

DETERMINATION OF THE BINDER IN SAND MOLDS WITH THE USE OF MICROWAVES

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Preliminary Note – Prethodno priopćenje

The paper presents results of preliminary examinations of possibility to measure binder content in traditional moulding sands using a new method employing electromagnetic waves. The presented examinations were carried-out with use of an innovative test station, the so-called microwave slot line. The measurements of binder content in moulding sand were based on the results of power balance investigation of microwaves affecting the specimen. An advantage of the suggested, new method of binder content measurement is short measuring time.

Key words: foundry, moulding sand, binder, microwaves

INTRODUCTION

In foundry practice, the most commonly applied among traditional moulding sands are those with synthetic binders. This is first of all related to the possibility of controlling composition and thus also technological properties of these sandmixes. The main components of a synthetic sandmix are sand base and a binder. The sand base of synthetic sandmixes most often consists of high-silica sands and less often of other sands, e.g. zircon, chromite or magnesite sand. From among the binders used in foundry practice, the most important with respect to binding capacity are bentonites [1].

Technological properties of a sandmix are first of all decided by its kind and composition. In the case of a specific sandmix grade, its technological properties are decided by quantity and quality of the binder (bentonite) and humidity. Knowledge of the binder content, especially of an active one and especially in the case of rebonding the circulating sandmix, is an important information about technological properties of this sandmix.

Analysis of the results of preliminary laboratory examinations carried-out using a microwave slot line in the Foundry and Automation Team of Wrocław University of Technology proved that it is possible to develop a new method of qualitative identification of a binder in the traditional moulding sand [2,3].

TEST STAND

The phenomenon of a standing wave present in a wave-guide, resulting from superposition of the wave reflected from the given medium and the wave incident

on this medium, is often used in microwave metrology. With its aid, it is possible to determine the standing-wave ratio (SWR) that plays an important role in heating processes, and the absorption loss. Microwave slot lines [4-7] are used in these measurements. Investigation of SWR of selected moulding materials was carried-out using a test stand composed of an electromagnetic wave source, rectangular wave-guide with movable probes and a SWR meter.

The wave-guide was so made that a measuring probe connected to the detector could be introduced inside through a specially made slot. The movable probe permits measuring distribution of the electromagnetic field

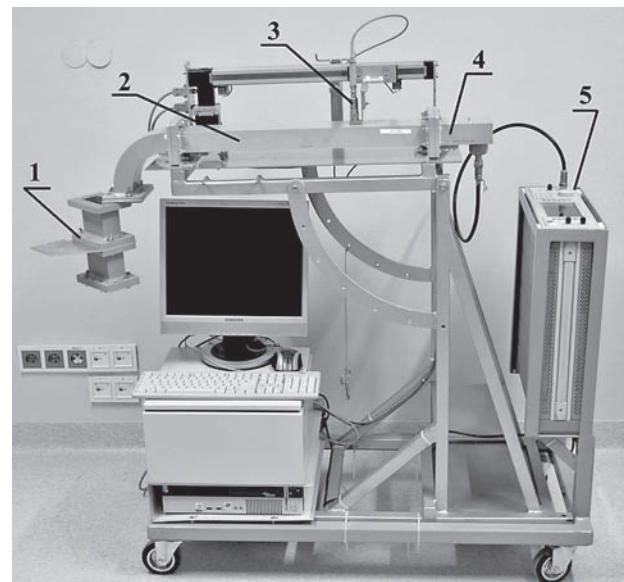


Figure 1 Layout of the test stand: 1 - load chamber with exchangeable substrates, 2 - wave-guide measuring line, 3 - probe with detector, 4 - transition of the wave-guide to the coaxial system in the WR340 standard, 5 - microwave generator

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inside the waveguide. On the ground of this distribution, the wave reflection coefficient can be determined as a function of the load impedance (of substrate).

Figure 1 shows layout of the test stand. A device made by Marconic Company, equipped with a frequency synthesizer, was used as the electromagnetic wave source. The signal generated by this device has constant power of 3,98 mW during the entire measuring cycle.

Modulus of the measured standing-wave ratio was read-off on the meter. Before the measurement, calculated was wavelength λ_f in the wave-guide for the measurement frequency 2,45 GHz. To this end, the equation (1) was applied, in that λ_0 is wavelength in vacuum [5-7]:

$$\lambda_f = \frac{\lambda_0}{\sqrt{1 - \left(\frac{\lambda_0}{\lambda_{gr}}\right)^2}} \quad (1)$$

The wavelength λ_{gr} of 188 mm for the limit frequency was calculated on the ground of the wave-guide dimensions and the accepted kind of field TE₁₀. The wavelength λ_f in the wave-guide was determined from the equation (1) as 174 mm. Places of the measured signal minimum and maximum values are repeated every 0,5 wavelength in the wave-guide, i.e. exactly every 87 mm. In addition, in order to allow reading-off the position of at least one minimum and one maximum, the condition of minimum wave-guide length should be met: $L \gg 0,5 \lambda_f$ [1].

MEASUREMENT OF MICROWAVE ABSORPTION

The performed research was aimed at determining precisely the part of microwave power input P_{in} that is absorbed by the examined material. Knowledge of this parameter permits, in the considered case, determining quantity of a binder in the sandmix.

Figure 2 shows balance of microwave power affecting the examined specimen.

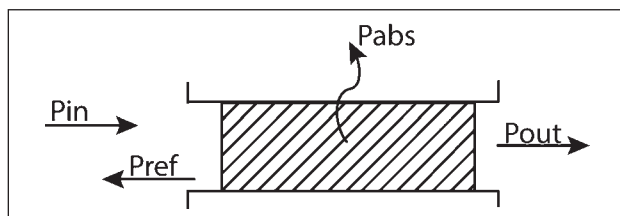


Figure 2 Balance of microwave power affecting the specimen

The respective equation is as follows:

$$P_{in} = P_{ref} + P_{abs} + P_{out} \quad (2)$$

where:

- P_{in} = power input,
- P_{ref} = reflected power,
- P_{abs} = absorbed power,
- P_{out} = power output.

The parameter directly related to the losses resulting from power absorption in the examined material is absorption damping A_d [6]:

$$A_d := \frac{P_{out}}{(P_{in} - P_{ref})} \quad A_d := 10 \cdot \log \left[\frac{1 - (|s_{11}|)^2}{(|s_{21}|)^2} \right] \quad (3)$$

where:

s_{11}, s_{21} – coefficients of the scattering matrix.

To determine the scattering parameters s_{11} and s_{21} properly, it is necessary to measure the reflection coefficient for the examined specimen with matched load and with shorting at the end of the slot line.

The input reflection coefficient for a symmetrical two-port loaded by impedance Z_L is described by the relationship:

$$\Gamma_{in} = s_{11} + \frac{s_{21}^2 \cdot \Gamma_L}{1 - s_{11} \cdot \Gamma_L} \quad (4)$$

The parameter s_{11} is determined directly from a measurement of the reflection coefficient for the examined specimen at matched load, for that $\Gamma_L = 0$,

and thus: $\Gamma_{in} = s_{11}$, (5)

where Γ_{in} is a complex quantity that can be written as:

$$\Gamma_{in} = |\Gamma_{in}| \cdot e^{i\Theta_{in}} \quad (6)$$

where:

$$\Theta_{in} = \pi + \frac{4\pi}{\lambda} \cdot dL \quad (7)$$

$$|\Gamma_{in}| = \frac{SWR_1 - 1}{SWR_1 + 1} \quad (8)$$

and

$$SWR_1 = \frac{U_{max}}{U_{min}} \quad (9)$$

where: U_{max} – maximum voltage, U_{min} – standing wave minimum voltage, d_L – standing wave minimum displacement, λ – wavelength.

The quantities U_{max} , U_{min} and d_L are determined during measurements on the test stand, see Fig. 1.

For the examined specimen and the line shorted at the end, the following expression for the parameter s_{21} is obtained from (4):

$$s_{21} = \sqrt{(s_{11} - \Gamma_{in2})(1 + s_{11})} \quad (10)$$

where Γ_{in2} is the measured reflection coefficient and s_{11} is determined from (5):

$$|\Gamma_{in2}| = \frac{SWR_2 - 1}{SWR_2 + 1} \quad (11)$$

$$SWR_2 = \frac{U_{max2}}{U_{min2}} \quad (12)$$

Therefore, determining absorption damping A_d requires obtaining measurements of maximum and minimum standing wave voltage (see formula 9 and 12), wavelength and wave displacement (see formula 7) for the specimen with matched load and with shorted slot line.

PREPARATION OF TEST SPECIMENS

The examined specimens were introduced to the constant-volume chamber installed at the end of the wave-guide. The chamber was made of a material with very low microwave damping coefficient, so that the wave freely penetrated through the chamber walls and then deep into the moulding sand present inside. The specimens were preliminarily compacted with a laboratory rammer LU-type to guarantee a constant thickening degree of the sandmix.

DETERMINATION OF ABSORBED POWER AND OUTPUT POWER OF MOULDING SANDS

Before the main research, preliminary measurements were taken to determine correlation between bentonite content, P_{abs} absorbed power and output power P_{out} of microwave energy. These measurements consisted in determining the P_{abs} and P_{out} values for dried moulding sand with various content of bentonites Specjal and Geco

Figures 3 to 6 show dependences of P_{abs} absorbed power and output power P_{out} on contents of bentonite Specjal and bentonite Geco in a traditional moulding sand.

Analysis of the preliminary results presented in Figs. 3 to 6 indicates that the changes of P_{abs} absorbed power and output power P_{out} are linear.

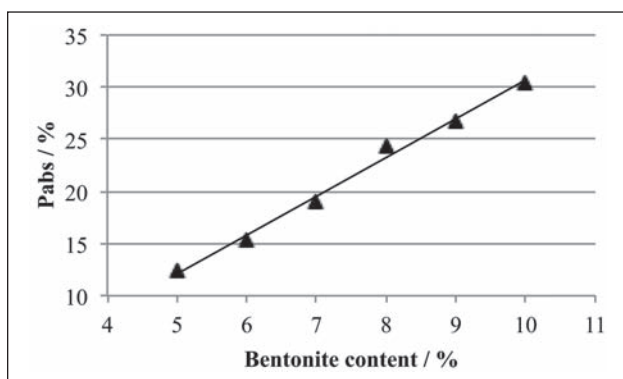


Figure 3 Effect of bentonite Specjal content in traditional moulding sand on absorbed power P_{abs}

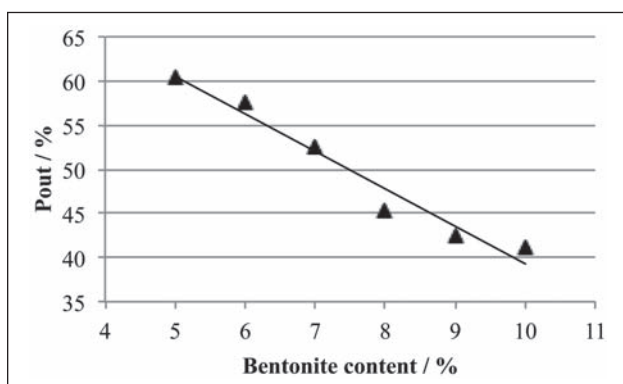


Figure 4 Effect of bentonite Specjal content in traditional moulding sand on power output P_{out}

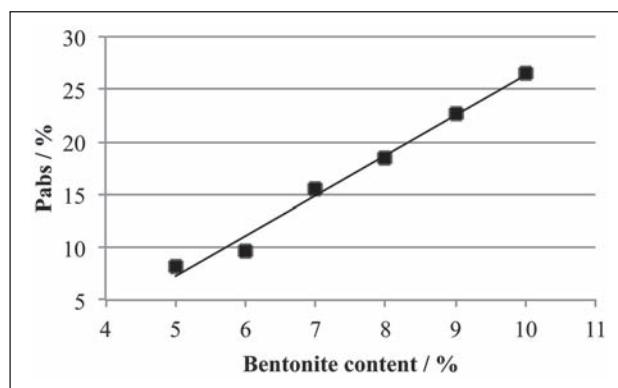


Figure 5 Effect of bentonite Geco content in traditional moulding sand on absorbed power P_{abs}

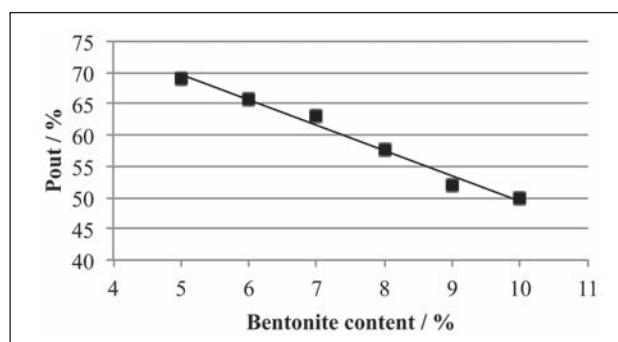


Figure 6 Effect of bentonite Geco content in traditional moulding sand on power output P_{out}

So, it can be found that it is sufficient to measure a single parameter only, namely P_{abs} absorbed power or output power P_{out} , to be able to determine concentration of bentonite contained in a sandmix.

FINAL CONCLUSIONS

Analysis of the obtained examination results leads to the following conclusions:

- It is possible to measure binder content in a moulding sand using a new microwave-based measurement method consisting in determining, by means of a slot line, values of one of the two parameters: P_{abs} absorbed power or output power P_{out} .
- An advantage of the new method of measuring binder content in moulding sand is short measurement time related to specificity of microwave radiation.
- The presented results of preliminary measurements with use of a microwave slot line, consisting in measuring parameters absorbed power P_{abs} and output power P_{out} , make an introduction to developing a method of measuring active binder content in circulating sandmixes, identifying binder grade and, at a further stage, determining humidity of a moulding sand.

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- Note:** The responsible translator for English language: INTER-TK, Translation Office, Wrocław, Poland