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Application of microwave energy for curing of molding sands containing oil binders

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Abstract

This works presents the results of studies concerning possibility of application of microwave heating in the curing process of molding sands containing oil binders. Molding sands prepared with three kinds of binders, that is oils C, DL and Retanol, have been subject to experiments. The sands have been dried with two methods: in a microwave chamber of 750W power and, for comparison, with classical method at the temperature of 200°C for 120 minutes. Tensile and bending strength of the samples have been determined after cooling down. It has been found that microwave drying in the low-power device used for experiments is effective only in case of molding sand prepared with addition of DL binder. The temperature of heated, even up to 32 minutes in a microwave chamber, blocks prepared from the remaining two masses, was insufficient to initiate binding process. The undertaken attempts of binder modification and introduction of additives intensifying microwave heating process allowed for achievement of satisfactory results. It has been found that power of the heating device is the main factor determining efficiency of microwave curing of molding sands containing oil binders. An additional experiment has been conducted on a laboratory workstation allowing for microwave heating of small mass samples with a high output power of magnetron concentrated in a small substrate volume. It has been observed that microwave drying process of molding sands was of dynamic character over a short period of time, not exceeding 120 seconds, thus assuring efficient curing of the sands containing the used oil binders. Therefore, application of devices of properly high microwave output power allows for efficient drying of oil molding sands, while simultaneously assuring the possibility to reduce time and energy consumption necessary for production of foundry cores of proper functional characteristics.

Keywords: Microwave drying; Core sands; Oil binder; Microwaves; Characteristics of molding sands.

1. Introduction

Counting on innovative solutions in foundry industry numerous attempts are undertaken to apply microwave energy, among others, in the processes of mold and core production. Energy and time consuming technologies can be substituted by cheaper and shorter ones, utilizing, for example microwave radiation. While comparing conventional and microwave heating processes, energy consumption in case of application of the latter solution is from 10 up to even 100 times lower and its time 10-200 times shorter than in case of conventional heating [1,2]. Positive research results as well as experience obtained during studies with application of microwave energy for heating, drying or hardening of molding sands [3-5], prompted the actions aimed at utilization of microwave radiation in the drying process of core sands with oil binders.

2. Preparation of core sands

The experimental sands have been prepared from high-silica sand from Nowogród Bobrzański sand mine of 0.40/0.32/0.20 main fraction and three kinds of oil binders offered by PEDMO S.A., of the properties (consistent with product specification) presented in table 1.

Tensile strength R_m^S per 1% of the introduced binder, in dry mass prepared with oil binder constitutes a parameter characterizing quality of the used binders. Molding sand strength, technologically required and related to a specific casting process, is obtained through selection of the oil binder of suitable class,

Table 1.
Specification of selected oil binders [7]

Binder	Characteristics	Density (20°C) g/cm^3	Given resistance R_m^S / 1% of the binder	Core drying temperature °C	Composition
Oil C	Oil binder of I class for preparation of complicated non-hygroscopic cores	0,90 ÷ 0,97	≥ 0,6 MPa	200 ÷ 240	The product of colophony and vegetable oil dissolution in solvent kerosene and/or neutral oil
Oil DL	Binder for preparation of core sands for small, medium-complicated cores	≤ 1,08	≥ 0,35 MPa	180 ÷ 200	Emulsion of dextrine water solution and vegetable oil
Retanol	Oil binder for preparation of non-hygroscopic cores	≈ 0,94	≤ 0,8 MPa	200 ÷ 250	-

from I (R_m^S / 1% > 0.5 MPa) up to III (R_m^S / 1% < 0.3 MPa) [6].

The sands have been prepared in a laboratory sand-mill retaining constant procedure in order to ensure their homogeneity: a portion of dry high-silica sand (4 kg) was poured and, after starting the mill, 2% of the selected oil binder was dosed in and mixed for 4 minutes. In case of application of modifying additives (see item 3), they were added to the mass 2 minutes after the start of mixing process.

Eight-shaped and elongated samples, for tensile and bending strength determination, have been prepared with a standard rammer from these oil masses [11]. The formed samples have been concentrated three times in order to guarantee their easy pulling out and maneuvering under laboratory conditions as well as ensuring constant sand concentration, important during the experiments [9].

3. Research methodology

The experiment objective was to determine possibility of application of the innovative, microwave drying of molding sands containing oil binders and comparison of its effects to the ones obtained during traditional furnace or dryer drying process. Classical sample heating has been conducted in a laboratory dryer at the temperature of 200°C for 120 minutes, while microwave process in a chamber of the laboratory workstation [4].

Three samples have been put into the multi-mode heating chamber of microwave device for determination of tensile or bending strength, ensuring proper magnetron function and identical conditions of the drying process. The output power of microwave generator was 750W.

Heating time of 8 minutes has been assumed, basing on result analysis of the initial studies and literature data [1-5]. It has been observed that such a short drying of oil sands in a low-power device cannot have a practical application (little positive influence has been noted only in case of the sand with DL binder – see discussion of the experiments' results). The sample temperature reached after this short heating time (120 ÷ 130°C) did not ensure complete drying of the investigated sands (table 1).

For this reason heating process has been extended from 1 cycle (lasting 8 minutes) to 4 cycles and 32 minutes of total microwave influence time.

Additionally, in order to increase heating efficiency of the investigated sands, a number of actions have been undertaken aimed at increase of the value of absorption coefficient $k = \varepsilon'_\gamma tg\delta$, responsible for transfer efficiency of microwave energy emitted by magnetron [8].

Composition and quantity (1.5 % percentage by weight) of the special modifying additive, added to the sand during its mixing process, have been determined basing on result analysis of additional experiments (see item 2). This resulted in a more efficient microwave absorption by the sand and heating process intensification, which is a very desirable effect in case of low-power microwave generating sources.

Extension of heating time and addition of the special substance however, have not resulted in a suitable increase of temperature required for proper curing of oil binders: C oil and Retanol (table 1).

A positive influence of microwaves on DL binder drying process has been observed during the experiments. During the first attempt already, lasting 8 minutes, the samples have been dried sufficiently to allow for determination of R_m^S and R_g^S strength. Another modification attempt of oil sands drying process through a change of binder composition has been undertaken. The sands have been prepared according to item 2. Quartz grains have been combined with oils: C or Retanol, combining each of them with DL binder (in 1:1 ration). Additionally, 1.5% of the substance intensifying microwave heating process have been added to the sand. This allowed for reduction, down to 24 minutes (3 cycles), of microwave drying time of the sands, while simultaneously ensuring their required strength.

4. Results

The results of tensile and bending strength determination of the investigated sands with 2% addition of oil binder, constituting mean value of three measurements, have been presented in figures 1 and 2 (R_m^S strength per 1% of the binder has to be considered while comparing the results with approximate values contained in table 1).

Table 2, on the other hand, presents description of the conducted attempts and their numbers have been assigned to columns in figures 1 and 2.

R_m^S values of classically dried sands (items 1, 2, 3 – fig. 1) compared to strength per 1% of the added binder are consistent with the ones given in a manufacturer's specification (table 1).

R_m^S strength of the sand, prepared with DL binder and microwave-dried for 8 minutes (fig. 1, item 4), is 50% lower than the one given in the manufacturer's specification (table 1).

Extension of heating time up to 32 minutes and addition of the special intensifying substance (fig. 1, item 5) resulted in the increase of R_m^S strength even by 22%, in comparison to the value obtained for the traditionally dried - for 120 minutes - sand containing DL binder. A positive effect has also been obtained in case of drying of the sands prepared with a mixture of two binders: C oil or Retanol with DL oil (item 6 and 7, fig. 1).

Table 2.
List and description of oil sands drying attempts

Attempt number	Binder:	Drying method:	Modification:
1	Oil C	Classical	-
2	Oil DL	Classical	-
3	Retanol	Classical	-
4	Oil DL	Microwave	t = 8 min
5	Oil DL	Microwave	t = 32 min; intensifying substance
6	Oil C + DL	Microwave	t = 24 min; intensifying substance
7	Retanol + DL	Microwave	t = 24 min; intensifying substance

As could be seen in figure 1, the proposed combination of binders allowed for proper drying of the sand. The obtained R_m^S strength is comparable to the one obtained in case of the sands dried traditionally in a laboratory dryer.

Bending strength R_g^S of the investigated sands, dried conventionally at the temperature of 200°C for 120 minutes, presented in figure 2 (item 1, 2, 3) remains within 1.32 MPa (oil C) up to 1.82 MPa (Retanol) range.

Application of 8-minute long microwave drying of the sand with DL binder has not yielded satisfactory results (item 4, fig. 2).

Application of 32-minute long microwave heating of the sand containing DL binder as well as the intensifying substance allowed for obtaining R_g^S strength similar to measured after classical drying of the sand containing Retanol binder (item 3, fig. 2).

Bending strength of the sand dried with microwaves for 24 minutes and prepared with a mixture of DL oil and C oil (in 1:1 ratio) and 1.5% addition of the intensifying substance (item 6, fig. 2) is comparable to the one measured for classically dried sands containing addition of C or DL oil (fig. 2, item 1, 2). The addition of Retanol and DL oil mixture, combined in identical ratio as previously, and identical amount of the intensifying substance allowed for drying of the sand during microwave process however, its bending strength is about 30% lower in comparison to classically dried sands containing addition of C or DL oil (item 1, 2, 7, fig. 2).

We have observed that extension of heating process does not significantly influence further temperature increase of the sands prepared with binders used during the experiments up to the value necessary for their complete drying (table 1). For this reason we have conducted additional experiments on the laboratory workstation allowing for microwave heating of small samples with a high output power of magnetron concentrated in a small substrate volume [10].

Thanks to application of this device it has been possible to reduce drying process time and determine its dynamics, very important in case of the sands containing oil binders characterized by low absorption coefficient k. Heating process of the sand sample placed in a wave-guide was dynamic and did not necessitate application of intensifying additives.

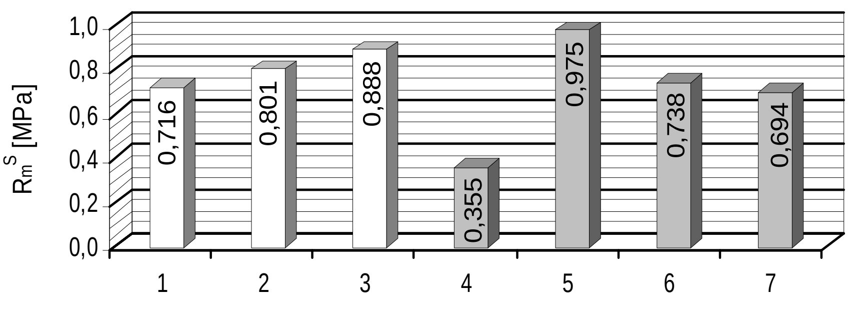

Fig.1. Tensile strength of the sands containing oil binders: white color – dried classically, gray color – microwave dried

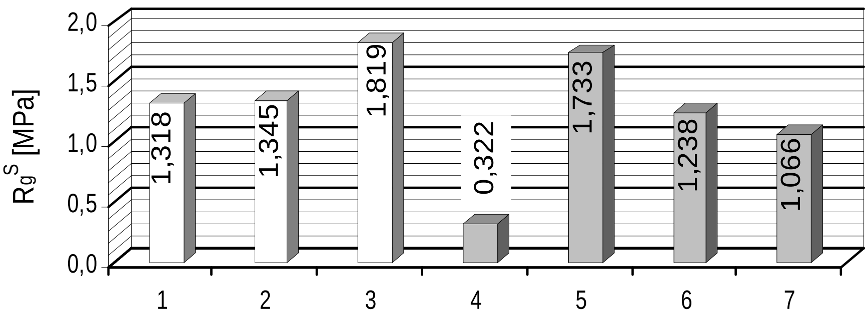

Fig.2. Bending strength of the sands containing oil binders: white color – dried classically, gray color – microwave dried

A satisfactory drying degree of the sands containing oil binders has been obtained as a result of these experiments, thus reducing microwave heating time to a minimum. Full control of the factors influencing the process efficiency, that is: microwave output power, sand drying temperature and heating time, constituted good points of the experiment.

5. Conclusions

It has been found, basing on result analysis of the experiments concerning microwave heating application for drying of sands with oil binders, that:

- microwave heating might well be applied for drying of oil sands prepared with currently available binders: C oil, Retanol and DL binder;
- correctly conducted microwave heating process ensures obtaining R_m^S and R_g^S strengths of oil sands comparable or superior to the values obtained for these sands during classical drying process;
- application of low-power microwave generator devices in some cases did not allow for obtaining of the temperature ensuring effective drying of oil sands;
- course of microwave drying process in low-power devices can be controlled by the use of specific modifications of the binders and/or addition of properly selected special intensifying substances;
- application of high-power microwave devices allows for efficient, easy and economical drying of oil sands, while simultaneously creating a possibility of process control as well as control of properties of this kind core sands.

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