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Compaction of Cores Made by Blowing Methods – Model Investigations

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Abstract

The results of model investigations of the influence of the blowing process selected parameters on the distribution of the compaction of the core made by the blowing method, are presented in the hereby paper. These parameters were: shooting pressure, shooting hole diameter, amount and distribution of deaerating holes. Investigations were performed using the horizontal core box of the cuboidal cavity and the same core box into which inner inserts were introduced. These inserts were dividing the primary volume into three sectors differing in their direction, introduction conditions and the character of the core sand flow. As the compaction measure the apparent sand density was assumed. The density was determined in five measuring points in case of uniform cores, and in three measuring points in case of cores obtained in the core box with three separated sectors. The apparent density of the compacted core sand in the core box cavity was determined on the basis of the measurements of masses and volumes of samples cut-out from the determined core places by means of the measuring probe. Investigations were performed at three values of the working pressure equal 0.4, 0.5 and 0.6MPa for two diameters of the shooting hole: 10 and 20 mm. During tests the core box deaeration, controlled by an activisation of the determined number of deaerating vents placed in the core box, was also subjected to changes.

Keywords: Core shooting, Blowing process, Core sand, Core box

1. Introduction

The moulding sand compaction degree, determined by various ways, is one of the main indicators determining the quality of cores and moulds [1, 2, 4, 6]. As it was shown in paper [3], this value determines the resistance and impact strength of core sand, which translates - at maintaining other sand parameters on the proper level (e.g. high temperature resistance) - into a possibility of its application for making cores exposed to essential mechanical loads occurring when the mould is filled with liquid foundry alloys.

Such factors as: core complex shape, core sand grade, parameters of shooting pressure as well as the recommended surface values and distribution of shooting and venting holes are the main elements deciding on the mould filling process and the moulding sand compaction [3, 5]. Apart from the mentioned parameters very essential, in the core production process by blowing methods, is the core sand type [especially its fluidity]. This is related to physico-chemical properties of the applied binders (e.g. high reactivity causing changes of the sand state, including viscosity and strength, before its compaction) and to conditions of their hardening, the most often by blowing gaseous hardening substances. Also the core box venting in modern cold core box technologies gains additional function. Regardless of the traditional task, the proper core box filling and sand compaction, the necessity of maintaining the favourable conditions for hardening of the sand by blowing through it in the core box and removing harmful substances formed during this process, is added. Several methods allow assessing the tested core sand property on the basis of certain technological tests reflecting the process procedure in the laboratory scale. The criteria defining either the degree or the indicator of the core box filling [3, 5], the coefficient of sand evacuation from the shooting chamber [6, 8], outflow intensity of the sand-air flux [4] create better possibilities of estimating the core sand behaviour during flowing and filling the core box. The result constitutes the value and structure of the obtained compaction, which after hardening, decides on the strength and permeability of castings.

2. State of the problem

The bases of blowing theories and technologies are presented in numerous domestic and foreign publications of 70-90 years of the previous century. The synthesis of these works, in Poland, is contained in monographs [2, 3, 4] and in other, devoted to one subject papers [5, 6, 8-17]. The previous investigations allow for the rational selection of the tested variables - from the point of view of practice - at the application of modern measuring equipment, programs for working out the obtained results as well as simulation programs. A wide game of new binders and obtainable properties of core sands justifies investigations aimed at actualization of information needed for the computer simulations. These simulations characterize the calculated course with regard to core sand properties (viscosity, density, coefficient of friction between core box walls and core sand) and assess the ability of core sands for the core box filling and for compacting in dependence of the applied binding materials, and parameters of the shooting machine (pressure, shooting hole diameter, deaeration surfaces). The numerical calculations verification is performed by experimental determinations of such quantities as the apparent density and its dependence on the sand grade, applied pressure and diameter (surface) of inlet nozzles. Knowledge of the influence of the core box deaeration degree and the distribution of venting holes on the density distribution in the core volume is important for the cores hardening process by gaseous factors.

3. The aim and program of investigations

The aim of the presented investigations was the determination of the influence of the blowing process parameters and the characteristics of experimental core boxes on the distribution of the core sand apparent density. The sand with the Cordis binder was applied in investigations as the model core sand, since this sand is characterized - as it was shown in the project [18] and paper [7] - by very good fluidity ensuring the proper filling the core box due to the shooting process. Following Cordis sand composition was applied:

Fresh silica sand	100 parts by weight.
Cordis 8322 binder	2.2 parts by weight.
Anorgit 8323	1.1. parts by weight.

Investigations were performed by means of the experimental shooting machine SR-3D, of the constructional volume of the perforated insert of the shooting chamber being 3.3 dm^3. This chamber was equipped with the shooting valve, Hansberg type, allowing for changing the increasing pressure intensity in the shooting chamber on the level: 7.2 – 8.4 MPa/s. The view of the experimental shooting machine is shown in Figure 1.

Tests were performed with using the horizontal core box, marked R-1, of the cuboidal cavity and the same core box into which inserts were introduced. These inserts were dividing the primary volume into three sectors differing in the direction, conditions of introduction and the flow character of the core sand. The pictorial presentation of the experimental core box with shaped inserts is shown in Figure 2. The dimensions of this core box without inserts are: 200 x 87 x 47 mm. For the total deaeration, the core box is equipped with 26 typical deaerating vents, presented in Figure 3. The applied vents were characterised by the nominal diameter of 12 mm, while their active surface - determined by means of the optical microscope - was 15.6 %. The following variants of the core box cavity deaeration and their arbitrary notations, were applied in the presented investigations:

– deaeration O1 – all 26 vents open, active deaeration surface – 470 mm^2, deaeration degree D_{deae} = app. 6.0 (5.98) for d_{shot} = 10 mm and D_{deae} = app. 1.5 (1.49) for d_{shot} = 20 mm,
– deaeration O2 – 8 vents in the upper plate of the experimental core box open, active deaeration surface – 144 mm^2, deaeration degree D_{deae} = app. 2.0 (1.83) for d_{shot} = 10 mm and D_{deae} = app. 0.5 (0.46) for d_{shot} = 20 mm.

Shapes of the applied inserts and the dimensions of cut-outs are shown in Figure 4. As can be noticed, they differ in the character of cut-outs (character of flows: bottom – upper part), forcing the direction and conditions of the core sand flow in the given sector of the core box.

Investigations were performed at three working pressure values, being 0.4, 0.5 and 0.6 MPa, respectively, for two diameters of the shooting hole 10 and 20 mm. Notations of versions of the obtained shapes of core box cavities, applied in investigations and their results analyses are presented in Table 1. During investigations each shot was recorded by the PHOTON camera with filming velocity 3000 frames/s.

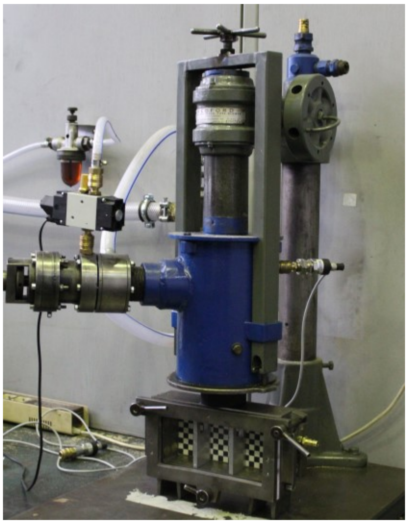

Fig. 1. Experimental shooting machine SR-3D

Table 1.
Notations of the obtained shaped versions of cavities of experimental core boxes applied in tests.

No.	Characteristics	Notation
1.	Cuboidal core box	R-1
2.	with 2 inserts as in Fig. 4a	R-2
3.	with 2 inserts as in Fig. 4b	R-3
4.	with 2 inserts as in Fig. 4c	R-4
5.	with inserts as in Fig. 4d	R-5

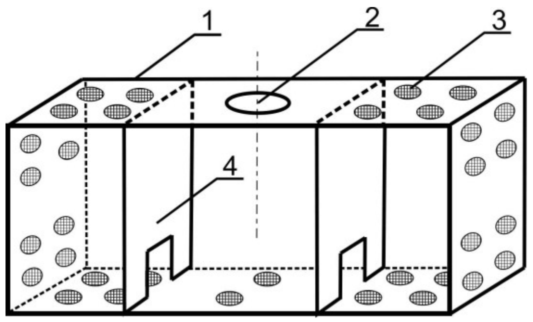

Fig. 2. Pictorial presentation of the experimental core box with shaped inserts: 1 – core box housing, 2 – shooting hole, 3 – deaerating vents, 4 – shaped insert


Fig. 3. Deaerating vents of the experimental core box. External diameter (for assembling) 12.15 mm, active surface 15.6 %

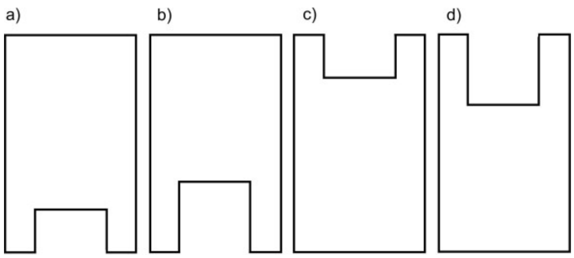

Fig. 4. Shapes of inside inserts of the horizontal experimental core box with the cuboidal cavity: a) insert with the bottom cut-out of a surface 200 mm^2, b) insert with the bottom cut-out of a surface 3 cm^2, c) insert with the upper cut-out of a surface 200 mm^2, d) insert with the upper cut-out of a surface 300 mm^2

4. Results of investigations

In the case of investigating the shooting process with the application of the cuboidal core box R-1 the apparent density of sand compacted in the core box cavity was determined on the basis of measuring weights and volumes of samples cut-out from the determined core places by means of the measuring probe. Five places of the core at which the compactness was measured are shown schematically in Figure 5.

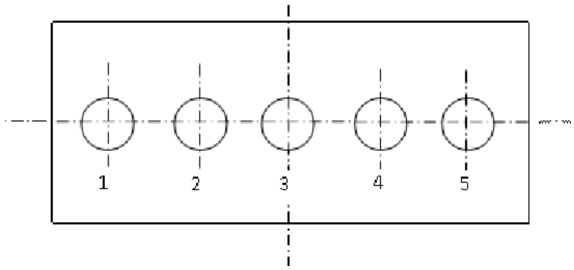

Fig. 5. Places from which the samples, for testing the apparent density and compactness distribution, were taken. Core box R-1

In the case of tests performed with using the core box R-1, two - described before - variants of the core box deaeration, are presented.
The results of measuring the distribution of the apparent density of cores performed at the total core box deaeration are shown in Figure 6. They can be considered as neutral, since the air flow was not forced in any the determined direction. Unevenness of the core sand compactness is clearly visible, the highest in the shooting hole axis and decreasing along with the sand distancing in the direction of the cavity side walls. It can be stated, on the bases of the obtained results, that an increase of the shooting hole diameter causes the sand density increase in the whole core, regardless - in practice - of the pressure value. Increasing of the pressure causes an increased growth of the apparent density when the diameter is smaller, since in such case the solid phase concentration in the air flux is lower and hydrodynamic properties as well as mobility of sand-air mixture are more intensely revealed [2, 4]. The maximum sand density of 1.66 g/cm^3, was obtained at the shooting pressure of 0.6 MPa and the shooting hole diameter of 20 mm. The obtained compaction degree of the sand matrix can be assessed - on the bases of investigations shown in paper [3] - as corresponding to the model, hypothetical compaction of grains of the coordination number 8.

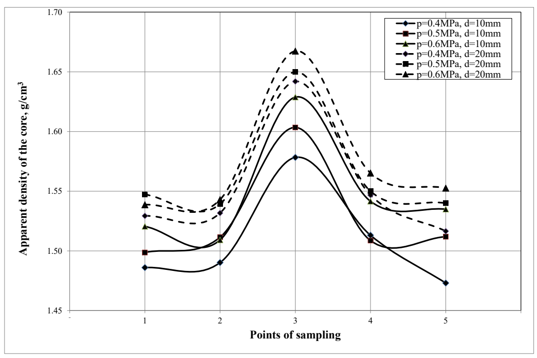

Fig. 6. Results of the apparent density distribution in cores made at the shooting hole diameter d = 10 mm and d = 20 mm and the total deaeration of the core box

The results of the compaction degree of the core made in the core box R-1, at the shooting hole diameter d = 10mm and deaerations of the experimental core box marked O1 and O2, are presented in Figure 7. The analysis of these results indicates that at similar conditions of the process (shooting hole diameter, shot pressure) higher compactions were obtained for deaeration O1, where the active surface was 470 mm^2.

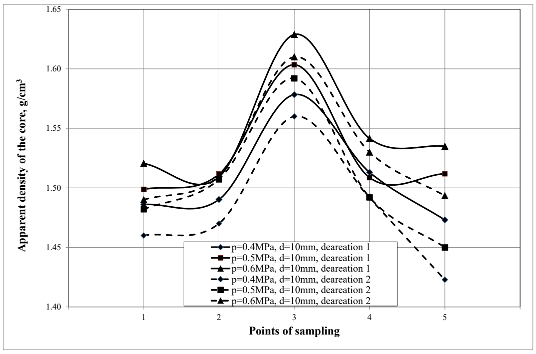

Fig. 7. Results of the compaction of cores made at the shooting hole diameter d = 10 mm and deaerations of the core box cavity corresponding to variants O1 and O2

The analogous effect of a higher compaction of cores made in better deaerated core boxes can be observed in results obtained for cores made at the shooting hole diameter being 20 mm, regardless of the fact that the deaeration degree of the core box was decreased from D_{deae} = 4.98 (d_{shot} = 10 mm) to D_{deae} = 1.49 (d_{shot} = 20 mm).

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The ensuing changes can be related to the air pressure increase in the cavity of the experimental core box, corresponding to variant O2. Examples of the pressure pathways in the shooting chamber and in the core box obtained at the working pressure of 0.4 MPa, shooting hole diameter d = 20 mm and deaeration variants O1 and O2, are presented in Figure 9.

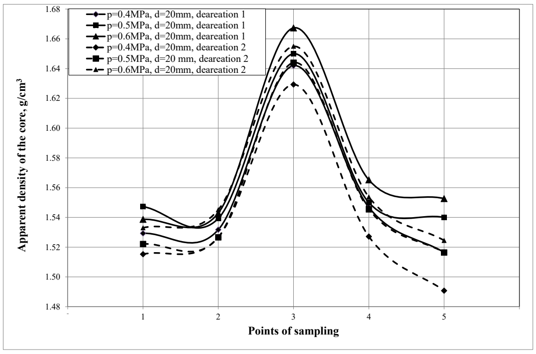

Fig. 8. Results of the distribution of the compaction of cores made at the shooting hole diameter d = 20 mm and deaerations of the core box cavity corresponding to variants O1 and O2

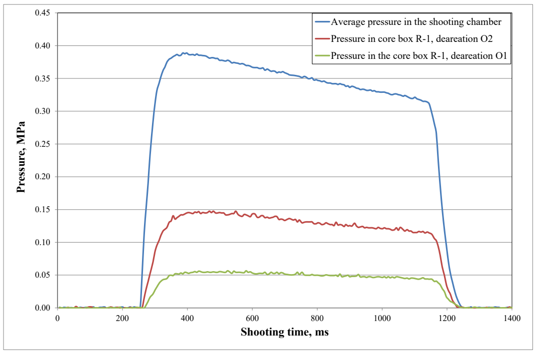

Fig. 9. Examples of the pressure pathways in the shooting chamber and the core box R-1. The shot pressure was 0.4 MPa, shooting hole diameter d = 20mm. Deaerations according to variants O1 and O2

The analysis of the core compaction distribution in core boxes obtained from dividing the core box R-1 into three sectors marked 1 to 3, was performed in three measuring points, marked schematically in Figure 10. In the successive versions of core boxes R-2÷R-5 (see Table 1), the bottom and upper places of the sand introduction into side sectors, obtained due to the symmetrical - versus the shot axis - cut-offs in inserts dividing the sectors, were taken into account. The results of the investigation of the apparent density of cores made in core boxes R-2÷R-5 (shown in the further part of this paper), were obtained at the deaeration corresponding to variant O1.

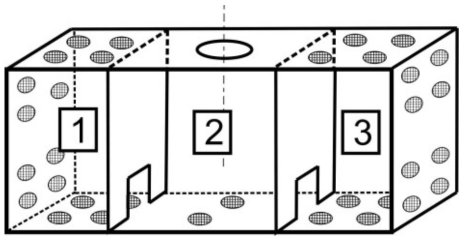

Fig. 10. Places of cut-out of samples for the density measurements in individual sectors 1-3 of core boxes R-2÷R-5

Results of the distribution of the apparent density of the core sand in core box R-2 are presented in Figure 11. They indicate very large difference of compaction in the central sector (2), which is similar to the values measured in the shooting hole axis (see Fig. 5-8) as compared to the apparent density in sectors 1 and 3, where the obtained results are at the level of the sand bulk density. Due to the change of direction of the core sand flux through the insert with a narrow bottom cut-out (see Fig. 4a), the flow is blocked and in consequence the situation presented in Figure 12 occurs. It can be noticed that sectors marked as 1 and 3 are not completely filled with the sand core. Because of that the average apparent density related to the volume of the total sector has such low values.

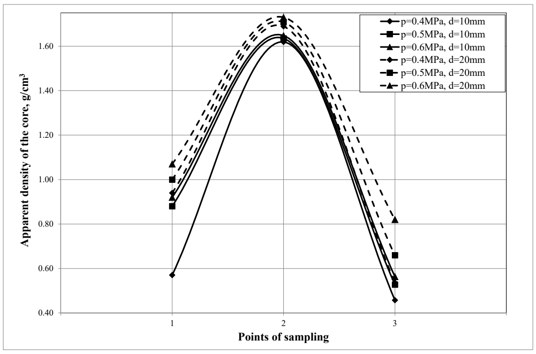

Fig 11. Distribution of the apparent density of the core sand for the core made in the core box R-2 at various pressures and diameters of shooting nozzles. Deaeration O1

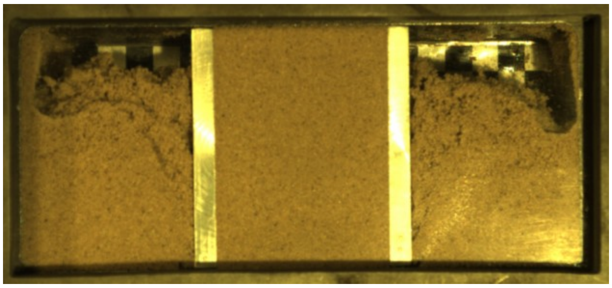

Fig. 12. Filling of the core box R-2 after the shot at the pressure of 0.6 MPa and the shooting hole diameter d = 20 mm

The comparative results of the sand apparent density obtained in core boxes R-2 and R-3, at the shooting hole diameter d = 20 mm and the shooting pressures of 0.5 and 0.6 MPa, are shown in Figure 13. The data indicate similar values of the apparent density in the central sector (2) for both core boxes regardless of the pressure. Whereas in sectors 1 and 3 higher apparent densities were obtained in core box R-3, characterised by a larger clearance of the insert (Fig. 4b) and - due to that - of relatively lower resistances of the core sand flow.

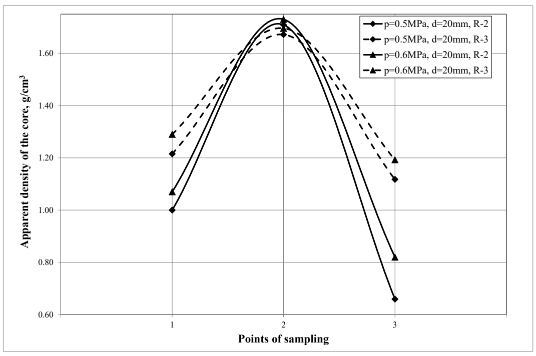

Fig. 13. Comparison of the density distribution in cores made in core boxes R-2 and R-3, at the same working parameters of the process

The comparative compilation of results of the apparent density of sands shot - by nozzles of diameters 10 and 20 mm - into core boxes R-2 and R-3 at various shooting pressure values, are presented in Figures 14 and 15. They confirm the results of the analysis presented in Figure 13. In measuring points 1 and 3 higher compaction values are obtained in core boxes of R-3 version. In the shooting hole axis higher values of the apparent density provides the process realised under conditions corresponding to the core box R-2 version.

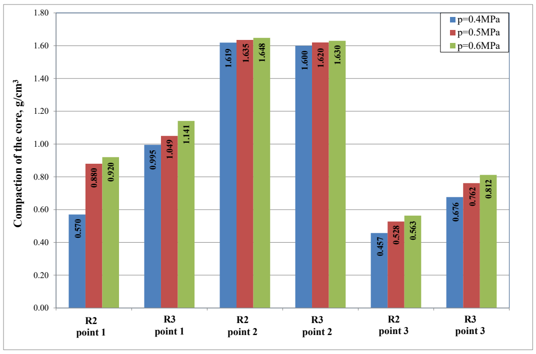

Fig. 14. Comparison of the sand apparent density distribution in core boxes R-2 and R-3, when shooting was performed at various pressure values. The shooting hole diameter equal 10 mm

The analysis of data presented in Figures 14 and 15 reveals the asymmetry of apparent density in sectors 1 and 3, which in spite of the same 'theoretical' deaeration conditions in these sectors is caused by different efficiencies of their deaeration systems.

The influence of changing the placement of holes and their clearance surfaces in inserts separating the central sector from side sectors is confirmed by the results presented in Figures 16 and 17. In this case inserts have cut-outs placed in the upper part of the same surfaces as in core boxes R2 and R3. The listing of the apparent density results obtained for cores made in core boxes of the R-4 and R-5 version indicates increasing density in sectors 1 and 3 in relation to the version of inserts with bottom cut-outs. It also indicates similar level of sand compaction obtained in these sectors, which suggests lower resistances of the sand flow and proper operation of the core box deaeration system.

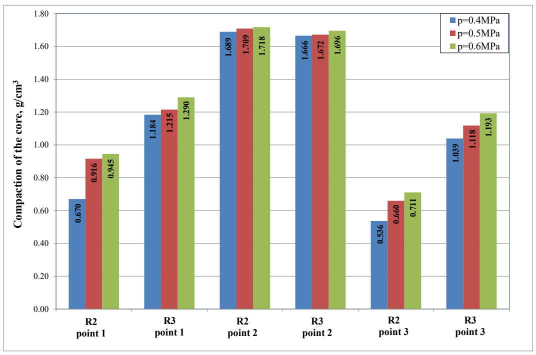

Fig. 15. Comparison of the apparent density distribution in cores R-2 and R-3 shot at various pressure values. Shooting hole diameter equal 20 mm

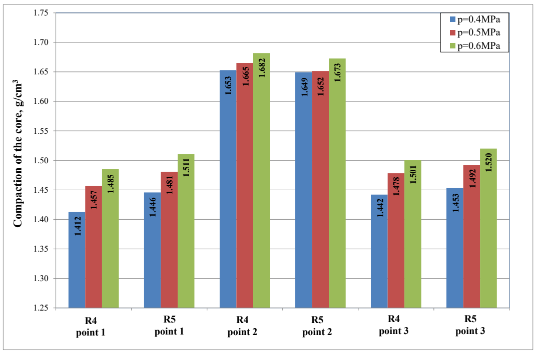

Fig. 16. Comparison of the apparent density distribution of core sands in core boxes R-4 and R-5 shot at various pressure values. Shooting hole diameter equal 10 mm

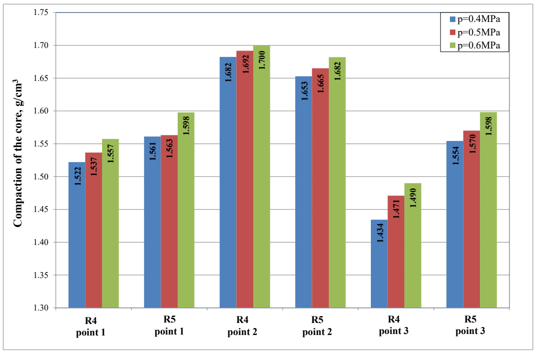

Fig. 17. Comparison of the core sand apparent density distribution in core boxes R-4 and R-5 shot at various pressure values. Shooting hole diameter equal 20 mm

5. Conclusions

The following conclusions and remarks concerning the operations of deaeration systems in core boxes, can be drawn on the bases of the presented results.

1. The strong asymmetry of the distribution of the sand apparent density occurs in core boxes filled with sands shot by individual shooting holes. Regardless of the applied pressure and nozzle diameter the highest apparent density of the sand occurs in the shooting hole axis and becomes lower when this sand is moving in the direction of the cavity side walls. The practical conclusion arising from investigations indicates that the highest strength related to the sand compaction degree has the analogous course as the apparent density curves. Whereas the gaseous permeability of the core, being of the inverse character in relation to the sand density at the lengthening of the shot axis is limited in relation to external layers of the core.

2. Increasing of the shooting hole diameter causes the increase of the sand density in the whole core, while the pressure increase causes a larger increase of the apparent density when the nozzle diameter is smaller.

3. The placement of the deaerating holes directly in front of the blowing hole should be avoided, since in such case the effect of limiting the free sand flow occurs, due to pressing the sand to deaerators by the evacuated air.

4. Narrowing parts occurring in the cavity cause increased resistances of the two-phase air-sand mixture flow. Thus, more advantageous conditions of influencing the compacting distribution can be obtained at a lower concentration of the solid phase in the air flux and at creating - by the deaeration system - the pressure gradient advantageous for the air flow to the core parts far away from the shooting axis. The majority of deaerators should be placed in the upper part of the core box or in the vicinity of the blowing hole.

5. When complex cores are shot the most advantageous is the separation of their sectors, which can be filled by individual shooting nozzles limiting the necessity of the sand flow inside the core box cavity. The system of the sector deaeration should be the proper one.

Acknowledgements

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