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Influence of the Matrix Grain Size on the Apparent Density and Bending Strength of Sand Cores

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Abstract

The results of investigations of the influence of the matrix grain sizes on properties of cores made by the blowing method are presented in the hereby paper. Five kinds of matrices, differing in grain size compositions, determined by the laser diffraction method in the Analysette 22NanoTec device, were applied in investigations. Individual kinds of matrices were used for making core sands in the Cordis technology. From these sands the shaped elements, for determining the apparent density of compacted sands and their bending strength, were made by the blowing method. The shaped elements (cores) were made at shooting pressures being 3, 4 and 5 atn. The bending strength of samples were determined directly after their preparation and after the storing time of 1 hour.

Keywords: Moulding sand, Core sand, Blowing method, Inorganic binder, Bending strength

1. Introduction

Grain size analysis constitutes an essential source of knowledge concerning polydispersive materials, often applied in industry. In case of foundry engineering this knowledge concerns first of all casting materials, their treatments and preparations, thus: high-silica sand, spent moulding sands, reclaims and products originated from treatment processes of these materials (dusts).

Properties of foundry cores made of moulding sands, of a single usage, by means of the blowing method depend on several factors such as: amount and character of a binder, hardening ways, production method and its technological parameters (e.g. time and shooting pressure), matrix grain sizes and others [1-5]. In the hereby presented investigations the focus was mainly placed on the influence of matrix grains sizes of core sands, made in the Cordis technology, on bending strength R_g^u and on the apparent density of cores being in a form of typical samples, compacted by the blowing method, for testing this strength.

Knowledge of grain size distributions in polydispersive materials, such as moulding and core sands used in foundry engineering, is essential for the proper interpretation of the results of technological processes investigations influencing the quality of the moulding and core sands and - in consequence - the casting quality. Investigations of grain size distributions of moulding sands are presently performed by means of sieve analysis, in accordance with binding standards in various countries. These standards are not fully compatible and require conversions of results obtained from different sources. The grain size analysis of selected moulding sands was performed by means of the ANALYSETTE 22 NanoTec device, for measuring particle sizes in a solid phase and in suspension. In this apparatus, which is presently the modern solution, the consistent laser flux is used for determining the grain size distribution in solids, water suspensions, emulsions and aerosols. Results are highly reproducible and accurate (nearly 99%). The laser light scattering (laser diffraction) is at present the most efficient method for determining the grain size distribution within a wide measuring range. A valuable advantage of this type of devices, apart from a high measuring accuracy, is a fast measurement and its automatic course. The Analysette 22 NanoTec device, allows measuring the particle size within a range: 0.01µm - 2000 µm, in a dry mode and/or in a wet environment. The apparatus has two semiconductor lasers of class III, wave length 650 nm and laser power 7 mW. All elements of the optical system are placed on the vertical aluminium rail (Fig. 1). Heads of the device applied for measuring grain sizes of the material introduced in a suspension and for dry mode measurements are assembled on separate rail guides. This device due to the solution allowing measuring the scattered light from the end, allows to measure a wide measuring band „high end" and particle diameters already from 10 nm [6].

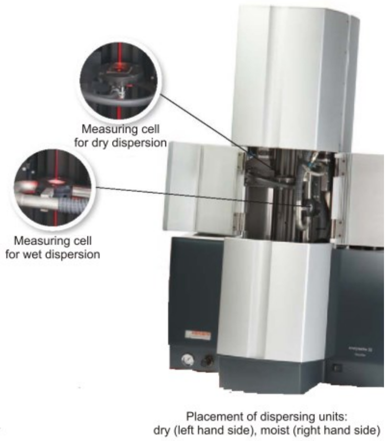

Fig. 1. General view of the Analysette 22 NanoTec device [6]

2. Materials applied in investigations

Investigations were performed for five types of quartz matrices of characteristic diameters dimensions and specific surfaces of grains, shown in Table 1.

Table 1.
Dimensions of characteristic diameters and specific surfaces of grains for the investigated matrices

Matrix type	d_a µm	d_g µm	d_r µm	S_t cm^2/g
O1	114.32	103.08	120.38	702.64
O2	135.36	120.08	143.55	584.52
O3	209.88	180.91	228.32	484.92
O4	234.75	208.18	240.93	415.09
O5	264.82	232.65	285.42	379.35

Where: d_a – arithmetical average diameter; d_g –geometrical average diameter; d_r - CIAT representative diameter; S_t – theoretical specific surface [1].

Distribution functions of grain sizes for the tested matrices (O1 - O5) obtained by using the Analysette 22 NanoTec device are shown in Figure 2, while the grain density distribution functions for the same matrices in Figure 3. It can be noticed, on the basis of analyses of results given in Table 1 and in Figures 2 and 3, that matrices significantly differing from each other were chosen for investigations. Matrices similar to O3 and O4 are the most often applied in the foundry practice. Matrices O1 and O2 can find applications for cores allowing to obtain high quality surfaces, while matrix O5 can be applied for producing cores of a high permeability. It should be noticed that results achieved in Analysette 22 NanoTec device corresponds to the results achieved from the typical sieve analysis [2].

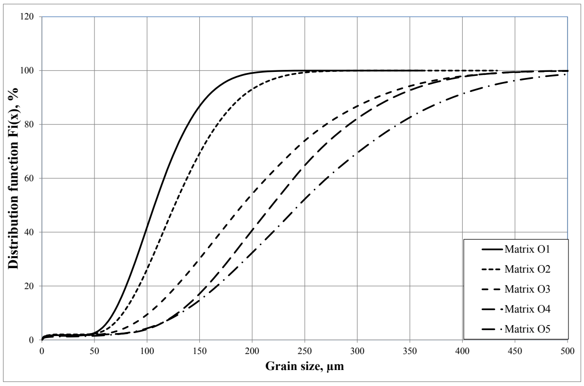

Fig. 2. Distribution function Fi(x) of grain sizes for matrices O1÷O5

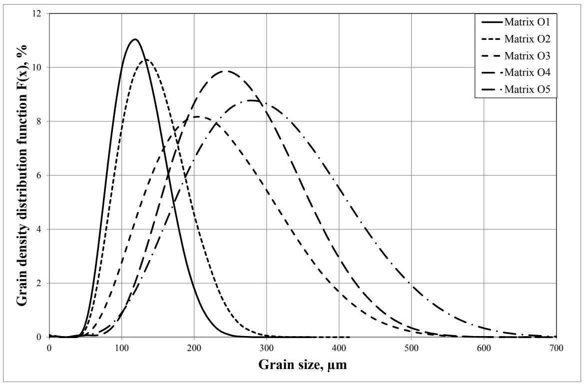

Fig. 3. Grain density distribution function F(x) for matrices O1÷O5

3. Experimental investigations

The scope of investigations consisted of the strength determination of samples heated in the core box. Moulding sand samples of dimensions: 22.2×22.2×180 mm was made by the blowing method by means of the LUT/c/CO2/An blower, intended for making shaped elements and small cores in the technologies: hot-box, cold-box, hardening by CO_2 and by hot air. The view of the measuring stand is given in Figure 4.

The following composition of core sands were applied:

– matrix (O1-O5) – 100 parts by mass,

– binder Cordis 8323– 2.2 parts by mass,
– addition Anorgit 8322 – 1.2 parts by mass.

Core sand was prepared in a room temperature in paddle mixer using following course of action: mixing of sand and binder (2 minutes) + Anorgit powder (2 minutes). Total mixing time – 4 minutes.

The binding system CORDIS was developed by the Hüttenes–Albertus Company. This binder is fully inorganic and water is the only solvent. The core sand containing CORDIS binder is shot into the core box heated to temperatures: 120 ÷ 160^{o}C. The hardening process can be significantly accelerated by additional blowing the core with hot air. In the presented study, additional blowing with the hot air was not applied.

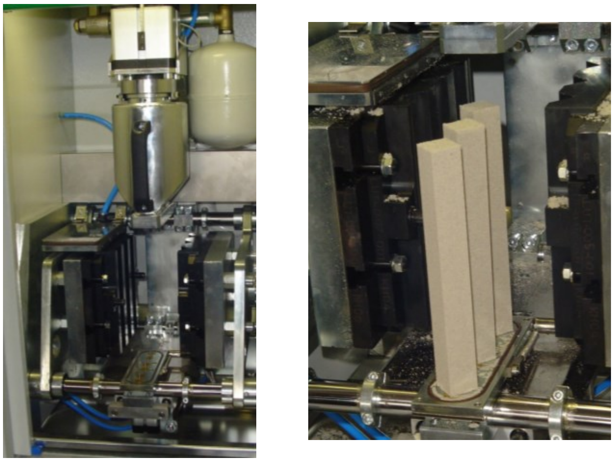

Fig. 4. View of the LUT/c/CO2/A blower stand and core samples

Te following shooting parameters were applied in the presented below investigations:
– shooting pressure: 3; 4; 5 atn.,
– shooting time: 0.9 sec,
– core box temperature: 150^{0}C,
– time of cores holding in the core box: 40 sec.

When the samples were made their apparent density, and bending strength R_g^u, were measured, directly after shooting and core hardening and after storing time of 1 hour.

4. Results and analysis of investigations

The bending strength results of cores prepared in the Cordis technology on matrices O1 - O5, described previously, are presented graphically in Figures 5-7. In the described below results the arithmetic average values calculated from five samples are presented.

It can be noticed, on the basis of the performed investigations, that geometrical characteristic of the matrix as well as the shooting pressures have an essential influence on the cores bending strength value. The highest influence of the matrix grain size on the bending strength can be observed in case of cores made at the shooting pressure equal 3 atn. The lowest bending strength were obtained for cores made on the finest O1 matrix. Along with the grain size increasing the bending strength increases and then maintains at a nearly constant level. In case of cores made at the shooting pressure being 4 and 5 atmospheres the tendency described previously is less intensive.

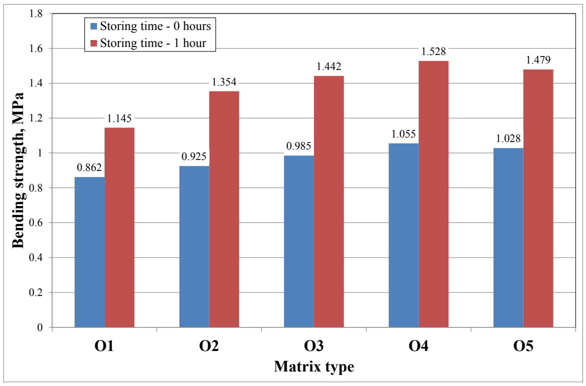

Fig. 5. Bending strength of cores prepared on O1- O5 matrices. Shooting pressure 3 atn.

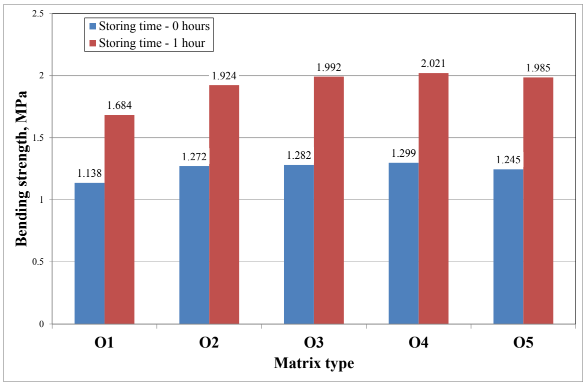

Fig. 6. Bending strength of cores prepared on O1- O5 matrices. Shooting pressure 4 atn.

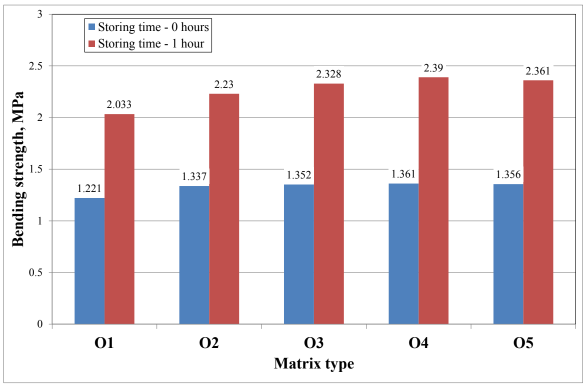

Fig. 7. Bending strength of cores prepared on O1- O5 matrices. Shooting pressure 5 atn.

The compilation concerning the percentage change of the bending strength of cores made on O1- O5 matrices, at various shooting pressures, in relation to the strength of the cores made on the O1 matrix, is shown in Figure 8.

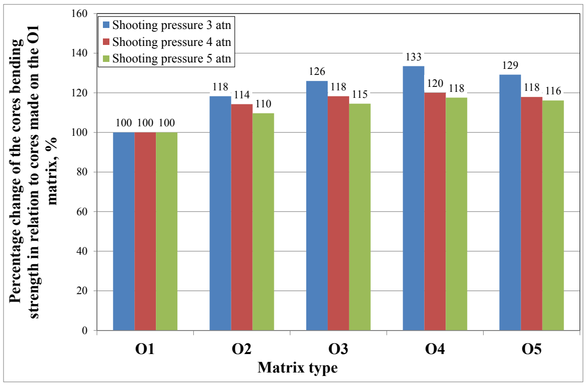

Fig. 8. Percentage change of the cores bending strength in relation to cores made on the O1 matrix

The compilation shown in Figure 8 confirms the previous observations, that the largest strength differences were obtained for the core sand prepared on the O1 matrix at the shooting pressure being 3 atn.

A certain explanation of this effect constitutes results presented in Figure 9, in which the influence of the matrix grain size and the shooting pressure on the average compaction of cores made by the blowing method, can be seen. In each case of cores prepared on the O1 matrix the lowest compaction value was obtained. Considering a small theoretical thickness "g" of the binding material coating on the matrix, being the result of its smallest diameter [7], determined on the basis of equation (1), (given in Table 2), the obtained results can be considered as likelihood ones.

$$g = d_a \cdot \sqrt[3]{(1 + L\frac{\rho_z}{\rho_g}} - d_Z = d_a \cdot \left(\sqrt[3]{(1 + L\frac{\rho_z}{\rho_g}} - 1\right) \quad (1)$$

where:
ρ_g - density of the spent binder coating; kg/m^3,
ρ_z - density of the sand matrix material; kg/m^3,
d_a – arithmetic diameter of matrix grains; m,
L – mass fraction of the binder in relation to the matrix (decimal fraction).

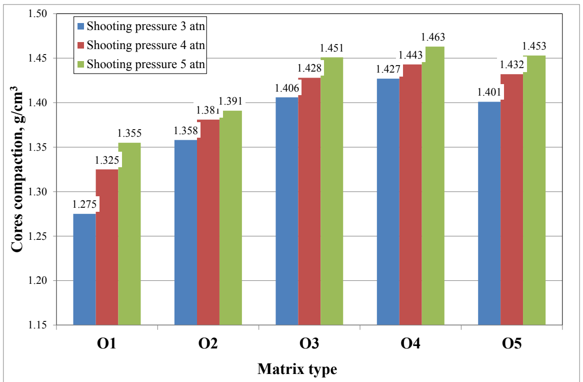

Fig. 9. Influence of the matrix grain size and the shooting pressure on cores compaction

Table 2.
Theoretical thickness g of binding material on grains of matrices: O1-O5

	O1	O2	O3	O4	O5
Thickness g, mm	0.0175	0.0208	0.0322	0.0361	0.0407

5. Summary

The final conclusions drawn on the basis of the performed investigations are given below.

1. The grain size of the matrix influences the strength of cores made by the blowing method. The lowest bending strength values were obtained for cores made on the O1 matrix, characterized by the smallest geometrical dimensions of grains and the largest theoretical specific surface.
2. When the grain sizes of matrices are larger, similar to the ones applied in practice, the grain size does not have so significant influence on the bending strength.
3. The grain size of the matrix has an influence on the compactness of cores made by the blowing method. The lowest compactness is obtained when fine-grained material, of grain sizes being in the lower range of grains acceptable for technology, is applied for matrices.

Acknowledgements

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