

ARCHIVES  
of  
FOUNDRY ENGINEERING



DOI: 10.2478/v10266-012-0102-1

 ISSN (2299-2944)  
 Volume 12  
 Issue 4/2012

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

25 – 30

# Parameters of the Two-Phase Sand-Air Stream in the Blowing Process

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Received: 09.07.2012; accepted in revised form: 03.09.2012

## Abstract

Theoretical problems concerning the determination of work parameters of the two-phase sand-air stream in the cores making process by blowing methods as well as experimental methods of determination of the main and auxiliary parameters of this process decisive on the cores quality assessed by the value and distribution of their apparent density are presented in the paper. In addition the results of visualisations of the core-box filling with the sand-air stream, from the blowing chamber, obtained by the process filming by means of the quick-action camera are presented in the paper and compared with the results of simulation calculations with the application of the ProCast software.

**Keywords:** Foundry cores, Blowing and shooting processes, Experimental investigations, Simulation calculations

## 1. Main and auxiliary quantities of the blowing process – parameters of the two-phase stream: air – solid phase

The analysis of parameters of a sand-air stream, 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:

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

As it was shown in papers [3-6], for the practical needs, it can be assumed that the mentioned quantities influence the moulding 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.

As a measure of a dynamic influence of the two-phase stream: air – solid phase on the measuring element placed on its path, the force value - in the axis of this force perpendicular to its vector – was assumed:

$$P_D = \rho_{str} \cdot c_m^2 \cdot f_1 \quad f_1 = 0,25 \cdot \pi \cdot D_1^2 \quad (1)$$

where:  $P_D$  – dynamic force; N,  
 $c_m$  – real stream speed in a steady motion; m/s,  
 $\rho_{str}$  – density of a two-phase stream; kg/m<sup>3</sup>,  
 $f_1$  – blowing nozzle cross-section area; m<sup>2</sup>,  
 $D_1$  – nozzle diameter in a blowing hole; m.

The sand-air stream outflow intensity, expressed in kg/s, is equal:

$$\dot{M} = \frac{\Delta m}{\Delta \tau} \quad (2)$$

where:  $\Delta m$  – amount of material dosed in one work cycle; kg,  
 $\Delta \tau$  – real time of material dosing; s.

Quantities concerning a two-phase stream can be considered either as the average values of the whole blowing process cycle (blowing, shooting), or as instantaneous values. Equations expressing the stream volumetric concentration (ratio of the solid phase (sand) amount,  $m^3$  to the gaseous phase (air) amount,  $m^3$  – are in a form:

$$\mu_v = \frac{\rho_{str} - \rho_p}{\rho_m - \rho_{str}}; \quad \mu_{v(\tau)} = \frac{\rho_{str(\tau)} - \rho_p}{\rho_m - \rho_{str(\tau)}} \quad (3)$$

Similarly, density of the two-phase stream expressed in  $kg/m^3$ , can be also presented either as the averaged or instantaneous value:

$$\rho_{str} = \frac{\dot{M}}{f_1 \cdot P_D}; \quad \rho_{str(\tau)} = \frac{\dot{M}(\tau)}{f_1 \cdot P_D} \quad (4)$$

It was assumed in these equations that the stream speed (m/s) is expressed by formulas:

$$c_m = \frac{P_D}{\dot{M}_{sr}} \quad \text{lub} \quad c_{m(\tau)} = \frac{P_{D(\tau)}}{\dot{M}(\tau)} \quad (5)$$

## 2. Experimental part

The performed investigations were aimed at the determination of the shooting pressure influence and the shooting hole diameter on values of the main and auxiliary parameters of the blowing process and the core sand compaction distribution in the core.

In addition, to visualise the filling of the experimental core-box with the core sand, the process was filmed by means of the quick-shot camera and the simulation calculations were performed using the ProCast software.

The sand with linseed oil of the following composition was used (mass%):

- sand 1K 0.20/0.16/0.32 J89-W<sub>K</sub>1.26->1400<sup>0</sup>C 97%,
- linseed oil varnish 2%,
- water 1%.

The core sand was prepared in the ribbon mixer. Mixing time was 5 minutes.

### 2.1. Research program and the experimental stand

The schematic presentation of the program and scope of the performed investigations, taking into account the applied values of the blowing machine work pressure ( $p$ ) and the shooting hole diameter ( $d$ ) is shown in Figure 1.

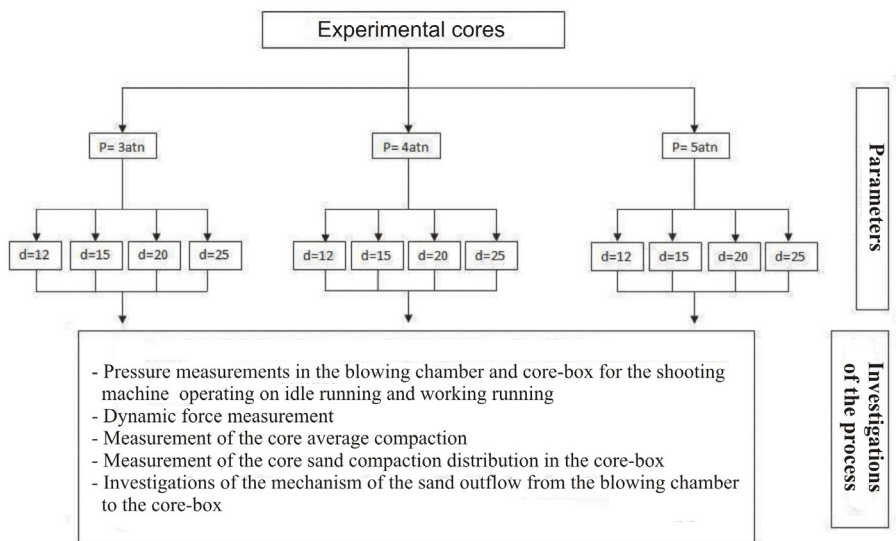


Fig. 1. Schematic presentation of the program and scope of the performed investigations

The research stand (Fig. 2) consisted of the experimental shooting machine of a blowing chamber volume equal  $3dm^3$  with the Hansberg type shooting valve. The shooting sleeve was in a form of a perforated insert in order to uniform the air distribution in the sand. Pressure in the blowing chamber and core-box was measured by means of piezoelectric sensors. The hydraulic –

pressure converter, introduced into the shooting machine measuring system, was used for measuring the force value. The measuring signals after their amplification and passing the analogue-to-digital converter were recorded in the PC computer. Shootings as well as times were controlled by the program.

In investigations of the average and local apparent density of sands the rectangular core-box RD-I of a cavity dimensions: 200x85x48 mm was used. The core-box capacity equals 0.816 dm<sup>3</sup>, and its slenderness is 0.425.

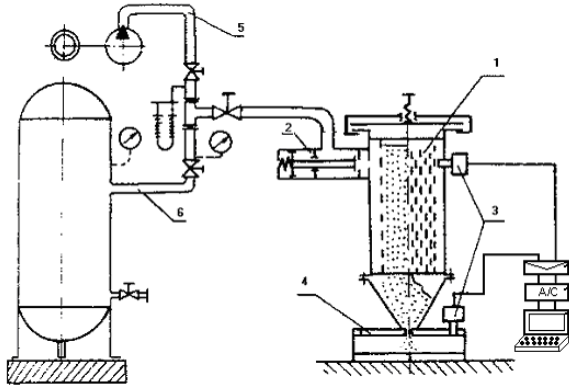


Fig. 2. Schematic presentation of the research stand of the shooting machine SR-3D, 1- Blowing chamber, 2 – Outlet with exchangeable nozzles, 3 – Pressure converter, 4 – Servo-motor, 5 – Low pressure installation, 6 – Network pressure installation, 7 – Amplifier, 8 – Analogue-to-digital converter, 9 – Computer

### 3. Experimental results

#### 3.1. Parameters of the two-phase stream

Data given in Figures 3-7 indicate an essential influence of the shooting pressure on the investigated properties of the two-phase stream. Both main process parameters: dynamic force value  $P_d$ , with which the sand-air stream presses against the core sand being in front of the shooting hole (Fig. 3) and the mass outflow intensity  $M$  (Fig. 4) increase as the shooting pressure and shooting hole diameter increases.

Auxiliary parameters characterising the stream density  $\rho_{str}$  (Fig. 5) and volumetric concentration  $\mu_{str}$  (Fig. 7) are decreasing, while the stream speed  $c_m$  (Fig. 6) increases with the shooting pressure increase.

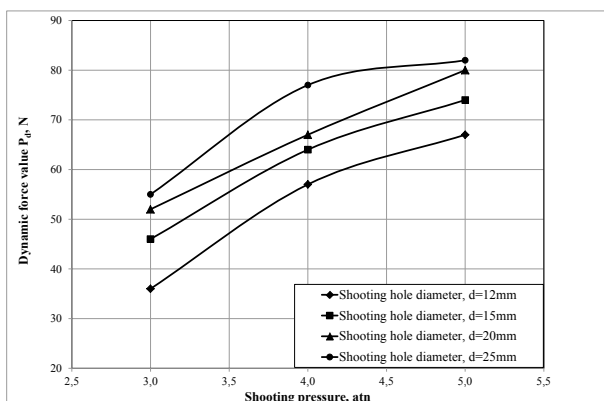


Fig. 3. Dynamic force value,  $P_d$ , as a function of the shooting pressure and the shooting hole diameter value

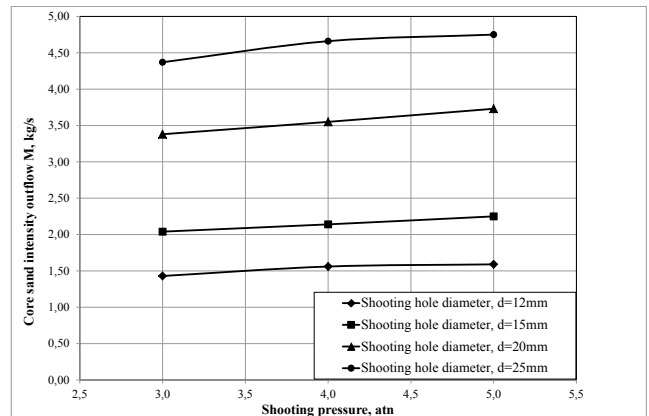


Fig. 4. Core sand intensity outflow,  $M$ , into the core-box as a function of the shooting pressure and the shooting hole diameter value

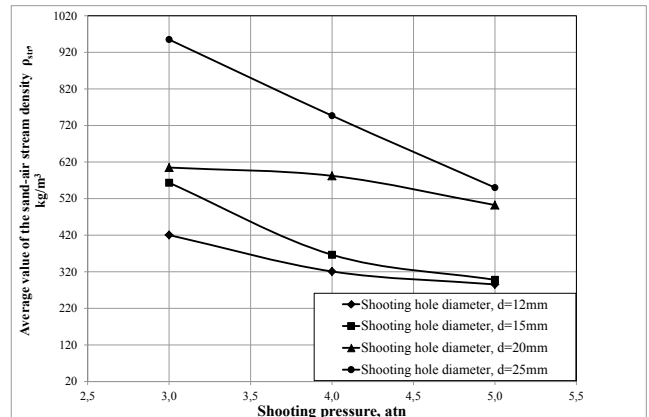


Fig. 5. Average value of the sand-air stream density,  $\rho_{str}$ , as a function of the shooting pressure and the shooting hole diameter value

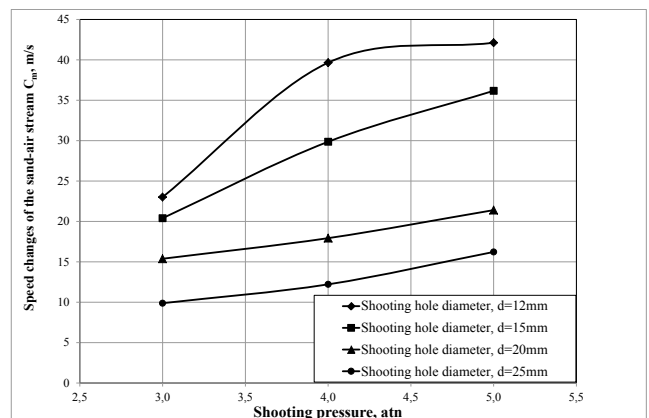


Fig. 6. Speed changes of the sand-air stream,  $c_m$ , as a function of the working pressure and the shooting hole diameter value

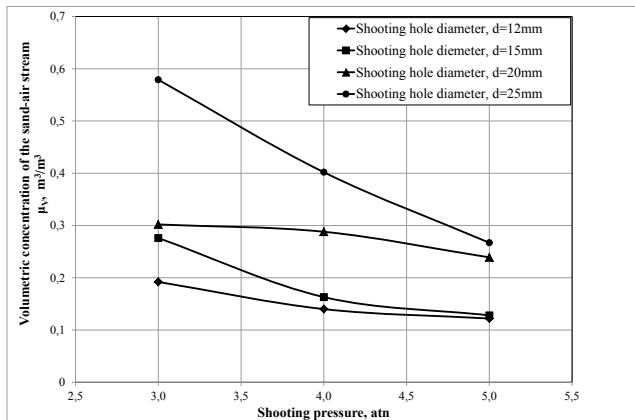


Fig. 7. Volumetric concentration of the sand-air stream,  $\mu_{str}$ , as a function of the shooting pressure and the shooting hole diameter value

### 3.2. Distribution of the core sand compactness in the core-box

In the process of sands compacting by blowing methods the characteristic increase of the sand apparent density is seen at the prolongation of the shooting hole axis as compared with zones in which the sand-air stream is not directly acting on sand layers. Such compactness distribution decreases the ability of the middle core zones to remove gases after the mould was poured with liquid metal. It is also not good for sands, which hardening is done by blowing the gaseous hardening agents through the core or through the mould.

Compactness unevenness is also often a reason of deteriorations and deformations of not fully hardened cores.

Samples were taken from the core-box by means of a probe in places shown in Figure 8. Samples weighted on the electronic scale allowed to determine the distribution of the core sand compactness in the core-box. The example, for the shooting hole  $d = 12$  mm, is presented in Figure 9.

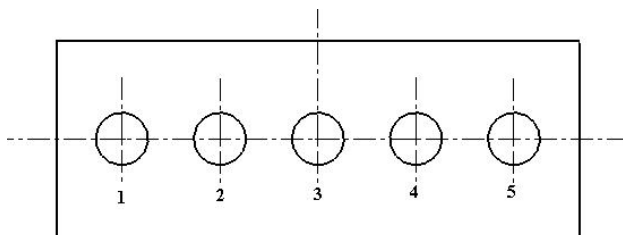


Fig. 8. Schematic presentation of the core sand sampling by means of the probe. Horizontal system core-box R-III, sample 3 in the shooting hole axis

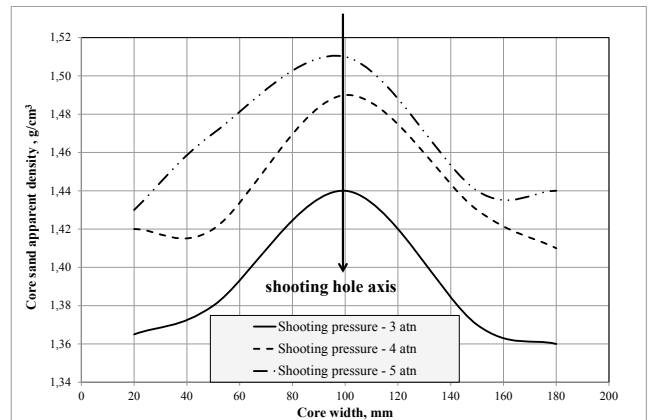


Fig. 9. Distribution of the local apparent density in the core-box RD-I, for the shooting hole diameter  $d = 15$  mm

### 3.3. Visualisation of filling the core-box

Analogue filming of fast-changing processes by quick-acting optic cameras is still an important way of performing documentation. In own investigations [3], the process filming by the camera of a velocity of 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 (of square sides 10mm) 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 blowing chamber.

The following process and equipment parameters were applied:

- shooting pressure: 0.6 MPa (5 atm),
- shooting hole diameter: – 15mm and 25 mm,
- time of the shooting valve opening: 0.5 – 1.0 s.
- experimental core-box RD-I (Fig. 10),
- core sand with linseed oil varnish.



Fig. 10. Horizontal experimental core-box of a capacity 0.816  $dm^3$  (the background mosaic is not seen)

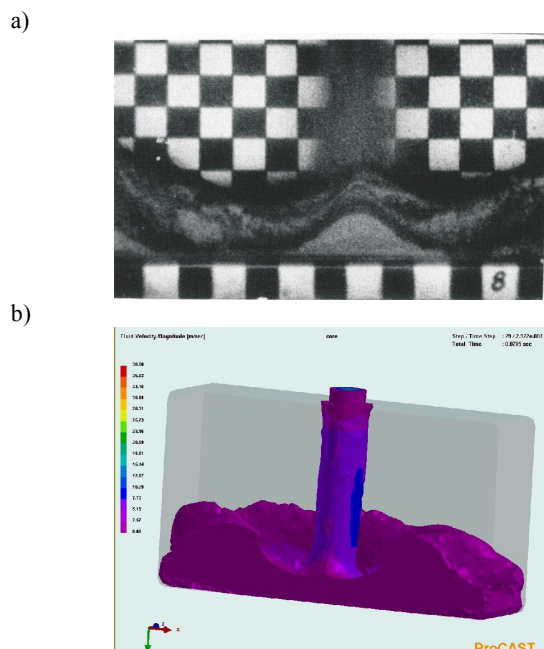


Fig. 11. Experimental core-box filling with the core sand, a) Recorded by the quick-acting camera, b) Results calculated by means of the ProCast software. Time: 0.080s

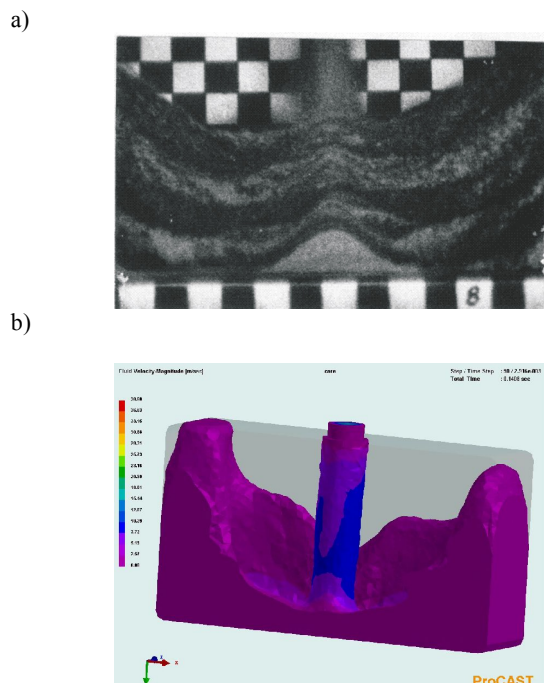


Fig. 12. Experimental core-box filling with the core sand, a) Recorded by the quick-acting camera, b) Results calculated by means of the ProCast software. Time: 0.140s

## 4. Conclusions

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 moulding 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.

It can be noticed that the classic sand with bentonite, able to the particles agglomeration, fills the experimental core-box cavity in such a way that after hitting - by the sand-air stream - the base (either the core-box bottom or the sand layer) particles are gluing and in a form of clusters displacing inside the cavity together with the air blowing from the shooting hole axis to places with venting openings - in accordance with the pressure gradient. Displacing clusters are forming layers, which when compacting one by one are raising in the shooting hole direction up to a complete filling of the core-box.

Observations of the process of the cold-box filling with sands of a resin type binder indicate a slightly different mechanism of filling. The sand-air mixture atomised in air flows into the core-box. After hitting the base, despite of changing the direction, the mixture maintains its dispersed character and displaces together with air in the direction of the most intensive air outflow. It sediments on venting elements and forms there a layer of increased thickness growing in the shooting hole axis direction. At the process end the region in the vicinity of the shooting hole is filled, but through this hole the sand is still pushed into the core-box causing compacting of layers introduced earlier.

The additional compacting effect in the hole vicinity is more distinct when the shooting holes in the shooting machine head are larger. This can be explained by smaller sand flow resistances at the occurring pressure difference, which to a smaller degree decreases the effect of 'a sand hydraulic impact', generated at abrupt blocking of the sand stream flowing into the already filled core-box.

When analysing the obtained results of simulation investigations one can notice certain differences in comparison to the model tests.

The most essential difference constitutes another character of sand outflow and the core-box filling near the shooting hole. 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 moulding sand properties and motion parameters of the core sand [9-14]. These data comprise static and

dynamic sand viscosity, its apparent density, permeability, coefficient of friction on the core-box walls. Thus, a formation of data bases concerning the mentioned factors, important for the optimisation core production processes with the application of modern binding materials technology, is fully justified.

## Acknowledgements

This work was elaborated under research and development study no 11.11.170.318, task 2

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