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Selected aspects involved in operation of monitoring system for moulding sand preparation process

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Abstract

The paper addresses selected issues associated with the monitoring of the moulding sand preparation processes where the monitoring of power factors in the mixer drive is of primary importance. The study compares the indicators of electric power consumption by various types of mixers, summarizes the preliminary test data of power consumption in a paddle mixer drive. Process parameters were varied during the tests: moisture content and load. Coefficients and factors characterizing electric power demand are recalled. Two aspects of the monitoring system are considered to be of major importance: potential optimization of the mixing process in the function of energy consumption and control of the mixing process and its impacts on the properties of thus prepared moulding sand.

Keywords: Foundry processes; Preparing of moulding sand; Monitoring of mixer operating.

1. Introduction

Techniques used to control the sand preparation processes are numerous, depending on the final quality requirements [2, 4, 5, 7, 13]. Typical systems take into account the relationship between sand properties and moisture content. Measurements of moisture content are taken with sensors placed directly inside the mixer, and also at the selected points in the sand preparation line (upstream and downstream the mixer). In practical applications, we have a wide range of available sensors. State- of- the art systems use specialized automatic devices capable of simultaneous measurements of several sand parameters: compactability, compression strength, temperature (Multicontroller SMC-PRO by DISA Group [19], Automatic Bond Determinator with Compactability Control by SIMPSON Group [16]). Apart from current monitoring of moulding sand parameters, they are capable of controlling the sand preparation, enabling on-line control of the dosing of mix components. Potential applications of effective and instantaneous power measurements to the assessment of the sand condition and control of the sand preparation process are explored in few publications only [3, 6]. Such measurements are often implemented in laboratory conditions, as reported in literature on the subject [15]. Currently, new developments of microprocessor systems enable practical implementation of such strategies [9, 10], also to the assessment of turbine mixer performance, where the dynamic behavior is most pronounced. Application of such systems on an industrial scale should be most profitable. Monitoring of power consumed by foundry machines and installations is of major importance for financial and environmental reasons [9, 12].

The starting point for the design of the system for the monitoring of moulding sand preparation becomes the schematic diagram in Fig. 1, based on the authors' earlier publications [8].

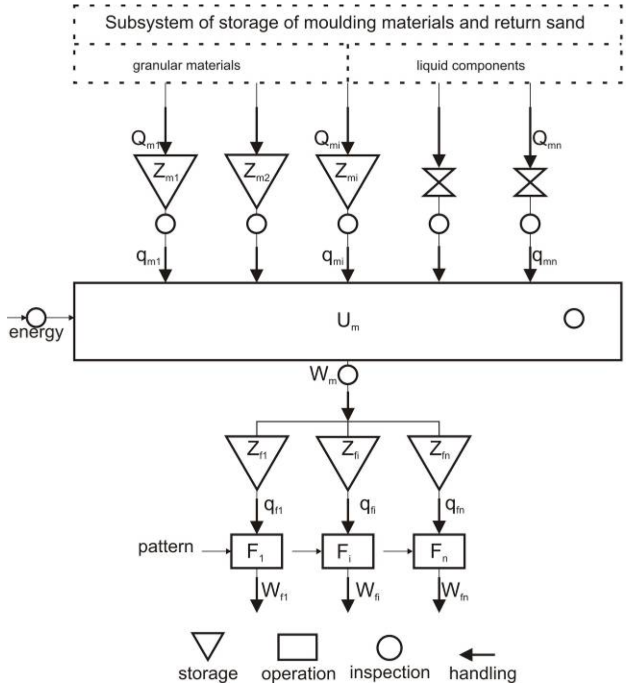

Fig. 1. General block diagram of moulding sand preparing subsystem and its surroundings;
Q_{mi} – components of moulding sand , Z_{mi} – parameters of storage devices, q_{mi} – flow rate of moulding sand components, U_m – characteristic of mixing device, W_m – total output of mixing device, Z_{mi} – parameters of moulding material storage devices in moulding sand preparing subsystem,
Z_{fi} – parameters of moulding sand storage devices in moulding subsystem, q_{fi} – individual flow rate of moulding sand (for "i" moulding stand), F_i – characteristic of individual moulding device

Indicated control operations in modern mixing systems involve the measurements of moulding sand and machine parameters by electric methods, supported by data acquisition and processing. Specialist software and hardware enable us to utilize the collected data to the control of moulding sand preparation processes. Currently available systems differ in their level of complexity. The use of extra signals from the power monitoring system defines the innovative approach. Hence the redundancy requirements in process control can be better satisfied.

Key functions include: recording and transmission of data associated with supervision and sequential control in the moulding sand preparation subsystem, direct control of mixing process in the context of producing sand mix with predetermined parameters and optimization of the mixer drive performance in terms of power demand. In order to find an effective solution to such complex problem it is required that the process of sand preparation be thoroughly identified. The purpose of the author's research program is to engineer a specialized system for measuring the power factors [10]. Furthermore, the authors seek to define the relationships between those power factors and moulding sand mixing process parameters [10, 11]. Accordingly, a control system shall be designed that utilizes the signals from the power measurement unit.

2. Key factors determining the parameters of the power consumption monitoring system

Performance data of currently available, selected mixers [14, 16, 17, 18] were utilized to graph the plots (Fig. 2-5) showing the approximate power demand required to prepare a unit mass of sand L_u [3, 11]. Load of the pan in selected series of types of mixers becomes the independent variable.

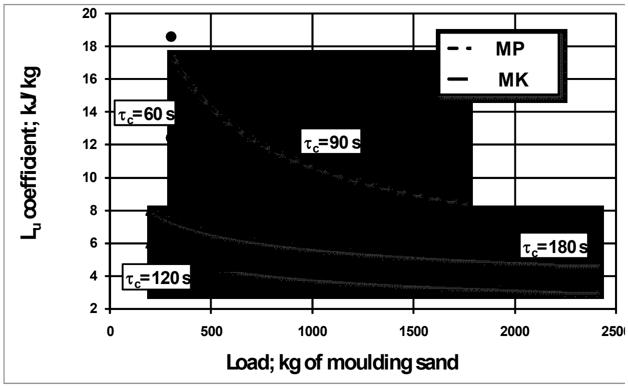

Fig. 2. Coefficient of mixer power demand L_u versus load for various type of mixers of Dozamet; MP – Speedmuller series, MK-Simpson type series

Recalling the plots and the relationships:

$$L_u = \frac{P}{W_m} \tag{1}$$

$$W_m = \frac{L}{\tau_c} \tag{2}$$

where:

P - nominal power of the mixer drive,
W_m - capacity/efficiency,
L - pan load,
τ_c - cycle time,

yields the parameters characterizing the given mixer in terms of its capacity, drive power and unit power demand.

Wide variability of the coefficient L_u is evident, depending on the mixer type and size. Fluctuations between the values of L_u are revealed also in the same group of mixers, though from different manufacturers. A relatively small fluctuation of the value of L_u depending on the mixer size is characteristic of traditional edge runner mixers (SIMPSON). Besides, the average value of L_u for the series of Polish mixers (Dozamet) and those offered by foreign manufacturers (SIMPSON Group) is nearly identical: about 4 kJ/kg for τ_c=120 s and 6 kJ/kg for τ_c= 180 s (Fig. 2 and 3). Since the coefficient L_u is only approximate and takes into account the mixer's idle run [11], the decreasing function L_u=f(L) appears to be a more reliable indicator (Polish mixers – Fig. 2, 4; mixers by other manufacturers: Fig. 5)

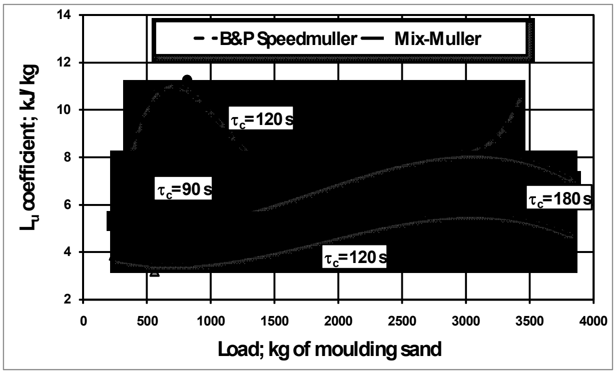

Fig. 3. Coefficient of mixer power demand L_u versus load for various type of mixers of Simpson Group

As regards the speedmullor type mixers, particularly those offered by Polish manufacturers, the fluctuation of the value of L_u is larger. The average value of L_u for speedmullor mixers produced in Poland is larger than for other mixers for the same cycle time (Fig. 2, 3). In the case of low-capability turbine mixers, the change of L_u is noticeable. In higher capacity machines, the deviation of the value L_u from the mean level (10 kJ/kg) is minor (that applies both to mixers offered by Technical – Fig. 4 and Künkel Wagner – Fig. 5).

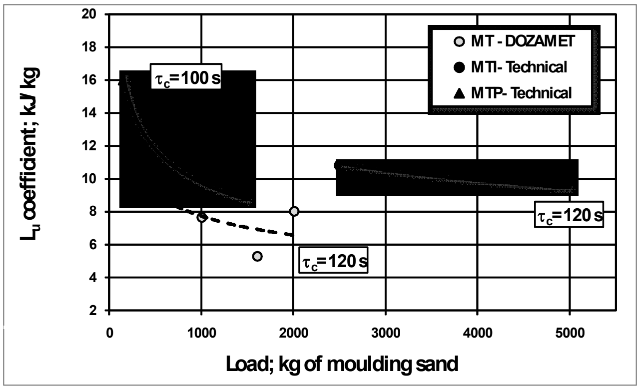

Fig. 4. Coefficient of mixer power demand L_u versus load for various type of turbine mixers of Dozamet (MT series) and Technical (MTI and MTP series)

A wide variability range of the value of L_u in various mixers implies that the mixing process can be potentially optimized, also in terms of drive power. A comprehensive analysis of mixer parameters shall be performed before the parameters of the monitoring system for power measurements are to be chosen. It is worthwhile to mention that even though theoretical formulas [1] take into account the relationship between drive power in selected mixer types and machine parameters as well as parameters associated with sand properties (e.g. friction factor), they are extremely difficult to obtain experimentally. That is why the final selection of the monitoring system parameters ought to be based on the identification of the sand preparation process in the conditions closely resembling those encountered in actual service (taking into account the mixer type and size and major technological parameters). The procedure, the apparatus and first results are described elsewhere [10, 11]. Fig. 6 shows selected results obtained during the first series of tests, run on a moulding sand with bentonite. Compressive strength R_c^w was 0.095 MPa, permeability P^w=3.2 m^2/MPa• s), the average moisture content W=4.2%.

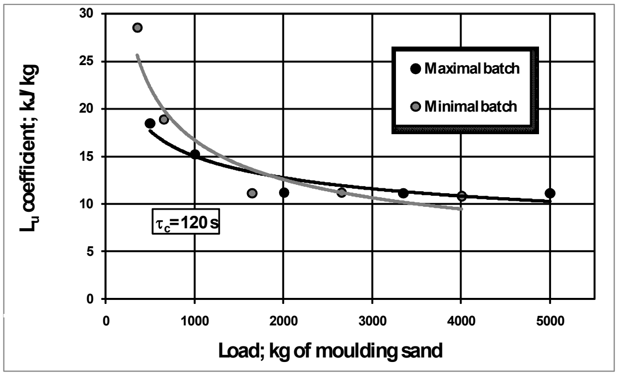

Fig. 5. Coefficient of mixer power demand L_u versus load for various type of turbine mixers of Künkel Wagner (WM series)

It is readily apparent (Fig. 6) that the relationship between the active power of the drive motor and the pan load becomes the growing function. It seems that power consumption is decidedly lower during the preparation of sand mixture with lower moisture content, when the drive motor works in the conditions of incomplete load, also in the range exceeding the nominal load (i.e. for small values of cos φ). Increasing the moisture content, thus changing its properties, leads to a vast increase of power consumption throughout the whole range of pan loads.

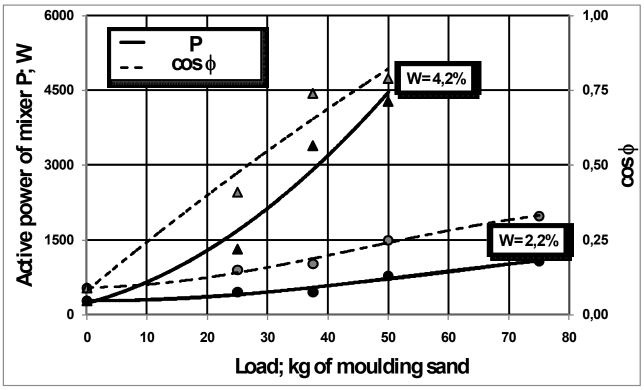

Fig. 6. Relationship between active power- P of paddle mixer MS- 075 (Dozamet), power coefficient cos ϕ and load for various moisture- W of moulding sand with bentonite; mixing time - τ=6 min.

It is reasonable to expect that in qualitative terms active power- pan load curves shall be similar for other mixer types, too. Selected characteristics are shown schematically in Fig. 7. The plots can be interpreted as static characteristics of the mixers. Variability ranges of key parameters are clearly indicated.

Pan load fluctuations ΔL might be attributable to the fact that supplementary components are still dosed into the system (correction of mix composition, instable parameters of dosing devices, particularly in the case of volumetric dosing systems). Variations of the moisture content ΔW are controlled by refill of process water in the circulating mass and perhaps also by correcting action prompted by the control system. The actual operating condition of a foundry plant depend on the type of the moulding sand preparation installation and the assortment of castings, hence fluctuations of moisture content in the stream of return moulding sand fed to the mixer might be far from minor.

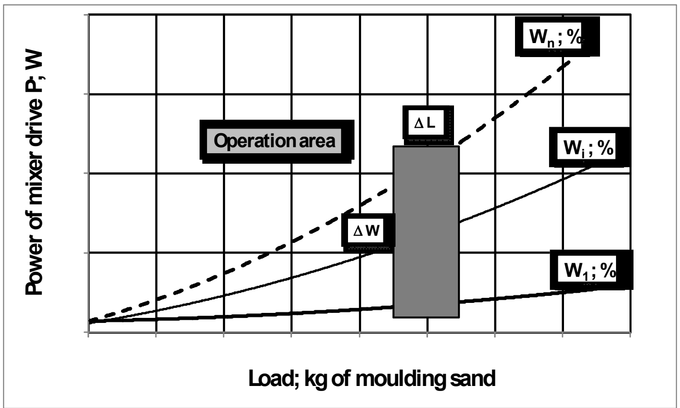

Fig. 7. Schematic presentation of mixer operation area connected with basic parameters deviation on the background of family of functions - $P= f(L)_{Wi=const}$;
W - moisture of moulding sand, L - load of mixer pan

There might be some disturbances of the mixing processes, for instance water might evaporate from the pan due to temperature increase. Precise identification of the operating conditions at the specified point of the mixing cycle becomes a most complex issue. The model above takes into account two parameters only: moisture content and power consumption.

The influence of other factors: variations of moulding sand composition, variations of the binder content shall be investigated thoroughly, also during the production processes. At the present stage it is justified to state that in order to utilize the power factors in the control of the mixing process, it is required that the actual amount of moulding sand present in the mixer at the given time instant should be known. That is why the monitoring system ought to take into account the signals from sensors incorporated in the dosing systems, pan load sensors and moisture sensors. Research work to date [10, 11] has focused on well-known parameters characterizing power demand: U [V], I [A], S [VA], Q [VAr], P [W] cosφ and the THD (total harmonic distortion) [%]. The fabricated microprocessor measuring system [10] enables the measurement of instantaneous power factors [9, 10]. Fig. 8 shows selected system components and first results of measurements of instantaneous power components.

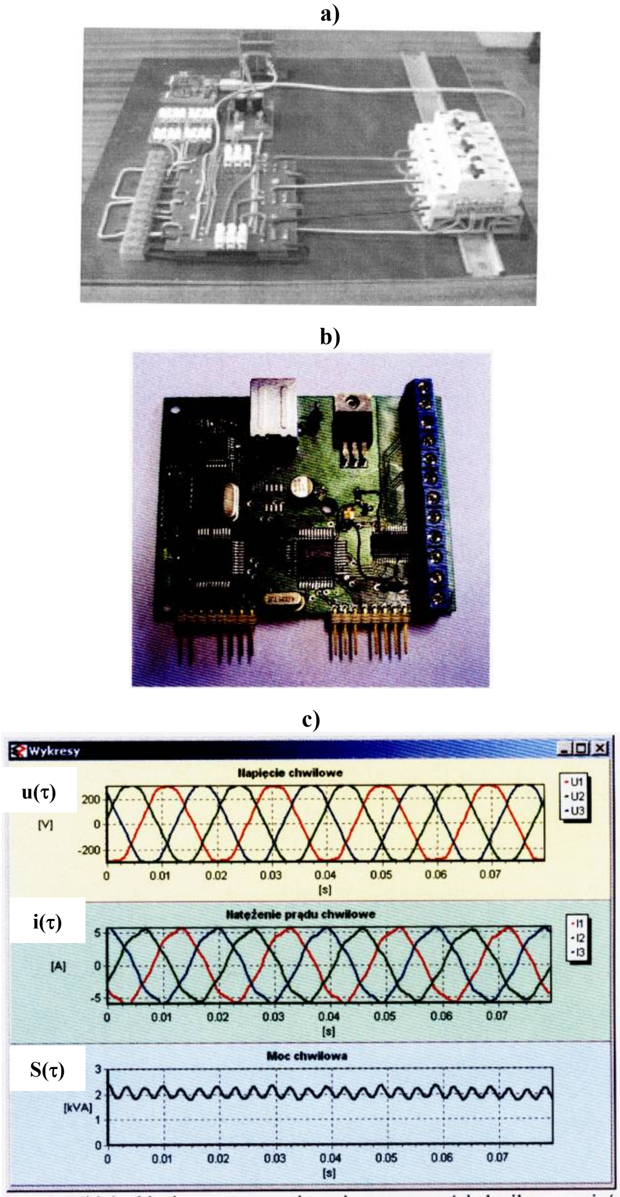

Fig. 8. View of main parts of measurement system: a) prototype of a mounting plate of input circuits system , b) electronics of measurements module and c) window in a program of recording of instantaneous currents – i(τ), voltages - u(τ) and apparent power - S(τ) (load of 075 MS mixer pan L=64 kg)

These measurements permit the identification of phenomena occurring during transient operating conditions.

4. Summary

Indicators of power demand for the sand preparation process in various mixer types will vary considerably, which is confirmed by the performed comparative analysis. It appears that selection of the mixer's drive power requires further rigorous research and analytical studies. In Polish foundry plants there are still old-type mixers with low-efficiency motors. These mixers operate in a periodic mode and fluctuations of power demand within one cycle are considerable. Measurements of instantaneous power consumption supported by the monitoring system might be well used in optimization of the operating cycle in terms of power demand. This approach might bring certain savings, particularly in the case of higher-capacity mixers. Variability of pan load during the mixer operation is controlled by several process parameters.

Hence the strict requirements imposed on the system for monitoring the power consumption by the mixer. A vast body of data has to be collected in a relatively short time. Application of a microprocessor-supported monitoring system shall facilitate the identification of the sand preparation process, helping to relate the power factors to moulding sand properties.

From the standpoint of automatic control, the process of moulding sand preparation is described as a nonlinear MIMO plant, operating in the conditions of large, variable distortions. It is reasonable to expect that the monitoring system ought to utilize advanced control systems supported by adaptive algorithms, neural networks or fuzzy algorithms.

Since the financial and environmental aspects of the problem are most important, further research work is merited to explore the potential applications of monitoring systems to support moulding sand preparation processes.

Acknowledgments

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