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The Influence of Microwave Drying Parameters on the Properties of Synthetic Moulding Sands

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Abstract

In this work, the influence of microwave drying parameters such as irradiation time and microwave power level on the properties of synthetic moulding sands is presented. Determination of compressive strength R_c^s, shear strength R_t^s and permeability P^s of synthetic moulding sands with the addition of two different bentonites, after drying process with variable microwave parameters were made. The research works were carried out using the microwave oven with regulated power range of the electromagnetic field. From the results obtained, the significant influence of both drying time and microwave power level on the selected properties of moulding sands was observed. In comparison to the conventional drying method, microwave drying allows to obtain higher compressive strength of the synthetic moulding sand. The influence of application microwave irradiation on permeability was not observed. Higher strength characteristics and shorter drying time are major advantages of application of the electromagnetic irradiation for drying of the synthetic moulding sand with regard to conventional drying method.

Keywords: Innovative foundry technologies, Drying, Moulding sand, Strength properties, Permeability

1. Introduction

From a technological point of view, the dry constituents of synthetic moulding sand such as: sand base, binder and additives, both mixed and densified, have no cohesiveness and useful properties. Giving them these properties is only guaranteed by water addition. Water, therefore, is a necessary component of synthetic moulding sand. But, nevertheless, it is the undesirable constituent due to increasing gases emission, creating condensation zone and reacting with liquid metal components. This, in consequence can cause casting defects [1,2].

The main objective of mould drying is increase in strength and permeability and reducing of gas emission during filling it with liquid metal. Major moulding sand drying methods are: drying by the cold or hot gas, heating with hot foundry tooling, infrared and high-frequency drying [3].

Microwave technology has been used in many various fields of science, technology, industry and medicine. In foundry engineering, more commonly applied are microwaves because of searching for more effective methods of heating and hardening moulding and core materials. Microwave heating is connected with the polarization effect of dielectric materials and semiconductors, to which the microwave energy with waveguides is delivered. [4-6].

Water plays a significant role in physics of material mixtures, which includes moulding sands. The water content determines physical state and properties of moulding and core sand. Water is the main radiation absorber in materials dried with microwave energy. Electrical properties of water have a major impact on behavior of such materials [7-10]. The presented research was aimed at determining influence of irradiation time and microwave power level on the properties of synthetic moulding sands.

2. Microwave drying

Drying of the synthetic moulding sand in conventional dryers is provided by passing the hot air. This results in movement of some water inside moulding sand. Conventional drying is energy- and time-consuming method and requires lot of space. The elimination of presented disadvantages is possible through microwave application. Heating mechanism of conventional and microwave process are shown in Fig.1.

The conventional drying method with electric or gas furnaces based on heating of wall and furnace chamber. Heat is transported to the specimen (heat transfer), which generates excessive energy consumption, especially in case of small amount of heating material [11]. In the case of microwave heating the heat is generated inside material (energy conversion). That way, specimen is heated directly without heating the furnace elements, which results in better drying efficiency. The power delivered to specimen can be adapted to sample size.

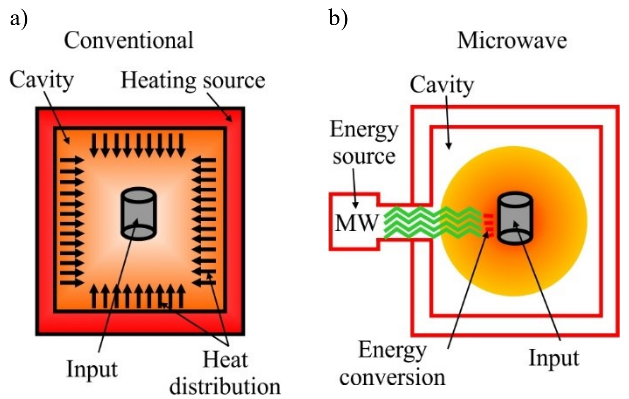

Fig. 1. A schematic diagram of the heating mechanism: conventional (a), microwave (b) [12]

2.1. Test stand

A scheme of the chamber heating system is presented in Figure 2. Main member (3) is a rectangular, cavity resonator made of metal walls reflecting electromagnetic waves. Microwave wave in the resonator is standing wave. To provide the uniform heating effect there is a need for making few resonance. For this purpose, dissectors (field mixers) are used. Dissector (4) is a metal, spinning component for wave from waveguide. In addition, in order to maximize the temperature uniformity, the input is placed on the rotary base (5). Research works were carried out with microwave chamber Panasonic NN-A823.

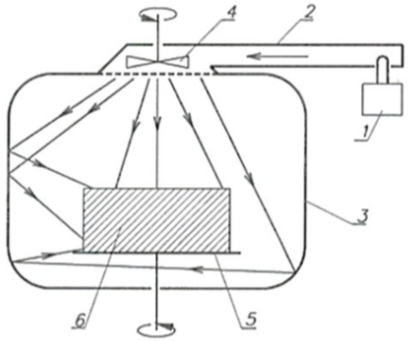

Fig. 2. A schematic diagram of the chamber heating system: 1 - generator, 2 – transmission waveguide, 3 – main member, 4 – dissector, 5 – rotary base, 6 – dried input [7]

2.2. Methodology

The experimental test were conducted in University of Technology in Department of Foundry Engineering, Plastics and Automation. Two kinds of moulding sands were made with two bentonites, differ in montmorillonite content, in order to determination of the influence of microwave drying parameters on moulding sand properties. Selected parameters of bentonites are given in Table 1. As the sand base was used high-silica sand from the mine „Grudzeń Las", (1K, 0.20 / 0.16 / 0.315, PN-85/H-11001).

Table 1.
Selected parameters of bentonites [13,14]

Parameter	Bentonite „Specjal"	Bentonite „Geko S"
Water content maximum [%]	12	14
Montmorillonite content minimum [%]	75	90
Carbonate content maximum [%]	5	5
Growth indicator minimum [cm^3/2g]	17	20

Moulding sands was prepared using the addition of 7% of bentonite with 93 % of sand. Test preparation was divided into two following stages. Firstly, dry constituents were mixed in laboratory mixer LM-1 for 2 minutes. Subsequently, half of the planned water quantity was added and mixed for 2 minutes. After the addition of the rest of water moulding sand were mixed for 2 minutes. In next stage moulding sands were aerated with sieve with 4 x 4 mm mesh. Prepared moulding sands was placed in tightly stoppered container for 2 hours, in order to homogenize it. The total weight of dry constituents was 4 kg.

Moulding sand water content determination was carried out with gravimetric method [2]. Moisture content (W) of prepared moulding sands had fluctuated between 3.37-3.54%. Standard cylindrical specimens, densified with standard rammer were made in accordance with PN-80/H-11073.

Prepared specimens were dried in microwave chamber with power level equal to 600W and 1000W and irradiation time: 3, 6, 9, 12 min. For comparison, specimens were dried in conventional drier (150˚C for 120 minutes) [3]. Dried specimens were chilled to room temperature and compressive strength, shear strength and permeability were determined, on the grounds of literature recommendations [2,3].

3. Results and discussion

Values of selected properties measurements of both conventional and microwave dried moulding sand are presented in Figures 3-8.

By exploring the influence of the microwave heating parameters on compressive strength R_c^s of two different bentonite-based synthetic moulding sands (Figures 3 and 4) it can be found a clear increase in compressive strength, which is 20 to 30% higher than moulding sand dried with conventional method. It refers to both power levels (600 and 1000W) and irradiation time equal to 6 and 12 minutes for "Geco S" bentonite.

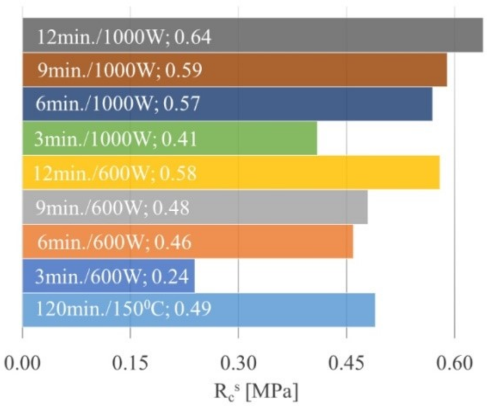

Fig. 3. The influence of irradiation time and power level on compressive strength R_c^s of moulding sand with "Specjal" bentonite

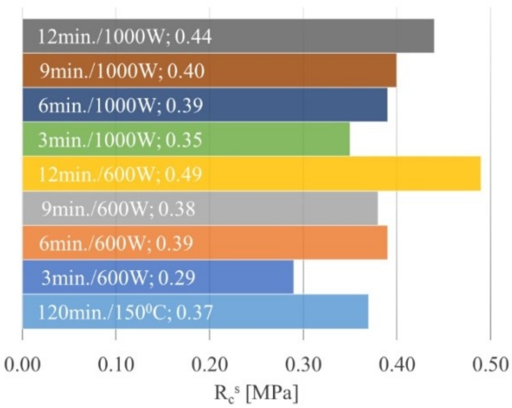

Fig. 4. The influence of irradiation time and power level on compressive strength R_c^s with "Geko S" bentonite

Figures 5 and 6 show the influence of the drying parameters on synthetic moulding sand shear strength R_t^s. There is noticeable increase in shear strength of both bentonite-based moulding sands (about 10% for time equal 12 min and two power levels) compared to conventional heating.

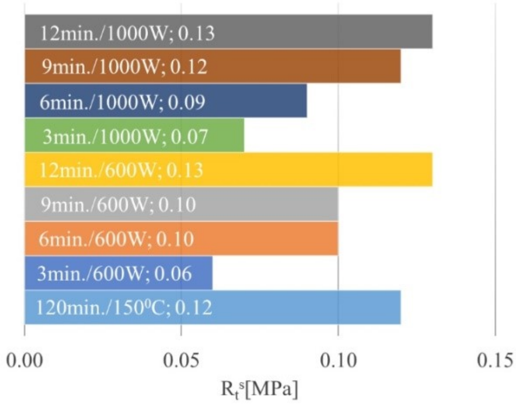

Fig. 5. The influence of irradiation time and power level on shear strength R_t^s of moulding sand with "Specjal" bentonite

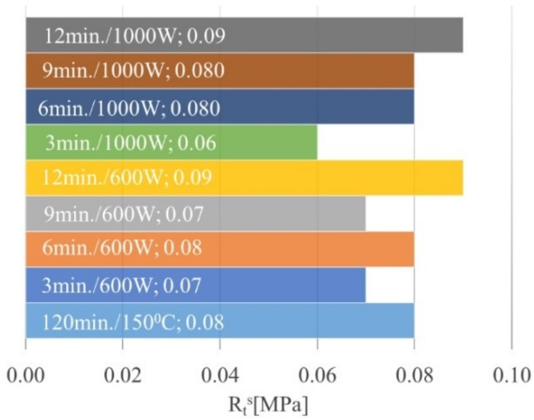

Fig. 6. The influence of irradiation time and power level on shear strength R_t^s of moulding sand with "Geko S" bentonite

In comparison to conventional dried moulding sands microwave irradiation time and power level have no significant effect on permeability results (Figure 7 and 8).

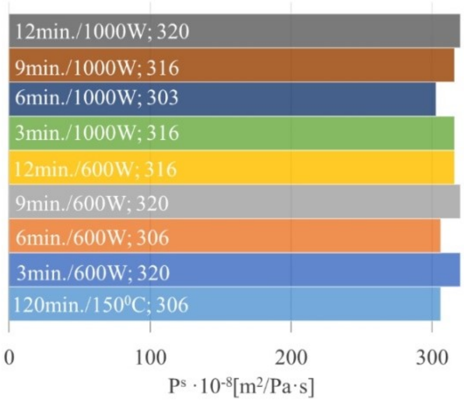

Fig. 7. The influence of irradiation time and power level on permeability P^s of moulding sand with "Specjal" bentonite

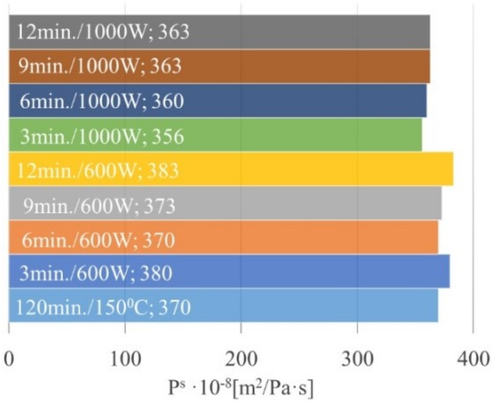

Fig. 8. The influence of irradiation time and power level on permeability P^s of moulding sand with "Geko S" bentonite

4. Conclusions

Analysis of the research results and literature review leads to the following conclusions:

- It is possible to apply of microwave heating for drying of the synthetic moulding sands.
- Microwave drying is characterized by up to 10 times shorter time than conventional process.
- Microwave dried moulding sands had higher compressive strength (20-35%) in comparison to conventional dried moulding sands.
- Moulding sands dried with microwaves, were characterized by higher shear strength (about 5-10%) then conventional dried moulding sands.
- Moulding sand permeability is independent of microwave irradiation time and power level.
- Increase in microwave irradiation time and power lever results in linear increase of the compressive and shear strength.

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