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Investigations of the Mechanism of the Sand Shooting into the Core Box

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Abstract

The results of investigations of sand shooting into the core box are presented in the hereby paper. The investigations concern the formation of the diphase sand-air flux, its motion, flowing and compaction in the cavity during the core forming. Conditions deciding on the course of individual phases of the process are discussed with taking into consideration the influence of such factors as: the shot pressure, shooting hole diameter, number and distribution of deaerating vents in experimental core boxes (of a single cavity and of multi cavities) on the core sand compaction state. Investigations were performed by means of the modernised experimental shooting machine SR-3D, of the shooting chamber volume of 3.3 dm^3, connected with the system of pneumatic supply ensuring the stable pressure supply of values: 0.4 MPa, 0.5 MPa and 0.6 MPa. Two diameters of the shooting hole, equal 10 mm and 20 mm, were applied for filling three experimental core boxes differing in dimensions of cavities and in number and distribution of deaerating vents. The filling process of core boxes was recorded by means of the digital camera PHANTOM V210 with the filming rate of 3000 pictures in second. Simultaneously, during the shot, other values allowing to determine the intensity of the core sand outflow from the shooting chamber to the core box, were tested. The presented in this publication results constitute the important element of the experimental verification of the blowing process simulation calculations which will be performed.

Keywords: Core shooting, Blowing process, Core sand

1. Characteristic of the problem

Growing requirements concerning the casting quality as well as tendencies to use structures and castings of thinner and thinner walls, are causing that the production of high quality complex cores becomes the requirement significantly influencing the quality and yield of the casting production. As it was stated in paper [1], the wide range of problems related to the blowing process investigation was illustrated in [2, 3] and numerous publications, domestic and foreign [2-7].

The theoretical model allowing the numerical calculations of the airflow flux in the set of blowing machines, was developed [1]. Depending on the assumed structural and operational parameters of the machine (volume of the shooting chamber and core box, shooting valve surface, pressure growing rate, blasting and venting holes surfaces, working pressure of the air) a possibility of influencing the sand compaction process is achieved.

The performed investigations of the core box filling by the sand-air flux, presented among others in papers [2-5], indicate that main factors determining the effects of this process are:

- intensity of the solid phase outflow,
- dynamic force value of the diphase flux.

Auxiliary factors in the analysis of the mechanism of sand shooting into the core box cavity are:

- density of the diphase flux, or values directly related to the density (concentration or volume fraction or weight fraction of the solid phase, porosity),
- average velocity of both phases of the sand-air flux,
- rubbing speed of the solid phase and the mutual velocity ratio of the solid and gaseous phase in the flux out-flowing from the shooting chamber to the core box.

The blowing process is specially related to the dynamic flow of the core sand from the shooting chamber to the core box. The suitability of the core sand for the core box filling and compacting, can be assessed on the basis of special technological tests reproducing - in the laboratory scale - the process course. One of the methods of the preliminary assessment of the core sand suitability for filling the core box and compacting by blowing methods, is the method used in own investigations [3,6]. In this method the special core box, patterned on the solution developed by Boenisch and Knauf [7], is used. As the result of investigations presented in paper [3] the currently applied core sands were compared with regard to their ability of the core box filling.

The base of the analysis of the blowing processes mechanism (blowing, sand shooting) constituted the previous [1] and current [2, 4, 18] investigations of moving of the determined core sand in the shooting chamber and in the core box, under various conditions reproducing determined technological situations concerning: pressure, diameters of shooting (blowing) holes, number and placements of venting holes [8-19].

2. Experimental investigations

The methodology developed in previous investigations [3] was applied in the current investigations, in which the core sand with the Cordis binder was used. This sand indicated the highest ability for filling the core box and for compacting. The composition of the sand used in the presented investigations was as follows:
high-silica sand – 100 parts by wt.,
CORDIS binder – 2.2 parts by wt.,
addition of anorgit – 1.2 parts by wt.

Experimental tests were performed by means of the experimental shooting machine SR-3D, of a constructional volume of the perforated insert of the shooting chamber being 3.3 dm^3. The experimental shooting machine SR-3D is equipped with the Hansberg valve, allowing the cores production within the pressure range 0.4 MPa, 0.5 MPa and 0.6 MPa, at the very fast growing pressure in the shooting chamber (7.2 – 8.4 MPa/s). The selected to research the range of parameters results from the parameters used in the industrial production core box machines.
The stand for fast photographs PHOTON, by means of which the core box filling courses were recorded (with the filming rate of 3000 cells/s) is shown in Figure 1.
The horizontal core box of the rectangular cavity of dimensions 200x86x47mm, marked as the R-1 version, and two other versions of the same core box, marked as R-2 and R-3, were used in investigations. In core boxes R-2 and R-3 the cavity was divided into three sectors by 2 walls with through cut-outs placed in the lower or the upper part. The core sand was shot by the centrally placed single shooting hole of various diameters. The shooting holes of diameters: d_1 = 10 mm, d_2 = 15 mm and d_3 = 20 mm were used in the tests. Cut-outs - of various cross-sections - in side walls allowed for changes the direction and conditions of the core sand flow from the central sector to side sectors. The observation and digital recording of the core box filling was carried out via the face wall made of the transparent material PMMA. The core box deaeration was realised by means of 26 typical vents of the active surface being 4.7 cm^2. In dependence of the shooting hole diameter, the deaeration degree was equal: 5.98 (d_1=10 mm), 2.65 (d_2=15 mm) and 1.49 (d_3=20 mm).

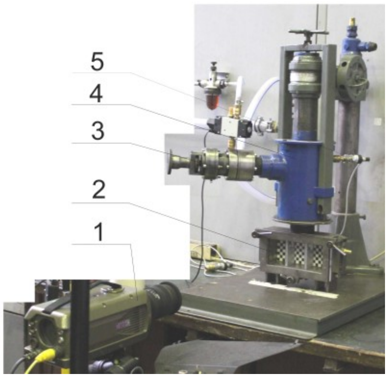


Fig. 1. Experimental stand: 1-PHANTOM fast camera, 2-Experimental core box, 3-Hansberg valve, 4-Shooting chamber, 5-Piezoelectric pressure converter (sensor)

The core box of the R-1 version is presented in Figure 2. On the back side of this core box there is a mosaic of black and white squares of a 1 cm side, allowing to determine the moving rate and to observe the cavity filling degree with the core sand.
In case of the core boxes of R-2 and R-3 versions (Fig. 3) cut-outs of a surface of 6.25 cm^2 were made in side walls. In the R-2 version these cut-outs were placed in low parts of walls, while in the R-3 version in upper parts.

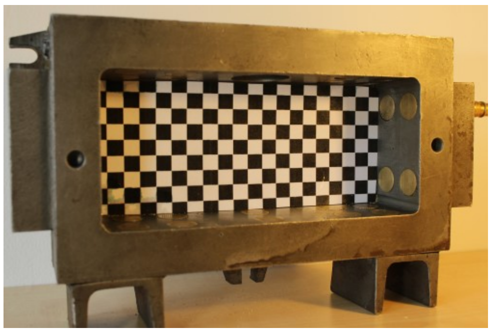
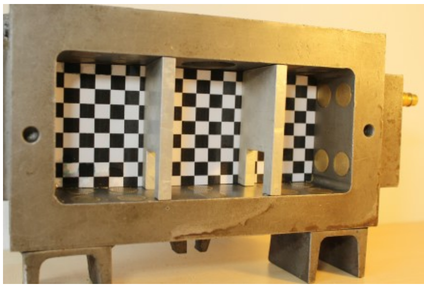


Fig. 2. Core box R-1 version, nominal cavity volume: 808.4 cm^3

a)



b)

Fig. 3. Core box, of R-2 (a) and R-3 (b) versions, effective cavity volume: 743.7 cm^3. Central sector volume: 258.7 cm^3, two side sectors volume: 485 cm^3

3. Results of investigations

The bases of the development of the blowing processes mechanisms (blowing, core sand shooting) constituted investigations of the core sand movement in the shooting chamber and in the core box. They were performed under variable conditions reflecting the determined technological situations concerning: pressure, diameters of shooting (blowing) holes as well as the number and placements of vents.

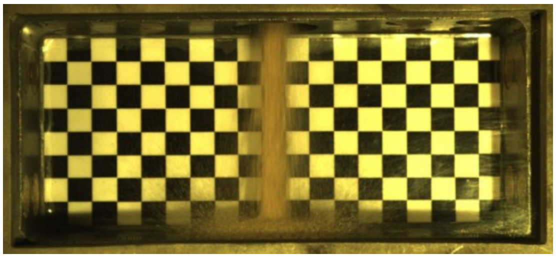
The visual analysis and recording of fast changing processes is currently done by means of digital cameras, while previously (beginning from 60-th of the previous century) the analogue filming by - modern in that time - optical cameras Pentazet 16, was applied. At the rate of 3000 cells for a second and the introduced time marker on the film perforation (every 0.001 second) the analysis of the sand movement in the core box was possible [1, 2, 6].

On the basis of the digital recording of the process the analysis of filling the experimental core box was performed and the following values were determined:

- velocity of the sand-air flux flow in the initial phase of the process, V-m/s,
- total time of the filling process, T -s,
- average value of the intensity of the core sand outflow from the shooting chamber to the core box of the shooting machine, M- kg/s,
- compaction of the core - expressed by the average apparent density, D - g/cm^3.

Pictures showing the initial period of the sand-air flux outflow from the shooting chamber into the core box, at the shot pressure being 0.4MPa and the shooting hole diameter 10 mm and 20 mm, are presented in Figure 4. On the bases of these pictures (and analogous ones, obtained for other parameters of the blowing process) the flux velocity, in the initial period of the core box filling process, was determined. The results obtained for the core box R-1 are given in Table 1 and in Figures 5 and 6. The successive phases of this core box filling are shown in Figure 7 (for d_2=15 mm and p=0.6 MPa).

a)



b)

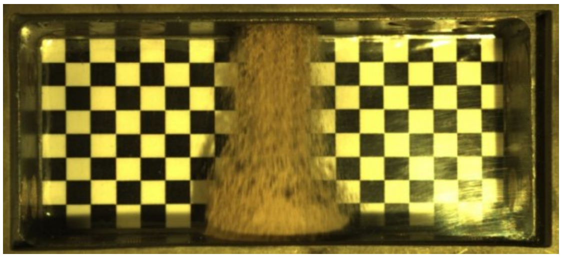


Fig. 4. Blowing process course in the core box R-1 version; a) d_1=10mm, p=0.5MPa, t=0.014s., b) d_3=20mm, p=0.5MPa, t=0.011s

Table. 1.
Results of the shooting process obtained on the basis of the analysis of recording its course and measuring the average apparent density. The core box R-1 version

Shot pressure	Diameter of the shooting hole	T	V	M	D
MPa	mm	s	m/s	kg/s	g/cm^3
0.4	10	0.943	6.14	1.365	1.593
	15	0.457	6.19	2.860	1.616
	20	0.253	6.27	5.189	1.624
0.5	10	0.894	6.61	1.456	1.610
	15	0.409	7.18	3.234	1.636
	20	0.215	7.81	6.269	1.667
0.6	10	0.832	7.81	1.577	1.622
	15	0.359	8.02	3.708	1.656
	20	0.197	8.60	7.041	1.715

T – total time of filling process; V - velocity of the sand-air flux flow; M - intensity of the core sand outflow from the shooting chamber to the core box, D - average core apparent density

It can be noticed, on the bases of data shown in Figures 5 and 6, that the velocity of the sand-air flux as well as the intensity of the core sand outflow from the shooting chamber into the core box depend on the shot pressure and on the diameter of the shooting hole. As long as the flux velocity not much differs (only within the range: 6.14÷8.60 m/s), the largest differences concern the sand outflow intensity. The lowest value, being equal to 1.365 kg/s.

was obtained for the shot pressure of 0.4 MPa and shooting hole diameter d_1=10 mm, while the highest value being equal to 7.041 kg/s., was obtained for the shot pressure of 0.6 MPa and shooting hole diameter d_3=20 mm. The calculated values of the coefficient q are for these cases equal 1.74 and 2.24 kg/cm^{2}s, respectively.

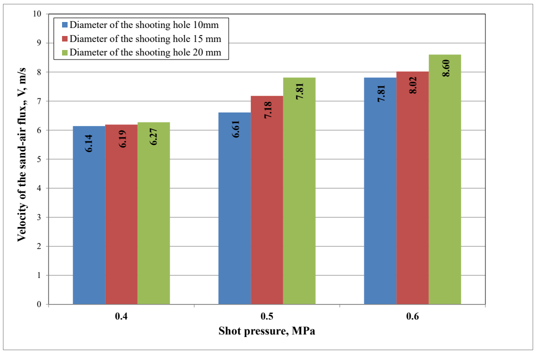


Fig. 5. Influence of the pressure and diameter of the shooting hole on the velocity of the sand-air flux in the R-1 core box

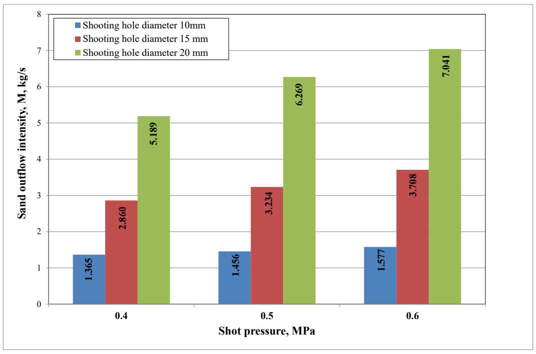


Fig. 6. Influence of the pressure and diameter of the shooting hole on the outflow intensity of the sand-air flux in the R-1 core box

Successive phases of the core box filling, recorded at the work pressure 0.6 MPa and diameter d_2=15 mm, are presented in Figure 8. The recorded process course confirms the theoretical analyses presented in paper [2]. The process of the core box filling can be divided into three phases: the preliminary phase consisting of the formation of the sand-air flux wave front and the formation of the compacted core sand on the core box bottom, then the main phase related to the total filling of the core box and finely the phase of the sand consolidation, mainly near the shooting hole. On the basis of the analysed pictures it can be noticed, that in the preliminary phase of the process the sand-air flux has a higher thickness than the out-flowing flux in the main phase. This is related to blocking and scattering of the wave front by the air resistance and its relatively low energy, not able to overcome the head resistance. The flux velocity in the main phase was not determined during the performed tests because the applied measuring method still requires verification.

a)
b)
c)
d)

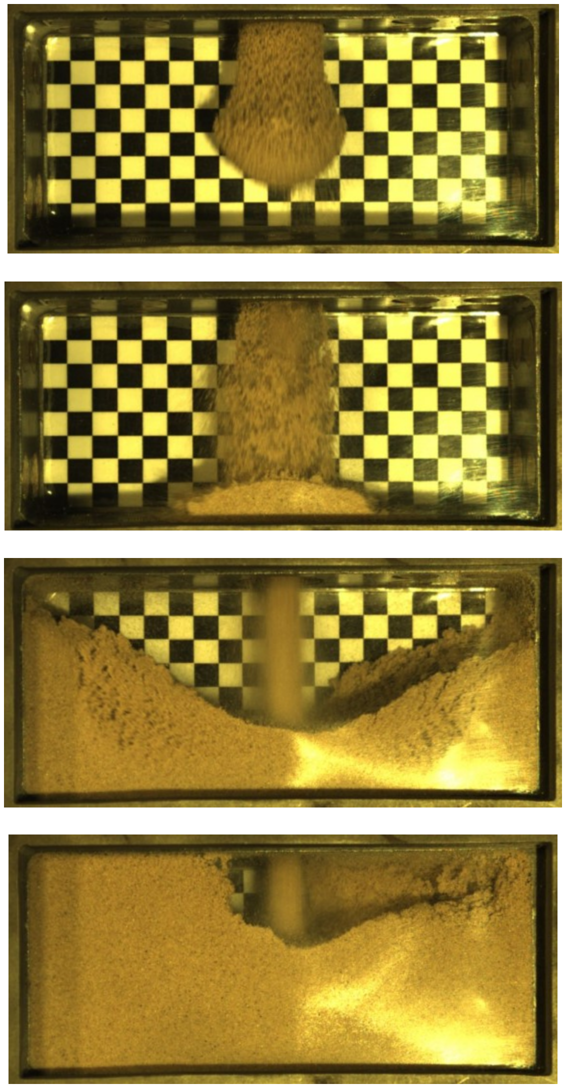


Fig. 7. Successive phases of the filling process of the core box R-1 version, d_2=15mm, p=0.6 MPa, a) Preliminary phase - formation of the flux wave-front, t=0.008s., b) Preliminary phase – formation of the core sand cone, t=0.017s., c) Main phase, t=0.077 s., d) Main phase, t=0.251 s.

The example of the course of filling the core box R-2 version is shown in Figure 8. It can be noticed that, under the existing conditions, the central sector - below the shooting hole - is privileged since it is completely filled with the sand subjected to compaction. Side sectors, into which the sand is introduced through cut-outs in the low part of walls dividing sectors, are only partially filled even at the end of the process. It means that the sand is not properly compacted. The analysis of average parameters of the sand-air flux is given in Table 2. Data concerning the average value of the outflow intensity of the sand-air flux as well as the average apparent density of the core obtained in the central sector D_{cent} , are taken into consideration.

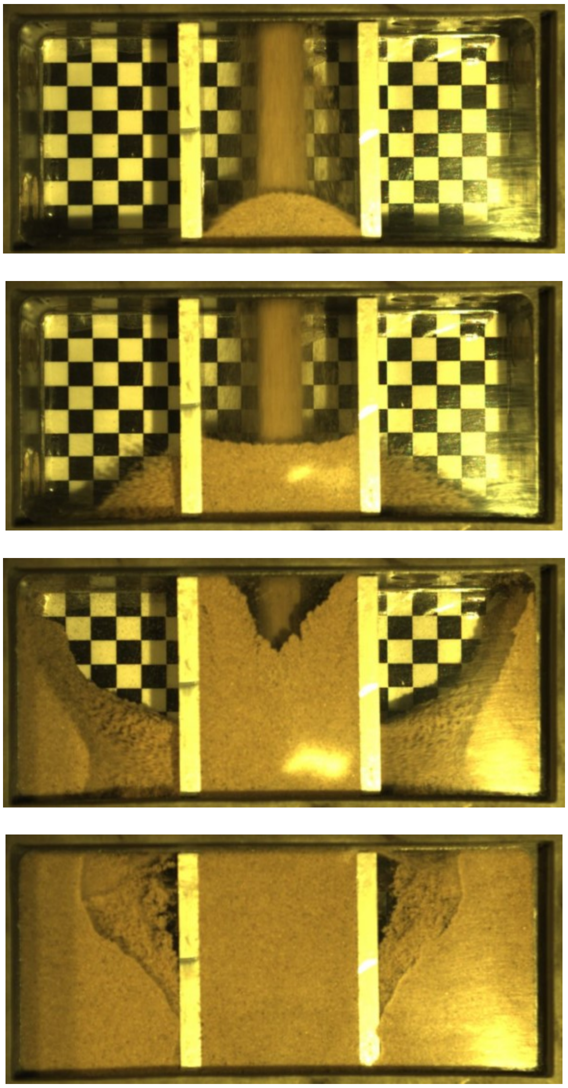
a)
b)
c)
d)


Fig. 8. Process course of filling the core box R-2 version, p=0.5MPa, d=20mm; a) t=0.015s., b) t=0.025s., c) t=0.080s., d) t=0.187 s. Effective cavity volume: 743.7 cm^3, (the central sector: 258.7 cm^3, side sectors: 2 x 242.5 cm^3)

The graphical analyses of these results are presented in Figures 9 and 10. It can be seen, that in the core central sector there is much higher compaction than in side sectors, which were not fully filled. The presented effect is caused by distancing the passage channel in side walls from the shooting hole, by the air pressure decrease, the necessary change of the flowing direction as well as by friction occurring in the zone of passage channels, which is increasing together with the increase of the core sand compaction in the central sector of the core. Increases of the shot pressure value and the shooting hole diameter lead to the decrease of the difference between the average core density value and the density in the central sector, which can be treated as the privileged one.

Table 2.
Results of the shooting process obtained on the basis of the analysis of recording its course and measuring the average apparent density. The core box R-2 version.

Shot pressure	Shooting hole diameter	T	M	D	D_{cent}
MPa	mm	s	kg/s	g/cm^3	g/cm^3
0.4	10	0.754	1.193	1.123	1.640
	15	0.425	2.876	1.164	1.652
	20	0.204	5.304	1.338	1.665
0.5	10	0.640	1.519	1.202	1.675
	15	0.315	3.254	1.274	1.680
	20	0.192	5.865	1.392	1.685
0.6	10	0.609	1.663	1.253	1.691
	15	0.285	3.886	1.324	1.699
	20	0.174	6.678	1.437	1.712

T – total time of filling process; V - velocity of the sand-air flux flow; M - intensity of the core sand outflow from the shooting chamber to the core box, D - average core apparent density

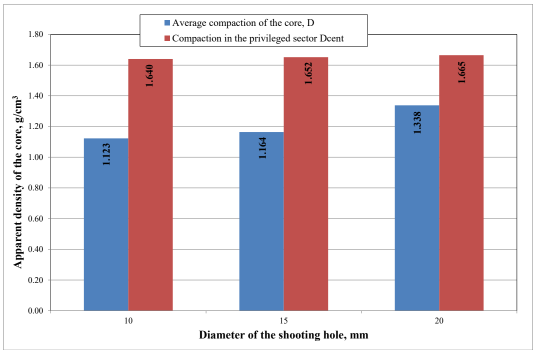


Fig. 9. Influence of the shooting hole diameter on the apparent sand density in individual sectors of the core box R-2 version, p=0.4MPa

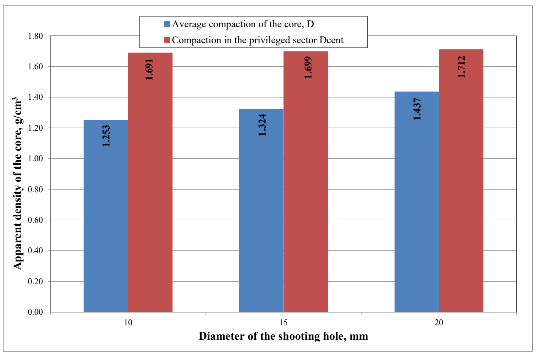
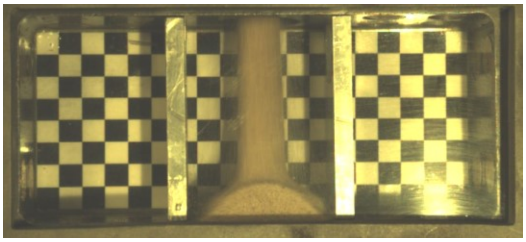


Fig. 10. Influence of the shooting hole diameter on the apparent sand density in individual sectors of the core box R-2 version, p=0.6MPa

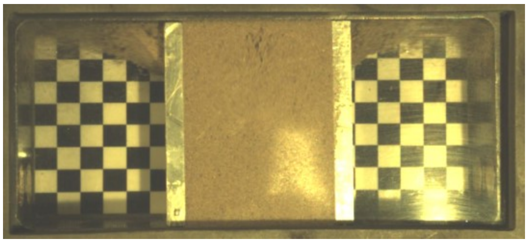
The limitation of the effect of blocking the sand-air flux due to the core box R-3 filling is shown in Figure 11. The shown example concerns shooting, at the shooting hole diameter d_3=20mm and pressure p=0.5MPa, when cut offs of the surface of 2 cm^2 situated in the upper parts of side walls were applied.

The comparison results of the average core density D_{cent} and the density in the privileged space, are presented in Figure 12a and 12b. In a similar fashion as in the case of the R-2 core box, in the R-3 core box the difference of the obtained apparent densities can be seen. The highest value of an apparent density occurs in the central (privilege) sector, however differences are not so large (from 8.29% to 12.22%) as in the core box with cut offs situated in the bottom part of side walls (from 16.06% to 31.32%).

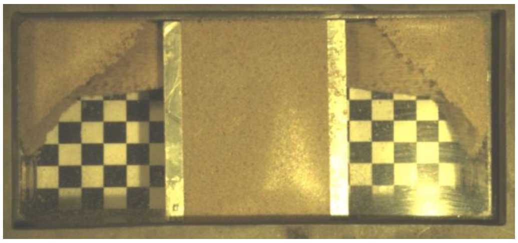
a)



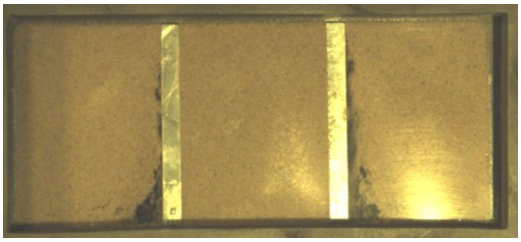
b)



c)



d)



e)

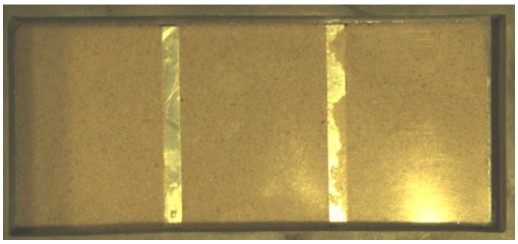
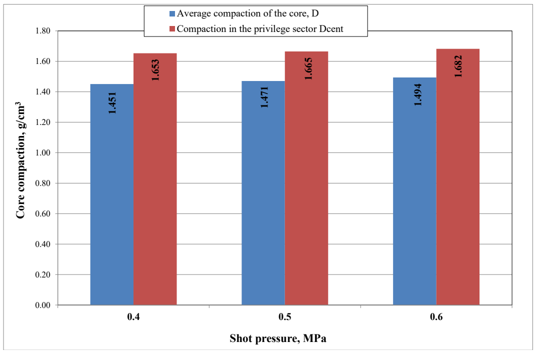


Fig. 11. Process course of filling the core box R-3 version, p=0.5MPa, d=20mm; a) t=0.015s., b) t=0.055s., c) t=0.100s., d) t=0.170 s., e) t=0.200 s. Effective cavity volume: 743.7 cm^3, (the central sector: 258.7 cm^3, side sectors: 2 x 242.5 cm^3)

a)



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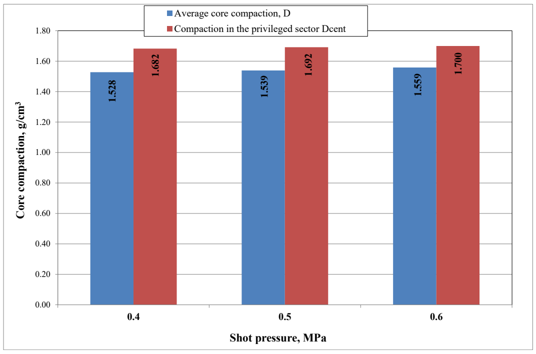

Fig. 12. Apparent density of cores made in the core box R-3 version; a) Shooting hole diameter d_1=10 mm, b) Shooting hole diameter d_2=20 mm

4. Conclusions

The results of investigations presented in the hereby publication constitute only a small part of the investigations realised within the research project [20]. Basing on the presented research some conclusions can be made:

- The velocity of the sand-air flux as well as the intensity of the core sand outflow from the shooting chamber into the core box depend on the shot pressure and on the diameter of the shooting hole.
- The process of the core box filling can be divided into three phases: the preliminary phase consisting of the formation of the sand-air flux wave front and the formation of the compacted core sand on the core box bottom, then the main phase related to the total filling of the core box and finely the phase of the sand consolidation, mainly near the shooting hole.
- When the core sand is blowed to more complicated core boxes (in presented research R-2 and R-3), where a change in the sand-air mixture flow direction occurs, the unfavourable effect of blocking the sand-air flow can take place. As a result of this the difference in the core compaction in different core areas may occur.

The presented research will be important for further work related to the simulation of the blow process. Which is planned in the realized project [20]. The simulation investigations of the motion of two and multiphase mixtures [9-19], the influence of binding agents properties on the process course and cores quality [6, 12], the influence of venting on the flow dynamics in the shooting process [8, 16, 17], still constitute the bases of the blowing processes analyses.

Acknowledgements

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