Assessment of core sands suitability for filling the core box and for compaction – by blowing methods

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Abstract

The obtained effects of filling the core box cavity and moulding sand compaction in processes of core production by blowing methods (blowing, shooting) depend on several factors. The most important are: geometrical parameters of cavity and complexity of its shape, number, distribution and shape of holes feeding sands as well as the way of deaeration of a technological cavity. Values of individual parameters are selected according to various criteria, but first of all, they should be adjusted to properties of the applied core sand. One of the ways of a preliminary estimation of suitability of a core sand for filling the core box and for compaction by means of blowing methods is the determination of its fluidity and assessment how this parameter is changing when core sand is awaiting to be shot. Another criterion of suitability of core sands for the blowing process is their apparent density obtained at filling the testing core box of a complicated shape (Boenisch test). Various methods developed by several researchers, including the authors, allow to assess the tested property on the basis of special technological tests projecting the process into a laboratory scale. The developed criteria defining a degree or a filling ability factor provide a better possibility of assessing the core sand behaviour during flowing and core box filling, which indicate the value and structure of the obtained compacting decisive – after hardening – for strength and permeability. The mentioned above aspects were analysed – on the basis of authors’ own examinations - in the hereby paper.

Keywords: core production, core blowing, core shooting, core sand

1. Compactibility as an assessment measure of the quality of core sands compacted by blowing methods

Compactibility is very important factor influencing the quality of cores manufactured by means of blowing techniques (blowing, shooting). To determine quality of a core compaction performed by blowing and shooting method, Boenisch and Knauf [2, 3, 6] proposed a complex analysis of several factors. They have introduced two notions, according to which the assessment of a sand compaction ability in a core box is being made. Those are:
- Maximum core box filling ratio obtained by shooting,
- Maximum degree of a sand matrix compaction.

The technological tests, together with the special method for assessing the core box filling ratio as well as the equipment suitable for the realisation of this method, were developed. The physical meaning is expressed by Equation:

$$ FG = \frac{M}{M_{\text{max}}} \cdot 100\% = \frac{V_{c} \cdot \rho_{\text{mm}}}{\rho_{\text{p}} \cdot V_{p} \cdot \rho_{\text{p max}}} \cdot 100\% = \frac{\rho_{\text{mm}}}{\rho_{\text{p max}}} \cdot 100\% $$ (1)
where:
- \( M_r \) – core sand mass obtained at the given conditions, kg,
- \( M_{\text{max}} \) – maximum core sand mass (standard), kg,
- \( \rho_{\text{pm}} \) – average density of core sand compacted by shooting, kg/m\(^3\),
- \( V_c \) – core volume, m\(^3\),
- \( \rho_{\text{max}} \) – apparent density of the standard core sand compacted by vibration, kg/m\(^3\).

The standard core is made of a typical sand for the classic cold-box technology, where phenol and polyisocyanate resins, hardened by blowing through the core – of amine compounds (from Ashland and Hüttens-Albertus Company), are the binding agents.

Maximum degree of a sand matrix compaction is obtained by means of vibrating of the core box filled with dry high-silica sand carried on until no increase of density is observed.

2. Filling ability factor \( K_{Zr} \) as a proposed method of assessment of a core compaction quality

Proposed method of assessment of a core compaction quality is based on the analysis of the filling ability factor of sands, expressed by Equation:

\[
K_{Zr} = \left( \frac{M_r}{M_{\text{st}}} \right) \times 100\% = \left( \frac{V_c \cdot \rho_{\text{pm}}}{V_c \cdot \rho_{\text{st}}} \right) \times 100\% = \frac{\rho_{\text{pm}}}{\rho_{\text{st}}} \times 100\% \tag{2}
\]

where:
- \( M_r, V_c \) – markings as in Equation (1),
- \( M_{\text{st}} = V_c \cdot \rho_{\text{st}} \) – apparent core sand weight, kg/m\(^3\),
- \( \rho_{\text{st}} \) – apparent density of a core sand obtained in a cylindrical sample after ramming performed three times by the standard rammer, kg/m\(^3\).

Data of Boenisch and Knauf as well as of authors’ own, for some selected kinds of sand cores at the application of a uniform scale (filling ratio \( FG \)) are presented in Figure 1. An additional scale was introduced in this Figure to illustrate the core box filling ability factor \( K_{Zr} \) for three sands used in own examinations, marked by symbols Ol, SW and B.

The relation between Equation (1) developed by Boenisch and Knauf and Equation (2) presented in publications of the authors of the hereby paper, can be obtained by the comparison of Equations (1) and (2) in consideration of \( \rho_{\text{pm}} \) which brings the following:

\[
K_{Zr} \cdot \rho_{\text{st}} = FG \cdot \rho_{\text{pmaks}} \tag{3}
\]

and

\[
K_{Zr} = \frac{FG \cdot \rho_{\text{pmaks}}}{\rho_{\text{st}}} \quad \text{or} \quad FG = K_{Zr} \cdot \frac{\rho_{\text{pmaks}}}{\rho_{\text{st}}} \tag{4}
\]

As it can be noticed both the filling ability factor \( K_{Zr} \) and the filling ratio \( FG \) are determined by means of measurements of the same values, i.e. \( \rho_{\text{pm}} \) and \( \rho_{\text{st}} \).

Analysis of a physical meaning of coefficients \( K_{Zr} \) and \( FG \) indicates that the factor \( K_{Zr} \) better exhibits the influence of a complicated shape of the core box cavity on a sand core compaction, while the filling ratio \( FG \) is advantageous at assessing of an apparent compactability of various sands in the same core box.

3. Coefficient of sand evacuation from a blowing chamber

One of the ways of a preliminary estimation of a core sand suitability for filling the core box and for compaction by means of blowing methods is determination of its free fluidity and assessment how this parameter changes when core sand is awaiting to be shot. However, this method allows only an approximate forecasting of core sands behaviour during compacting performed by means of blowing methods. More promising seems the method of determining the coefficient of sand evacuation from the blowing chamber of the testing apparatus (schematically presented in Figure 2) developed by Boenisch and Knauf [1], and applied in authors’ own examinations [4,5]. It should be mentioned that forms and dimensions given in Figure 2 and Table 1, do not concern the original test described in the reference [1], but were reproduced for its similarity. Outline dimensions of the blowing chamber of the testing apparatus are given in Table 1.

The coefficient of sand evacuation from the blowing chamber of the testing apparatus was calculated according to Equation:

\[
e_v = \frac{\Delta M}{m_0} \times \frac{m_0}{m_n} \times 100\%	ag{5}
\]

where:
4. Core sands applied in examinations and their preparation

Four grades of core sands of different compositions and technological properties were used in examinations. They can be treated as representative for various core sands, provided that they have similar physical and mechanical properties. The following markings were used for individual sands:

- Sand with linseed oil varnish - symbol 'Ol',
- Sand with water-glass - symbol 'SW',
- Sand with furfuryl resin 1031 for the hot-box process - symbol 'Z1',
- Sand with furfuryl resin MM-155 for the hot-box process - symbol 'Z2'.

Sands were prepared in the paddle-ribbon mixer, LM-R1 type. In order to eliminate influence of sands aging and changes of their technological properties, fresh sands were prepared for each pressure and for each series of tests.

5. Experimental stand – apparatus for testing the core sand evacuation

The experimental stand for measuring the core sand evacuation, presented schematically in Figure 3.

![Experimental stand diagram](image)

Fig. 3. Schematic presentation of the experimental stand together with the equipment for the determination of sand inclination to evacuate from the blowing chamber [4]: 1 - shooting valve, 2 - blowing chamber, 3 – stand, 4 - testing apparatus, 5 - press bolt, 6 - air container 7 - shooting time controller.

6. The obtained results

The basic criterion of qualifying the given core sand as suitable for the blowing process was its apparent density obtained at filling the testing core box of a complicated shape (analogy to Boenisch test).

Dependence of the sand evacuation coefficient on core densities – determined at shooting core sand into the testing apparatus at a pressure impulse time being 0.2s – is graphically presented in Figure 4. The influence of pressure – at which core sand shooting was done – on the filling ability factor \( K_z \) is shown in Figure 5. It can be seen, that in the case of data given in Figure 5 the results are practically linear and defined by given equations. This indicates that there is a possibility of arranging sand grades, from the point of view of their suitability for the blowing process, on the bases of determining the sand evacuation coefficient - without the necessity of performing the compaction quality examination every single time.

Presently used methods of determining core sands suitability for the blowing process can be only considered as intermediate ones since they are based on various methods of determining sand fluidity, whereas those methods do not exhibit similarity to the blowing process. The aim of the performed examinations was to establish whether it is possible to assess the suitability of core sands - for the core box filling and compacting by blowing methods - by means of determination of the sand evacuation caused by a single air pressure impulse in the shooting and blowing apparatus. The obtained results allow to estimate positively the suitability of measuring the filling ability factor as well as the coefficient of sand evacuation from the blowing process.
chamber of the experimental apparatus – analogous to the one
used by Boenisch for the core compaction quality assessment.

15
20
25
30
35
40
45
1 1.1 1.2 1.3 1.4 1.5 1.6
Core density \( \rho_{\text{pm}} \), g/cm³

Sand evacuation coefficient ev, %

Sand Z1
Sand Z2
Sand SW
Sand Ol

Fig. 4. Dependence of the sand evacuation coefficient on the
core apparent density.

At the present stage of tests it can be stated that there is
practically a linear dependence between the sand evacuation
coefficient and the amount of sand shot into the core box. Thus,
this provides the justified grounds for the development of the
technological test allowing to assess the suitability of the given
sand for the blowing process.

Eventual further developments of the apparatus for determining
the sand inclination for compaction by blowing methods should
comprise different placement of deaeration holes in the testing
core box in order to improve its filling.

\[
K_{Zr}(\text{Ol}) = 0.595\times P + 0.6485 \\
R^2 = 0.9829
\]

\[
K_{Zr}(Z1) = 0.8507\times P + 0.5259 \\
R^2 = 0.9994
\]

\[
K_{Zr}(SW) = 0.4014\times P + 0.6190 \\
R^2 = 0.9995
\]

\[
K_{Zr}(Z2) = 0.5921\times P + 0.4904 \\
R^2 = 0.9863
\]

Fig. 5. Dependence of the filling ability factor \( K_{Zr} \) on the
shooting pressure.

6. Conclusions

Presently used methods of determining core sands suitability for
the blowing process can be only considered as intermediate ones
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caused by a single air pressure impulse in the shooting and
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well as the coefficient of sand evacuation from the blowing
chamber of the experimental apparatus – analogous to the one
used by Boenisch for the core compaction quality assessment.

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