

Quality stabilisation of synthetic sand containing bentonite in process lines

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Abstract

Stabilisation of sand quality requires the monitoring and control of sand moisture contents and its other parameters at each stage of sand processing, i.e. during the preparation of return sand mix and rebonding processes. Stabilisation of sand quality necessitates the use of reliable control equipment and evaluation procedures. This study outlines the scope and results of research work aimed to improve the control equipment to enhance the performance of turbine mixers.

The paper reviews the measurement and control systems and equipment available from domestic manufactures and the evaluation procedures based on the principles of statistic process control.

Keywords: sand mix processing, sand quality stabilization, moisture control

1. Introduction

The process lines to handle synthetic sand containing bentonite include the sand preparation plant (Fig 1) where the return sand mix is prepared) and the rebonding unit.

Typically, sand processing lines incorporate vibro-airslide coolers and turbine mixers. Both coolers and mixers supported by control equipment, allow for process stabilisation with optimal effects such that the minimal amount of sand should be maintained in circulation and the time of sand-re-use should be shortened.

Vibro-airslide coolers produce an extensive interface zone, enabling the quick exchange of heat and moisture between the sand mix and the cooling air. Application of the water dosage system enables the effective evaporative cooling, as the evaporation heat of water is considerable. The flow rate of cooling water is automatically controlled. Selected characteristics are shown in Fig 2, 3 [9, 15]. Adding water to the return sand after the knockout should ensure its moisture content of 1.5%, which is the moisture at the dusting limit.

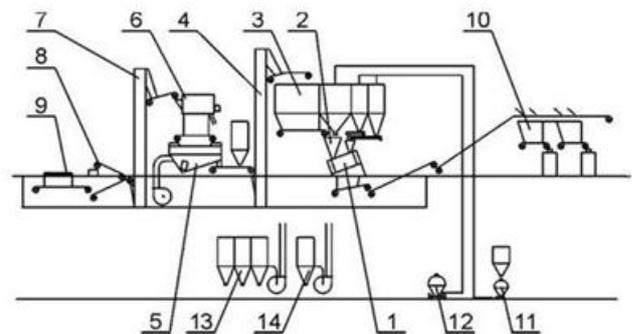


Fig. 1. Schematic diagram of a sand processing line [13]: 1- turbine mixer; 2- dosing unit; 3- battery of containers; 4- bucket feeder; 5- vibro-airslide cooler; 6- rotary screen separator; 7- bucket feeder; 8- electromagnetic separator; 9- knockout grid; 10- rebonded sand tank; 11- pneumatic conveying of sand; 12- pneumatic handling systems of rebonding agents; 13- dust control system SPM; 14- dust control system in a cooler

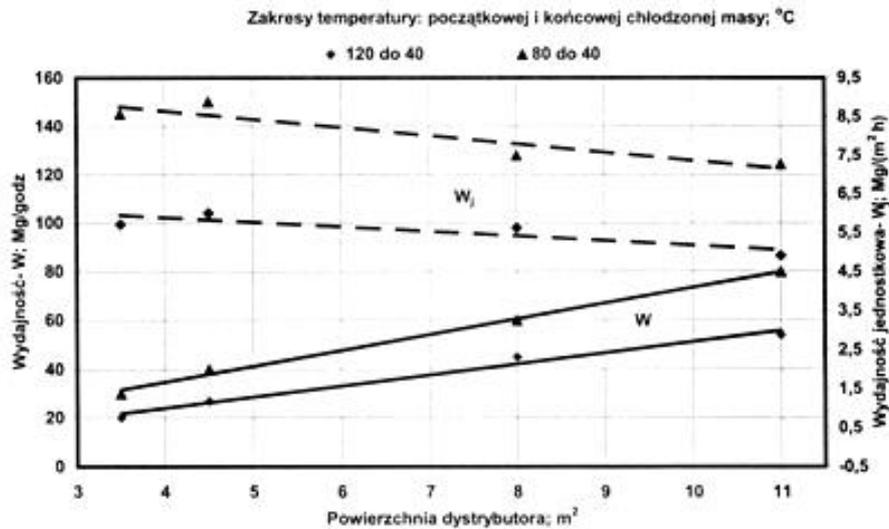


Fig. 2. Efficiency of the series of types of vibro-airslide coolers CFM (CWFM) P.P.P. TECHNICAL Nowa Sól; Efficiency W, unit efficiency $W_j=f$ (distributor's surface area- cooler bottom), temperature range: initial and final temperature of the sand mix being cooled "C

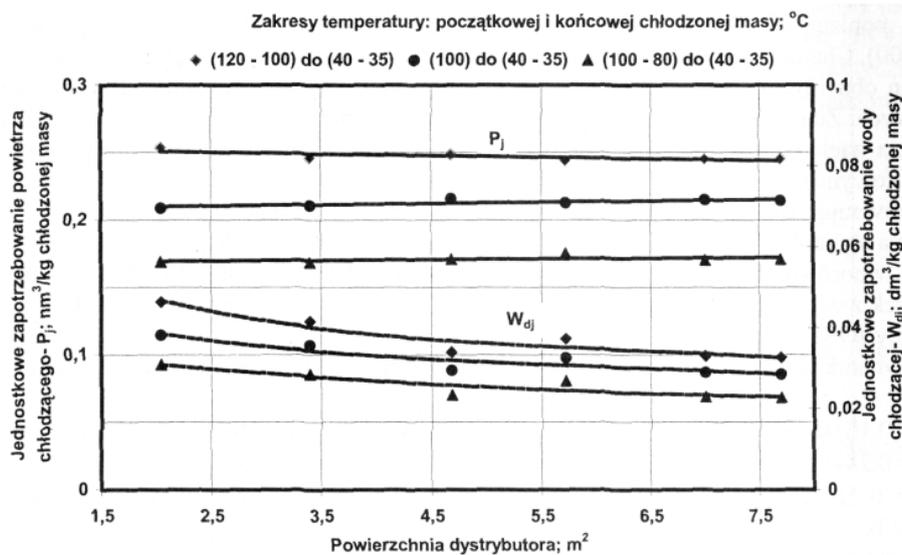


Fig. 3. Unit consumption of cooling air and dosed water for the series of types of vibro-airslide coolers DFW (KUTTNER JOST): Unit consumption of cooling air P_j ; m³/kg of the sand mix being cooled and unit consumption of cooling water W_{dj} ; dm³/kg of the sand mix being cooled

Turbine mixers are now commonly used for rebonding mixing. The used sand mix, after rebonding mixing, achieves the required technological parameters and the high degree of aeration, which is of primary importance in the context of presently used thickening methods. The ranges of relevant constructional and operating parameters of turbine mixers are given as [8, 12]: N_c/W - installed power/efficiency = 2.35÷3.40 kW/(Mg/h), m/W -

mixer's mass/efficiency = 0.17÷0.27 Mg/(Mg/h); A/W -space occupied/efficiency = 0.12÷0.27 m² (Mg/h).

Typical equipment of the sand mix preparation station includes:

- turbine mixers,
- electronic scales for dosing used sand, green sand, bentonite and coal dust,

- feeding systems to handle used sand (belt conveyor systems) and green sand (belt conveyors or vibratory systems),
- worm feeders supplying powder components.

Because of considerable differences between the weight proportion of the main ingredients (used sand, fresh sand) and additives (bentonite, coal dust), two separate scale tanks are required, differing in design and weighing precision. The tanks are attached to the load bearing structure via strain transducers. They form a resistance bridge connected to an electronic weight meter converting analogue signals from the bridge into digital signals. These signals are transmitted to the supervising controller, where it is processed accordingly. The masses of the sand mix components are read off with the accuracy of $\pm 1\%$ [1, 2].

Depending on the amount of a single feed to the mixer, the mix components may be dosed in two stages. Application of two-gear drives allows the two-stage feeding: preliminary stage-feeding of large amounts, final stage-feeding the twice smaller amount in order to reach the predetermined value.

When feeding the sand mix ingredients, the main components, i.e. those whose proportion is the largest are to be supplied first.

The duty cycle of a turbine mixer can be monitored by recording the power delivered by the rotor's drive motor or current intensity. The plot of current intensity during the rebonding mixing is shown in Fig 3. The data were obtained for the mixer MTP-500, operated in a foundry plant in Poland [12]. Process parameters are: mixing time $\tau_m = 170$ s; rotor rpm speed $n_w = 634$ 1/min; pan rpm speed $n_m = 15.3$ 1/min; blade inclination angle $\beta = 15^\circ$, mass of dosed water $m_w = 14.26$ kg; current intensity under idle run $I_{max} = 52$ A.



Fig. 3. Power consumption by the drive in the mixing system of a turbine mixer MTP-500: I- charging of mix components; II- homogenisation; III- water dosing; IV- mixing of wet sand; V- emptying the mixer

Power consumption tends to increase during the mixing cycle, reaching its maximal value at the moment the sand mix is ready and has predetermined parameters and properties.

2. Measurement and control systems

The control system allows for the unmanned operation of the entire rebonding plant, for maintaining the sand mix parameters

on the stable, predetermined levels, as well as for process visualisation and control. Besides, it enables the recording of technological parameters, selection of an arbitrarily chosen sand mix recipe, assigning the model number to a particular recipe and the online control of the system operation and troubleshooting.

The system controls the mixer's drives and mechanisms as well as the sand dosing units and sand distribution units. The system generates signals triggering the input control circuits (contact coils, valves, signalling elements). An integral part of the control system is the system monitoring the performance of all controlled circuits and mechanisms. That is why particular units of the machine are equipped with control elements, such as induction position sensors used for controlling the position of mobile mechanisms, contact sensors used for controlling the position of mobile mechanisms driven by pneumatic cylinders incorporating the BSPT systems (contactless position signal of piston rod); induction sensors for controlling the motion and slippage of belts in feeding and conveying systems, sensors for controlling the motion of rotating mechanisms and capacitance and resistance probes for controlling the degree of the tanks filling.

The amount of water fed to the mixer and to the cooler determines the mixing and cooling performance. The amount of supplied water is determined on the basis of:

- amount (mass) of the used sand; the mass is determined using an electronic scale to weigh the specified volume of sand,
- moisture content and temperature of the used sand; moisture measurements are taken with rod condensers immersed in sand and incorporated inside the weighing container; temperature measurements are taken with sensors mounted on the tank's walls and submersed in sand.

The measurement data are transmitted to the central unit (moisture meter) which calculates the required amount of water to be fed throughout the process in order to achieve the specified moisture content. The moisture control system is an integral part of the system controlling the sand processing plant.

Automatic control of sand moisture may be based on various measurement methods, including automatic moisture control based on dielectric loss measurements (dielectric permittivity), measurements of electrical conductivity, apparent density, moulding capacity, thickening parameters, as well as electro-nuclear methods [14]. Measurements of dielectric loss are in widespread use in foundry engineering.

The automatic measurement and control of sand moisture are implemented using the RMW systems [5,8], manufactured by PPP Technical, FSE-19S (Lipke systems), FS-CC6-PLC systems (Foundry Control) or Minicomp Uni G-CH [10, 15] (Michenfelder Elektrotechnik). These systems enable the control of the sand moisture with the accuracy level 0.1% H₂O ($\pm 0.05 \pm 0.1\%$ from the preset value). The moisture control system RWM-1, from a domestic manufacturer, features temperature, moisture and apparent density measurement units as well as actuating systems controlling the water feeding to the mixer.

The measurement and control system Micomp Uni [10.15] supporting coolers of various types ensures the moisture stabilisation at the output in the range of 2-3%, with the accuracy $\pm 0.15 \pm 0.2\%$. The control system maintains the moisture

difference between the cooled sand and the required sand moisture after rebonding in the range 1,0-1.5 % H₂O, which is the condition imposed by the requirements of the mixer's duty cycle. When this difference were larger, large mounts of water would have to be fed, which would prolong the mixing cycle.

Temperature sensors TTJ-Fe-CuNi incorporating specially-designed transducers with the measurement range 0÷150°C are mounted inside the weighing container, opposite one another and at different levels so as to obtain best averaged results. Sensors were manufactured to meet the specificity of their application, their shapes are specially designed and they are resistant to erosive action of sand and mix.

Water dosage is implemented by single- or double-valve systems. A double-valve system performs the main dosing process, followed by high-precision dosing. The mount of water to be fed is predetermined before the used sand and mix components enter the mixer. Water is added within the first few seconds of the mixing process, which ensure optimal effects whilst the entire sand preparation cycle is as short as possible. The amount of water to be fed is measured by the water dosing system (Maschinenfabrik Gustav Eirich) or by a volumetric dosing system using a flow sensor incorporating a control module [15, 13].

The available measurement and control system may also be based on measurements of sand parameters (properties) which determine its moulding capacity. This ability is associated with sand quality and depends on its moisture content.

The optimal working moisture is understood as the moisture content at which the value of the moulding capacity index equals $W_f=75\%$ [7].

The indicator of the sand's moulding capacity and thickening is thickening capacity, particularly when the final stage of the process involved the pressing [4]. The optimal working moisture is taken to be that at which the thickening capacity should equal $Z=40\%$. The thickening capacity appears to vary strongly with moisture content. It varies also with the applied pressing pressure, though to a lesser degree. The sensitivity of thickening capacity to variations of moisture content is utilised to control the sand moisture during the process of sand mix preparation [4].

Domestic manufacturers of process line equipment have in their offer an automatic unit Vedimat, for controlling the thickening capacity of sand mix and for measurement of its compression strength, thus yielding the amounts of bentonite in the sand mix upstream the moulding station. The system Michenfelder, that is the system Vedimat supported by Micomp Uni G-CH ensures that moisture content and thickening capacity are maintained within narrow limits. Vedimat is mounted directly on the process line, upstream of the moulding unit. Signals from the Vedimat system are transmitted to the Micomp Uni system that regulates the amount of water to be fed during the mixing cycle. Generally, application of the control system allows the mixing conditions to be predetermined by presetting either constant moisture or thickening capacity [10].

The system is supervised by the central unit MiPro which monitors and controls the sand mix quality, supporting

continuous control of sand circulation and measurements and regulation of the applied units. The complete measurement and control system enables the monitoring of the thickening capacity and strength parameters, downloading the online values and following the changes. Besides, it allows for selection of the measurement procedure, data archiving and statistical treatment of measurement data. The Michenfelder system, supported by equipment manufactured by PPT Technical, was first used in the sand processing line in the foundry engineering plant skoda in Mlada Boleslaw (Czech Republic) [10].

3. Procedures of sand quality evaluation

Statistical methods, including control charts, are of primary importance in quality control processes. Control charts belong the group of SPC (Statistical Process Control) tools. They are used for current quality control, at the same time helping to improve the quality of manufactured products. The data collected in an analytic spreadsheet are used to create a control chart (Shewhart's chart), being a graphic representation of the process under control [3, 11].

The principles of control charts of properties with the continuous value distribution are:

- regularity of time intervals, depending on the type of manufacturing processes;
- maintaining the constant number of random samples, typical sample size being $n=5$ as it is found to be optimal by practitioners;
- recording of interventions in the manufacturing process
- recording the data about the test time, measurement equipment and controllers

The description and importance of control charts in the light of quality assurance standards of castings are reviewed by J. Piaskowski [11]. As regards the properties of moulding sand, the work [3] gives examples of charts with the determined tolerance limits T and standard deviations σ of the investigated parameter. The data quoted in [3] refer to sand moisture after the rebonding mixing. Moisture measurement data were used to evaluate the Process Capability Index C_p , in accordance with the standard PN-ISO 3534-2, whose value changed favourably when the process conditions were varied: $C_p=0.95$ - initial level; $C_p= 1.37$ after the intervention.

The Process capability Index is expressed as the ratio of admissible variability due to process requirements to the internal variability of the process ($C_p=T/6\times\sigma$). The higher the index C_p , the higher the process capability. We also evaluate the shifting of the mean value with respect to the nominal value by finding the index C_{pk} - Corrected Process Capability Index. In practical applications we assume that capability indices should exceed 1.33.

Selected results of thickening capability tests are shown in Fig 4.

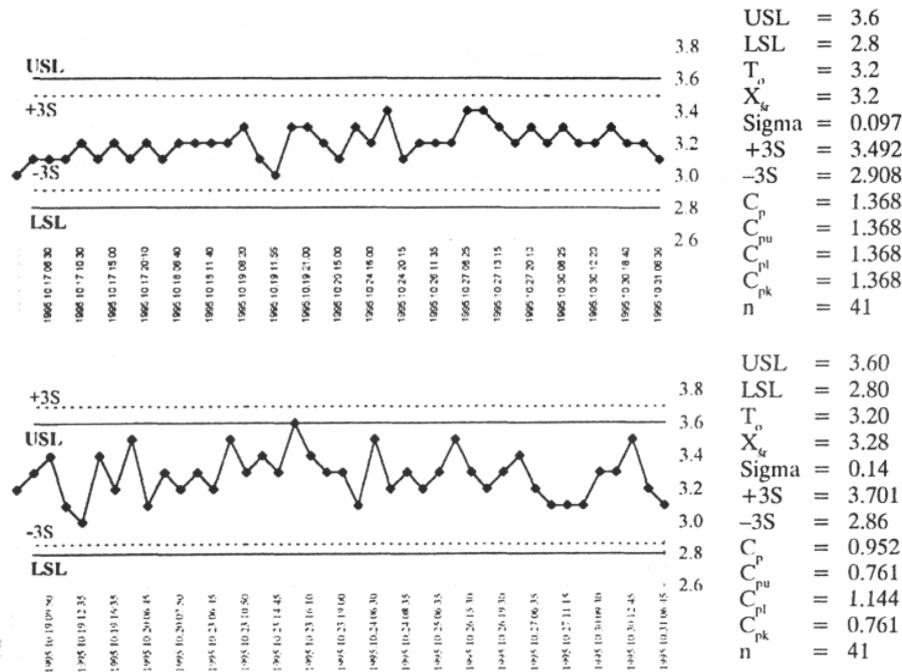


Fig. 4. Control charts showing compactability with the indicated tolerance limits: upper limit GLT and lower limit DLT and the process variability range $\pm 3 \times \sigma$

Regular and systematic laboratory tests of the sand mix yield the scatter of the relevant parameters and enable us to utilise this collected information to update the settings of the machines in the process line and to improve the process conditions [6].

3. Conclusions

Sand process lines produced by domestic manufacturers and equipped with measurement and control systems guarantee the sand mix circulation in statistically stabilised conditions. Technological processes may be controlled on a regular basis and process parameters are monitored online and optimised, when necessary. The applied control equipment and procedures ensure that the requirements set forth in the technical standards of the series ISO 9000 should be met.

Monitoring of preparation of used sand and rebonding mixing involves the diagnostics and supervision procedures. Supervision, widely understood, implies not only preventing failures or mitigation of their adverse effects, but also optimisation of the system operation to obtain the optimal effect, in terms of the highest process capability index, and to evaluate the process stability as a part of the quality assurance system.

Acknowledgements

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