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Effect of Water-Glass Content on Electrical Properties of Silica Sand-Based Moulding Sand

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Abstract

In the paper, presented are measurements of permittivity ε_r and loss factor tgδ of moulding sand depending on bonding material content, taken at 2.45 GHz by perturbation method on a stand of wave-guide resonance cavity. The determined electrical properties are crucial for kinetics of microwave heating of sandmixes containing water-glass as a binder. The measurements were taken for two sandmixes with various sand grains. The results indicate that, for a moulding sands containing water-glass, the relationship between loss factor value and binder concentration is linear. All the examined moulding sands, irrespective of their base, show a relatively high susceptibility to action of microwave field of frequency 2.45 GHz. The presented measurements make a ground for developing a mathematical model of microwave heating of the systems moulding sand-foundry tooling.

Keywords: Innovative foundry technologies, Microwaves, Moulding sand, Water-glass, Electrical properties

1. Introduction

The innovative process of microwave heating finds wider and wider application in many fields of science and technology. This results from its remarkable properties ensuring eco-friendly nature and measurable economic benefits. In contrast to the traditional methods, volumetric nature of action of microwave radiation contributes to increased speed and effectiveness of heating, as well as to improved quality of the materials [1,2].

Application of microwave heating for drying or hardening moulds and cores made of sandmixes containing inorganic binders, in particular water-glass and biodegradable binders, makes it possible to obtain measurable benefits in form of shorter process time and smaller content of bonding material [3,4].

Power dissipated in the microwave-heated material depends, among others, on intensity and frequency of electromagnetic field, as well as on relative permittivity ε_r and loss factor tgδ of the material [5]. Therefore, evaluation of the possibility to apply microwave heating in foundry processes requires determining electric properties of moulding sands, since these properties determine efficiency and effectiveness of microwave-supported manufacture of casting moulds and cores are by [2,5,6].

Among many factors determining qualitative and quantitative selection of components of a moulding sand, variable techniques of preparing of foundry moulds and cores can be distinguished [7]. Heating of moulding sands subject to action of microwave field proceeds in various ways, determined by their chemical, mineralogical, qualitative and quantitative compositions. The presented research was directed to gaining fundamental knowledge about kinetics of microwave heating of moulding and

core sands prepared with use of variable bonding materials by determining their basic electrical properties. As a result, it will be possible in the future to obtain finished castings of suitable quality using disposable moulds and cores dried and microwave-hardened, thanks to the developed mathematical model of the process of microwave heating of foundry materials.

2. Idea and methodology of the research

2.1. Materials used in the research

On the ground of the literature review [7, 8] and own experiences, two kinds of sand base of moulding sands with similar physico-chemical properties were selected for examinations of electrical properties. Selected were: high-silica sand from the mine "Grudzeń Las" with grain size distribution 0.20/0.315/0.16 and high-silica sand from the mine "Szczakowa" with grain size distribution 0.20/0.315/0.40. Grains of both types of sands are shown in Fig. 1.

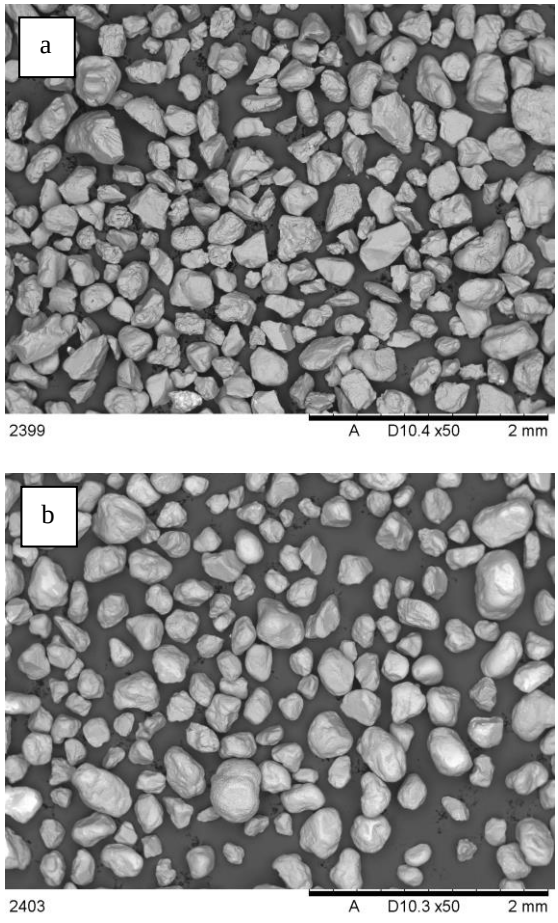

Fig. 1. Grains of high-silica sand: a) from „Grudzeń Las", b) from „Szczakowa". 50x, SEM

On the ground of the basic literature data [1,6,7], water-glass grade 145 with molar module (SiO_2/Na_2O) between 2.4 and 2.6 was chosen for the examinations.

Sandmixes based on the selected sands were prepared using variable contents of water-glass, ranging from 1 to 6 wt%. The sandmixes were prepared in a paddle mixer. Next, cylindrical shapes were compacted using a vibratory device.

2.2. Scope and methodology of the research

Behaviour of materials in alternating electromagnetic field is described by two main parameters. One of them is relative permittivity ε_r that describes the way how the material is polarised in this field. The other parameter is loss factor (loss tangent) tgδ that determines the part of energy converted to heat in the material subject to action of microwaves. At constant strength and frequency of a microwave field, the product of these two parameters enables arranging materials with respect to their effectiveness to absorb microwave radiation [5,6].

Electrical properties of the sandmix containing water-glass were determined by perturbation method at 2.45 GHz on the stand of waveguide resonance cavity described in [9]. The measurements were taken at 20 °C and relative air humidity of 40%, on three specimens of each moulding sand. The sands were preliminarily dried at 105 °C.

3. Results

Average values of the measurements of permittivity and loss factor are given in Table 1. In addition, the table includes measurements of electrical properties of pure silica sand and water-glass 145.

Table 1.
Electrical properties of moulding sands containing water-glass 145 at microwave frequency of 2.45 GHz

Component	Water-glass content [wt%]	Average Permittivity ε_r	Average loss factor tgδ	Product ε_r*tgδ
Water-glass	X	3.56	0.0387	0.138
High-silica sand from „Grudzeń Las" mine	0	2.21	0.0015	0.003
	1	2.00	0.0105	0.021
	2	1.95	0.0220	0.043
	3	1.94	0.0294	0.057
	4	1.96	0.0358	0.070
	5	1.83	0.0377	0.069
	6	2.01	0.0476	0.096
High-silica sand from „Szczakowa" mine	0	2.29	0.0024	0.005
	1	2.00	0.0128	0.026
	2	1.96	0.0236	0.046
	3	1.91	0.0291	0.056
	4	1.97	0.0366	0.072
	5	2.00	0.0366	0.073
	6	1.94	0.0463	0.090

Analysis of the measurements of permittivity for the sandmixes and their components indicates that values of this parameter for pure sand grains are close to those for the prepared moulding sands. Permittivity of water-glass 145 is ca. 1.8 times higher than those for the moulding sands.

The measured values of loss tangent indicate that all the examined sandmixes are characterised by significant dielectric lossiness and thus high susceptibility to absorbing microwave energy. As was expected, the highest values of this parameter were determined for the sandmix containing 6 wt% of water-glass (tgδ equal to ca. 0.047 for both kinds of base) and the lowest ones for the sandmix containing 1 wt% of water-glass (tgδ equal to ca. 0.011 for both kinds of base).

From among all the examined sandmixes, the one based on silica sand from „Szczakowa" mine with an addition of 6 wt% of water-glass absorbs microwave energy most effectively. This is confirmed by value of the product of permittivity and loss factor equal to 0.090, which presents 65% of this product value for water-glass ($\varepsilon_r * tg\delta = 0.138$).

Figures 2 and 3 show relationships between the examined electrical properties of the sandmixes and concentration of water-glass. For each relation, a trend line and coefficient of determination R^2 were determined by the least squares method.

The relationships between permittivity values of sandmixes and contents of water-glass are described by third and fourth order polynomial functions, see Fig. 2. The relationships between loss factor values of sandmixes and contents of water-glass are described by linear functions, see Fig. 3. Values of coefficient of determination R^2 indicate that, in all the analysed cases, the applied models very well describe the complex relationships between electrical properties of moulding sands and contents of water-glass in these sands.

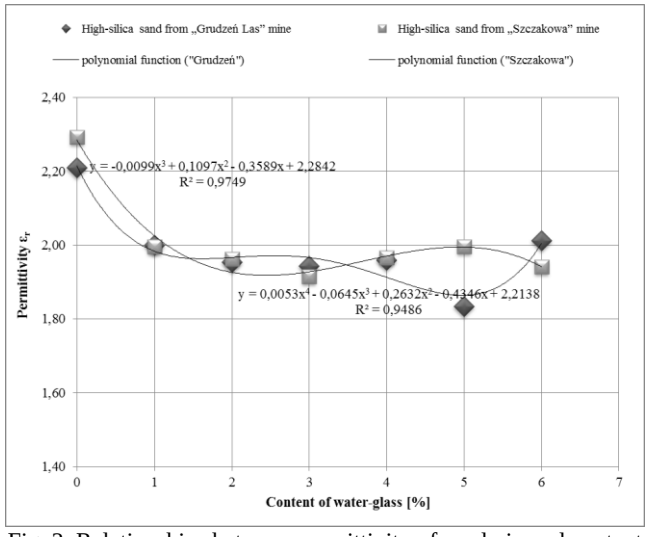

Fig. 2. Relationships between permittivity of sandmix and content of water-glass 145

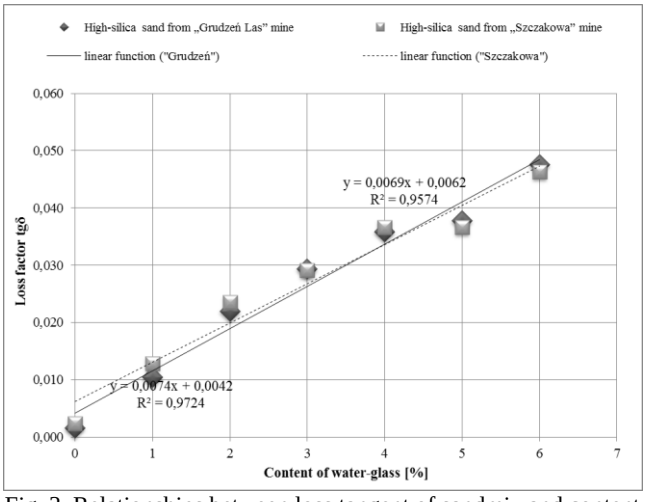

Fig. 3. Relationships between loss tangent of sandmix and content of water-glass 145

4. Conclusions

The results of the research on the effect of bonding material content on electrical properties of moulding sands based on silica sand lead to the following conclusions:

- Determining electrical permittivity ε_r and loss factor tgδ of pure quartz sand and water-glass enables optimum selection of these components for moulding sands designed for hardening by microwave heating.
- The moulding sands based on quartz sand and containing 1 to 6 wt% of water-glass effectively absorb microwave energy at 2.45 GHz.
- A polynomial relationship exists between permittivity of a sandmix and concentration of water-glass in this sandmix.
- A linear relationship exists between loss factor of a sandmix and concentration of water-glass in this sandmix.
- The effect of various grades of water-glass on effectiveness and efficiency of heating sandmixes based on various sands, designed for hardening by microwave heating, will be determined in further research works.

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References

[1] Granat, K., Stachowicz, M. & Nowak, D. (2010). Application of innovative method of microwave hardening in manufacturing processes of cast-steel castings for machine-building industry, *Archives of Mechanical Technology and Automation*. *30 (1)*, 19-27 (in Polish).

[2] Kowalski, S.J., Rajewska, K., Rybicki, A. (2005). *Physical basics of microwave drying*. Poznań: Editorial Office of Poznan University of Technology (in Polish).

[3] Stachowicz, M., Granat, K. & Nowak, D. (2011). Application of microwaves for innovative hardening of environment-friendly water-glass moulding sands used in manufacture of cast-steel castings. *Archives of Civil and Mechanical Engineering*. *11 (1)*, 209-219. DOI: 10.1016/S1644-9665(12)60184-8.

[4] Grabowska, B. & Holtzer, M. (2007). Application of microwave radiation for crosslinking of sodium polyacrylate/silica gel system used as a binder in foundry sands. *Polimery*. *52 (11/12)*, 841-847. ISSN: (0032-2725). (in Polish).

[5] Ashby, M., Shercliff, D. & Cebon H. (2011). *Materials Engineering, vol. 2*. Publishing House Galaktyka Sp. z o. o, Łódź. (in Polish).

[6] Mujumdar, S.A. (Ed.) (1995). *Handbook of Industrial Drying* . New York: Marcel Decker.

[7] Lewandowski, L. (1997). *Materials for casting moulds*. Kraków: Akapit.

[8] Dobosz, St.M. Grabarczyk, A., Major-Gabryś, K. & Jakubski, J. (2015). Influence of quartz sand quality on bending strength and thermal deformation of moulding sands with synthetic binders. *Archives of Foundry Engineering*. *15 (2)*, 9-12.

[9] Granat, K., Opyd, B., Stachowicz, M., Nowak, D. & Jaworski, G. (2013). Usefulness of foundry tooling materials in microwave heating process. *Archives of Metallurgy and Materials*. *58 (3)*, 919-922. DOI: 10.2478/amm-2013-0101.