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SOME ASPECTS OF MONITORING OF FOUNDRY MOULDING SANDS PREPARATION PROCESS

WYBRANE ASPEKTY MONITORINGU PROCESU SPORZĄDZANIA ODLEWNICZYCH MAS FORMIERSKICH

The study outlines the basic features of a newly-designed computer-supported system for monitoring and recording the instantaneous power consumption, used to control the operating parameters of foundry mixers as well as moulding sand preparing process course. Basic idea of monitoring of power demand treated as the factor of quality evaluation of moulding sand preparation process have been described. The main coefficients and factors characterizing electric power demand by mixer drive are recalled. Comparison of values of the indicators of power consumption by various types of mixers has been done. The study has also summarized the preliminary test data of power consumption during moulding sand preparation process in a paddle mixer drive and roller mixer (Simpson type). Process parameters were varied during the tests: moisture content in moulding sand, load of the mixers pan and mixing time. Electric power demand is expressed by effective values, assuming the balanced load. As the mixing levels change, the technological parameters will change, too, and this fact might be utilized in monitoring of the mixing process. The power factor of the mixer drive cos φ would vary considerably during the mixer's operation under loading. The selected results of tests performed to find the relationship between the technological and operational parameters and power consumption by a mixer drive have been presented. 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 and quality of thus prepared moulding sand. Potential following applications of the module for fast recording of instantaneous currents and voltages in a single or triple phase power supply system in other foundry machines and devices have been pointed out. Further research areas are indicated, to extend the system and the range of its using.

Keywords: foundry processes, preparing of moulding sand, monitoring of moulding sand preparing process

Praca przedstawia w zarysie podstawową charakterystykę nowego, komputerowego systemu przeznaczonego do monitorowania i rejestracji chwilowego zapotrzebowania mocy, przeznaczonego do kontroli parametrów pracy mieszarek stosowanych w odlewnictwie jak również przebiegu procesu sporządzania masy formierskiej. Opisano podstawową ideę monitoringu poboru mocy przez mieszarkę traktowanego jako wskaźnik oceny jakości procesu sporządzania masy. Przedstawiono główne współczynniki i parametry charakteryzujące zapotrzebowanie mocy elektrycznej przez napęd mieszarki. Porównano wskaźniki charakteryzujące pobór mocy elektrycznej przez mieszarki różnych typów. Zaprezentowano także wyniki wstępnych badań poboru mocy przez mieszarkę łopatkową i krążnikową (typu Simpson). Badania prowadzono przy zmiennych parametrach, takich jak : wilgotność masy formierskiej, wielkość załadunku misy mieszarki oraz czas mieszania. Zapotrzebowanie mocy scharakteryzowano wartościami skutecznymi, uwzględniając załadunek mieszarki. Podczas procesu mieszania ulegają także zmianie parametry technologiczne, co może być wykorzystane w kontroli procesu sporządzania masy. Zaobserwowano istotną zmianę współczynnika mocy poboru mocy – cos φ, podczas pracy mieszarki przy zmiennym załadunku. Przedstawiono wybrane wyniki przeprowadzonych badań mających na celu określenie zależności pomiędzy parametrami technologicznymi a parametrami pracy mieszarki oraz zapotrzebowaniem mocy. Podkreślono dwa podstawowe, ważne aspekty monitoringu poboru mocy: możliwość optymalizacji procesu mieszania z punktu widzenia jego energochłonności oraz kontrolę procesu uwzględniającą właściwości i jakość sporządzanej masy formierskiej. Wskazano możliwe, kolejne zastosowania szybkiej rejestracji chwilowych wartości natężenia i napięcia prądu w jedno i trójfazowych systemach zasilania maszyn i urządzeń odlewniczych. Zasygnalizowano obszary dalszych prac zmierzających do rozbudowy systemu i rozszerzenia jego zakresu zastosowania.

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1. Introduction

Operating costs of foundry machines are largely controlled by their power demand, in terms of the actual electricity consumption.

Monitoring of power consumption by foundry machinery enables a thorough analysis of process parameters as well as its cost-effectiveness. Requirements imposed by electricity suppliers on the foundry plants, relating to self-balancing of positive reactive power, and the attempts to reduce the operating costs prompt the careful analysis of all power components and the consumption levels. The analysis of power consumption of a foundry machine enables the optimal selection of its operating parameters. Such analysis requires a system for online monitoring of reactive and active power demand and the total power consumption.

This study outlines the major stages of implementation of an integrated computer system for monitoring of power consumption by selected foundry mixers. For the purpose of verification, the authors investigated the power consumption of a paddle mixer and the Simpson type mixer, filled with variable amounts of moulding sand. The control of sand preparation might use several measurement techniques [3, 6, 14, 15, 22]. Certain control systems are supported by simultaneous measurements of several moulding sand parameters [6, 7, 25, 28]. Applications of the (effective or instantaneous) power demand signal to the evaluation of sand condition were explored in [14, 18]. Presently, new developments of microprocessor systems enable practical implementation of those concepts [17, 18, 19], also with reference to intensive mixers (with rotating mixing pan and high-speed rotor). The research work undertaken by the authors is focused on two aspects: fabrication of a measuring systems and identification of key relationships between power factors and process parameters. The results presented here should be viewed in the long-term perspective.

2. Functional objectives of the power demand recording system

The newly- designed and implemented computer-supported system for recording power demand by moulding sand mixers enables:
- measurements of instantaneous currents and voltages in the triple phase systems, to determine the instantaneous power demand and the apparent, active and reactive power,
- separation by galvanisation of measurement circuits and computer ports,
- transfer of measurement data to the computer (via a USB port) with an installed dedicated program for data acquisition, processing and visualization,
- taking a large number of high-precision measurements in a unit of time.

The system requires elaborate power electronics elements. Several designs and implementations have been completed by joint research teams from the Department of Mechanisation, Automation and Designing of Foundry Plants (Faculty of Foundry Engineering) and the Department of Metrology (Faculty of Electrical Engineering, Automatics, Computer Science and Electronics) of the AGH-UST.

The system is preliminarily assumed to include several modules:
- input circuit module, comprising voltage and current transducers, separated by galvanisation from the further portion of the control circuit and the computer,
- micro-processor – a data processing module,
- serial transmission module (in the selected standard), transmitting the measurement data to the computer,
- IBM PC computer equipped with an appropriate interface, with a dedicated program controlling the overall system operation, including data acquisition, transmission and processing of measurement data.

The power electronics module has the following functional blocks:
- measurement system supported by CS5451A (Cirrus Logic) [30],
- data transmission system completed with CS5451A to the microprocessor, supported by a programmable integrated circuit M4A3-64, version 7VC-10VI (Lattice),
- microprocessor system ATMega8551 (Atmel),
- data transmission system to the computer via an USB interface, supported by an integrated circuit FT245BM (FTDI).

An integrated circuit CS5451A is a six channel transducer. It comprises an integrated serial interface allowing for data transfer to the microprocessor, to be further processed. Specifications and technical data are available on the manufacturer's website [30].

Input circuit components include voltage and current transducers, manufactured by an American company LEM [31].

Voltage transducers LV-25P enable the measurements of direct or alternating current voltage as well as impulse voltages in the range 10-500 V, they are insulated by galvanisation. This transducer operates in a feedback system, with an analogue current output.

Measurements of instantaneous currents are taken with current transducers LA-25-NP, capable of direct, alternating and impulse current measurements in the ranges up to 5, 6, 8, 12, 25 A, also insulated by galvanisation.

The system of input circuits in the designed version has three measurement paths (for triple phase systems), each comprising one voltage transducer LV-25P and one current transducer LA-25NP. these transducers with additional electronic elements are power-supplied with constant voltage ±15V.

In the preliminary version of the computer program for reading the measurement data received by the computer from the power electronics module via an USB interface. As the power electronics module has no memory to store the module name, the program window displays this module as the Device 1. Data transmission from the USB port is supported by the DLL libraries, provided by the manufacturer of the integrated circuit FT245BM, FTDI company [32].

The computer program was written using a DELPHI 2005 compiler. As a large number of bites are to be transmitted (2000 measurement data from 6 channels per second), the data are written directly to hard disc (without processing and graphic display) [17]. The time history of the measured parameters is executed by an extra function (application), and the user indicates the file with data stored on the computer's hard disc [1, 13].

3. Calculation of energy- parameters on the basis of registered instantaneous values

Time run of instantaneous values current and voltage in alternating current system let on the simplified estimation of the shape of these course [4, 11, 12, 13]. To the basic energy-parameters for these course belong among others:

Effective value of voltage and current, given by the formula [11]:

$$U = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} u^2(t)dt} \tag{1}$$

$$I = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} i^2(t)dt} \tag{2}$$

where:

U, I – effective values of voltage and current, respectively in V and A,

$u(t), i(t)$ – instantaneous values of voltage and current, respectively in V and A,

T – period of course, s,

t_o – the beginning of the temporary section for which the integration is realized

Total harmonic distortion in [9]:

$$THD = \frac{\sqrt{\Sigma_{m=2}^{40} U_m^2}}{|U_1|} \cdot 100 \tag{3}$$

where:

$U_2, \ldots U_{40}$ – the efficient value of following harmonics, from 2nd to 40th, V,

U_1 – the efficient value of first harmonic, V.

Active power [11]:

$$P = U \cdot I = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} u^2(t)dt} \cdot \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} i^2(t)dt}. \tag{4}$$

Apparent power [11]:

$$S = \frac{1}{T}\int_{t_0}^{t_0+T} u(t) \cdot i(t)dt. \tag{5}$$

The value of cosφ is obtained from the following proportion [11]:

$$\cos\varphi = \frac{P}{S} \tag{6}$$

Apparent power for the set number of measurements of instantaneous current and voltage in triple phase system is given by the formula:

$$S = \frac{1}{N}\sum_{j=1}^{N}(u_{1j}i_{1j} + u_{2j}i_{2j} + u_{3j}i_{3j}) \tag{7}$$

where:

N – number of measurements,

u_{1j}, u_{2j}, u_{3j}, – voltages in the j-th moment in particular phases, V,

i_{1j}, i_{2j}, i_{3j}, – current in the j-th moment in particular phases, A,

Active power in such conditions:

$$P = \sqrt{\frac{1}{N}\sum_{j=1}^{N}(u_{1j}^2 + u_{2j}^2 + u_{3j}^2)} \cdot \sqrt{\frac{1}{N}\sum_{j=1}^{N}(i_{1j}^2 + i_{2j}^2 + i_{3j}^2)} \tag{8}$$

For evaluation of some mentioned above quantities the calculations of each harmonic must be done with using of FFT (Fast Fourier Transformation) [10, 20] .

4. Basic description of monitoring of moulding sand preparation process

Monitoring in moulding sand preparing system, following measurements, serves two major functions: broadly understood recording and transmission or operational data and evaluation of mixing quality. Firstly, of major importance are the issues associated with the selection of the mixer drive and optimization of its performance. Secondly, utilization of measurement signals to the supervision of the mixing process provides a further option of using the acquired information in process control. A good example of the monitoring function is that of power consumption by a sand mixer [18, 19].

Techniques used to control the sand preparation processes are numerous, depending on the final quality requirements [3, 6, 7, 22]. 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.

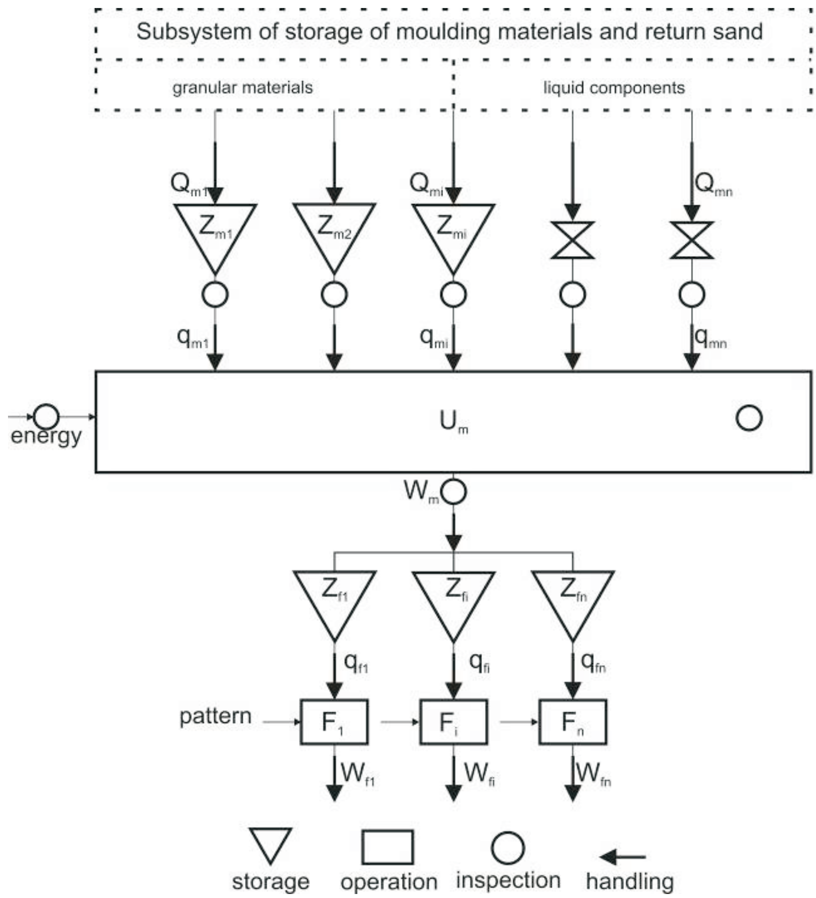

Fig. 1. General block diagram of moulding sand preparing subsystem and its surroundings; Q_{mi} – components of moulding sand , Z_{mi} – parameters of storage devices, q_{mi} – flow rate of moulding sand components, U_m – characteristic of mixing device, W_m, – total output of mixing device, Z_{mi} – 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

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 [28], Automatic Bond Determinator with Compactability Control by SIMPSON Group [25]).

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 [2, 5, 14]. Such measurements are often implemented in laboratory conditions, as reported in literature on the subject [24]. Currently, new developments of microprocessor systems enable practical implementation of such strategies [17, 18], 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.

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 [16].

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 [18]. Furthermore, the authors seek to define the relationships between those power factors and moulding sand mixing process parameters [18, 19]. Accordingly, a control system shall be designed that utilizes the signals from the power measurement unit.

5. Key factors determining the parameters of the power consumption by moulding sand mixers

Performance data of currently available, selected mixers [23, 25, 26, 27, 28] were utilized to graph the plots (Fig. 2-5) showing the approximate power demand required to prepare a unit mass of sand L_u [5, 19]. Load of the pan in selected series of types of mixers becomes the independent variable. Recalling the plots and the relationships:

$$L_u = \frac{P}{W_m} \tag{9}$$

$$W_m = \frac{L}{\tau_c} \tag{10}$$

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.

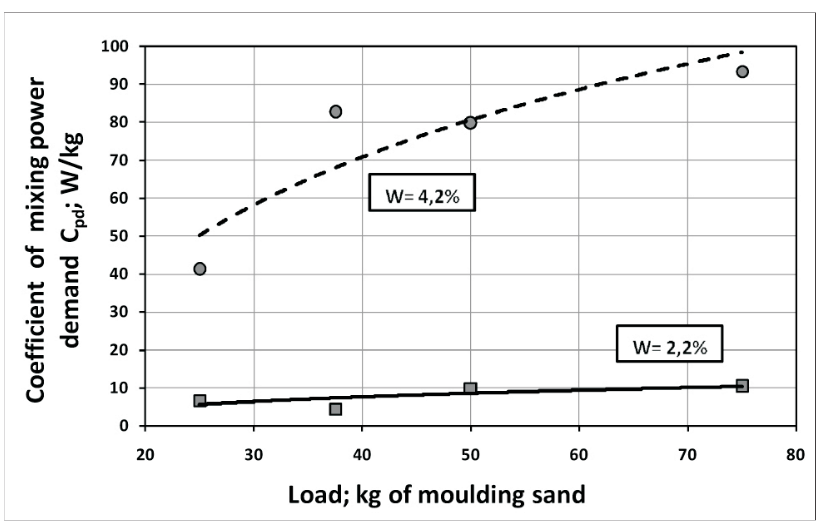

Fig. 2. Coefficient of mixer power demand L_u versus load for Simpson type mixers series; A, E – code of following producers, τ_c – cycle time

Wide variability of the coefficient L_u is evident, depending on the mixer type and size. The analysis takes into account the three main type of mixers: the Simpson type mixers, speedmullor type mixers and currently widely used rotor mixers (also known as turbine mixers). 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 roller mixers (SIMPSON). Besides, the average value of L_u for the series of mixers of A producer and those offered by E producer is nearly identical: about 4 kJ/kg for τ_c=120 s and 6 kJ/kg for τ_c= 180 s (Fig. 2). Since the coefficient L_u is only approximate and takes into account the mixer's idle run [19], the decreasing function L_u=f(L) appears to be a more reliable indicator.

As regards the speedmullor type mixers, particularly those offered by A manufacturer, the fluctuation of the value of L_u is larger. The average value of L_u for speedmullor mixers produced by A manufacturer is larger than for other mixers (E producer) for the same cycle time (Fig. 3). Especially for small machines.

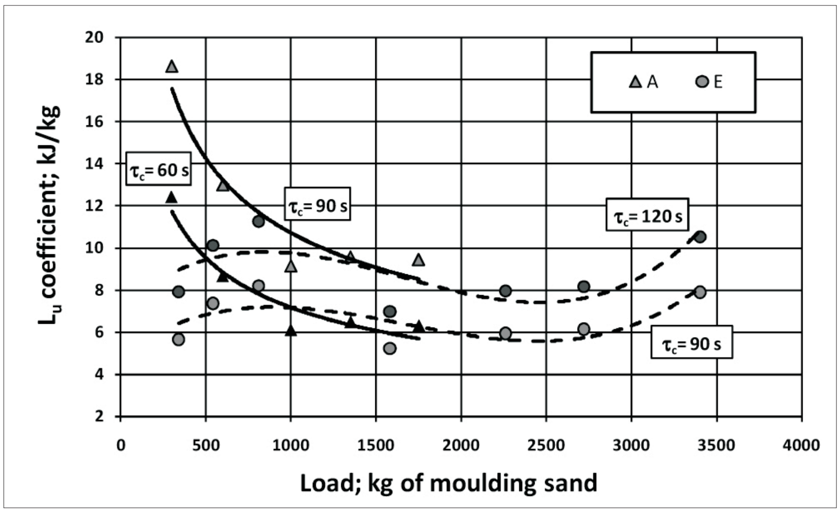

Fig. 3. Coefficient of mixer power demand L_u versus load for speedmullor type mixers series; A, E – code of following producers, τ_c – cycle time

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 all producers – Fig. 4).

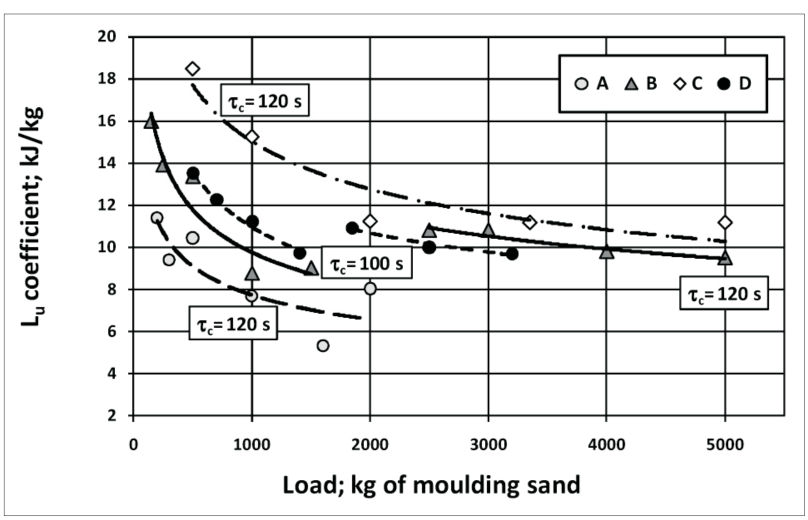

Fig. 4. Coefficient of mixer power demand L_u versus load for various type of turbine mixers series; A, B, C, D – code of following producers, τ_c – cycle time

The decreasing character of function- Lu= f(L) one can see also for core sand mixer – Fig. 5.

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 [2] 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 [18, 19].

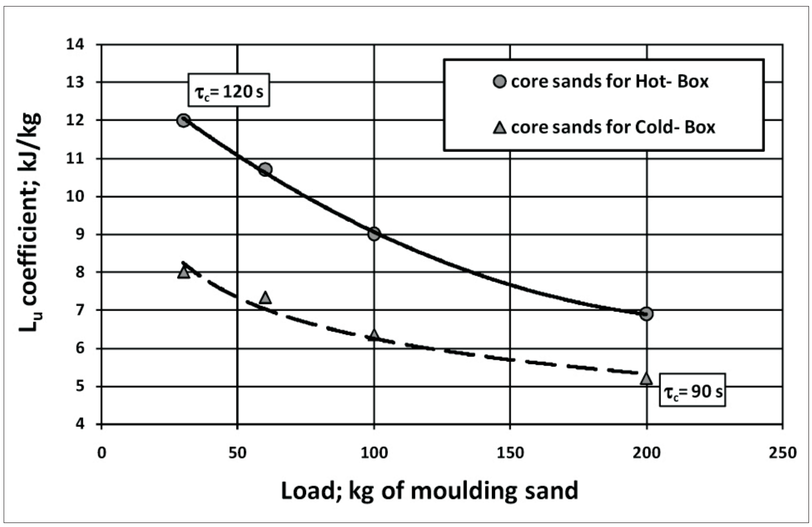

Fig. 5. Coefficient of mixer power demand L_u versus load for mixers series used for core sands preparing ; code of producer – F, τ_c – cycle time

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%. Power measurements were taken with described above system as well as a BM155 meter for checking procedure. The investigated paddle mixer – 075 MS (Polish company DOZAMET [23]) is destined rather for core sand but the nearing construction system is used as the part in many turbine mixers. In the initial experiments paddle mixer has also played a function of moulding sand aerator. The advantage of this mixer was strong dependence between power demand and pan load as well as moulding sand moisture. 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. 7 shows the relationship between the unit power demand and the pan load.

The power demand factor is given by the equation:

$$C_{pd} = \frac{P - P_0}{L} \tag{11}$$

where

C_{pd} – coefficient of mixing power demand, W/kg,
P – active power of the mixer, W,
P_0 – idle run power of the mixer, W,
L – load of the mixer pan, kg of moulding sand.

Multiplying this coefficient by mixing time τ_c yields the actual value of the factor L_{ur}, expressing the power supply required to prepare a unit mass of moulding sand (Eq. 12).

$$L_{ur} = C_{pd} \cdot \tau_c \tag{12}$$

where

τ_c – mixing time

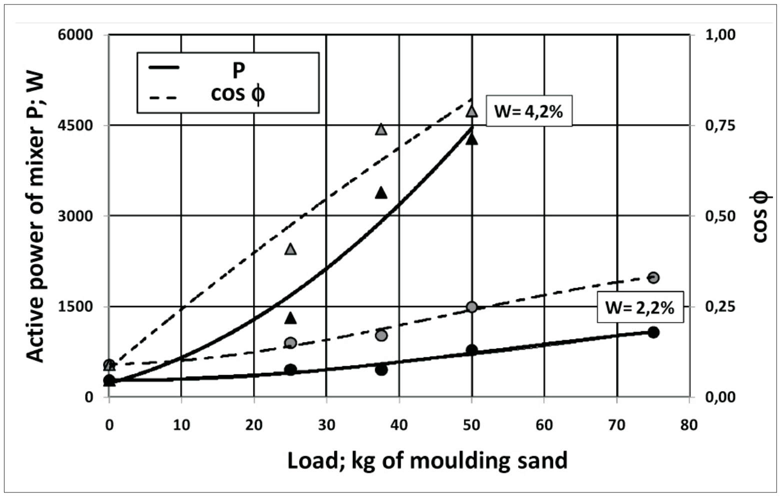

Fig. 6. Relationship between active power- P of paddle mixer MS- 075 (Dozamet), power coefficient cos φ and load for various moisture- W of moulding sand with bentonite; mixing time – τ_c=6 min.

This coefficient does not take into account the idle run power, which is of major importance when the mixer motor operates underloaded (Figs.6). In relation to L_u, the coefficient L_{ur} better captures the power demand associated with mixing of sand with precisely determined properties.

It is readily apparent (see Fig. 7) that in the wide range around the nominal load level the value of C_{pd} varies only slightly but it strongly depends on moisture content and the properties of moulding sand containing bentonite clay. Taking into account another parameter of the moulding sand (for instance R_c^W) after a specified mixing time allows the power demands during mixing to be more precisely defined. The parameter L_{ur} would then express the unit power required to obtain the sand with precisely controlled parameters. It is found out that the power consumption by the mixer drive increases more slowly when the mixing time is increased. Stabilization of power consumption during the mixing in a paddle mixer is hampered by sand thickening at the pan bottom, which is responsible for increased power consumption. On the other hand, when the mixing time is long, the sand temperature tends to increase and water contained in sand tends to evaporate. When the mixing time exceeds 10 minutes, moisture content will decrease by about 1 %.

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. 8. 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).

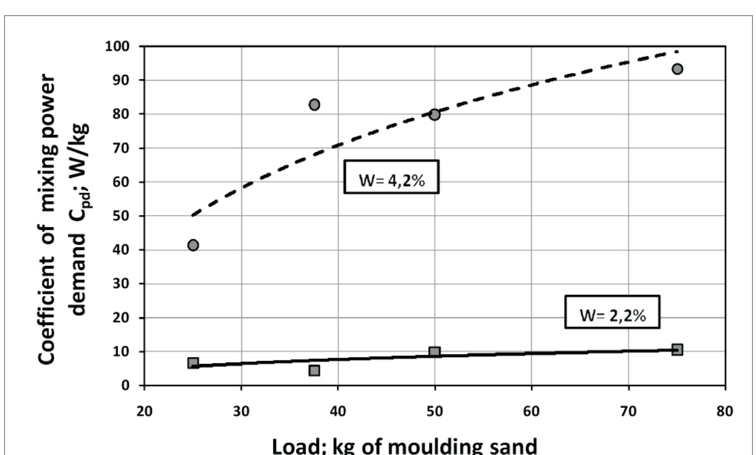

Fig. 7. Coefficient of mixing power demand C_{pd} versus load for different moisture content W

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.

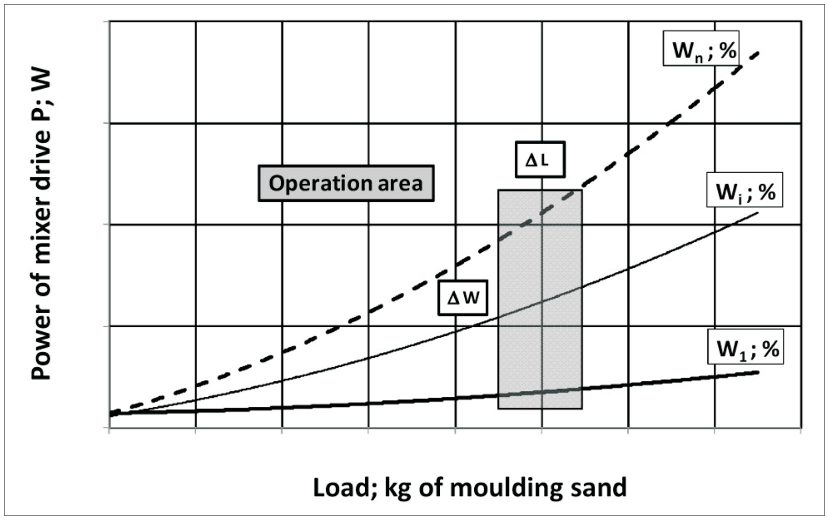

Fig. 8. Schematic presentation of mixer operation area connected with basic parameters deviation on the background of family of functions – $P= f(L)_{Wi=const}$; W – moisture of moulding sand, L – load of mixer pan

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 actual plot of power consumption by a mixer drive during the mixing process (Fig. 9) resembles that of $R_c^w=f(\tau)$, widely quoted in literature [6]. In qualitative terms, this plot is represented by a broken line. Finding the correlation between those two patterns might become the starting point for the development of a system to control the mixer operation. For that purpose measurements of instantaneous power consumption seem merited and the use of a microprocessor system, described elsewhere [18, 19] is fully recommended. Besides, Fig. 9 shows that an increased moisture content of sand leads to the increased power consumption by the mixer drive.

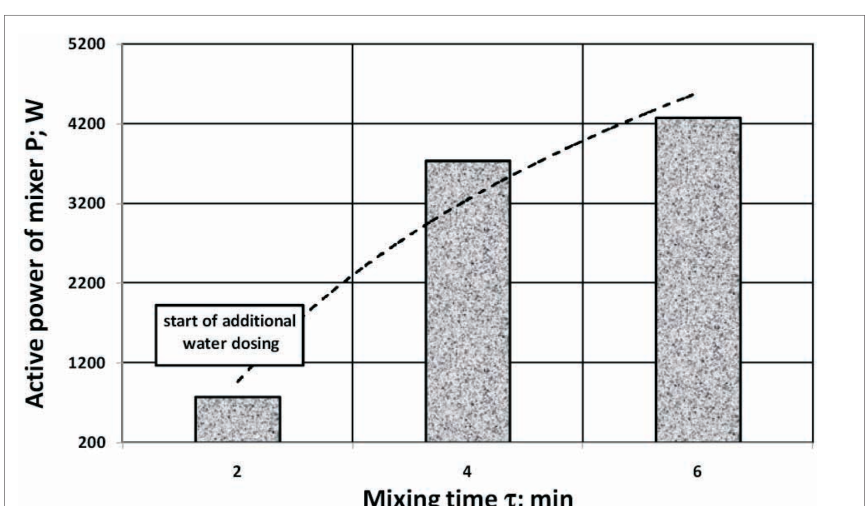

Fig. 9. Influence of mixing time- τ on active power of the mixer- P; moisture of moulding sand- W= 4,2 %, load of mixer pan: 50 kg of moulding sand

The influence of other factors: variations of moulding sand composition, variations of the binder content shall be investigated thoroughly, also during the production processes.

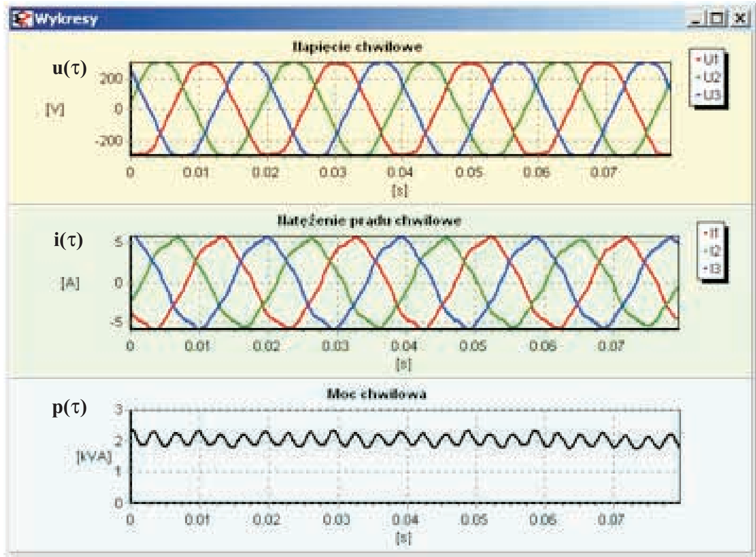

Fig. 10. View of window in a program of recording of instantaneous values: currents – i(τ), voltages – u(τ) and power – p(τ) ; (load of 075 MS mixer pan L=64 kg); first version of the software

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 [18, 19] 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 [18] enables the measurement of instantaneous power factors [17, 19]. Figs. 10 and 11 shows selected system components and first results of measurements of selected energy-parameters. These measurements permit the identification of phenomena occurring during transient operating conditions.

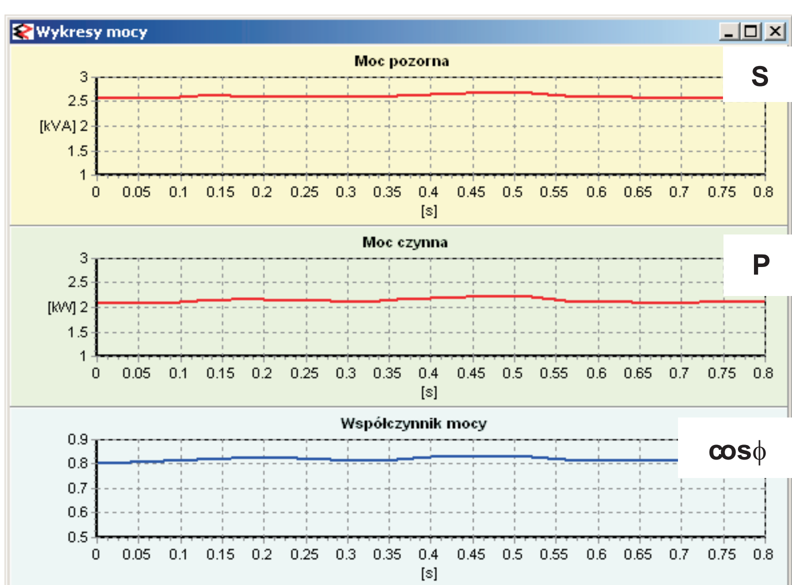

Fig. 11. Window displaying the plots of apparent- S, active power – P values and power factor- cosφ (load of 075 MS mixer pan L=64 kg); first version of the software

On the Fig. 12 and 13 are presented some results of energy parameters of data registration for preparing of moulding sand with bentonite (8%) in edge runner mixers (SIMPSON type). The main parameters of the moulding sand in this series were as follow: compressive strength R_c^w was 0.077 MPa, permeability P^w=3,0 m^2/MPa· s), the average moisture content W=3,0 %.

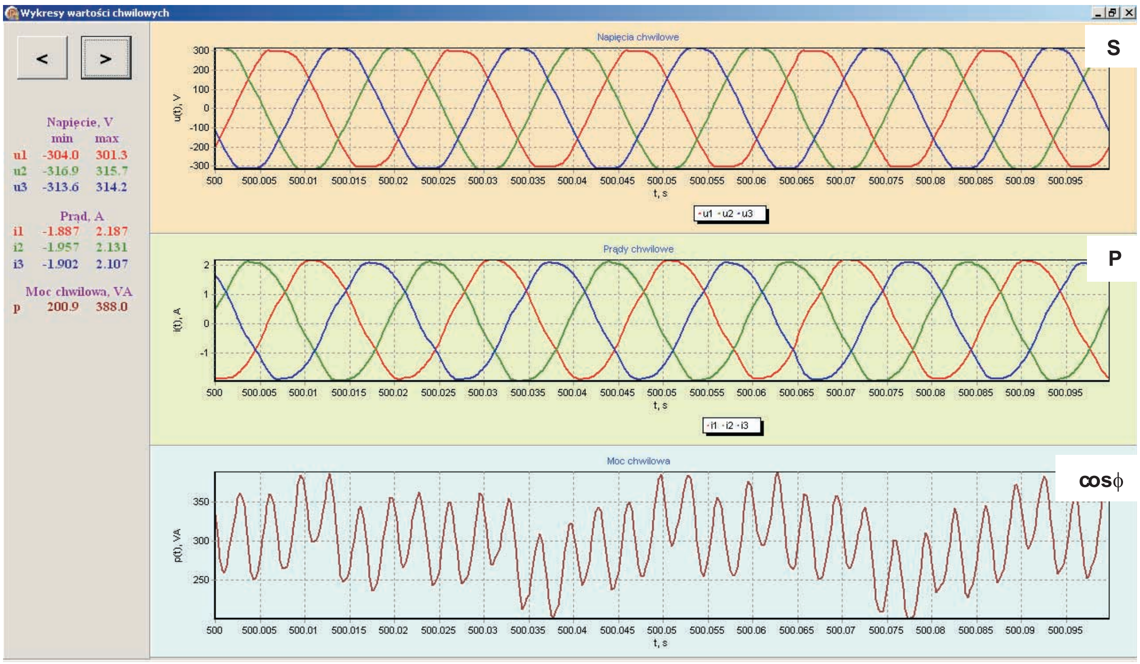

Fig. 12. View of window in a program of recording of instantaneous voltages – u(τ), currents – i(τ),and power – p(τ) (Simpson type mixer- LM ; load: 3 kg of 3% moistened moulding sand); latest version of the software

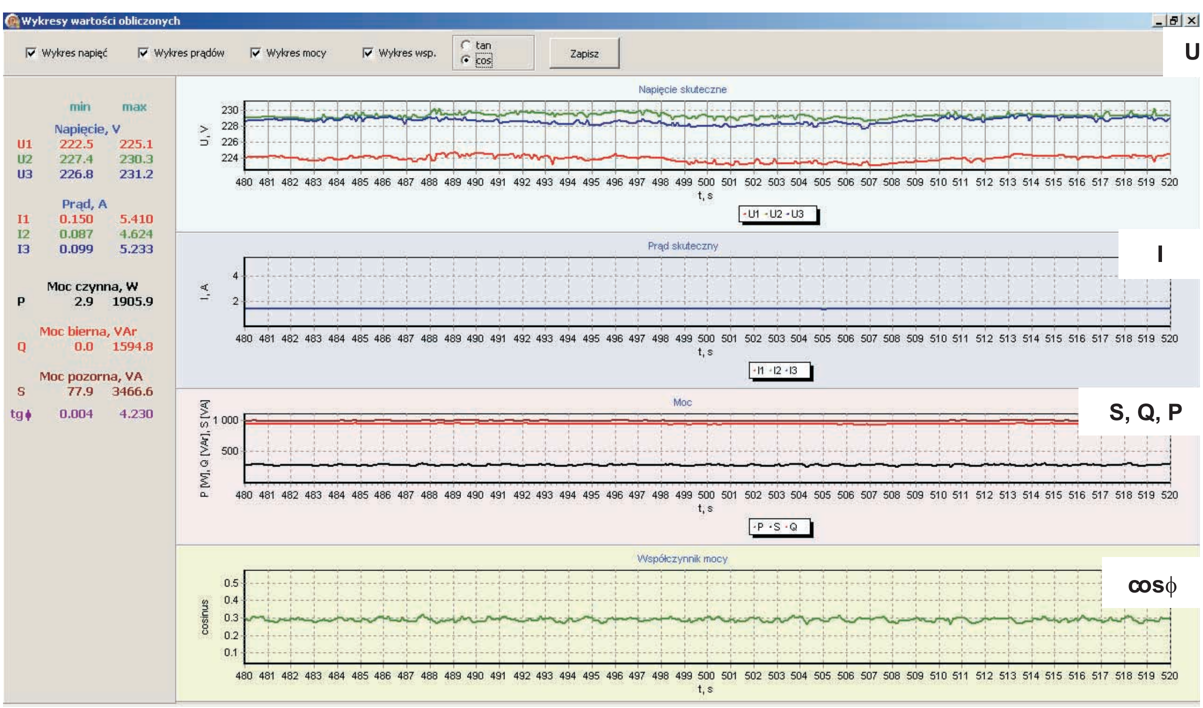

Fig. 13. View of window in a program of recording of effective voltages – U, currents – I, apparent- S, reactive- Q, active – P power values and power factor- cosφ; (Simpson type mixer- LM; load: 3 kg of 3% moistened moulding sand); latest version of the software

The experiments have proved the very low efficiency of using electrical energy [21] (low value of power factor – Fig. 3) despite the load of the pan was within the nominal range. The changes of active power during tests connected with the changes of other parameters for example load, moisture were rather small then expected according to [14]. The reason of this situation can be the relatively large values of L_u coefficients for small machines – Figs. 2-5 and the mixing way in the edge runner mixers (SIMPSON type) [2, 8].

6. Summing up

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 or other foundry process using the devices with electrical drive.

The outlined methodology of power consumption measurements and the obtained test data fully merit further research work associated with the concept of using the monitoring of power consumption to the control of moulding sand preparation. Research data are indicative of major changes in the mixer loading levels due to the specificity of mixing processes. Further analytical and experimental studies are required to optimize the mixing processes in terms of power demand. Variations of power consumption during the mixing process due to changed properties of molding sand are well pronounced, which is of major importance from the standpoint of metrology. Application of a newly-developed microprocessor system to the monitoring of power consumption will result in an improved accuracy of measurements, at the same time facilitating the analysis of measurement data.

The proposed system for measurements of power parameters is fairly universal and might be well applied while testing a majority of electric-driven foundry machines and devices, power- supplied from the single phase or triple phase AC grid. As electric drives are widely used in foundry machinery, the system proves to be particularly useful. Other potential applications include: online monitoring of power consumption by a machine whereby measurement results are further utilised to control the machine's performance, handling the emergency conditions, using the measured signals as indicators in process control, optimisation of drive selection at the stage of prototype testing. The system allows for measurements of other parameters associated with power demand, which cannot be handled by other systems based on effective values of pertinent quantities. Results of preliminary tests confirm the adequacy of the proposed system. Further research work is merited to improve the hardware and software features.

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