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

BADANIA PARAMETRÓW WPŁYWAJĄCYCH NA WYPŁYW DWUFAZOWEGO STRUMIENIA PIASKOWO-POWIETRZNEGO Z KOMORY NABOJOWEJ I WYPEŁNIENIE RDZENNICZY W PROCESIE DMUCHOWYM

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

W publikacji przedstawiono zagadnienia związane z wypływem strumienia piaskowo-powietrznego z komory naboջowej i zapełnianiem rdzennicy metodami dmuchowymi z wykorzystaniem strzelarek i nadmuchiwarek. Tendencja do konstrukcji odlewów o coraz cieńszych ściankach i skomplikowanych kanałach, sprawia, że produkcja wysokiej jakości rdzeni jest nadal czynnikiem determinującym jakość oraz wydajność produkcji odlewów. Ważnymi właściwościami ogółu mas rdzeniowych stosowanych w procesach dmuchowych jest ewakuacja masy z komory naboջowej maszyny dmuchowej oraz zdolność do zapełniania i zagęszczania masy w rdzennicy. Właściwości te, decydują często o możliwości wykonania skomplikowanych rdzeni oraz o efektywności procesu technologicznego. Przedstawione badania dotyczą ustalenia kryteriów oceny ewakuacji masy z komory naboջowej oraz zdolność do wypełniania rdzennicy i zagęszczania kilku nowoczesnych mas formierskich, zarówno organicznych jak i nieorganicznych, pochodzących technologii hot box, warm box, warm air.

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.

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TABLE 1

Investigated sand types

Name	Composition	Designation	1,55 kg/m ³
Core sand CORDIS (warm air)	Binder- 2.2 parts by weight Powder 1.2 parts by weight	CO	1,56 kg/m ³
Core sand INOTEC (warm air)	Binder- 2.2 parts by weight Powder 1.2 parts by weight	IN	1,51 kg/m ³
Core sand FURESAN (warm box)	Binder- 2.2 parts by weight Powder 1.2 parts by weight	FU	1,52 kg/m ³
Core sand THERMSET (warm box)	Binder Thermset – 2 parts by weight Hardener Harter 0.3 parts by weight	TH	1,45 kg/m ³

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]:

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

- box filling factor [2,5,9,10]:

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

- 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_{maks} – maximal core mass (from the standard sand mix); kg,

ρ_{pm} – average density of core sand compacted by shooting; kg/m³,

V_c – core volume; m³,

ρ_{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,

ρ_{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 of 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

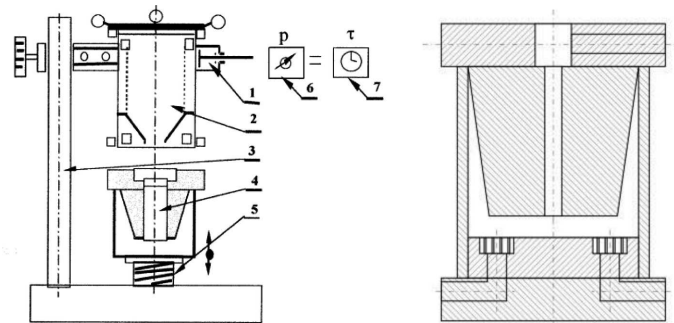


Fig. 1. Experimental stand complete with the apparatus for determining the effectiveness of sand ejection from the shooting tank: 1- shooting valve, 2- shooting tank, 3- tripod, 4- tester, 5- setting unit, 6- air tank, 7- shoot time control, 8- core box

4. Results

Experiments were performed to find out whether the performance of the box filling process and sand compaction by the blowing methods can be reliably evaluated by finding the amount of sand ejection caused by a single air pressure impulse in the blowing or shooting machine.

Thus obtained apparent densities of investigated core sands in the function of pressure are shown in Figure 2 and 3 (for the shooting time 0.35 s and 0.5 s). Fig. 4 shows the relationship between the box filling factor and the shooting

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 CO₂ 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 than others under the low shooting pressures (CO and FU) whilst their performance tends to deteriorate once the values of this parameter are higher.

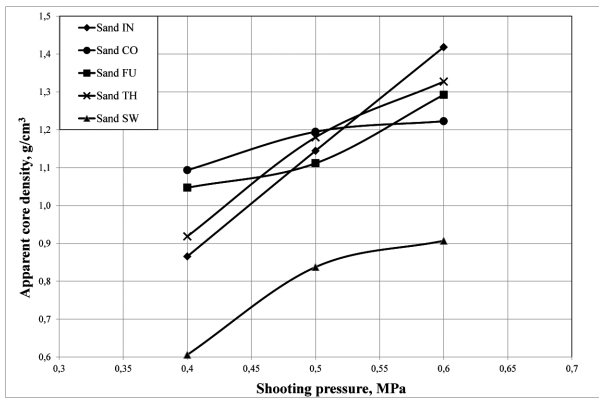


Fig. 2. Apparent density of sand in the core box vs working pressure for investigated sand types (shooting time 0.35 s)

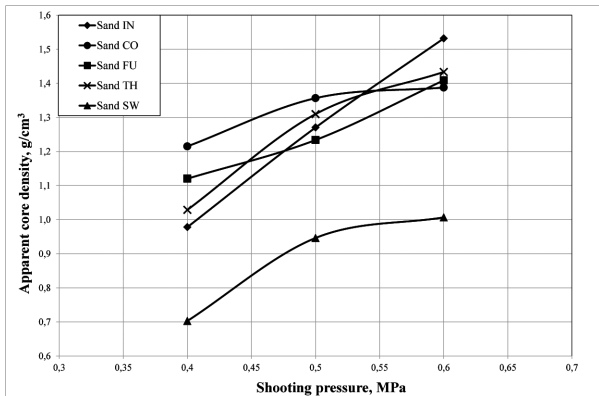


Fig. 3. Apparent density of sand in the core box vs working pressure for investigated sand types (shooting time 0.5 s)

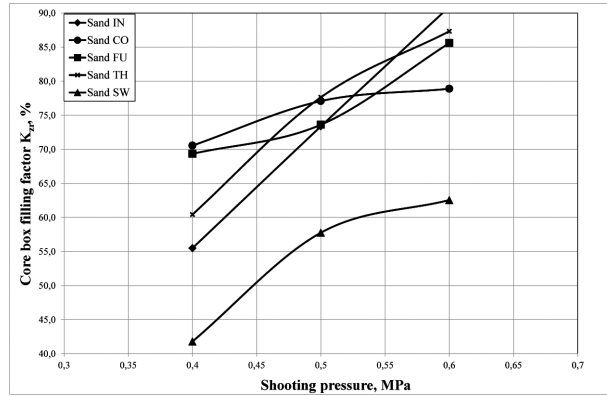


Fig. 4. Box filling factor K_{zr} vs the critical pressure for selected sand types (shooting time 0.35 s)

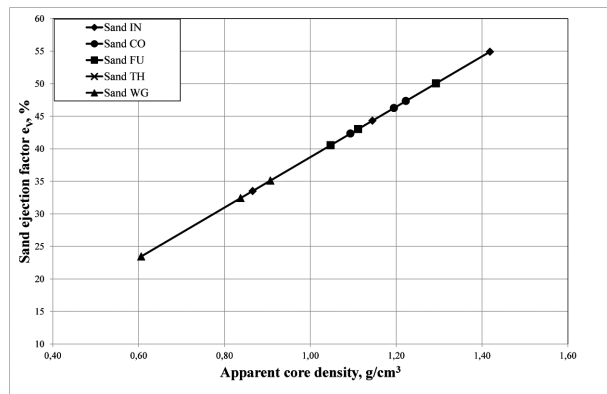


Fig. 5. Sand ejection factor e_v vs the apparent density of core (shooting time 0.35 s)

The remaining parameters of the blowing process are summarised in Table 2, including the box filling factor K_{zr} , mass ejection factor e_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_{zr} , e_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_{zr} and e_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

Experimental values of K_{zr} , e_v for various shooting pressures and opening times of the shooting valve

Parameter	Pressure MPa	Tested core sands									
		CO		IN		FU		TH		WG	
		Shooting time, s									
		0,35	0,50	0,35	0,50	0,35	0,50	0,35	0,50	0,35	0,50
$K_{zr}, \%$	0,4	70,5	78,4	55,5	62,7	69,3	74,2	60,4	67,7	41,8	48,5
	0,5	77,1	87,5	73,4	81,4	73,6	81,7	77,6	86,2	57,8	65,3
	0,6	78,9	89,5	90,9	98,2	85,6	86,0	87,3	94,3	62,5	69,4
$e_v, \%$	0,4	42,3	47,0	33,5	37,9	40,5	43,4	35,6	39,8	23,5	27,2
	0,5	46,3	52,5	44,3	49,2	43,0	47,8	45,7	50,7	32,4	36,6
	0,6	47,3	53,7	54,9	59,3	50,0	54,5	51,4	55,5	35,1	39,0

TABLE 3

Calculated values of the coefficient $K_{zr} \cdot e_v$ (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

Parameter	Pressure MPa	Tested core sands				
		CO	IN	FU	TH	WG
		Shooting time, 0,5 s				
$K_{zr} \cdot e_v$	0,4	0,368 (1)	0,238 (4)	0,322 (2)	0,269 (3)	0,132 (5)
	0,5	0,459 (1)	0,400 (3)	0,390 (4)	0,437 (2)	0,239 (5)
	0,6	0,480 (3)	0,582 (1)	0,469 (4)	0,523 (2)	0,270 (5)
M, kg/s	0,4	0,329 (1)	0,265 (4)	0,304 (2)	0,279 (3)	0,190 (5)
	0,5	0,368 (1)	0,344 (3)	0,334 (4)	0,355 (2)	0,256 (5)
	0,6	0,376 (4)	0,415 (1)	0,382 (3)	0,388 (2)	0,273 (5)
Average value and rank place		1,83 (1)	2,66 (4)	3,16 (4)	2,33 (2)	5,00 (5)

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

Average score	Suitability level	Sand type
1,0-1,99	Very good	CO (1,83)
2,0-2,99	Good	TH (2,33);IN (2,66)
3,00- 3,99	Acceptable	FU (3,16)
In excess of 4,00	Unacceptable	WG (5,00)

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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