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## THE RATIONALIZATION OF CONSTRUCTION AND OPERATION OF THE EQUIPMENT FOR THE MOULDING SAND PREPARATION

### RACJONALIZACJA KONSTRUKCJI I EKSPLOATACJI URZĄDZEŃ DO PRZEROBU MASY FORMIERSKIEJ

The rationalization of construction and vibro- fluidised bed coolers and turbine (rotary) mixers, allows for keep sufficiently high quality and increasing their utility values. This concerns optimization of construction and operation to increase the efficiency of their work. The presented research results illustrate a range of the work designed primarily to supplement theoretical foundations of realized processes in industrial devices, including the topics vibro- fluidization , evaporative cooling and refreshing mixing. Presented results concern the investigation of the industrial devices, which is difficult in the practical accomplishment. The part of testing was conducted in real terms of the functioning devices in the industry.

*Keywords:* mechanisation and automation, moulding sand preparation, vibro- fluidised bed coolers, turbine mixers

Racjonalizacja konstrukcji i eksploatacji chłodziarek wibrofluidyzacyjnych oraz mieszarek wirnikowych pozwala na utrzymanie odpowiednio wysokiej ich jakości i zwiększanie ich walorów użytkowych. Dotyczy to optymalizacji konstrukcji i eksploatacji urządzeń celem zwiększenia efektywności ich pracy. Prezentowane wyniki badań ilustrują zakres prowadzonych prac mających przede wszystkim na celu uzupełnienie podstaw teoretycznych realizowanych procesów, w tym o zagadnienia wibrofluidyzacji, chłodzenia wyparowego i mieszania odświeżającego. Zaprezentowane wyniki dotyczą, trudnych w realizacji praktycznej badań urządzeń przemysłowych. Część badań przeprowadzono w rzeczywistych warunkach pracy urządzeń w przemyśle.

### 1. Introduction

The moulding sand treatment includes preparation of the return sand and preparation – mixing with refreshing additives. Preparation of the return sand consist of impurities removal, crushing, sieving, homogenization and cooling. The substantial role of two recent operations is being emphasized in the many research works [e.g. 1,2,3]. It concerns especially automatized foundry plant. There is no doubt that the proper run of moulding sand preparation processes decide about the quality of the moulding sand [4,5,6]. In this area the optimization of construction and operation parameters of devices for moulding sand treatment is especially meaningful [7,8,9]. One should also emphasize meaning of the energy consumption in the correct selection of parameters of devices above discussed [10].

### 2. General characteristics of the operation parameters of the equipment for the moulding sand preparation: vibro-fluidised bed coolers and turbine mixers

For many years for return sand cooling are used primarily the vibro- fluidised bed coolers [1,2], (Fig. 1).

It should be emphasized interdependence of many values characteristic for vibro-fluidization process and their simultaneous interaction both on transport of the sand and achieved cooling effect. Depending on the extent values appropriate factors are formed: average flow velocity of material handled  $v$ , layer height  $H$  and her porosity  $\varepsilon$ . These values decide about device output and contact time of fluidizing medium (air) with sand, which directly affects on intensity and efficiency of cooling system.

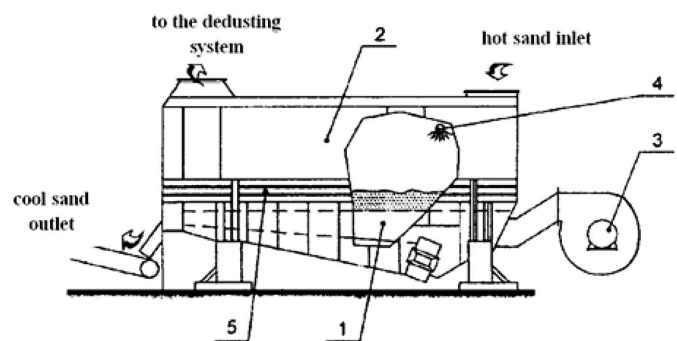


Fig. 1. Vibro-fluidised bed cooler production PPP. Technical- [www.technical.com.pl]: 1- operation chamber, 2- separation chamber, 3- fan, 4- water nozzles, 5- air distributor

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The capacity of vibro-fluidised conveyers, in this vibro-fluidised bed coolers depends mainly on: the width  $B$  of air distributor (through) – Fig. 2, speed movement of material handled  $v$ , layer height  $H$  and her porosity  $\varepsilon$  and tilt angle of the through. Layer height  $H$  and her porosity  $\varepsilon$  are influenced essentially by parameters of vibration (vibration acceleration, frequency, etc.) and speed  $u$  of the fluidizing medium [1,2].

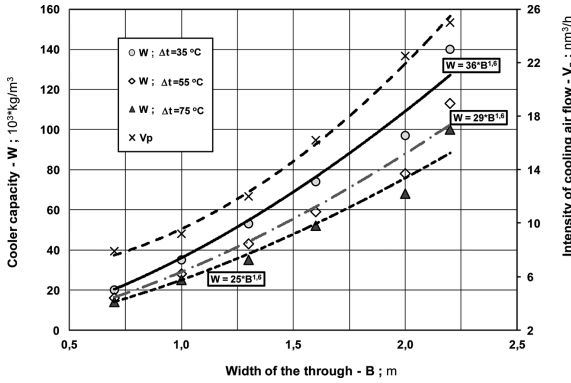


Fig. 2. Dependence between capacity of the cooler CFM –  $W$ , intensity of cooling air flow –  $V_p$  and the width of the through –  $B$  (air distributor) at different cooling efficiency –  $\Delta t$ ; maximal outlet temperature of the sand –  $45^\circ\text{C}$

The study of the evaporative cooling carried out in experimental vibro-fluidised feeders and industrial conditions by using the prototype cooler CFM 3510 with dimension of air distributor  $3,5 \times 1,0$  m [1,2]. The flow of moulding sand, synthetic with bentonite, cooled in tested cooler CFM 3510 averaged  $\dot{m}_{fp} = 5,56$  kg/s (max.  $\dot{m}_{fp} = 8,33$  kg/s) by initial moisture of sand  $w = 0,5 \div 1,5$  %.

The drive of through of cooler represented two electrical vibrators (Fig. 1), with the possibility of changing the position of the rotating masses. The line amplitude was  $a_{max} = 3,75$  mm, rotation speed  $n = 960$  rpm, power  $P = 1,6$  kW. Designed speed of material handled transport  $v = 0,1 \div 0,2$  m/s.

Supply in air cooling provided the blowing fan about capacity  $V = 2,2$  m<sup>3</sup>/s, rotational speed  $n = 2940$  rpm, power  $P = 11$  kW and compression  $\Delta p_c = 3150$  Pa. Obtaining the assumed underpressure in operation chamber of the cooler provided a connection to the exhaust with capacity about  $V = 2,55$  m<sup>3</sup>/s,  $n = 2940$  rpm,  $P = 15$  kW and  $\Delta p_c = 3750$  Pa. The water supply system consisted of 3 rows of nozzle (Fig. 1). The capacity of water flow by one nozzle was  $1,4 \div 2,4$  dm<sup>3</sup>/min.

Result testing of cooling sand with use of the cooler CFM 3510 allowed for verify a design assumptions [2], in this calculation of an efficiency of the exchange process of the heat and mass. The analysis a measurement data consisted of balance calculations for appropriate heat flows:

$$\dot{Q}_1 - \dot{Q}_4 + \dot{Q}_3 = \dot{Q}_5 - \dot{Q}_2 + \dot{Q}_R, \quad (1)$$

where:  $\dot{Q}_1, \dot{Q}_2, \dot{Q}_3$ , – heat flow supplied to cooler with hot sand, cooling air and addition water,  $\dot{Q}_4, \dot{Q}_5$  – heat flow discharged from cooler with cooled sand and exhaust air.

Equation (1) can be represented in the following form:

$$\Delta \dot{Q}_{mf} + \dot{Q}_3 = \Delta \dot{Q}_{pch} + \dot{Q}_R.$$

and simplified form by introducing  $\Delta \dot{Q}_{mf} + \dot{Q}_3 = \Delta \dot{Q}'_{mf}$ :

$$\Delta \dot{Q}'_{mf} = \Delta \dot{Q}_{pch} + \dot{Q}_R \quad (2)$$

where:  $\Delta \dot{Q}'_{mf}$  – heat flow exchanged by the cooled moulding sand with cooling air and environment,  $\Delta \dot{Q}_{pch}$  – heat flow related with change a enthalpy of cooling air;  $\dot{Q}_R$  – heat flow dispersed to the environment and the deviation resulting from measurement errors.

Calculations contain also a balance of moisture. An example indicator, of many designated [2], is volume specifying of amount cooled sand by 1kg air (Fig. 3). The value of this indicator was shaped from 2,3 do 2,5 kg cooled sand by 1 kg air of given properties.

Accumulated at work [1,2] research data constitute basic of studies a suitable control algorithms and selection work parameters of the cooling devices.

Sufficiently wide an adjustment ranges of basic parameters cooler: vibration amplitude, intensity of cooling water flow, and feed rate of the hot sand, the intensity of cooling air create the possibility of selecting the optimal working point of device by a different technological conditions and environment.

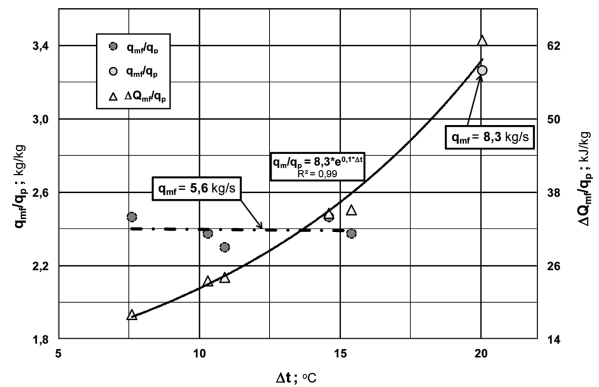


Fig. 3. Relation between amount of moulding sand cooled by 1 kg of air expressed by the ratio –  $q_m/q_p$ , efficiency of cooling air using expressed by the ratio –  $\Delta Q_m/q_p$  and cooling effect –  $\Delta t$ ;  $q_m$  – intensity of moulding sand flow in kg/s,  $q_p$  – intensity of cooling air flow in kg/s,  $Q_m$  – intensity of heat flow (received from hot sand) in kJ/s

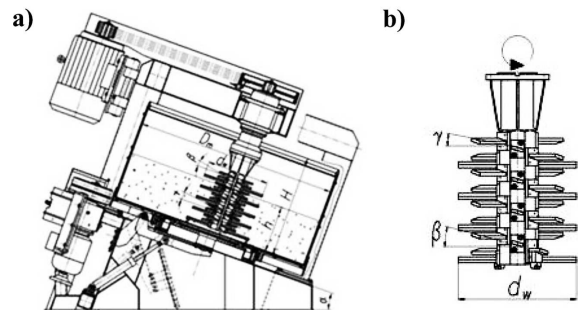


Fig. 4. Scheme a rotary mixer type MTP with moving, tilted pan a) and rotor b);  $D_m$  – diameter of pan,  $H$  – height of pan,  $h$  – height of resource sand,  $\alpha$  – angle inclination of bottom pan,  $\beta$  – angle inclination of rotor blades,  $\gamma$  – inclination of helical deployment of blades

Work in the scope of rotary mixers concerned both the theoretical and practical issues – construction assemblies and

operating parameters [4,5,6,8,10]. The results test allowed the rational choice of design and motor parameters for maximizing of technological properties of synthetic moulding sand with bentonite.

The schemes of rotary (turbine) mixers type MTP and MTI and their main characteristics are shown in Fig. 4÷6. In contrast to other construction mixers these have rotary pan and rotors positioned in stationary housing.

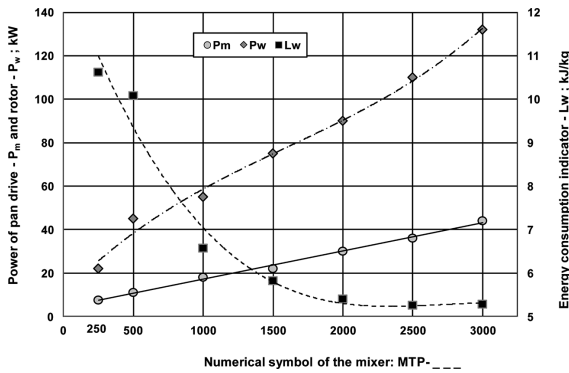


Fig. 5. Characteristics of series of MTP mixer. Energy consumption indicator –  $Lw = P_c * T_c / L$ ,  $P_c$  – total power of motors,  $T_c$  – mixing cycle (assumed: 90 s),  $L$  – load of the pan (values on the horizontal axis represent numerical symbol of the mixers eg. MTP – 500 and simultaneously volume of dosed sand during one loading in  $dm^3$ )

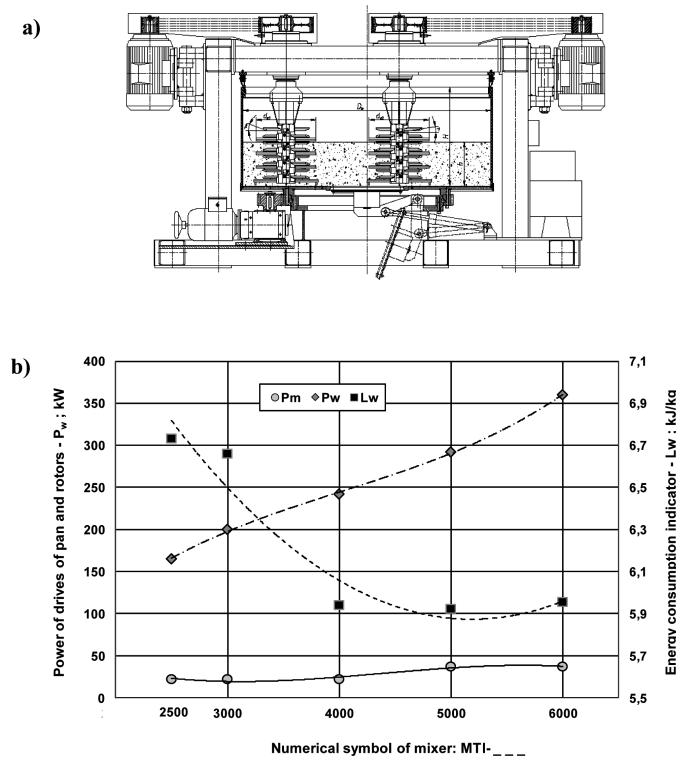


Fig. 6. Scheme – a) and characteristics of series – b) of rotary mixer with moving, horizontal pan, type MTI. Energy intensity indicator –  $Lw = P_c * T_c / L$ ,  $P_c$  – total power of motors,  $T_c$  – mixing cycle (assumed: 90 s),  $L$  – load of the pan (values on the horizontal axis represent numerical symbol mixers eg. MTI – 2500 and simultaneously volume of dosed sand during one loading in  $dm^3$ )

Construction – operating indices of rotary mixers this: slender pan amounting for mixer,  $H/D_m = 0,40 \div 0,66$ , rate of installed power in relation to the efficiency  $N/W = 2,31 \div 4,07$

and height filling pan of moulding sand relation to the diameter of pan  $h/D_m = 0,15 \div 0,32$ . Currently produced the rotary mixers (Technical Company, Nowa Sól) characterized by wide range of efficiency, which specifies volume of loading ( $V = 250 \div 6000 dm^3$  and cycle time of mixing =  $90 \div 120 s$ ). Research topics related mainly to: design parameters of rotor, shape and arrangement the blades, working parameters, such as direction and rotational speed of bowl and rotor(s), time of mixing load size, etc.

Parameter optimization was based on setting technological properties of sand in that compressive strength  $R_c^w$  and permeability  $P^w$  [8,9]. Parameter characterizing the process was also recorded current of the rotor drive. Example of its run found at Fig. 7.

Changes in power consumption (expressed by the current values) of the rotor driver for each of tested time mixing, reflect changes in moisture sand inside the mixer during the mixing process. Fig. 8 gives a chosen fragment of time run of dynamically measured values of current and moisture during the operation of the MTI-3000 mixer (time diagram from Fig. 8a elaborated on base of data from [3]). As one can see there is a good compatibility between sequence of both characteristics (Fig. 8a) and the good correlation between values of these quantities read from time course at the same time points (Fig. 8b).

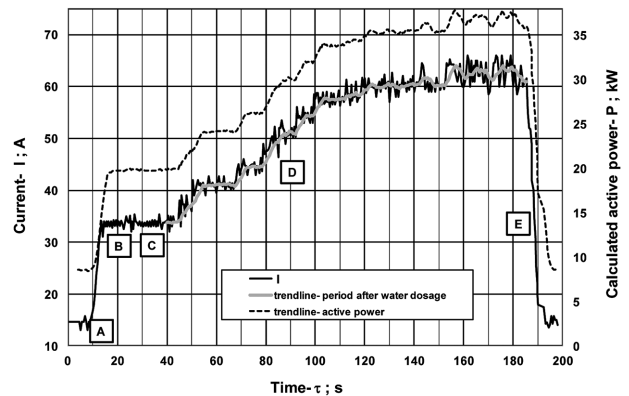


Fig. 7. Time run of current –  $I$  and calculated active power –  $P$  of rotor drive during operation of the MTP-500 mixer; A – loading, B – homogenization of the mixture, C – water dosing, D – mixing of moistured moulding sand, E – unloading. Active power calculation was performed assuming the constancy of voltage and power factor –  $\cos\varphi$  (stable conditions of operation)

Maximum power and current values reflects the state of obtaining by the moulding sand homogeneous properties. In addition to optimization studies was performer also analysis and characteristics events accompanying the refresher mixing. It was found that it is essential a shifting and aeration operation. Also appears rubbing and crushing. Important role in explaining a running events had testing changes in viscosity of the sand resulting from rheological properties synthetic sand with bentonite. The synthetic sand with bentonite is unstable rheological material, which results in decrease of viscosity thixotropic system during felling.

The decrease in dynamic viscosity, which is result of "destruction" thixotropic structure, depend on  $t$  time and speed of mixing (shear of water- clay paste). The scope of these changes was determined by methods ultrasonic testing, involving a da-

ta recorder the changes of ultrasonic wave velocity [7,11,12]. Compared data from ultrasonic testing been found, that in the case sand of rotary mixer occurs a greater reduction the viscosity than in the case a moulding sand mixing in the roller mixer. On viscosity reduction has primarily due a dynamics of the preparing process in the rotary mixer.

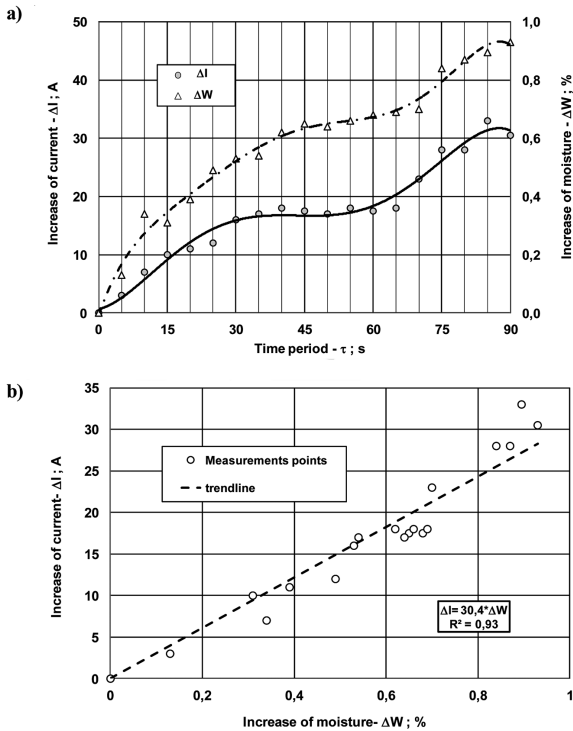


Fig. 8. Selected period of the MTI-3000 mixer operation (after water dosing): a) changes of current and moisture during mixing (dynamical measurements), b) correlation between increase of moisture of the moulding sand and current values read from time run at the same time point (data from [3])

### 3. Summary

Performed in industrial conditions the measurements and analysis of the results provided valuable material to verify the theoretical assumptions of work a vibro-fluidised bed coolers. Experimental verification the characteristics of coolers was necessary because in the source materials there are no comprehensive research results a vibro-fluidised bed coolers. Setting ranges of basic parameters the vibro-fluidised bed coolers work such: vibration amplitude, intensity of cooling water flow, intensity of cooling air flow, and feed rate the sand, create the possibility of selecting the optimal working point of device by a different technological conditions and environment. There are deliberate further research activities especially designed to improving algorithms controlling of work device.

Effectiveness of rotary mixers recommends them for general use – confirm this performed analysis and comparison test of different types of mixers. The circulation sand allowed to refresher mixing achieved the desired level of technological properties. Special attention was paid her high permeability

and high degree of disintegration (important in the implementation of modern techniques density of sand).

Construction and operational parameters of mixer significant impact on mixing process. Through the appropriate choice can be stimulated conditions of impact on sand the mixing units (intensity range). The studies confirmed that recovery properties of sand due to activation coating of bonding material. Important for the mixing process is fact the rheological properties of mixture water and clay.

The planned expansion of drive control systems of device surely will further increase its functionality and allow further optimization of working parameters in aspect energy intensity.

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