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Conceptual Design of a Core Making System

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Abstract

The paper presents the topics related with the production of small and medium-sized cores by means of blowing methods. The basic information concerning the manufacturers of the blow-ing machines and the general characteristics of machines offered by them are presented. The basic design of blowing machines are presented with discussions of the theoretical works of Boenisch, Axionov and J. Dańko determining important from the technology point of view sand and air flow parameters including different methods of core box filling factors and the factor e_V representing the sand ability to evacuate from the shooting chamber.

Key words: Foundry cores, Blowing and shooting processes, Experimental investigations, Simulation calculations

1. Introduction

Automatic systems for small and middle-sized core manufacturing typically use core shooting or blowing machines for core box filling and sand compaction. Such machines are now available from well-known European manufacturers, such as DISA (Norican Group), LAEMPE and EUROTEK, enabling core-making by various technologies. The machines differ in the level of automation of core-making processes, the core size, core box separation area and the capacity.

The group of manufacturers includes also the Ferro-Masz company, specialising in mechanised core making equipment, particularly for the cold-box technology [1]. Relying on the expertise of the research team from AGH-UST and their own experience in implementing core making solutions, the Ferro-Masz company undertook to design an universal core making system.

The universal core making system is based on solutions already implemented in several foundry plants in Poland, utilising the cold-box technology. The shooting machine is the key component of the system, also incorporating a mixer, dosing units and feeders, hardening agent dosing and a pneumatic-powered sand supply.

2. Preliminary assumptions. Current expertise

The size of the currently available core shooting machines defined by their characteristic parameter: the core volume is : 2-25 dm^3 (Eurotek) and 20-250 dm^3 (DISA). Similar capacity of the sand shooting tank is available in shooting machines manufactured by the Laempe company (1-200 liters).

The analysis of current demand from the domestic foundry plants has prompted the design engineers to prepare the technical documentation required to commence the production of a series of universal core making machines, with the sand shooting tank volume V_{km}=12, 16, 20, 25, 40 dcm^3, the basic machine in this series being a core shooter with the shoot volume V_{km}= 20 dm^3.

Technical parameters of an universal shooting machine with the shoot volume 20 dm^3 are summarized in Table 1. A schematic diagram of the core making solution with gas-hardening is shown in Fig 1.

Table 1.
Technical parameters of an universal shooting machine [1]

	Specification	Unit of measu-rement	Quantity
1	Nominal core volume	l	20
2	Maximal core box depth	mm	800
3	Maximal core box height	mm	600
4	Minimal core box height - horizontal parting	mm	~ 300
5	Maximal box width - vertical parting	mm	1. 200
6	Maximal shooting area	mm	400×400
7	Vacuum area for box installation	mm	350×200
8	Vertical thrust height	mm	do 70
9	Working pressure of compressed air	MPa	0,6
10	Electric power supply- AC 50 Hz	V	400/230
11	Maximal length of the core-making machine	mm	3400
12	Maximal width of the core-making machine	mm	2390
13	Maximal height of the core-making machine	mm	2300
14	Installed power	kW	ok. 23
15	Mass of the core-making machine	Mg	ca' 5,5

The newly-designed core shooting machine offers universality and flexibility as it is provided with the following functional units:

- an exhaust valve with the controllable exhaust area and controllable dynamic behavior to allow for adjustment of the pressure increase rate – a characteristic parameter of the shooting and blowing processes,
- shoot tank allowing the supply of air onto the upper surface of the sand mass column (blowing action) or, via a perforated hopper, to the side surfaces (shooting),
- blowing and shooting heads, varying in shape, configuration and opening sizes, also provided with the cooling system for use in hot processes.

The solutions chosen for implementation are selected basing on the analysis of their construction and the range of their operational parameters.

Of particular importance is the construction of blower/shooting valves, which strongly impacts on the core-making performance. A survey is made of valve constructions applied in shooting machines to find the common features that are required for the core-making process. On that basis the guidelines for valve design will be formulated accordingly.

The model of the blowing process has been developed, based on the analysis of functional units and components in a shooting machine. The objectives and input data for modelling of the blowing processes are confined to the analysis of functional units and factors affecting the air flow in the sand-free system comprising the grid- equalising tank- shoot tank- core box-ambience. The variables in the calculation procedure include the air pressure in the grid, volumes of the equalising tank, shoot tank and of the core box, the surface area of the shooting valve and the exhaust opening in the shooting head, the level of venting.

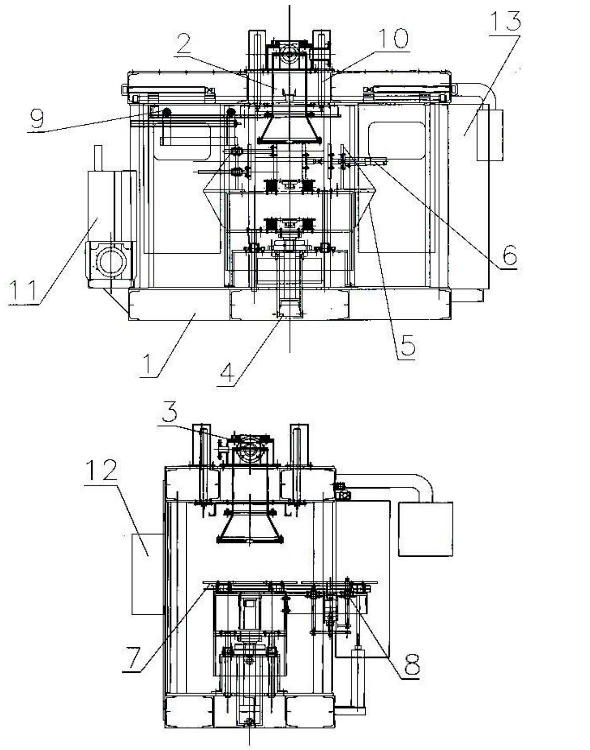

Fig 1. Schematic diagram of a shooting machine: 1 – machine frame, 2 – shooting head, 3 – shoot valve, 4 – table-lifting cylinder, 5-core box table, 6 – core box opening, closing and clamping assembly, 7 – core removal mechanism, 8 – core push assembly, 9 – gas hood with ejection plate, 10 – clamping of horizontally split core box; 11 – hydraulic-pneumatic installation, 12 – hydraulic system, 13 – electric-powered supply and control system

Theoretical calculations of parameters of blowing and shooting machines take into account the influence of the opening speed on the rate of ultimate pressure increase pbgran and pc gran and on the intensity Ip of pressure increase in the shoot tank.

Supported by the extended and specialised Aksonov's model [2,3] and the created numerical program, the calculation and simulation procedure is applied in the investigation of an air flow valve intended for a shooting machine with the shoot tank volume V_b=20 dm^3.

3. Technology requirements

The flexible design of the main blowing unit (blower, shooter) and of the remaining devices must take into account the requirements imposed by the particular core-making process technology. The wide range of sand mix types is considered: loose self-hardened, quick-hardened sand mixes containing organic and inorganic binders, loose fast binding mixes, including those to be used in the Croning moulding hot box and warm box processes, thermo-hardened (Thermoshock) and warm air processes.

Depending on the type of the core-making process, the following parameters were determined:

- technological properties of core sand, pertaining to the core-filling with the sand-air mixture and indicators of the core mixing ability to fill the core box,
- level and quality of box filling and sand compaction, taking into account such parameters as: the type of core sand, intricacy of the core shape, air pressure, size of blowing and venting holes.

Within the framework of the Author's previous research program [3], empirical formulas were developed to compute the average compaction level for the given type of the core sand, basing on the initial apparent density of loose mix, working pressure and the blowing hole diameter. These data, supported by simulations of critical pressure levels pbgr, yield the average apparent density of the sand in the model core.

The characteristics of box filling and sand compaction by the blowing and shooting methods are obtained by measuring techniques and methods, using the experimental set-up and equipment:

- LUT/c/CO2/An device for fabricating shaped elements and small cores in the hot-box and cold-box processes, CO_2 and hot air gassing,
- blowing machine PS-1 for establishing the core compaction parameters, chiefly in the hot-box and cold-box processes,
- blowing/shooting machine SR-3D provided with a valve with the adjustable opening stroke and with bushings in the housing in the form of cylindrical inserts containing core sand; the machine is used to determine the effect of the air pressure and its distribution within the shooting tank on the major (flow rate of sand, thrust force) and minor parameters (sand-air flux density, its velocity and volumetric concentration) of the blowing process;
- hot-air hardening unit,

Modernised testing apparatus for determining the sand ability to leave the shooting tank and fill the core box (Fig 2).

Tests performed in this set-up have led to the development of a laboratory- scale testing procedure to reconstruct the evaluation of applicability of sand mix types to be used in shooting or blowing processes, similar to the approach suggested by D.Boenisch and Knauf [4]. Thus formulated criteria defining the degree of the box filling (box filling factor) allow us a better insight into the behaviour of sand during the flow and box filling controlling the compaction level and structure, which in turn determines the durability and permeability of sand mix after hardening.

The property of the sand mix associated with the box filling quality is expressed as the box filling factor, which may be used as the basis for evaluating the efficiency of sand compaction by the methods discussed here.

According to [4], the box filling factor is given by the formula:

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

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/m^3
V_c- core volume; m^3
ρ_{pmax}- apparent density of the standard core sand compacted by vibrations until reaching the fixed value; kg/m^3

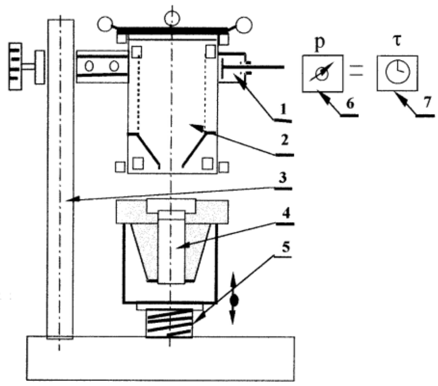

Fig 2. Experimental set-up complete with the apparatus for determining the effectiveness of sand ejection from the shooting tank and box filling processes, comprising the following assemblies:

- testing apparatus; a tripod (3) to which the shooting tank in the shooting machine (2) is attached, complete with a shooting valve (1),
- air tank (6) with an integrated manometer for pressure measurements;
- shoot time control (7) integrated with a PC computer to determine the real shoot time and shooting pressure,
- tester (4) with a profiled niche section and with the set screw (5)

In this method the maximal compaction of sand grains is obtained by applying vibrations to a core box filled with dry silica sand for a time period after which the apparent density increase effect is not longer observed.

An alternative method [5-8] involves the analysis of the box filling factor, expressed by the formula:

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

where:
M_r, p_{pm}, V_c- designations as in formula (1),
$M_{st}=V_c$ □ρst – assumed core mass; kg/m^3,
P_{st}- apparent density of sand in a cylindrical sample after a treble compaction with a standard rammer; kg/m^3.

The physical interpretation of the two coefficients K_{zr} and FG implicates that K_{zr} better reveals the influence of intricacy of the core box niche on the sand compaction effect whilst the box filling factor FG is useful when evaluating the tendency of various sand mixes to thicken when inside the core box.

The effects of shooting pressure on the value of the box filling factor K_{zr} for the selected core sand types are shown in Fig 3.

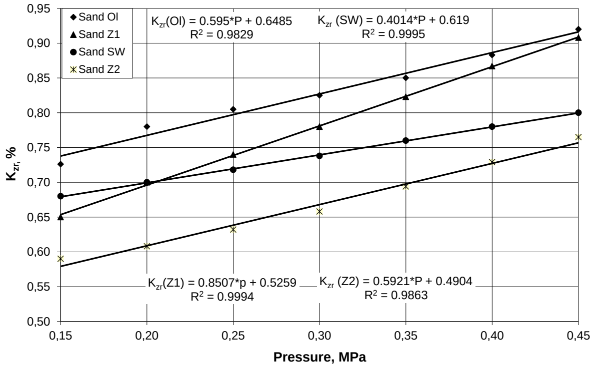

Fig. 3. Dependence of the filling ability factor K_{zr} on the shooting pressure. Ol - Sand with linseed oil varnish, SW-Sand with water-glass, Z1- Sand with furfuryl resin 1031 for the hot-box process, Z2- Sand with furfuryl resin MM-155 for the hot-box process

An alternative measure of the sand suitability to be compacted by the blowing methods is the coefficient of sand ejection from the shooting tank e_v, in accordance with the relevant formulas [4,5]:

$$e_v = \frac{\Delta M}{m_0} = \frac{m_0 - m_1}{m_0} \cdot 100\% \qquad (3)$$

where:

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

ΔM- the amount (mass) of sand which entered the core box (tester); g

Basing on that data, assessment can be made of the maximal achievable level of mass ejection from the shoot tank under the specified working pressure, which is particularly useful when estimating the amount of the core injected in the given core making machine and for the given core sand type.

3. Summing-up

Core-making machines vary in terms of their technological advancement and the level of specialisation of the implemented solutions, and the tendency is revealed for connecting the machine type with the given process technology. In the context of this approach, manufacturers provide a wide range of core-making machines- starting from single units to integrated, computer-controlled, unmanned systems. State-of-the-art core-making machines are developed, utilising advanced process technologies and provided with ancillary equipment (gas neutralisers, scrubbers). Core-making, finishing (cleaning, shell coating and drying), assembly and storage for transport are now fully automated. The core-making now uses also robots which perform manipulative tasks, including the replacements of parts and units. It is a general principle that currently available the blowing /shooting machines can be easily configured to adapt to the requirements imposed by the core-making process technology whilst more universal solutions are hardly available, mainly due to the necessity to adapt to operation within a wide range of process parameters. That makes the implementations of core-making technologies unavailable to small and medium –sized foundries.

The newly designed and successively manufactured series of machines allowing for adapting their tools and equipment to the needs imposed by various process technologies, including the hot-air process, will cater for the needs of several foundry plants in Poland as they are open to novel solutions of universal and flexible blowing /shooting machines.

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