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The Technique of Inorganic Core Sand Shooting with Reduced Pressure in Venting System

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Abstract

The publication presents a new shooting technique with reduced pressure in venting system for manufacturing foundry cores using inorganic sand mixture with Cordis binder. Traditional technologies for producing casting cores using blowing methods, despite their undeniable advantages, including the ability to produce cores in series, also come with some disadvantages. The primary drawbacks of the process involve uneven compaction structure of the cores, with denser areas primarily located under the blow holes, and under-shooting defects, which often occur in regions away from the blow hole or in increased core cross-sectional areas. In an effort to improve core quality, a concept was developed that involves incorporating a reduced pressure in the core box venting system to support the basic overpressure process. The solutions proposed in the publication with a vacuum method of filling the cavities of multi-chamber core boxes solve a number of technical problems occurring in conventional blowing technologies. It eliminates difficulties associated with evacuating the sand from the chamber to the shooting head and into technological cavity and increases the uniform distribution and initial degree of compacting of grains in the cavity. The additive role of this "underpressure" support is to enhance corebox venting by eliminating 'air cushions' in crevices and structural elements that obstruct the flow of evacuated air. The publication presents the results of studies on core manufacturing using blowing methods conducted in three variants: classic overpressure, utilizing the core box filling phenomenon by reducing pressure, and an integrated approach combining both these methods.

Keywords: Foundry engineering, Sand moulds and cores, Inorganic binder materials, Core shooting technique

1. Introduction

The currently available knowledge in the field of theory and practice of conventional blowing processes is based to a large extent on the previous work of a number of researchers who focused their research efforts to a greater extent on the technological aspects of the process and its application to the core materials of the time and to the research methods and measurement possibilities that existed at that time [1]. Publications from the last

decade are evidence of great interest in both improving the technological side of the blowing process itself, as well as significant progress in the construction of blowing machines in response to the needs of the dynamic development of automotive technology and machine construction [3-10]. The monograph [2] contains a synthesis of practically the most up-to-date research on the blowing process and the following factors influencing its course:

- mechanism for creating a two-phase sand-air stream in the outlet part of the shooting or blowing head,



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- evacuation of the core sand from the cartridge chamber in the form of a free sand-air stream flow,
- phases of filling the core box with a sand-air stream with a changing concentration of the solid phase,
- final sand compaction resulting from the packing of matrix particles under the influence of the kinetic energy of the stream and the movement of sand layers of a pressing nature, associated with the pressure to overcome the hydraulic resistance during air filtration through the sand into the vent holes.

Existing technologies for making cores using blowing methods, which use the possibility of forming the hydrodynamic properties of a mixture of the solid phase and air in order to improve the process of filling and compacting the core sand in the technological space, will continue to be used in foundry regardless of the 3D incremental techniques used [11-14]. The state of knowledge of blowing processes allows attention to be extended to the possibilities of existing solutions by using granular material "sucked in" from the technological cavity through vent holes to shape the core internal structure.

The solution proposed in the publication with a vacuum method of filling the cavities of multi-chamber core boxes [15] solves a number of technical problems occurring in conventional blowing technologies. The practical implementation of the proposed solution means moving away from blowing heads with one central outlet to multi-hole heads and an autonomous venting system. Thus, it eliminates difficulties associated with evacuating the sand from the cartridge chamber to the head and technological cavity and increases the uniform distribution and initial degree of packing of grains in the cavity. As a result of directed air filtration, under the influence of the pressure difference, subsequent layers of sand introduced and remaining in the cavity are moved frontally and compacted. This also creates better conditions for compaction by shooting an additional portion of the sand in a process already carried out in a conventional way (so-called additional compaction). The solution being the subject of the publication consists in the integration of two methods of filling the core box cavity: a) overpressure shooting of core sand from the cartridge chamber into the core box, b) using a vacuum core box venting system to direct the flow of the sand-air mixture stream in its cavity.

2. Experimental station

Tests on the shooting of foundry cores both in the classic (overpressure) system and in the so-called integrated one were carried out on an experimental version of the SR-3D laboratory shooter. The classic version of the position was widely described in publications [1,5,8,15,16]. The modernization of the station consisted of connecting the vacuum-generating system to the existing station, which is schematically shown in Figure 1.

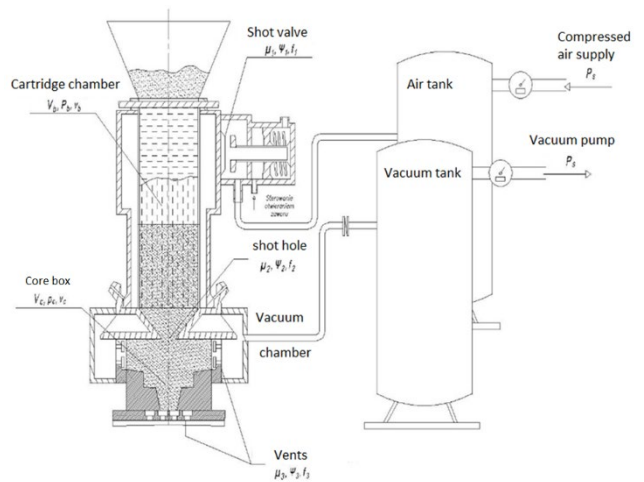


Fig. 1. Schematic of the modernized SR-3D core shooting station allowing for testing the overpressure and underpressure processes [2, 15,16]

The working space of the experimental core box was divided into three sectors with a volume of 300.4 cm³ each, by using partitions with orifice through which the sand-air stream flows from the sector located under the blow hole to the side sectors. In this case, the rectangular orifices of area 2.5 cm² each were symmetrically arranged at the bottom in two mounted partitions. The view of the core box with installed partitions are shown in Figure 2.

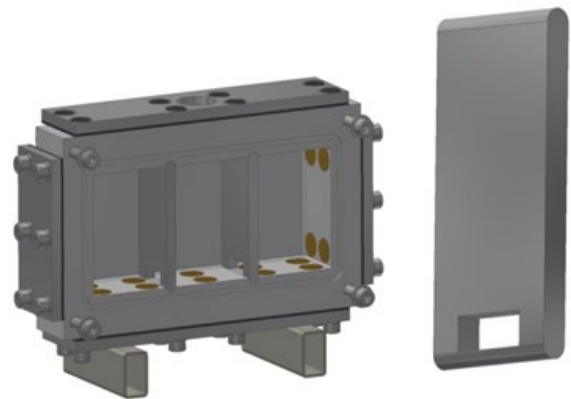


Fig. 2. View of the core box with installed partitions, and view of the partition with a rectangular through-hole with an area of 2.5 cm² [2, 15, 16]

3. The course of research

The tests were carried out on sand with the inorganic binder Cordis based on a silicate solution. The matrix was "Sibelco" quartz sand -1K 0.40/0.32/0.20, J88, >14000C, WK = 1.20 (according to PN-83/H-11077) - 100 parts (weight), cordis binder – 2.2 parts w., anorgite 8322 – 1.2. part w.

Due to the fact that the research concerned only the process of filling the cavity of the core box, the core sand mixture was not subjected to the hardening process both for the standard process and with the use of vacuum pressure. The research was carried out according to the scheme presented in Figure 3.

The process was divided into two stages. In the first stage, the classic system of the overpressure blowing process was tested, which was treated as a reference system for further research carried out on the shooting machine.

The overpressure process was carried out for one blow hole of 25 mm and three supply pressures of 0.3, 0.4 and 0.5 MPa. While filling the core box, the pressure patterns in the cartridge chamber and the core box were recorded.

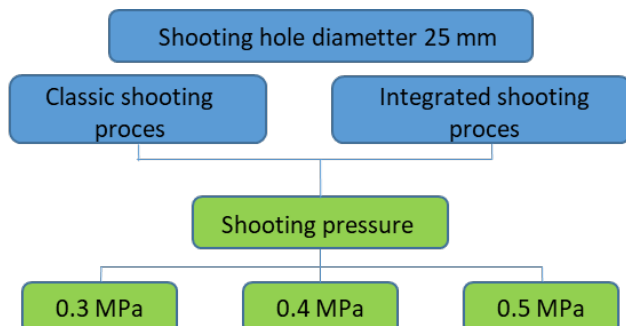


Fig. 3. Test scheme for the testing of classic overpressure process and the integrated process system [15]

The second stage, i.e. the integrated process system, was carried out with the same shot pressure settings, while a quasi-vacuum system was connected to the system of active vent holes. The place of connecting the vacuum and pressure transducers in the core box is shown in Figure 4.

The following criteria were adopted to assess the compaction effect:

- the amount of core sand shot into the core box, calculated from the weight balance of the sand introduced into the shootin chamber and the remains after the shot,
- density measurement, which involves extracting the entire sand from each separated space and then relating it to the volume of a given sector.

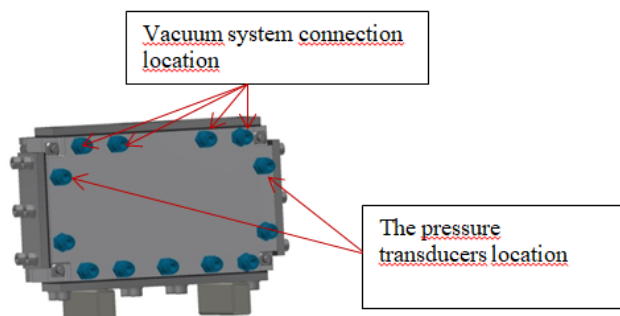


Fig. 4. Placement of the connection points of the vacuum system and the air pressure measurement system in the second stage of the tests.[15].

4. Research Results

As the research has shown, the flow holes used in the partitions limit the movement of the sand and air mixture from the central sector located directly under the blast hole to the side sectors. For a blow hole diameter of 25 mm, this process is particularly visible for the lowest value of the supply pressure of 0.3 MPa. For this pressure, sectors 1 and 3 were underfilled, as illustrated in the photo below (Fig. 5). After shooting sand in the classic overpressure method, 142.7 g (20.4%) of sand was found in the left sector (No. 1), and 137.6 g (19.4%) of sand in the right sector (No. 3). The central sector (No. 2), completely filled, contained 418.2 g (58.9%) of sand.



Fig. 5. Visualization of filling the core box sectors for a shooting pressure of 0.3 MPa and a blow hole diameter of 25 mm with the classic method of shooting [15]

The use of an integrated process in which a vacuum system is connected to active vent holes significantly improves the process of filling the entire core box, as shown by the data on the apparent density values obtained as a result of filling the side sectors even for the lowest pressure (Fig. 6), but also equalizes the apparent density between individual sectors visible at the blow pressure. In this case, with an increase of 27.7% in the total amount of sand shot into the core cavity, its amount in the left sector No. 1 was 347.7 g (30,9%) of sand, and on the right side sector No. 3- 362,8 g (32,3%). The central sector No. 2, which was fully filled, contained 411.7 g (36,7%) of sand.

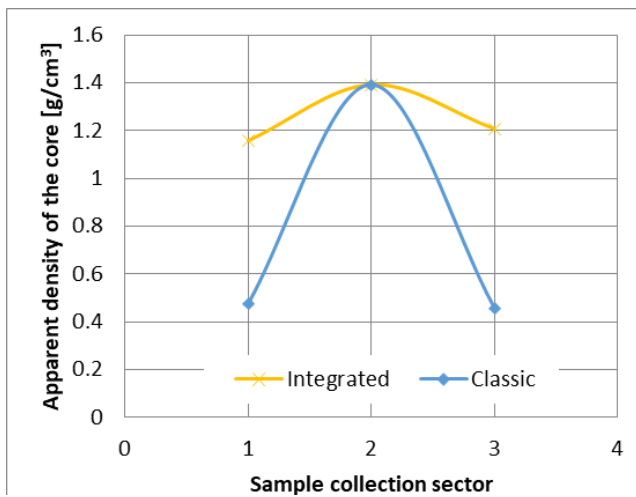


Fig. 6. Distribution of the apparent density of the core sand for a supply pressure of 0.3 MPa for the classic and an integrated system (with pressure $p = -0.1$ MPa, relative to atmospheric pressure) [15]

As the process pressure increases, for the classical system, the side sectors of the core box are increasingly filled, and for a shooting pressure of 0.5 MPa, the side sectors are almost completely filled, as illustrated in Figure 7. Data regarding the apparent density in the tested sectors are shown in Figure 8.

The increase in the total amount of sand accumulated in the three sectors caused by the higher shooting pressure combined with the use of reduced pressure in the technological space is 37%. In the discussed case, in the left sector (No. 1) relative to the core box axis, after the filling process, 246.0 g (25.7%) of sand was found, and on the right side (No. 3) 287.9 g (30.1%). The central sector, (No. 2) which was fully filled, contained 423.4 g (44.2%) of sand.



Fig. 7. Visualization of filling the core box sectors for a shooting pressure of 0.5 MPa and a blow hole diameter of 25 mm, for an integrated process (with pressure $p = -0.1$ MPa, relative to atmospheric pressure) [15]

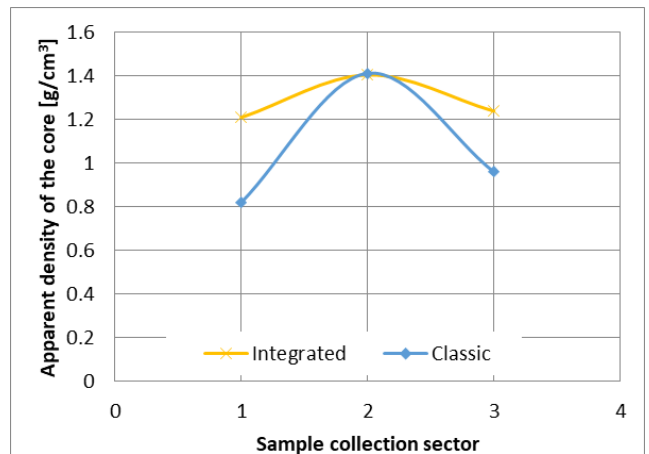


Fig. 8. Distribution of the apparent density of the core sand for a supply pressure of 0.5 MPa for the classic and integrated system (with pressure $p = -0.1$ MPa, relative to atmospheric pressure) [15]

During the tests, the influence of the test time was found, using a sand Cordis with the same composition and method of preparation, but used immediately or after a standing time of several hours. In general, it can be stated that the results of tests on fresh mixture give higher values than the used sand, both in the conditions of shooting in the classic system and with the support of the venting system by means of under pressure. Under these conditions, taking into account the integrated process itself, regardless of the supply pressure, almost equal density values were obtained both between the side sectors, which amounted to approximately 1.2 g/cm³ (Fig. 6 and Fig. 8). The amount of core sand shot into the core box for all three pressures was also at the same level and amounted to an average of 1145.4 g. A summary of the average weight of the cores for both methods of implementing the processes and the given system supply pressures is presented in Figure no. 9.

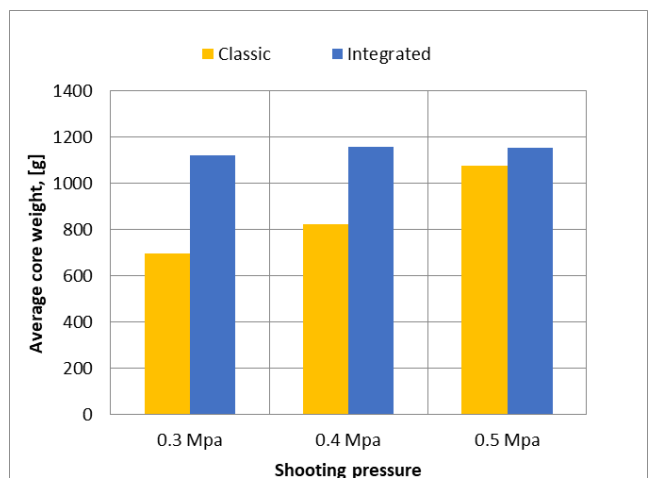


Fig. 9. Summary of the average weight of feed pressure cores 0.3; 0.4 and 0.5 MPa for the classic and integrated system (with negative pressure $p = -0.1$ MPa, relative to atmospheric pressure)

5. Summary

The example of testing the influence of core shooting using reduced pressure included in the article concerned a deliberately selected, unfavorable situation of filling a three-cavity core box with one blow hole located in the central sector. This creates the need for the stream to flow through the holes in the partitions to the side sectors and is associated with the loss of part of the energy of the sand stream to overcome frictional resistance.

In practice, when the core sand is shot into multi-sector cavities of the core box, then the shooting heads are used in which the number of blast holes corresponds to the number of sectors and the intra-sectoral movement of the shot sand is limited to the advantage of the achieved compaction effect.

Own tests at the SR 3D shooting station using a three-sector core box and core mass with an inorganic Cordis binder, carried out by shooting in a classic (overpressure) system and in an integrated system - a number of benefits are already revealed at this stage.

Forced air suction from the inside of the core box through ventilation holes into the vacuum system tank can be used to control the density distribution beneficial in core hardening technologies by blowing with active gases or hot air. The use of reduced pressure makes it possible to fill sectors distant from the blow hole, which would not be possible in the system of a traditional single-hole blow head. After using the partitions at the lowest pressure of 0.3 MPa, their density improved by approximately 30-60% compared to the classic process, and for the pressure of 0.5 MPa by approximately 40%. The integrated filling process also increases the average core weight. For a process pressure of 0.3 MPa, the core sand for the classic process was 698,5g, while for the same pressure in the integrated process it was 1122,2g. (more by 57.2%) In the case of a pressure of 0.5 MPa in the classical process, the average core weight was 957,4g and in the integrated process 1155,3g.

It seems that by using reduced pressure in venting system we can both improve the density of the cores, especially in places with difficult flow, but also extend the life of the core box itself by reducing its tribological wear at a reduced process pressure.

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References

- [1] Dańko, J. (1992). *Process of production of moulds and cores by mean of blowing methods. Theory and tests*. Series Dissertations and Monography. AGH Publishing House. (in Polish).
- [2] Dańko, R. (2019). *Blowing Processes and Machines in Core making technologies for Foundrie*. Katowice-Gliwice: Archives of Foundry Engineering. (in Polish).
- [3] Delimanová, P., Vasková, I., Bartošová, M. & Hrubovčáková, M. (2023). Influence the composition of the core mixture to the occurrence of veinings on castings of cores produced by cold-box-amine technology. *Archives of Metallurgy and Materials*. 68(3), 947-953. DOI: <https://doi.org/10.24425/amm.2023.145458>.
- [4] Dańko, R., Dańko J. & Skrzyński, M. (2017). Assessment of the possibility of using reclaimed materials for making cores by the blowing method. *Archives of Foundry Engineering*. 17(1), 21-26. 10.1515/afe-2017-0004.
- [5] Walker, M., Palczenski, S., Snider, D. & Williams, K. (2002). Modeling Sand Core Blowing: Simulation's Next Challenge. *Modern Casting*. 92(4), 41-43. ISSN: 0026-7562.
- [6] Dańko, J., Dańko, R., Burbelko, A. & Skrzyński M. (2012). Parameters of the two-phase sand-air stream in the blowing process. *Archives of Foundry Engineering*. 12(4), 25-30. DOI: 10.2478/v10266-012-0102-1.
- [7] Fedoryszyn, A. Dańko, J., Dańko, R., Aslanowicz, M., Fulko, T. & Ościłowski. A. (2013). Characteristic of Core Manufacturing Process with Use of Sand, Bonded by Ecological Friendly Nonorganic Binders. *Archives of Foundry Engineering*. 13(3), 19-24. DOI: 10.2478/afe-2013-0052.
- [8] Aksjonow, P.N. (1965). *Selected issues in the theory of foundry machines*. Katowice: „Śląsk” Publishing House. (in Polish)
- [9] Budavári, I., Hudák, H., Fegyverneki, G. (2023). The role of acid hardener on the hardening characteristics, collapsibility performance, and benchlife of the warm-box sand cores. *Archives of Foundry Engineering*. 23(1), 68-74. DOI: 10.24425/afe.2023.144282.
- [10] Czerwinski, F., Mir, M. & Kasprzak, W. (2015). Application of cores and binders in metal casting. *International Journal of Cast Metal Research*. 28(3), 129-139. <https://doi.org/10.1179/1743133614Y.0000000140>.
- [11] Sivarupan, T., Balasubramani, N., Saxena, P., Nagarajan, D., El Mansori, M., Saloni, K., Jolly, M. & Dargusch, M.S. (2021). A review on the progress and challenges of binder jet 3D printing of sand moulds for advanced casting. *Additive Manufacturing*. 40, 101889, 1-17. <https://doi.org/10.1016/j.addma.2021.101889>
- [12] Cheng, Y., Li, Y., Yang, Y., Tang, K., Jhuang, F., Li, K. & Lu, C. (2022). Greyscale printing and characterization of the binder migration pattern during 3D sand mold printing.

- Additive Manufacturing*. 56, 102929, 1-13. <https://doi.org/10.1016/j.addma.2022.102929>.
- [13] Liu, H., Lei, T. & Peng, F. (2023). Compensated printing and characterization of the droplet on the binder migration pattern during casting sand mold 3D printing. *Journal of Manufacturing Processes*. 108, 114-125. <https://doi.org/10.1016/j.jmapro.2023.10.073>.
- [14] HA Group (2024). *Additive Manufacturing*. Retrieved February 20, 2024, from [https://www.ha-](https://www.ha-group.com/pl/en/products-and-services/products/additive-manufacturing/)
[group.com/pl/en/products-and-services/products/additive-manufacturing/](https://www.ha-group.com/pl/en/products-and-services/products/additive-manufacturing/)
- [15] Dajczer, G. (2024). *Integrated process of making casting cores by blowing method using reduced pressure of venting the core box*. PhD dissertation. AGH Krakow.
- [16] Dańko, R., Dańko, J. (2023). Processes and mechanized systems for manufacturing casting core. In Chapter IV of *Foundry's Guide*, volume 2. Polish Kraków: Foundrymen's Association.