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Comparative Analysis of Power Measurement Results in the Testing of Sand Mixers

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Abstract

Investigations of operating parameters of widely used sand mixers reveal a wide variability range in the values of parameters associated with their power demand. Power efficiency of manufacturing processes has received a great deal of attention lately, which encourages the research efforts to optimise this aspects of operation of machines and installations as well. In the first place these machines and installations have to work properly as a part of the process line- which applies also to moulding sand mixers. Experiments conducted by the authors suggest that the same goal can be achieved at variable energy input levels. To obtain information about the power demands of sand mixers requires the use of highly specialised equipment, methodology and result processing procedures. This study provides a brief characteristic of measurement equipment and results of measurements taken on a unit AG-015 (based on a roller mixer) and a laboratory rotor mixer.

Keywords: Sand preparation, Power measurements of mixers

1. Introduction

One of the available methods of monitoring and diagnosing the manufacturing processes using machines and installations powered from the mains involves the measurements of voltage and current intensity whilst in service. Basing on the measurement data, the demand for active, reactive and apparent power is determined accordingly. Power measurements can be taken with conventional meters and recorders, both analogue and digital ones, or with the use of dedicated computer systems [1, 2, 7]. An example of a computer system is a recorder of instantaneous voltage and current levels, whose operating principles and applicability range are explained elsewhere [3, 4, 8, 9]. The recorder was designed and fabricated at the Laboratory of Mechanisation, Automatic and Foundry Design (Faculty

of Foundry Engineering AGH-UST) in collaboration with the Department of Metrology (Faculty of Electrical Engineering, Automatics and Electronics AGH-UST). In some cases commercially available metering devices may prove inadequate and their applicability range restricted. The group of portable analysers includes the power quality analyser KEW 6310, manufactured by Kyoritsu (Japan). To determine the range of its applicability, sand preparation process is investigated in a small foundry plant, with a low level of mechanisation, equipped with the AG-015 unit based on a roller mixer. The applicability of the device designed by the authors is verified through testing done on a laboratory rotor mixer.

2. Measurement equipment

Industrial tests of the unit AG-015 are performed using a power quality analyser KEW 6310, manufactured by Kyoritsu company, Japan (Fig. 1a), enabling the recording of power parameters in single- or three-phase systems and in 2, 3, 4 – cable installations. The KEW analyser is provided with a measurement and recording system to register the following parameters:

- voltage and current intensity in each phase and in the zero lead (rms values),
- active, reactive and apparent power and the power factor $\cos\phi$,
- active, reactive and apparent power energy,
- phase angle and frequency,
- harmonic components of voltage and current intensity,
- voltage drops and surge voltages, transients, start-up currents, asymmetry of power supply.

The power quality analyser KEW6310 enables the measurement of sine voltages up to 1000 V with the accuracy level of $\pm 0.3\%$. Voltage and current leads are connected to the supply main with the use of clamps. Extra clamps enable the power measurements in the zero lead. The clamps for current measurements can be applied in the measurement range: 5, 200, 200, 500, 1000, 3000 amperes.

The harmonic analysis of voltage or current intensity can involve up to the 63rd harmonic, assuming that the first harmonic frequency should fall in the range between 45 and 65 Hz.

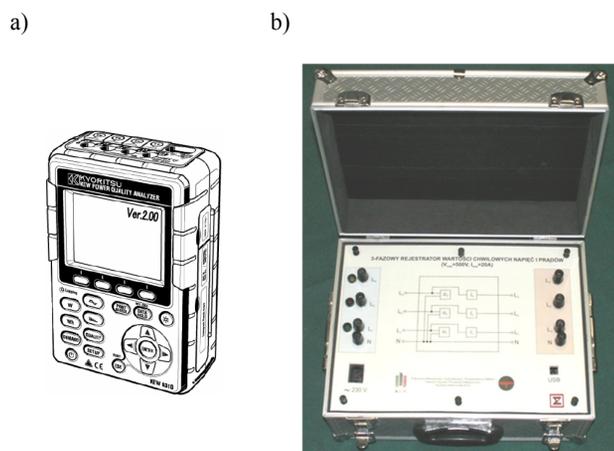


Fig. 1. Power quality analyser KEW6310 – a) and a prototype 3-phase recorder of instantaneous voltage and current levels (PMAiPO, WO AGH-UST) – b) [4, 6]

Measurements of active, reactive and apparent power can be taken in the time intervals 1, 2, 5, 10, 15, 20 and 30 s and every 1, 2, 5, 10, 20, 30, 60 min. Measurement data can be stored in the internal memory of the recorder or on the Compact Flash type card and further processed in a computer, connected via a USB port.

Further tests were performed in the laboratory set-up complete with a state-of-the-art rotor mixer, in which the rotor and mixer pan drives are equipped with frequency converters.

Measurements were taken with a recorder of instantaneous voltage and current levels (Fig. 1b) [4, 5]. The recorder is intended for use in measurements of power parameters in the systems effecting the power supply from frequency converters. It has an integrated current transformer LEM, enabling the measurement of current level up to 20 A for each phase. This enables simultaneous recording of 4000 measurement data per second, in each of the 6 channels. A detailed description of the recorder and its technical specification is presented elsewhere [4, 5]. A dedicated computer software is used to support the recording and processing of measurement results and the calculation procedures based on digital signal processing algorithms.

3. Power measurements during the operation of the sand preparation unit AG-015 and a laboratory rotor mixer

Plots of power demand by investigated machines in the function of time are shown in plots in Fig. 2 and 3.

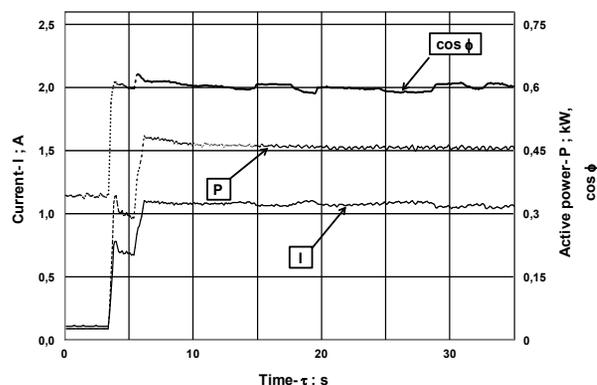


Fig. 2. Current intensity I, active power P and $\cos\phi$ during the duty cycle of a laboratory rotor mixer: idle run

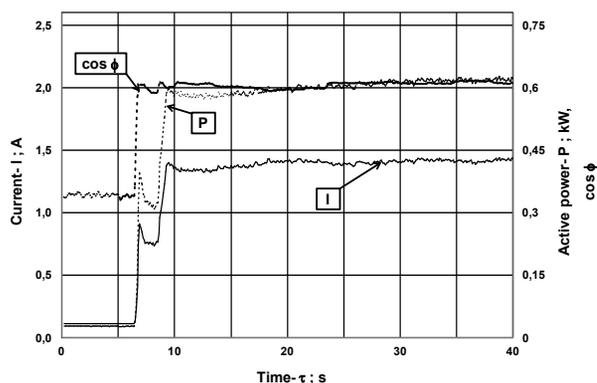


Fig. 3. Current intensity I, active power P and $\cos\phi$ during the duty cycle of a laboratory rotor mixer: 5 kg load of the pan

Plots in Fig. 2 and 3 show the time patterns of current intensity (the mean value for three phases whilst the load asymmetry was insignificant), of active power and the power factor $\cos\phi$ under various stages of operation. For an older type unit AG-015, of particular importance is the strong dependence of the power factor on the applied load mass; its low value (less than 0.6 under large loads and of the order of 0.2 during the idle run) is undesired from the standpoint of the power network performance in foundry plants. In newer laboratory mixers, the power factor approaches 0.6 and with a power increase due to increased rpm speed of the rotor and pan its value may become even larger. In the case of the two mixer types, the dependence of active power on the applied load is clearly revealed (Fig. 2, 3).

Plots evidence the occurrence of an overcurrent effect during particular stages of the sand preparation process. Power measurements with the KEW6310 device were taken at 1 s time intervals, in the case of the recorder of instantaneous power indicators, the rms values were registered every 0.1 s. Measurement results were approximated by the trend lines (adjusted mean).

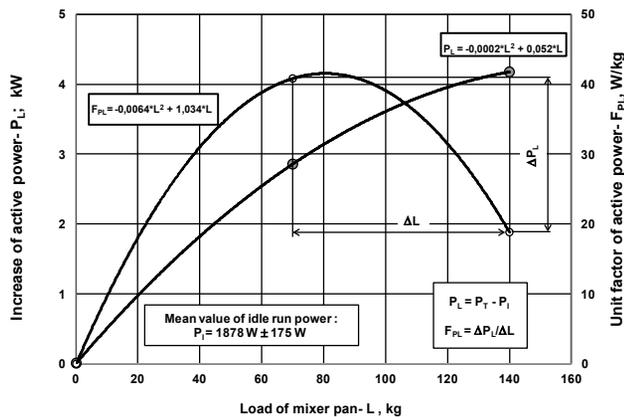


Fig. 4. Variations of power- P_L and a unit power factor- F_{PL} associated with the load change- L in the unit AG-015

Variability patterns of those quantities may differ for investigated mixer types, due to differences in their design features and the manner of executing unit processes during the mixing (Fig. 4 and 5) of particular importance are the differences in the power factor F_{PL} . In the investigated range of pan loads, the maximum value of the relationship $F_{PL}=f(L)$ is registered for the roller mixer. This may be attributable to a weaker dependence of power consumption by a roller moving on the sand layer on the thickness of this sand layer. A stronger dependence between the load mass and power consumption can be expected in the case of a plough system.

The joint drive for the two systems precludes a separate analysis of power consumption by the two systems. It would be possible in laboratory conditions- following the disassembly of particular units. Power measurements would have to be taken for the plough and roller system separately. Data shown in Fig. 2 and 4 are related to measurements taken in an operative foundry plant, where such measurements were not possible.

Variations of power consumption associated with variations of moisture content depend on the mixer type - Fig. 6. These

differences seems to be attributable to differences in engineering design and interactions between the mixing implements and the sand.

Because of the manner of water supply, the input signal – water flow rate- can be treated as a rectangular signal, its duration time being decidedly less than the response time- the signal of active power change caused by sand being moistured. In rotor mixers in which the ‘volumetric’ mixing process is adopted, the patterns of response signals are similar, both for a small laboratory mixer and for a larger prototype rotor mixer (based on a paddle mixer MS-75, manufactured by the Dozamet Company in Nowa Sól, Poland). In the case of the unit AG-015 the time pattern of power level reveals a maximum, after which the power demand stabilises on the level slightly higher than the initial one. It might be attributable to stabilisation of the new thickness of the sand layer on which the roller is moving and the minor influence that variations of the moisture content have on the rolling resistance can be neglected. Power increase (time: 160-180 s) during this stabilisation period can be associated with the operation of the plough system.

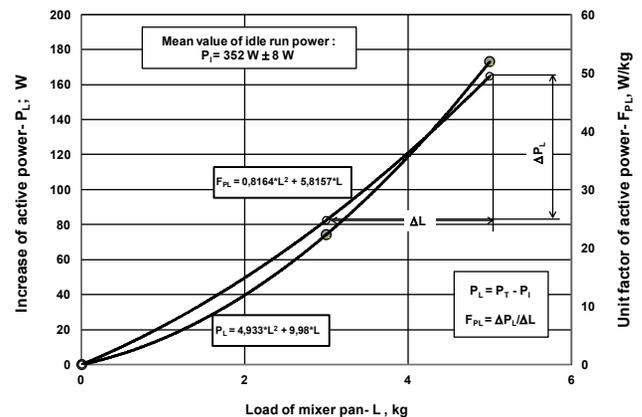


Fig. 5. Variation of power- P_L and unit power factor- F_{PL} associated with variation of the laboratory rotor mixer load

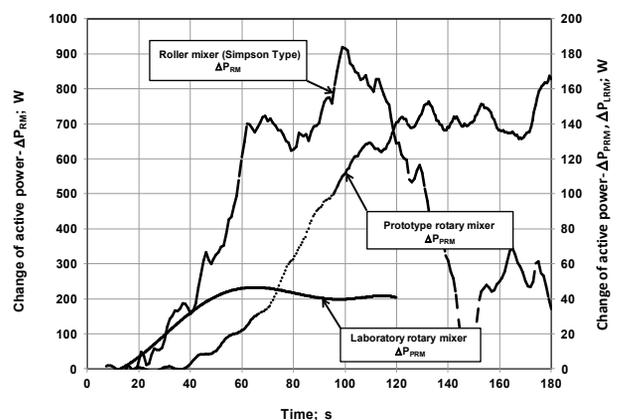


Fig. 6. Time pattern of active power consumption after water dosing to three types of mixers. (trend lines are revealed for the measured active power signals)

The level of active power consumption by a mixer depends on several factors, such as load mass and moisture content in sand. The influence of these parameters on power consumption should be investigated by identifying the parameters of the function in two input variables and the output variable (active power consumption). The analysis of differences between power consumption levels should take into account potential voltage fluctuations in the supply network, which may be independent of loading conditions of the investigated machine but associated with operation of other machines and installations in power network sub-systems.

4. Summing-up

Measurement data and analysis of measurement results suggest that the power quality analyser seems an effective tool to be used in monitoring of electric-powered foundry machines and installations [9]. Measurements and analysis of variability range of selected power energy parameters (voltage, active or apparent power consumption, voltage fluctuations or distortions of the voltage or current patterns in the selected phase of the supply system) offer us a good insight into phenomena taking place during the technological process. A major constraint restricting the use of a power quality analyser in performance monitoring is the control of power energy parameters on supply leads exclusively, ahead of the frequency converter.

The other recorder, developed by the authors, should be categorised as a new-generation device. It can be connected at several points of the power-supply system, for example behind the frequency converter [5, 6]. Measurements of instantaneous values of parameters enable a more reliable analysis of complex phenomena occurring during the sand preparation in various types of mixers.

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