ARCHIVES
of
FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 15
Special Issue
2/2015

13 – 16

3/2

Assessment of Core Sands Properties in Blowing Process

R. Dańko
AGH - University of Science and Technology, Faculty of Foundry Engineering, Reymonta 23 str., 30-059 Kraków, Poland
Corresponding author. E-mail address: rd@agh.edu.pl

Received 31.03.2015; accepted in revised form 01.06.2015

Abstract

The effects of filling the core box cavity and sand compaction in processes of core production by blowing methods (blowing, shooting) depend on several main factors. The most important are: geometrical parameters of cavity and complexity of its shape, number, distribution and shape of blowing holes feeding sands as well as the venting of a technological cavity. Values of individual parameters are selected according to various criteria, but mostly they should be adjusted to properties of the applied core sand.
Various methods developed by several researchers, including the authors own attempts, allow to assess core sands properties 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 are analysed – on the basis of authors' own examinations - in the hereby paper.

Keywords: Foundry, Core, Blowing process, Core sand

1. Introduction

The analysis of parameters of a sand-air stream during core production, by means of blowing methods, which aerodynamic properties are determined by a solid phase fraction in an air stream is difficult, since there is either the necessity of parallel measurements of flow intensities of both phases or using dynamic stream properties determined by [1]:

– solid phase outflow intensity,
– dynamic force value of a two-phase stream.

As it was shown in papers [2-3], for the practical needs, it can be assumed that the mentioned quantities influence the core sand compaction and its structure in the core-box as well as the real time of filling the mould cavity. Quantities, which are here called the auxiliary ones and which represent other parameters of the stream of the air-solid phase mixture, analysed as a pneumatic transport are:

– density of the two-phase stream or quantities directly related to density (concentration or a solid phase volume or mass fraction, porosity),
– averaged speed of both phases of the sand-air stream,
– solid phase rubbing speed and mutual speed ratio of a solid and gas phase in the stream outflowing from the blowing chamber to the core-box.

To determine quality of a core compaction performed by blowing and shooting method, Boenisch and Knauf [4] 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 [2]:

– 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:

$$FG = \frac{M_r}{M_{max}}100\% = \frac{V_c \cdot \rho_{pm}}{V_c \cdot \rho_{pmax}}100\% = \frac{\rho_{pm}}{\rho_{pmax}}100\% \quad (1)$$

where:
FG – filling ratio, %
M_r – core sand mass obtained at the given conditions, kg,
M_{max} – maximum core sand mass (standard), kg,
ρ_{pm} – average density of core sand compacted by shooting, kg/m^3,
V_c – core volume, m^3,
ρ_{pmax} – apparent density of the standard core sand compacted by vibration, kg/m^3.

The Author's way of assessment of compaction quality is based on the analysis of the filling ability factor of sand K_{zr}, expressed by Equation:

$$K_{zr} = \frac{M_r}{M_{st}}100\% = \frac{V_c}{V_c} \cdot \frac{\rho_{pm}}{\rho_{st}}100\% = \frac{\rho_{pm}}{\rho_{st}}100\% \quad (2)$$

where:
$M_{st} = V_c \cdot \rho_{st}$ – apparent core sand weight, kg/m^3,
ρ_{st} – apparent density of a core sand obtained in a cylindrical sample after ramming performed three times by the standard rammer, kg/m^3.

The question, concerning the relation between Equation (1) developed by Boenisch and Knauf and Equation (2) presented in publications of the authors of the hereby paper, arises.

Comparison of Equations (1) and (2) in consideration of ρ_{pm} brings the following:

$$K_{zr} \cdot \rho_{st} = FG \cdot \rho_{pmaks} \quad (3)$$

and

$$K_{zr} = FG \cdot \frac{\rho_{pmaks}}{\rho_{st}}; \quad FG = K_{zr} \cdot \frac{\rho_{st}}{\rho_{pmaks}} \quad (4)$$

2. Testing stand and examination methods

Examinations of shooting core sands – of a composition given in Table 1 – were carried on according to the method presented in papers [2-3].
Experimental core shooting machines of charge chambers capacity of 3-5 dm^3 and perpendicular or cylindrical core boxes of a capacity of 0.8 –1.5 dm^3 were used. Shooting machines were equipped with an automatic control of a shooting time and a pressure recording device both in a shooting chamber and in a core box. Experiments shown below encompass an operational pressure range pr = 0.4–0.7 MPa and diameters of shooting nozzles d1=15–25 mm. Measurements of the apparent average density and/or the density in the selected region of the core were performed for the given shooting parameters. Permeability was determined according to the Polish Standard - 80/H-11072 on cylindrical samples of ϕ50 x 50 mm compacted in a standard way or shot into a cylindrical sleeve of the same internal dimensions.

Table 1.
Composition and properties of sands used in authors' own examinations

Sand composition - in parts by weight					
		Ol	SW	B	Ż
Silica sand		100	100	100	100
Linseedoil varnish		2.0	-	-	-
Sodium water-glass M=2.5		-	5.0	-	-
Bentonite		-	-	6.5	-
Clay		-	3.0	-	-
Water		1.0	1.0	2.0	-
Resin U404U		-	-	-	1.2
Hardener 100T3		-	-	-	0.6
Sand properties					
Compression strength of fresh sand R_c	[N/cm^2]	0.45	0.9	6.5	0.7
Permeability	[cm^4/ G min]	150	188	170	165
Free floability P_s	[g]	35.4	28.3	12.5	37.0
Bulk density ρ_{us}	[kg/m^3]	1250	1050	900	1200
Standard density ρ_{st}	[kg/m^3]	1720	1685	1590	1710

3. The obtained results

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 to illustrate the core box filling ability factor Kzr for three sands used in own examinations, marked by symbols Ol, SW and B.

Performed investigations exhibit the fact that, regardless of the sand core kind, there is a continuation of the obtained dependences of a porosity (linear dependence), as well as permeability (exponential dependence), which justifies their mutual presentation in the form of a synthetic graph in Figure 3. It should be emphasised, that examinations of an apparent density, permeability and porosity were determined on core sand samples of normalised dimensions compacted by shooting of the given sand into a sleeve of ϕ50 x 50 mm at various pressures and diameters of the shooting hole.

Unevenness of compacting occurs for each kind of core sands, and depends both on the shooting pressure and the shooting hole diameter (see Figure 4). The most unfavourable distribution of sand compaction – from the point of view of its permeability - takes place in long, horizontal cores shot by a single hole (Fig. 4a). The smallest sand permeability occurs there at the prolongation of the shooting hole axis. Substituting one outlet by two or more holes in the shooting head (Fig 4b) allows to decrease the compaction unevenness, creating a zone of a relatively better permeability in the core central part.

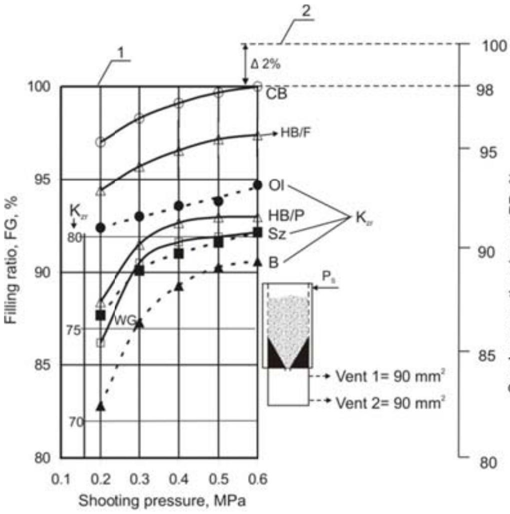

Fig. 1 Influence of pressure on the filling ratio FG for various core sands according to Boenisch and Knauf [3] (continuous lines) and authors' own results (broken lines [2]). Marking: CB–cold-box sand, HB/F – hot-box sand - furan resin, HB/P – hot-box sand - phenol resin, Ol, SW, B - sands like in Table 1

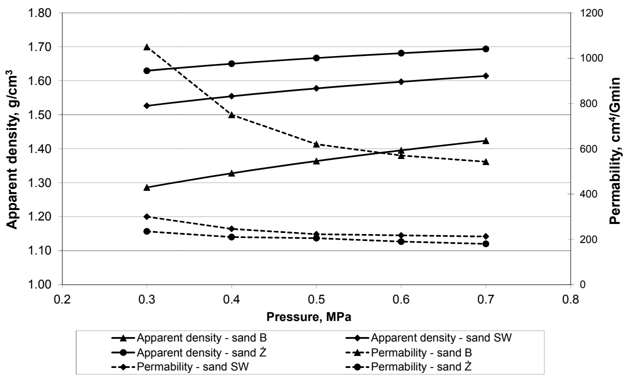

Fig. 2 Dependence of the average apparent density and permeability on the shooting pressure for various kinds of sands

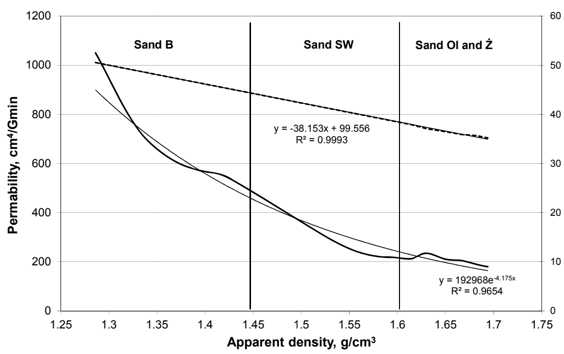

Fig. 3 Interpolation of data illustrating the influence of the sand apparent density on its permeability and porosity, for the examined sands

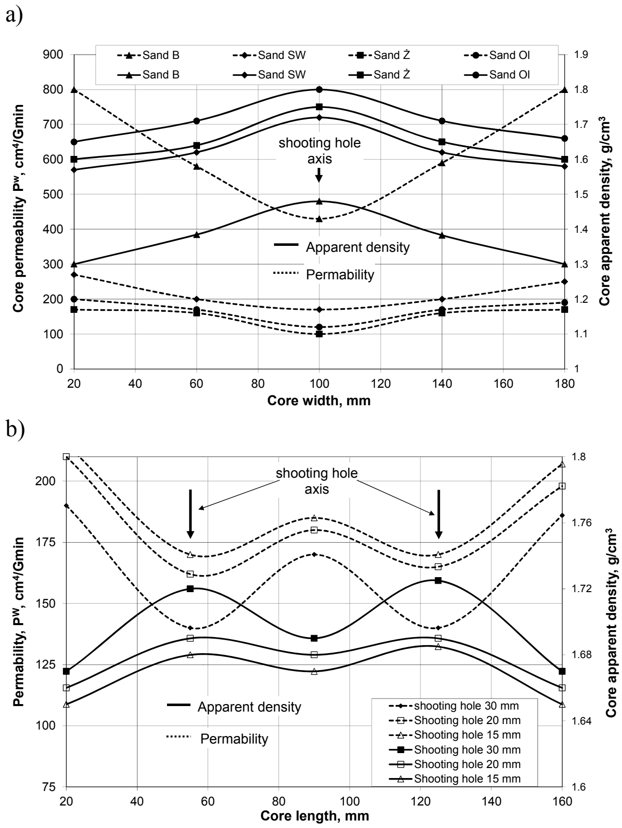

Fig. 4 Distribution of the apparent density and permeability along the length of the core made by sand shooting at a pressure of 0.65 MPa: a) by a single shooting hole of 15 mm, sands: Ol, B, SW, Ż, b) by using two shooting holes of diameters 15, 20, 30 mm-sand „Ol"

4. Visualisation of filling the core-box

Analogue filming of fast-changing processes by speed optic cameras is still an important way of performing documentation. In own investigations [2], the process filming by the camera of a 3000 frames for second was applied. In order to be able to film the front wall of the core-box was made from transparent methyl polymethacrylate, while the background of the black and white mosaic was applied on the back wall. For the analysis of the core-box filling the sand of contrasting colours was used (in this case: black and white). The sand was loaded alternately by layers of equal volume in the shooting chamber. The following process and equipment parameters were applied:

- shooting pressure: 0.6 MPa,
- shooting hole diameter: – 15 mm,
- time of the shooting valve opening: 1.0 s.
- experimental core-box: 140x85x48 mm,
- core sand with linseed oil varnish.

Analysing the results from the numerical simulations it seems that the 'simulated' pathways are characterised by too high flowability similar to liquid. As the result a part of the core, being near the shooting hole is being filled as the last one and its compaction – on the bases of calculations – does not show diversification in relation to the remaining part. Under real conditions in the vicinity of the shooting hole the highest compaction of cores is obtained. The reason of such situation can result from the lack of introducing into the calculating program the data characterising the core sand properties and motion parameters of the core sand [5-7].

a)

b)

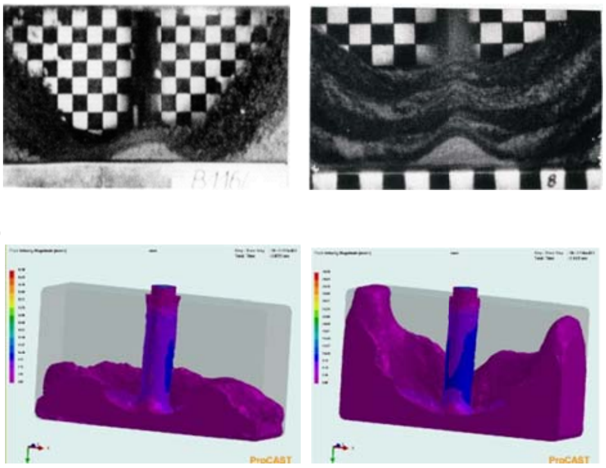

Fig. 5 Experimental core-box filling with the core sand, a) Recorded by the speed camera, b) Results calculated by means of the ProCast software. Time for both cases: 0.065 sec. (left side); 0.140 sec. (right side)

5. Summary

It has been shown that regardless of the kind of sands and parameter values at which the given value of the apparent density was obtained there is a continuation of the time-history of porosity (linear dependence) as well as permeability (power dependence) on the obtained apparent density.

The results of the performed investigations indicate that the formulation of the problem is very important in the simulation calculations. Such formulation, regardless of the shooting process and equipment parameters (shooting pressure and a rate of its growing in the cold-box, shooting hole diameter, venting area), should accurately take into account also factors characterising physical and mechanical properties of the core sand related to the applied binder and the core geometry. For the assumed parameters of the shooting process, being of the forcing character, the core-box filling and sand motion within this box depends, to a high degree, on the binder rheological properties. The core sands applied in the model investigations differed significantly in respect of the mentioned properties and therefore their different behaviour during the core-box filling was observed.

Acknowledgements

The study was performed within the ‘AGH Project No.11.11.170.318, task. 2

References

[1] Aksjonow, P.N. (1965). *Selected problems of theory of foundry machines*. Katowice: „Śląsk” Publishing House.

[2] Dańko, J., Zych & J., Dańko, R. (2009). Diagnostic methods of technological properties and casting cores quality. *Archives of Metallurgy and Materials.* 54(2), 381-392.

[3] Dańko, J. (1992). *Process of manufacturing of foundry cores and moulds by means of blowing methods. Investigations and theory.* Kraków: AGH Scientific Letters Metallurgy and Foundry no.145.

[4] Boenisch, D. & Knauf, M. (1991). Kernschiessen-untersuchungen mit neuartigen prufkorpern und verschiessen kernbindern. *Giesserei.* 18, 640-646.

[5] Reek, R. (2005). Optimierung des füll-und hartungsvorgangs von Giessereisandkernen durch 3-D Simulation der strömungsvorgänge. *Giessereiforschung.* 57(3), 2-14.

[6] Walker, M., Palczenski, S., Snider D. & Williams K. (2002). Modeling Sand Core Blowing: Simulation’s Next Challenge. *Modern Casting. April*, 41-43.

[7] Winartomo, B., Vroomen, U., Buhrig-Polaczek, A. & Pelzer M. (2006). Multiphase modelling od core shooting process. *International Journal of Cast Metals Research.* 18(1), 13-20.