatment for curing sands with 2.5 % sodium water glass content and module from 2.0 up to 3.3 results in the improvement of properties in comparison to classical CO\textsubscript{2} process.

Key words: innovative materials and technologies in foundry, microwaves, molding sand, water glass, module

1. Introduction
Microwaves are electromagnetic waves of small length, within 1m to about 1nm range. They are broadly applied in such fields as telecommunications, meteorology or chemistry. Microwave energy might also be used, among others, in foundry and curing process of molding sands, including water glass molding sands [1-4]. Energy consumption during microwave heating, in comparison to a conventional process, is even 10 to 100 times lower, while microwave heating process time compared to the conventional heating is 10-200 times shorter [1,2,5].

2. Measuring post
Hardening process investigation (drying, dehydration [6]) of molding sands conducted in commonly used microwave ovens does not guarantee parameter repeatability and full process control. These ovens have a simple power pack which does not allow for a smooth magnetron power output control. In our studies we used a microprocessor controlled device allowing for magnetron power control and regulation of microwave amplitude (which allows for a smooth power control) as well as possibility of duration and heating cycle number setting, selected according to a degree of working chamber filling with stock [2,7]. The studies have been conducted at the post presented by Figure 1.

2. Preparation of molding sands
It has been determined, basing on literature data as well as results’ analysis of initial studies [2], that introduction of 05.\% of water addition to a mass containing quartz sand and water glass is beneficial for a microwave hardening process. We used a standard quartz sand from Nowogród Bobrzański mine of 0.32/0.2/0.16 main fraction and water glass manufactured by Zakłady Chemiczne „Rudniki” S.A.,whose properties (consistent with certificate) are presented in table 1, for preparation of molding sands applied in our studies. The sands have been prepared
3. Sample curing process

The study has been conducted in two stages of two series. In the first stage the samples were hardened with two classical methods. The first method consisted in blowing of the samples with carbon dioxide for 30 seconds. The second method consisted in drying of the samples in a conventional dryer at the temperature of 110°C for 120 minutes. After cooling of the samples down to ambient temperature their resistance to compression, bending and tensile strength as well as permeability and abrasion resistance [8-10] have been formed on a standard rammer from these sands.

The results of the first stage constitutes comparative basis for the studies with microwave energy application for sand curing (second stage). The samples of the first series of second stage were subject only to microwave hardening. Three samples for compression, bending and tensile strength measurement were put into a heating chamber. This number of samples ensured a proper operation of magnetron and identical curing conditions. Hardening time and power of 240 seconds and 700 W, respectively, were assumed basing on literature data [11-17]. The samples were left to cool down after curing. The second series of the second stage of our study was conducted on the samples which were previously hardened in a classical way during CO₂ process for 30 seconds and next by microwaves, applying the same parameters as in case of the first series. The samples were also cooled down to ambient temperature afterwards.

Because compression resistance of the dried samples hardened by microwaves exceeded measurement range of the universal laboratory device, determination of this parameter was conducted using Instron 1126 resistance machine ensuring identical pressure increase velocity of 0.25 N/cm².

4. Research results

Figures 2 to 5 present a list of study results of sodium water glass module influence on resistance to compression, bending and tensile strength of the sands used for both stages. For comparison purposes the figures present results for both series of the conducted studies. Measurement points constitute mean value for three assays.

As appears from analysis of figure 2, resistance to compression, bending and tensile strength of water glass molding sands hardened with carbon dioxide is not high and does not depend on module of the used water glass. The same sands dried conventionally are characterized by many times higher resistance depending on the binder module. A significant decrease of all the determined resistance parameters is observed for water glass kind with module greater than 2.9.

Figure 3 presents the influence of mole module of water glass on permeability and abrasion resistance of the investigated molding sands cured with CO₂ process and conventionally.

Permeability of the studied sands is practically constant and does not depend on water glass module, while higher values are reached in case of the sands hardened with carbon dioxide. In this case also an obvious decrease of permeability is observed for the sands prepared with water glass of 2.9 module characterized by very high viscosity (table 1).

Table 1.

<table>
<thead>
<tr>
<th>Kind</th>
<th>Mole module SiO₂/Na₂O</th>
<th>Oxide content (SiO₂+Na₂O) %</th>
<th>Density (20°C) g/cm³</th>
<th>Fe₂O₃ % max</th>
<th>CaO % max</th>
<th>Dynamic viscosity (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>1.9±2.1</td>
<td>40.0</td>
<td>1.50±1.53</td>
<td>0.01</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>149</td>
<td>2.8±3.0</td>
<td>42.5</td>
<td>1.49±1.51</td>
<td>0.01</td>
<td>0.1</td>
<td>7</td>
</tr>
<tr>
<td>145</td>
<td>2.4±2.6</td>
<td>39.0</td>
<td>1.45±1.48</td>
<td>0.01</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>140</td>
<td>2.9±3.1</td>
<td>36</td>
<td>1.40±1.43</td>
<td>0.01</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td>137</td>
<td>3.2±3.4</td>
<td>35</td>
<td>1.37±1.40</td>
<td>0.01</td>
<td>0.1</td>
<td>1</td>
</tr>
</tbody>
</table>
Fig. 2. Influence of water glass mole module on resistance to compression, bending and tensile strength of molding sands hardened in CO$_2$ process and conventionally dried.

Fig. 3. Influence of water glass mole module on permeability and abrasion resistance of molding sands hardened in CO$_2$ process and conventionally dried.
Fig. 4. Influence of water glass mole module on resistance to compression, bending and tensile strength of molding sands hardened by microwaves or in a two-stage process by CO$_2$ and by microwaves.

Fig. 5. Influence of water glass mole module on permeability and abrasion resistance of molding sands hardened by microwaves or in a two-stage process by CO$_2$ and by microwaves.
Abrasive resistance of conventionally dried sands is low (practically amounting to zero) and does not depend on water glass module (fig. 3). On the contrary, in case of sands cured with CO₂ this parameter strongly depends on water glass module. A very high sand resistance to abrasion is observed in this case for glass with module 2.0 as well as quick increase of the sand abrasion resistance corresponding to water glass module increase. Similarly to permeability, where this parameter decreased for the water glass with module of 2.9 (kind 149) and high viscosity, abrasion resistance of this sand was so high that final determination of this parameter was impossible.

While analyzing figure 4, we can see that resistance to compression, bending and tensile strength of water glass molding sands hardened with microwaves is very high and close to the values measured for the same sands dried conventionally at the temperature of 110°C for 120 minutes. A similar resistance decrease of the investigated sands prepared with water glass with the highest modules of 3.0 and 3.3 is observed as in case of the conventionally dried sands. Resistance to compression, bending and tensile strength of molding sands hardened in two stages, first in a classical way with CO₂ and next by microwaves, is significantly lower than of those cured with microwaves but much higher in comparison to the sands hardened in a classical way, with CO₂ process. In this case also sand resistance decreases visibly with the increase of water glass module, as in case of those cured with microwaves.

Figure 5 shows influence of water glass mole module on permeability and abrasion resistance of the investigated molding sands cured with microwaves and in two stages, with CO₂ process and microwaves.

Permeability of the investigated sands is practically constant and does not depend on water glass module or curing method. Only the sands prepared with water glass 149 and 2.9 module and – when compared to other kinds – very high viscosity, are characterized by lower permeability.

Abrasion resistance of the sands cured with microwaves is practically zero, while in case of those dried in two stages (CO₂ and microwaves) it strongly depends on water glass module. In this case a sudden abrasion resistance increase of the sands with water glass of module higher than 2.5 is observed; it is higher than in case of the sands hardened with carbon dioxide.

5. Final conclusions

While analyzing results of the studies of water glass mole module influence on basic parameters of molding sands hardened with carbon dioxide and dried conventionally, constituting comparative basis for microwave curing it has been found that:

- all used in our studies and offered on the market kinds of binders (including the most commonly applied in foundry sorts 145 and 149) after microwave heating guarantee reaching a very good resistance to compression, bending and tensile strength as well as permeability and abrasion resistance, comparable with the ones obtained during the classical drying process at the temperature of 110°C for 120 minutes;
- decrease of sands’ properties, similar in its course as in case of conventional drying, occurs with the increase of water glass module (to over 2.9);
- application of microwave heating in the process of two stage hardening of the investigated molding sands (CO₂ and next microwaves) ensures obtaining of higher strength, compared only to carbon dioxide curing, and decreasing with the increase of water glass module;
- module influences abrasion resistance of the investigated molding sands and in case of values higher than 2.5 it is so high that it eliminates application of these sands after two-stage curing process;
- no influence of water glass module on permeability of the investigated sands has been observed;
- molding sands prepared with water glass of module 2.0 – 2.9 (sorts 145, 149 and 150) are characterized with the best properties during both curing processes;
- application of microwave curing process of water glass molding sands ensures notable economic benefits resulting from a significant reduction of curing time as well as from reduction of energy consumption, while simultaneously assuring excellent properties of molding and core sands.

Literature


