EXAMINATIONS OF PARAMETERS INFLUENCING THE OUTFLOW OF TWO PHASE AIR-SAND STREAM FROM MACHINE CHAMBER AND CORE BOX FILLING IN SHOOTING PROCESS

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The study investigates the key aspects involved in the flow of the air-sand stream from the machine chamber and in the core box filling in the core shooting and core blowing processes.

The prevailing tendency to manufacture thin-walled castings with intricate channel structures has become the major determinant of castings quality and production rates. An important parameter of most core sand used in the shooting processes is the ability to eject from the machine chamber and the core-box filling capability. These properties are the key factors determining the feasibility of manufacturing intricate cores and the process efficiency. The research work outlined in this study focuses on establishing the performance criteria of core sand ejection from the machine chamber and of core box filling and sand compaction.

The results given below were obtained for several new-generation core sand types, containing organic and inorganic binders, and designed to be used in hot-box, warm box and warm air processes.

Keywords: core production, core shooting, core blowing

1. Evaluation of usability of the core sand in box filling and sand compaction by blowing methods

Optimisation of core production by the shooting method involves the selection of operating parameters of the box-filling and sand compaction processes as well as sand hardening using gases or by thermal methods. The degree of core sand ejection from the core chamber controls the effective volume of core achievable in the given core machine [1-8]. It is dependent both on the machine construction, particularly the shooting valve and the method of air supply to the core sand to eliminate air channels, and on physico-chemical parameters of the core sand, which affect its flowability. Factors controlling the core box filling and sand compaction processes include the intricacy of the core shape, core sand type, shooting pressure parameters and recommended surface areas and spacing between the shooting and venting holes. Those issues were investigated previously [2,9] and tests were done on conventional core binders (oil or linseed oil varnish, water glass, resins for hot-box processes).

In the case of the state of the art cold-box and warm air technologies, there is a need to modify the parameters of the blowing process in relation to core sands used previously. This is associated with physico-chemical properties of the applied binders (high reactivity, low viscosity) and the sand compaction conditions, particularly through airing with gaseous agents [10-13].

2. Evaluating the quality of core sand compaction by the blowing methods

Methods employed now to establish the suitability of particular core sand for use in the blowing process should be regarded as approximate only. They are mostly based on various techniques of determining the core sand flowability and the processes involved do not resemble the blowing process.
### Investigated sand types

<table>
<thead>
<tr>
<th>Name</th>
<th>Composition</th>
<th>Designation</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core sand CORDIS (warm air)</td>
<td>Binder: 2.2 parts by weight, Powder 1.2 parts by weight</td>
<td>CO</td>
<td>1.56 kg/m³</td>
</tr>
<tr>
<td>Core sand INOTEC (warm air)</td>
<td>Binder: 2.2 parts by weight, Powder 1.2 parts by weight</td>
<td>IN</td>
<td>1.51 kg/m³</td>
</tr>
<tr>
<td>Core sand FURESAN (warm box)</td>
<td>Binder: 2.2 parts by weight, Powder 1.2 parts by weight</td>
<td>FU</td>
<td>1.52 kg/m³</td>
</tr>
<tr>
<td>Core sand THERMSET (warm box)</td>
<td>Binder Thermset – 2 parts by weight, Hardener Harter 0.3 parts by weight</td>
<td>TH</td>
<td>1.45 kg/m³</td>
</tr>
</tbody>
</table>

In publications on the subject the assessment criteria are provided, relating to the core sand flow from the core tank to the core box:

- the degree of box filling FG, expressed by the formula [1][1]:
  \[
  FG = \frac{M_r}{M_{max}} \cdot 100\% = \frac{V_c \cdot \rho_{pm}}{V_r \cdot \rho_{pmax}} \cdot 100\% = \frac{\rho_{pm}}{\rho_{pmax}} \cdot 100\% \quad (1)
  \]

- box filling factor [2,5,9,10]:
  \[
  K_z = \frac{M_r}{M_st} \cdot 100\% = \frac{V_c \cdot \rho_{pm}}{V_r \cdot \rho_{st}} \cdot 100\% = \frac{\rho_{pm}}{\rho_{st}} \cdot 100\% \quad (2)
  \]

- sand ejection factor [2,5,9,10]:
  \[
  e_v = \frac{\Delta M}{m_0} = \frac{m_0 - m_1}{m_0} \cdot 100\% \quad (3)
  \]

where:
- \( M_r \) – core mass obtained under the given conditions of the blowing/shooting process; kg,
- \( M_{max} \) – maximal core mass (from the standard sand mix); kg,
- \( \rho_{pm} \) – average density of core sand compacted by shooting; kg/m³,
- \( V_c \) – core volume; m³,
- \( \rho_{pmax} \) – apparent density of the standard core sand compacted by vibrations until reaching the fixed value; kg/m³,
- \( M_{st} = V_c \cdot \rho_{st} \) – assumed core mass; kg/m³,
- \( \rho_{st} \) – apparent density of sand in a cylindrical sample after a treble compaction with a standard rammer; kg/m³,
- \( m_0 \) – the amount (mass) of sand admitted to the shooting tank of the test apparatus; g,
- \( m_1 \) – the amount (mass) of core sand remaining in the shooting tank of the test apparatus; g.

### 3. Experimental

#### 3.1. Core sand types

Tests aimed to verify the adequacy of the applied method were done on core sands used in warm air, warm box and cold box processes. Parameters of investigated core sands are summarised in Table 1.

The main criterion used when evaluating applicability of sand mix types to be used in shooting or blowing processes is the apparent density obtained when filling the intricately shaped model box under the specified shooting pressure and within the given process time (similar to the approach suggested by D.Boenisch).

#### 3.2. Experimental stand

Experiments were performed with the use of the test facility (Fig. 1a) designed to investigate the flow of the air-sand stream. Figure 1b shows the core box used in the testing, whose total volume was 135.5 cm³.

The first stage involved the initial testing aimed to establish the optimal shooting time (basing on the pressure levels registered in the shoot tank and in the core box), allowing a reliable comparison of core sand parameters. The results of the initial tests would yield the parameters of the blowing process to be recalled in subsequent stages of the experiment:
- shooting time 0.35, 0.5 s
- shooting pressure 0.4; 0.5; 0.6 MPa

![Fig. 1. Experimental stand complete with the apparatus for determining the effectiveness of sand ejection from the shooting tank: 1- shooting valve, 2- shooting tank, 3- tripod, 4- tester, 5- setting unit, 6- air tank, 7- shoot time control, 8- core box](image)
pressure. The plotted data reveal that the lowest values of apparent density of cores are registered for cores made of core sand containing water-glass (commonly used and hardened by CO\textsubscript{2} airing).

Cores made of the remaining sand types display a higher apparent density. It is worthwhile to mention that some core sands offer perform better that others under the low shooting pressures (CO and FU) whilst their performance tends to deteriorate once the values of this parameter are higher.

![Fig. 2. Apparent density of sand in the core box vs working pressure for investigated sand types (shooting time 0.35 s)](image)

![Fig. 3. Apparent density of sand in the core box vs working pressure for investigated sand types (shooting time 0.5 s)](image)

![Fig. 4. Box filling factor K\textsubscript{zr} vs the critical pressure for selected sand types (shooting time 0.35 s)](image)

![Fig. 5. Sand ejection factor e\textsubscript{v} vs the apparent density of core (shooting time 0.35 s)](image)

The remaining parameters of the blowing process are summarised in Table 2, including the box filling factor K\textsubscript{zr}, mass ejection factor e\textsubscript{v} and the outflow rate of the core sand M. These data enable us to formulate the ranking list of core sand types based on particular criteria: K\textsubscript{zr}, e\textsubscript{v} and M. When the values of the first two quantities become less than 100% (or 1.0), the potentials of the optimal process performance are reduced, therefore a new coefficient is defined, expressed as a product of K\textsubscript{zr} and e\textsubscript{v}, and computed accordingly for particular shooting pressures and the filling time 0.5 s. Thus calculated data are allocated the numbers showing their ranking position, as shown in Table 3.

**TABLE 2**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pressure MPa</th>
<th>Tested core sands</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.35</td>
<td>0.50</td>
</tr>
<tr>
<td>K\textsubscript{zr}, %</td>
<td>0.4</td>
<td>70.5</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>77.1</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>78.9</td>
</tr>
<tr>
<td>e\textsubscript{v}, %</td>
<td>0.4</td>
<td>42.3</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>46.3</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>47.3</td>
</tr>
</tbody>
</table>
Calculated values of the coefficient $K_{ze}$ (expressed as a decimal fraction) and the outflow rate of the sand $M$ in the investigated pressure range and for the fixed time of the shooting valve opening

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pressure MPa</th>
<th>Tested core sands</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CO</td>
</tr>
<tr>
<td>$K_{ze}e$</td>
<td>0.4</td>
<td>0.368 (1)</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.459 (1)</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>0.480 (1)</td>
</tr>
<tr>
<td>$M$, kg/s</td>
<td>0.4</td>
<td>0.329 (1)</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.368 (1)</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>0.376 (4)</td>
</tr>
<tr>
<td>Average value and rank place</td>
<td>1.83 (1)</td>
<td>2.66 (4)</td>
</tr>
</tbody>
</table>

Having determined the critical values to differentiate between the levels of sand suitability for the given blowing process, we can now proceed to arrange the sand types in the order defined by their usability. In the case considered here the categorization is suggested as shown in Table 4.

### Table 4

Suitability of the core sands for use in the given processes

<table>
<thead>
<tr>
<th>Average score</th>
<th>Suitability level</th>
<th>Sand type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0-1.99</td>
<td>Very good</td>
<td>CO (1.83)</td>
</tr>
<tr>
<td>2.0-2.99</td>
<td>Good</td>
<td>TH (2.33); IN (2.66)</td>
</tr>
<tr>
<td>3.00-3.99</td>
<td>Acceptable</td>
<td>FU (3.16)</td>
</tr>
<tr>
<td>In excess of 4.00</td>
<td>Unacceptable</td>
<td>WG (5.00)</td>
</tr>
</tbody>
</table>

5. Summing-up

Most methods employed now to establish the suitability of particular core sand for use in the blowing process should be regarded as approximate. They are mostly based on various techniques of determining the core sand flowability and do not reproduce the conditions of the blowing process.

The established criteria based on the box filling factor, the sand ejection factor and the outflow rate of the air-sand stream afford us a more reliable assessment. Their behavior can be evaluated during the flow and during the box-filling, which result in the quality and structure of sand compaction which in turns determines the core strength and permeability (after hardening).

Evaluation of sand properties basing on experimental testing reproducing the conditions of the blowing process in the laboratory scale is more reliable as it allows a direct comparison of various core sand types in the context of their suitability for use in the blowing processes.

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REFERENCES


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