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INFLUENCE OF MOLDING AND CORE SANDS MATRIX ON THE EFFECTIVENESS OF THE MICROWAVES ABSORPTION

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The paper presents the results of applying microwaves to support the drying, redrying and hardening process of molding and core sands made of different types of matrix. In the tests of the microwave heating process a slot line measuring stand was used. Being based on the dielectric parameter measurement it enabled the evaluation of power losses of microwaves penetrating: chromite, magnesite, corundum, zircon and silica molding matrix samples. The survey revealed an impact of humidity and chemical compound of sands on microwave absorption. The study enabled the systematization of knowledge about the influence of selected types of matrix on the effectiveness of the microwave heating process.

Key words: foundry, molding sand matrixes, microwave absorption

INTRODUCTION

The silica sands, primarily for economic reasons, are the most commonly used material in casting practice. Other types of matrix, usually much more expensive than silica, are also used for preparation of molding and core sands. That is because of their more advantageous physical and chemical properties from the point of view of foundry technology. Their application is mainly related to the need for achieving: greater fire resistance of casting molds and cores, better surface quality and dimensional stability of castings [1].

The matrix is also a major component of molding sands from a quantitative point of view, thus it can determine the effectiveness of their microwave heating process. Due to the possibility of application of microwave heating on sandmixes composed of different matrix, appropriate research on determination of the effectiveness of electromagnetic radiation absorption was performed. The following sands with bulk density given in brackets were selected for the study: zircon (2,82 g/cm^3), chromite (2,8 g/cm^3), magnesite (1,63 g/cm^3), corundum (1,92 g/cm^3) and silica (1,7 g/cm^3). In order to see more precisely the difference in the absorption level of different materials the water content was changed during the measurements. The research should systematize knowledge about usefulness of these materials in the microwave: hardening, drying and redrying process of foundry molds and cores. Measurements of microwave absorption of the selected sands were preceded by a grain and chemical composition analysis as well as Scanning Electron Microscope (SEM) observations of the shape and surface topography of grains.

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The second important sandmix component having a significant impact on the castings quality is water [2]. In green molding sands its presence is essential. It can be added separately to the mix or chemically bound with binding materials or other additives. Furthermore, it can be a product of chemical or physical reactions during hardening of the sandmixes. Neither positive nor negative effect of water addition can be determined. In some cases its presence is essential, eg. in green molding sands, however, in other situations it is not always a desired component. It can cause the reduction of mechanical properties of molding sands[3] and also react with the components of a liquid casting alloy resulting in casting defects. In order to avoid these problems in many molding sands preparation technologies it is recommended to eliminate water (by drying or redrying). Popular technologies such as self-hardening molding sands with inorganic binders, eg. water glass [4-6], as well as organic (synthetic resins) [7] and even high – tech biodegradable binders [8] use more and more frequently microwave heating for reduction of excess water and thus achievement of the required sand mix strength. Microwave supported drying process can also be applied to efficient and rapid removal of the solvents from refractory protective coatings (water and alcohol based) in core and molding sands production.

In drying, redrying and hardening processes a microwave furnace can be successfully applied as an independent or supporting solution. It uses the phenomenon of absorption of microwaves by dielectric materials among which the most important absorber of microwaves at a frequency of a magnetron (2,45 GHz) is water. As a result of influence of electromagnetic forces on dielectric molecules placed in an external electromagnetic field these molecules begin to rotate and collide with each other. They transfer the acquired energy by friction and turn it into heat. An additional positive effect of the above mentioned phenomenon is the fact that in microwave heated materials or mixtures containing water the drying process occurs simultaneously in their entire volume. The advantage of such a drying method is therefore a quick disposal of humidity outwards unlike traditional and much longer drying in convection furnaces. Thanks to the use of microwave heating the elimination of the bottlenecks (for foundry these are: drying, redrying and hardening processes of molding and core sands) is possible.

Measuring stand

In the tests of microwave absorption of molding sands a prototype microwave line slot measuring stand was used. The operational principles of the device are described in [9]. Microwave signal generator model M 2031 used in the measuring set allows propagation of electromagnetic waves with the defined parameters of power – 3,98 mW and frequency – 2,45 GHz. Samples of an appropriate type of humid and compaction matrix were placed in a pre-defined section of the waveguide. In the measuring stand proposed for testing some of the microwave input power (P_{in}) propagated in the waveguide WR340 filled with the tested material is lost. The level of these losses is described by equations 1 and 2. They present loss parameters related to the scattering matrix coefficients s_{11} and s_{21}, such as: RL (Return Loss) and IL (Insertion Loss) expressed in dB:

$$RL = 20\log|s_{11}| \quad dB \tag{1}$$

$$IL = 10\log|s_{21}| \quad dB \tag{2}$$

On this basis, with the use of equation 3 the microwave absorption P_{abs} was estimated for each type of matrix:

$$P_{abs} = (1-(10^{\left(\frac{IL}{10}\right)} + 10^{\left(\frac{RL}{10}\right)})\cdot 100 \ [\%] \tag{3}$$

To verify the correctness of the results one used equation 4 which shows the balance of microwave power affecting the samples during the measurement [10]:

$$P_{in} = P_{ref} + P_{abs} + P_{out}, \tag{4}$$

where P_{ref} determines the level of reflected power and P_{out} the output level after passing through the test substrate. These parameters are expressed with formulas 5 and 6:

$$P_{ref} = \left(10^{\left(\frac{RL}{10}\right)}\right)\cdot 100 / \% \tag{5}$$

$$P_{out} = \left(10^{\left(\frac{IL}{10}\right)}\right)\cdot 100 / \% \tag{6}$$

Test results

Table 1 presents averaged results of the chemical composition analysis of five selected types of matrix used in foundry practice performed by a scanning electron microscope Hitachi TM-3000.

Table 1 **EDS analysis of the chemical composition of examined matrixes / wt. %**

	Zircon ($ZrSiO_4$)	Mage-site ($MgCO_3$)	Corun-dum (Al_2O_3)	Chro-mite ($FeCr_2O_4$)	Silica (SiO_2)
O	51,82	71,22	59,19	24,79	59,17
Zr	36,17	-	-	-	-
Si	11,49	-	-	0,50	29,02
Cr	-	-	-	43,28	-
Fe	-	-	-	24,36	5,01
Al	-	-	31,18	-	-
Mg	-	24,35	-	-	-
oth	0,52	4,43	9,63	7,07	6,80

Figures 1 – 5 present SEM images showing the grains surface topography of examined matrix types with locations of chemical composition analysis marked. They also show grain size distribution curves determined from sieve analysis.

It was found that all matrixes are homogeneous according to BN-68/4021-18. Sand types: magnesite, chromite and silica have a similar grain size while zircon and corundum have a finer one. Silica and zircon grains are characterized by rounded edges and oval shape. A sharp-edged shape of magnesite, corundum and chromite sand grains results from grinding which is a part of the preparation process of these sand types.

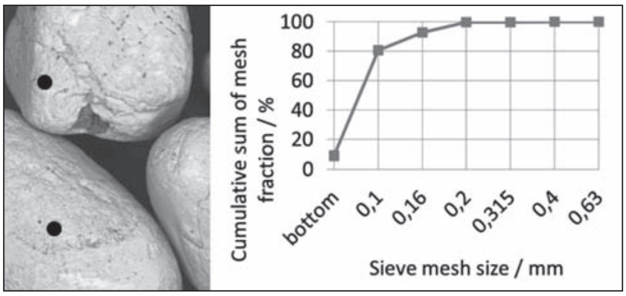

Figure 1 View of zircon sand grains and grain size distribution curve

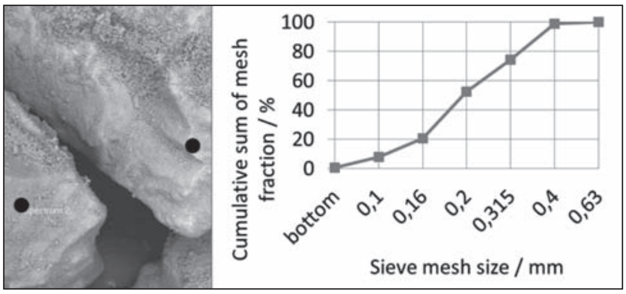

Figure 2 View of magnesite sand grains and grain size distribution curve

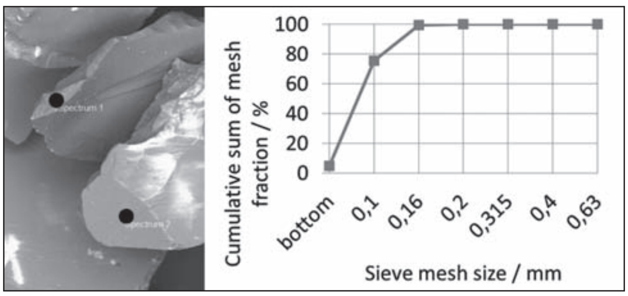

Figure 3 View of corundum sand grains and grain size distribution curve

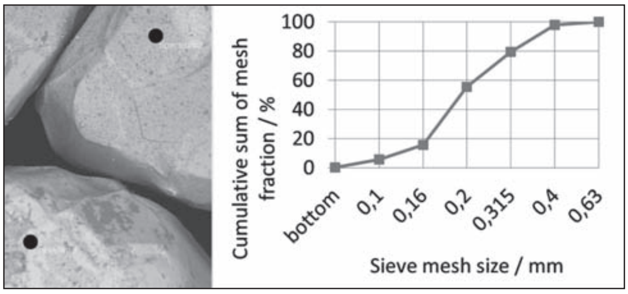

Figure 4 View of chromite sand grains and grain size distribution curve

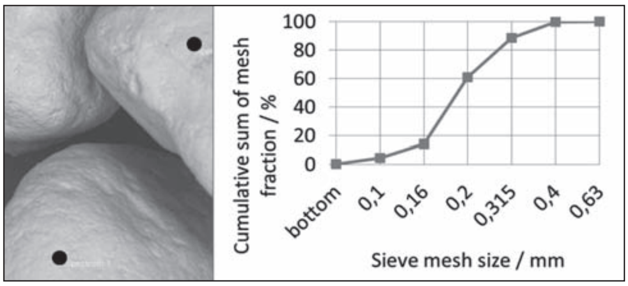

Figure 5 View of silica sand grains and grain size distribution curve

Measurements results of the loss parameters: RL and IL were converted by the formulas 3, 5 and 6 into proportional shares of individual components of power. Then the power balance was verified by equation 4. For all examined matrix types it has been observed that the P_{ref} growth occurs with the increasing water content and mainly by the loss of P_{out}. Figure 6 presents the results of the estimation of power absorbed by examined humid sands P_{abs} – the most significant parameter for determination of microwave heating effectiveness in dehydration and curing processes. As a result of the graph analysis there were no noticeable relations between the values of P_{abs} and density grain shape and granularity of examined sands. However the P_{abs} increase observed for some of matrixes occurs with increasing water participation in the mixture and its variation is related to the chemical composition (see Table 2). Therefore the share of specified chemical elements has most significant influence on the achieved P_{abs} value. The study confirmed former assumptions [9] in which iron and its compounds have an influence on higher P_{abs} value. The presence of elements in matrix such as: Cr, Zr and Si will have further impact on the growth of microwave absorption than Al or Mg.

For each of the sands a linear regression analysis was performed (with assumption p = 0,05) to describe the relation between the value of absorbed energy and added water.

Table 2 **Results of statistical analysis**

Type of matrix:	Correlation: P_{abs} / humidity:	Correlation coeff. „r”:	Coeff. of slope:
Zircon	Yes	0,65	2,86
Magnesite	Yes	0,84	2,23
Corundum	Yes	0,85	4,26
Chromite	Yes	0,61	6,56
Silica	Yes	0,86	5,99

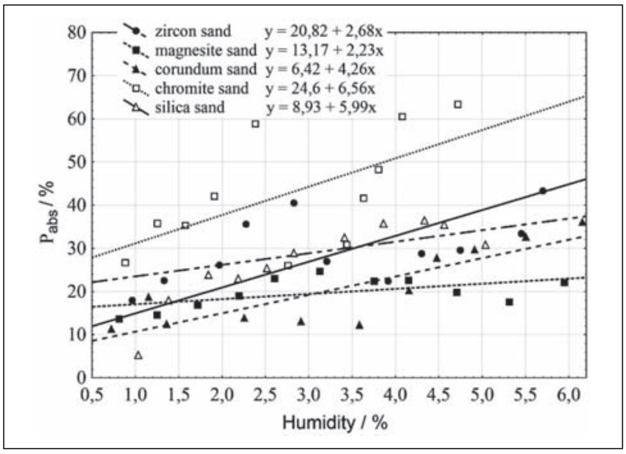

Figure 6 Graph with correlation between P_{abs} and humidity of tested molding matrixes

CONCLUSIONS

On the grounds of presented results in Figure 6, confirmed by statistical analysis presented in Table 2, it can be stated that:

- The highest growth rate of microwaves absorption (value of slope coefficient) characterized the following sands: chromite (67,64 % Cr+Fe), silica (34,03 % Si+Fe), and then corundum (31,18 % Al),
- The lowest dynamics of P_{abs} change was observed for zircon (47,66 % Zr + Si) and magnesite (24,35 % Mg) sands,
- For the water content up to about 3 – 3,5% the most favorable sands from the microwave absorption effectiveness perspective are as follows: chromite (30 – 45 %), zircon (25 – 30 %), silica (15 – 30 %), magnesite (17 – 20 %) and corundum (10 – 20 %),
- For the water content above 3,5 % most beneficial sands will include: chromite (45 – 65 %), silica (30 – 45 %), zircon (30 – 35 %), corundum (20 – 33 %) and magnesite (20 – 22 %).
- The most advantageous molding and core sand matrixes to be used in microwave heating process (P_{abs} > 20 %) are: chromite, zircon and silica.

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Note: The responsible translator for English language is lector from Wrocław, University of Technology, Poland