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USE OF OVERALL EQUIPMENT EFFECTIVENESS INDICATOR FOR ANALYSIS OF WORK TIME OF TEST BENCH

WYKORZYSTANIE WSPÓŁCZYNNIKA OGÓLNEJ EFEKTYWNOŚCI URZĄDZENIA DO ANALIZY CZASU PRACY STACJI WZORCOWNICZEJ

A b s t r a c t

This article presents information about the Overall Equipment Effectiveness indicator – a key measure used in the Total Productive Maintenance. The research object has been characterized – test bench, which enables a simultaneous, multiposition calibration, adjustment and verification of single- phase or three- phase electricity meters. In the research part, the analysis of effectiveness of the test bench by means of TPM and Overall Equipment Effectiveness indicators was presented.

Keywords: Overall Equipment Effectiveness indicator, test bench, calibration, adjustment, verification

S t r e s z c z e n i e

W artykule zaprezentowano informacje dotyczące Całkowitej Efektywności Urządzenia – kluczowego miernika stosowanego w Kompleksowym Utrzymaniu Maszyn TPM. Scharakteryzowano obiekt badawczy – stację wzorcowniczą, która umożliwia jednoczesną, wielostanowiskową kalibrację, adiustację i legalizację jednofazowych i trójfazowych liczników energii elektrycznej. W części badawczej zaprezentowano analizę efektywności stacji wzorcowniczej z zastosowaniem współczynników TPM i współczynnika Całkowitej Efektywności Urządzenia.

Słowa kluczowe: współczynnik Całkowitej Efektywności Urządzenia, stacja wzorcownicza, kalibracja, adiustacja, legalizacja

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1. Introduction

THE Overall Equipment Effectiveness OEE indicator [1–3] is a primary measure used in the Total Productive Maintenance, which is applied to evaluate the current state of technical objects. Any company producing a specific product, in response to customer needs, gives it a certain value. Effective adding value requires an effective use of technical objects, so that they bring the least losses (breakdown, changeover, micro-stoppages, reduced speed, quality defects, startup). The Overall Equipment Effectiveness OEE indicator includes not only the number of products that can be produced by a machine in a specified time frame [3, 4]. Calculation of the machine performance indicator that is the comparison between the actual volume of production and the volume of production planned (among others resulting from the established technology) is one of the elements of the Overall Equipment Effectiveness OEE indicator. Furthermore, this indicator includes the comparison of a potential machine operating time of machine with the time in which the machine is actually used for the production – it calculates the availability indicator of a machine and the quality indicator by comparing the amount of manufactured products and the quantities of products that meet customer's requirements. Multiplying the indicator of performance, availability and quality results in obtaining the Overall Equipment Effectiveness OEE indicator, which is expressed as a percentage [3, 4]. It can be attributed to individual machines, production positions or the whole assembly lines.

2. Characteristics of the research object

Test bench is a device that enables a simultaneous, multiposition calibration, adjustment and verification of single- phase or three- phase electricity meters. Calibration is an action which in certain conditions, firstly determines the relationship between mapped by the standard measurement of values quantity with their measurement uncertainties and the corresponding indications with their uncertainties and, secondly, uses this information to determine the relationship that allows to get results measurement based on the indication. A protocol, calibration function, calibration diagram, calibration curve, or calibration table can be the result of the calibration [5]. The adjustment of a measuring system is a set of activities performed by means of a measuring system to ensure that the values quantity, which they have to be measured, corresponds to the correct indication. The adjustment of a measuring system should not be confused with calibration, which is the prerequisite [5]. Verification is a set of activities involving checking, statement and certifying the proof of verification that the measuring instrument complies with the requirements [6].

Test bench consists of the following components: rack with the quick fixing device system, 3 current sources, 3 voltage sources, reference standard meter (meter used to measure the unit of electricity. It is generally constructed and used in a way to obtain the highest accuracy and stability properties in a controlled laboratory environment [7]), errors calculators and photoelectric scanning heads, separating transformers, computer with control software.

To determine the error of the tested meters, test bench uses the method of reference standard meter. The principle of this method involves a simultaneous measurement of energy by the tested meters and by the reference standard meter. An error of the tested meter is determined by comparing the number of impulses generated by the reference standard meter with the number of impulses which correspond to measured energy from tested meters. Photoelectric scanning head detects the movement of the electromechanical meter disc (identification of black spots on the disc of the meter) or the LED flash of the tested static meter (electronic). During the test, the circuits of the tested meters are serial connected in different phases and operate at the same voltage values and phase shifts. The control software provides automation of the process and prevents interference in the operation of the process.

Figure 1 presents a 6-position test bench with components [10].

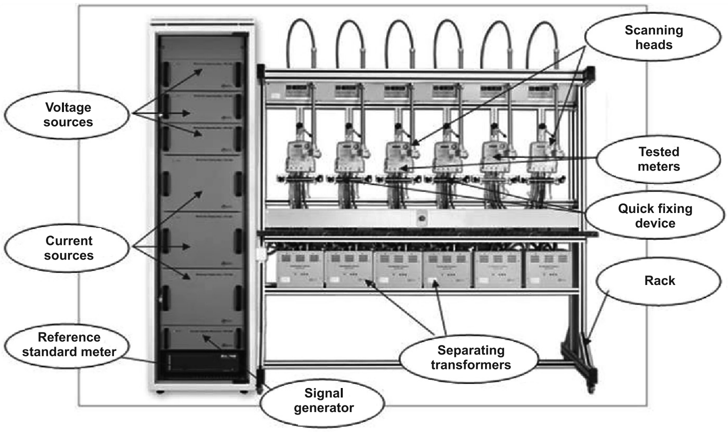

Fig. 1. A 6-position test bench with components [10]

According to the Decree of the Minister of Economy of 7 January 2008 [8] errors of static meters are tested according to the following rules (Table 1).

Table 1

The maximum permissible errors of indications and load points of static meter

Type of meter **and load**	**Load point**		**The maximum permissible errors of meters indications expressed in [%] for accuracy classes**		
	Load current	**Power factor cos φ**	**C**	**B**	**A**
Single phase meters	0.1 I_b	1	± 0.5	± 1.0	± 2.0
	I_b	1	± 0.5	± 1.0	± 2.0
	I_b	0.5(inductive)	± 0.5	± 1.0	± 2.0
	I_{max}	1	± 0.5	± 1.0	± 2.0

Three phase meters loaded symmetrically	$0.1\ I_b$	1	± 0.5	± 1.0	± 2.0
	$0.5\ I_b$	1	± 0.5	± 1.0	± 2.0
	$0.5\ I_b$	0.5(inductive)	± 0.5	± 1.0	± 2.0
	I_b	1	± 0.5	± 1.0	± 2.0
	I_b	0.5(inductive	± 0.5	± 1.0	± 2.0
	I_{max}	1	± 0.5	± 1.0	± 2.0
Three phase meters with a load of only one phase	I_b	1	± 1.0	± 2.0	± 3.0
	I_b	0.5(inductive)	± 1.0	± 2.0	± 3.0

Base current I_b – current value, for which important characteristics of the meter are determined [8], e.g. for transformer meters is rated current.
Maximum current I_{max} – the highest value of current at which a meter error in the reference conditions does not exceed the maximum permissible errors [8].

During the verification of meters of active electricity for alternating current, single-phase and three-phase meters, induction meters and static meters, accuracy class 0.5; 1 and 2, are used according to the requirements corresponding to classes C, B and A [9].

3. Analysis of the effectiveness of test bench by means of OEE indicator

The analysis of effectiveness of the use of test bench time work [1–4, 11–13], by means of the Overall Equipment Effectiveness OEE indicator was carried out during the last 12 weeks of 2015 year.

Table 2 presents the summary of test results of the effectiveness of 24-position test bench, which makes a verification of three- phase meters of C class to indirect measurements (with the meters assembly in a quick fixing device system).

Table 2

Analysis of the effectiveness of the test bench in 12 weeks

Research period [week]	TZ. Shift fund of the working time [h]	Planned time of machine stoppage [h]	Work time [h]	Unplanned stoppage of machine [h]	Time of the net exploitation [h]	WD. Availability indicator [%]	Production [unit]	Ideal time per unit [h\unit]	Actual time per unit [h\unit]	WPD. Speed working indicator [%]	WW. Performance indicator [%]	Number of failures [unit]	WJ. Quality indicator [%]	OEE. Overall Equipment Effectiveness [%]
1	80	0	80	0	80	100.00	480	0.163	0.167	97.80	97.80	0	100.00	97.80
2	80	0	80	0	80	100.00	480	0.163	0.167	97.80	97.80	0	100.00	97.80
3	80	0	80	0	80	100.00	480	0.163	0.167	97.80	97.80	0	100.00	97.80
4	80	0	80	0	80	100.00	480	0.163	0.167	97.80	97.80	0	100.00	97.80

5	64	0	64	0	64	100.00	384	0.163	0.167	97.80	97.80	0	100.00	97.80
6	80	8	72	0	72	100.00	432	0.163	0.170	95.88	97.80	0	100.00	97.80
7	80	0	80	0	80	100.00	480	0.163	0.167	97.80	97.80	0	100.00	97.80
8	80	0	80	0	80	100.00	480	0.163	0.167	97.80	97.80	0	100.00	97.80
9	80	0	80	8	72	90.00	432	0.163	0.170	95.88	97.80	0	100.00	88.02
10	80	0	80	0	80	100.00	480	0.163	0.169	96.45	97.80	0	100.00	97.80
11	48	0	48	0	48	100.00	288	0.163	0.169	96.45	97.80	0	100.00	97.80
12	48	8	40	0	40	100.00	240	0.163	0.169	96.45	97.80	0	100.00	97.80

Graphic interpretation of the selected indicators is showed in Fig. 2.

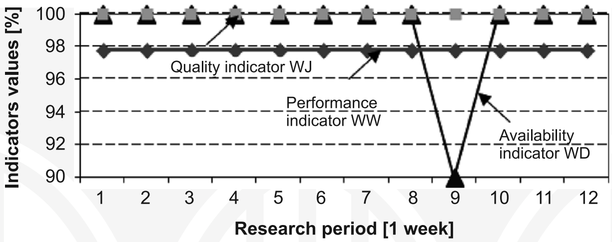

Fig. 2. Graphic interpretation of the availability indicator, performance indicator and quality indicator in the research period for test bench

From the data presented in Table 2 and Fig. 2 it can be concluded that the availability, performance and quality indicators are at a high level, which exceeds 90%. The availability indicator amounts to 100% for all weeks except week 9, where there were unplanned stops of the machine. The performance indicator for all weeks is at the level above 97% and the quality indicator amounts to 100% for all weeks.

Figure 3 presents a graphical interpretation of the Overall Equipment Effectiveness indicator for the test bench in the research period of 12 weeks.

From Fig. 3 it can be concluded that the Overall Equipment Effectiveness indicator is at a very high level, which exceeds 97%, except 9 week, where the OEE decline was caused by the unplanned stops of test bench.

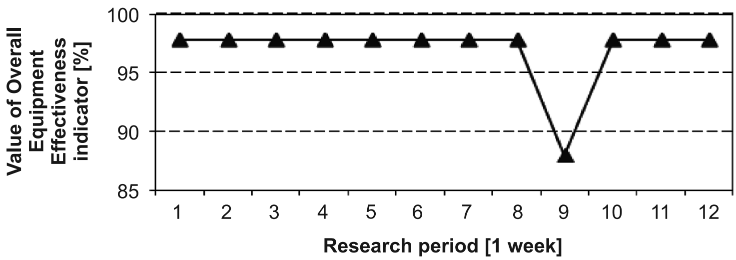

Fig. 3. Graphic interpretation of the Overall Equipment Effectiveness indicator for test bench in the research period

4. Conclusion

To calculate the effectiveness of the use of test bench time work, the Overall Equipment Effectiveness OEE indicator was used. It allowed for evaluating the current state and "condition" of test bench. Thanks to this analysis it can conclude on further activities related to the maintenance of these machines and activities related to the improvement.

The Overall Equipment Effectiveness OEE indicator for test bench is very high and exceeds 97% (except 9 week). The results suggest low losses related to the working time of test bench (only in the ninth analyzed week were was an unplanned machine downtime), the speed of the machine work shows a slight loss of just over 2%. In the analyzed period of 12 weeks there were no losses associated with quality. Such a high indicator of the Overall Equipment Effectiveness for test bench results from, among others, a close cooperation of operators and workers from the maintenance department, training systems and effective supervision by the authorities of legal metrology (Offices of Measures). The reliable and modern design of the test bench, automation of the process and its documentation, application of software with a database of types of meters and passes and control of the course of the verification process are factors which contribute to the high level of the Overall Equipment Effectiveness indicator.

References

[1] Borkowski S., Selejdak J., Salamon Sz., *Efektywność eksploatacji maszyn i urządzeń*, Sekcja Wydawnictw Wydziału Zarządzania Politechniki Częstochowskiej, Częstochowa 2006, 192-195 [in Polish].

[2] Borkowski S., Ulewicz R., *Zarządzania produkcją. Systemy produkcyjne*, Oficyna Wydawnicza „Humanitas", Sosnowiec 2008, 213-216 [in Polish].

[3] The Productivity Press Development Team, *OEE dla operatorów. Całkowita Efektywność Urządzenia*, Wydawnictwo ProdPress, Wrocław 2009, 12-13 [in Polish].

[4] *Wskaźnik OEE – Teoria i praktyka. wydanie II*, http://www.neuron.com.pl/pliki/oee.pdf (date of acc. 15.06.2016).

[5] *Międzynarodowy Słownik Terminów Metrologii Prawnej*, https://www.gum.gov.pl/media/473882/mi_dzynarodowy_s_ownik_termin_w_metrologii_prawnej.pdf (date of acc.: 15.06.2016).

[6] *Prawo o miarach z dnia 11 maja 2001 r.* (Dz.U. Nr 63, poz. 636) [in Polish].

[7] Norma PN-EN 50470-1:2008 Urządzenia do pomiarów energii elektrycznej (prądu przemiennego). Część 1: Wymagania ogólne, badania i warunki badań. Urządzenia do pomiarów (klas A, B i C).

[8] *Rozporządzenie Ministra Gospodarki z dnia 7 stycznia 2008 r. w sprawie wymagań, którym powinny odpowiadać liczniki energii elektrycznej prądu przemiennego, oraz szczegółowego zakresu sprawdzeń wykonywanych podczas prawnej kontroli metrologicznej tych przyrządów pomiarowych* (Dz.U. 2008 nr 11 poz. 63) [in Polish].

[9] MID – Measuring Instruments Directive – Directive 2004/22/EC of the European Parliament and of the Council of 31st March 2004 on measuring instruments.

[10] Materiały Firmy MeterTest Sp. z o.o., http://www.meter-test-equipment.com/ [date of acc. 15.06.2016].

[11] Jagusiak M., Borkowski S., Mielczarek K., *Effectiveness exploitation of autoclave basing on the TPM coefficients*, [in:] Borkowski S., Kročko V. (eds.), *TPM and PAMCO as basis of estimation*

of machines exploitation efficiency, Publishing and Press Association of Universities Russia Saint Petersburg, Saint Petersburg 2008, 101-106.

[12] Krynke M., Knop K., Mielczarek K., *Analysis of the modernity and effectiveness of chosen machines in the processing of high-molecular materials*, Production Engineering Archives, **3** (2), 2014, 18-21.

[13] Zasadzień M., *Wpływ implementacji kart przeglądów na wydajność maszyn w wybranym przedsiębiorstwie produkcyjnym*, Management Systems in Production Engineering, **4** (20), 2015, 225-229.