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Strength measurement of impulse compacted moulding sand

T. Mikulczyńsk*, S. Ciskowski
Laboratorium Podstaw Automatyzacji, Instytut technologii Maszyn i Automatyzacji,
Politechnika Wrocławska
* Corresponding author. E–mail address: Tadeusz.mikulczynski@pwr.wroc.pl

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Abstract

Analysis of impulse compaction process shows that during compaction process moulding sand is subject to deformation and changes of total pressure, measured inside compacted moulding sand, represent fading sinusoid. Measured pressure values in stationary states (after compaction process) are equal to the sum of squeezing pressure p_c and the pressure resulting from compacting the sandmix p_u, which expresses the obtained strength. Therefore experimental research of moulding sands were conducted. Strength factor *R*c and pressure p_u values were determined as a function of densening degree δ. Analysis of presented results proves that p_u pressure resulting from compacting of the moulding sand expresses compressive strength factor R_c. This confirms that developed methodology permits strength measurements of moulding sand in the mould. Moreover as it is possible to determine p_u values with simulation research of developed mathematical model of impulse process it is possible to determine compressive strength factor.

Keywords: Mechanization and automation of foundry engineering; Moulding sand; Impulse compaction process; Mathematical model; Strength measurement

1. Introduction

From among numerous properties of moulding sand, of significant importance are mechanical properties characterizing resistance of the moulding sand to loads occurring in the mould after it is poured with liquid metal. Mechanical properties of moulding sand are determined on the ground of strength moduli.

According to applied load of a moulding sand, the following moduli are distinguished: tensile modulus, flexural modulus, shear modulus and compressive modulus. All of them are determined for standardized moulders characterized by approximately identical densening degrees [1]. However, the moulding sand in various mould areas is densed to different extent, which results from various heights of sand columns and friction against model and moulding box. Varied distribution of densening degree in the mould results in different strength of the moulding sand changing its mechanical properties in different parts of moulding box.

As it is shown in this paper compressive strength factor R_c of moulding sand can be determined on the ground of internal pressures in the sand measured during impulse compaction process as well as during simulation examination of developed mathematical model of impulse compaction process of moulding sand.

2. Strength measurement of moulding sand

Analysis of the compaction process indicates that moulding sand is subject to deformation, which results in strengthening (densening) of the sand. Pressures in individual phases of the process accept the following forms [2,3]:

- In nonstationary states, pressures in moulding sands are equal to the sum of internal pressures connected with deformation and internal friction and those resulting from compacting the sandmix.
- In stationary states, pressures in moulding sands are equal to the sum of squeezing pressure and the pressure resulting from compacting the sandmix (p_{ui}), which expresses the obtained strength.

Therefore, the total pressure in the impulse compacted moulding sand can be described by the following relationship [3-5]:

$$p_{Ci}(\delta) = \frac{k_C(\delta)\cdot\left[x_i(t) - x_{i+1}(t)\right] + k_T(\delta)\cdot\left[\dot{x}_i(t) - \dot{x}_{i+1}(t)\right]}{A} + p_{Ui}(\delta) \qquad (1)$$

where:

p_{ci} – total pressure in i-th layer of the moulding sand,
$kc(\delta)$ – elasticity coefficient of the moulding sand,
$kt(\delta)$ – viscosity coefficient of the moulding sand,
p_{ui} – pressure in i-th layer, resulting from compacting of the moulding sand,
x_i – coordinate of i-th layer,
A – cross-section area of the moulding box.

Figure 1 shows experimental examination results of impulse compaction process, demonstrating changes of total pressure $p_c=f(t)$ and pressure $p_1=f(t)$ measured in technological space above moulding sand, carried out for moulding sand with 5% of bentonite and humidity W=2.5%. The pressure p_u resulting from compacting of the moulding sand represents strength the moulding sand acquired during deformation process and is equal to subtraction between total pressure p_c and pressure p_1 measured above moulding sand [5,6].

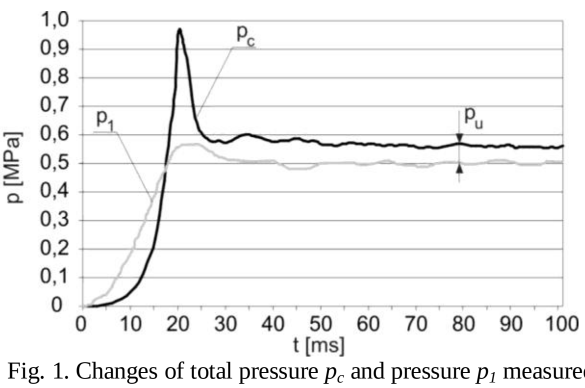

Fig. 1. Changes of total pressure p_c and pressure p_1 measured above moulding sand surface for the moulding sand with 5% of bentonite and humidity W=2.5%

In order to determine correlation between p_u pressure values and compressive strength factor R_c of moulding sand experimental examinations were carried out.

First step was to determine p_u pressure values as a function of densening degree δ of moulding sand. These experimental examinations were conducted on the specially constructed stand shown in Fig. 2.

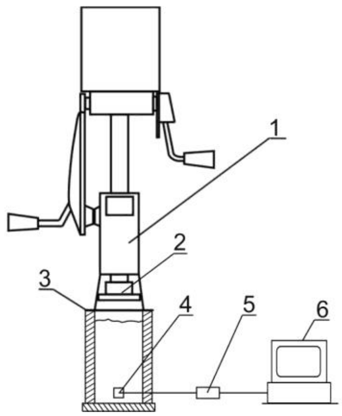

Fig. 2. Diagram of the test stand: rammer LU (1), rectangular foot (2), measurement chamber filled with moulding sand (3), piezoelectric sensor (4), charge amplifier (5), PC computer (6)

The laboratory test stand for measuring p_u pressure values consists of rammer LU (1), rectangular foot (2), measurement chamber filled with moulding sand (3), measurement line for recording pressure in moulding sand. Piezoelectric sensor (4) used for measurements of the dynamically changing pressures was located at the bottom of the compacted column of moulding sand. Additional components of the measurement line were charge amplifier (5) and PC computer (6).

On the presented measuring stand, moulding sand was dosed by weight. The weighted portion of the sand should be 350 g.

After each stroke of laboratory rammer pressure p_u and height of densed sand column was measured. This allowed to relate pressure p_u with densening degree δ of specified moulding sand.

The next step covered measurement of compressive strength of moulders characterized by different densening degree δ determined at the laboratory stand for compressive yield strength test. In this way relationship between compressive strength factor R_c and densening degree δ of moulding sand has been determined.

Figure 3 shows measurements results of pressure p_u and compressive strength factor R_c of moulding sand as a function of densening degree δ. All experimental examinations were conducted for moulding sands with selected bentonite content and humidity.

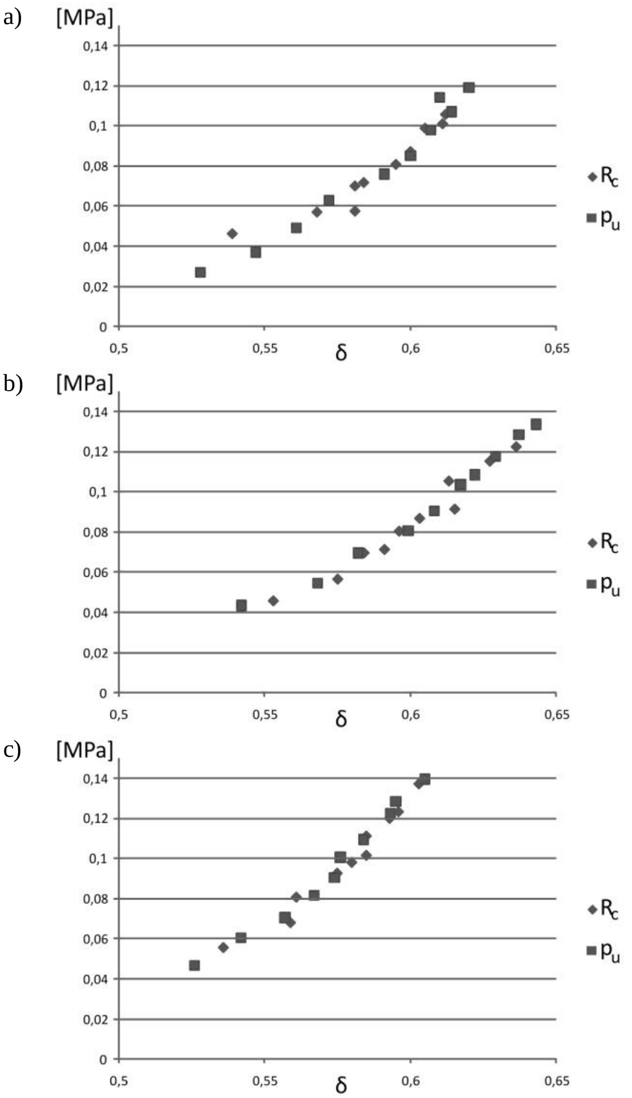

Fig. 3. Compressive strength factor R_c and p_u pressure as a function of densening degree δ for moulding sand with: 5% of bentonite and humidity W=2,7% (a), 5% of bentonite and humidity W=3,2% (b), 6% of bentonite and humidity W=2,9% (c)

Analysis of the relationships shown in Fig. 3 indicates that p_u pressure values, resulting from compacting of the moulding sand, expresses the obtained strength and are almost equal to the strength factor R_c . As far as it is possible to obtain p_u pressure values while conducting simulation research of developed mathematical model of impulse process it is possible to determine compressive strength factor R_c [5].

3. Simulation research results

Theoretical research works related to description of the process of moulding sand compacting, as well as experimental investigation of this process have been carried out for many years in the Laboratory of Basic Automation of the Institute of Machine Engineering and Automation of Wroclaw University of Technology (ITMiA PWr).

These works resulted in developing a mathematical model of the impulse compacting process of moulding sands, based on mathematical description of the impulse compacting head and mathematical model of the moulding sand deformation process.

This mathematical model, developed by authors, completely describes the impulse compaction process of moulding sands permitting simulation research of impulse compacting of moulding sands to obtain results for any volume of the compacted moulds [5-7].

Notably it is possible to determine total pressure values p_{ci} as well as p_{ui} pressure resulting from compacting of the moulding sand in any layer of moulding sand column. As far as p_u pressure values expresses the obtained strength of the mould it is possible to determine compressive strength factor R_c of mould for any volume of the compacted moulds.

Figure 4 shows changes of pressure p_{ui} resulting from impulse compacting of the moulding sand as function of height of the sandmix layer. The examinations were performed for the moulding sand with 5% of bentonite and humidity W=2.5% for three values of initial compressed air pressure p_0 in the accumulator tank of impulse head [4,8,9].

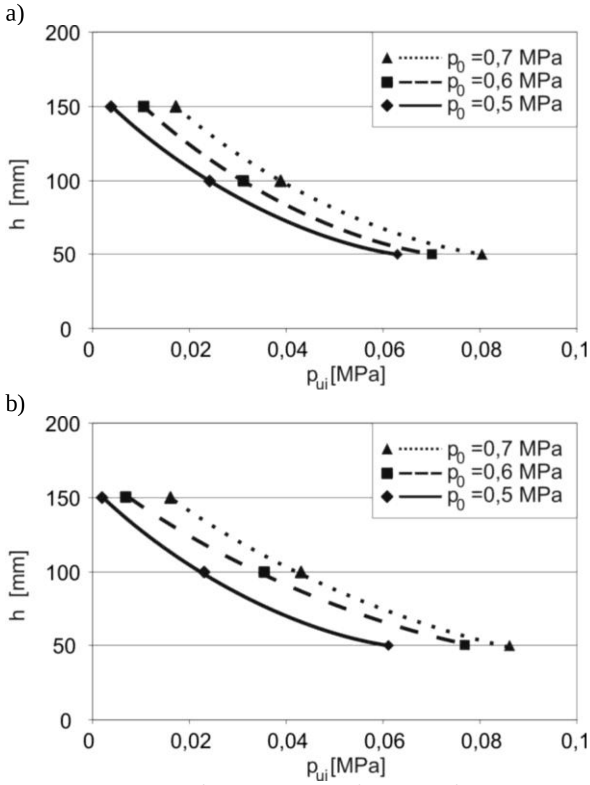

Fig. 4. Changes of pressure p_{ui} in function of sandmix column height for initial compressed air pressures p_0 = *0.5; 0.6; 0.7 MPa*: simulation results (a) and experimental results (b)

Simulation investigations of this mathematical model were carried out in the Matlab – Simulink environment and their experimental verification was performed on a specially prepared laboratory test stand [8].

It can be found on the grounds of presented simulation and experimental results that the formulated mathematical model correctly represents the real course of the impulse compacting process of moulding sands (pressure p_{ui} in particular) and can be used for determining compressive strength factor R_c of compacted moulding sand.

4. Conclusions

Analysis of the process of impulse compaction of moulding sand evidence that pressure in the moulding sand during impulse compaction process is total of pressure exerted by the densening medium (in this case compressed air) and pressure resulting from densening and mould deformation. Pressure p_u equal to subtraction between total pressure p_c and compressed air pressure measured at the surface of moulding sand determines its strength after densening. Therefore, as it was proven in the paper, compressive strength factor R_c of the compacted moulding sand can be determined on the ground of experimental examinations of p_u pressure measurement in moulding. Moreover R_c strength factor can be determined with simulation examination of mathematical model of impulse process.

Analysis of presented simulation and experimental results justifies the statement that the presented mathematical model very well describes the real course of the impulse compaction process of moulding sands and can be applied for designing and optimising the impulse compaction process.

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