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ANALYSIS OF MACHINES EFFECTIVENESS IN THE COMPANY WHICH PRODUCES ELECTRONIC EQUIPMENT

9.1 INTRODUCTION

Maintenance of technical objects is systematic and daily work performed in the company. This work is connected with performance of tasks (one-time, periodic or scheduled) to prevent degradation in the quality of the equipment and the occurrence of a failures or, if they occur - to remove them in order to restore the full functionality of these devices [1, 2].

Analyzing systems maintenance in the twentieth century, can be seen, that 4 generations, related to the maintenance of technical objects were formed. It can be divided them into unplanned and planned. Tab. 9.1 shows the characteristics of these systems.

Tab. 9.1 Characteristics of systems maintenance

The name of the system, generation	The period of formation	Nature of the system	Characteristics
After-failure repairs system – generation I	30-40 years of the twentieth century	Unplanned	Based on a strategy of „failure to failure". Repairs take place only after a failure. Attitude to produce the largest number of products.
Planned - preventive system - generation II	50-60 years of the twentieth century	Planned	Periodic repairs, maintenance operations as recommended by the manufacturer (eg. after a specified number of hours worked by a machine). Training operators to using and the basic operation of the machine.
Preventive inspection system - generation III	70-80-90 years of the twentieth century	planned	Executing an inspections or an observations, to plan maintenance operations, technical inspections and repairs. More emphasis on technical diagnostics and health and safety during the operation of technical objects.
Proactive system - generation IV	90 years of the twentieth century, nowadays	Planned	It focuses on the technical objects damages in microscale. Using advanced techniques to analyze the chemical composition of operating fluids.

Source: own elaboration based on [1, 2]

By connecting assumptions of planned maintenance systems, it comes to the concept of the Total Productive Maintenance TPM [1, 2, 7, 8]. When in the 50s of the twentieth century it began in Japan to implement a planned - preventive system in Nippoden-

so factories producing auto parts, developed it as an effective system for machine maintenance. Japanese, combining the knowledge of machine operators with workers from maintenance department, improved the concept of "one produces, the other repairs." In addition to the inclusion of all employees in the continuous, total maintenance, research to analyze the chemical composition of operating fluid was implemented.

Total Productive Maintenance TPM [1, 2, 7, 8] focuses on the most effective use of technical objects and maximizing the effectiveness of the equipment. It creates the maintenance system, which includes the whole company and combines all types of maintenance and committed workers from maintenance department and operators. The main aim of TPM is pursuing to zero accidents and failures, increasing the productivity of the production system, increasing the effectiveness of technical objects and more profit and increasing employee satisfaction. The substance of the Total Productive Maintenance TPM is essentially regular cleaning activities, controlling, lubrication and checking the accuracy of the technical objects, early detection of abnormal operation of technical objects and the immediate reaction to the improper operation of technical objects.

9.2 CHARACTERISTICS OF THE RESEARCH SUBJECT

The subject of research is a company located in the Silesian Voivodeship, engaged in the production of modern devices, circuits and systems, metering and billing of power and electric energy. The basic range of company mainly includes single and three-phase electronic meters of electric energy in direct, semi-direct and indirect circuits, which are equipped with interfaces of remote communication to commonly used telecommunication networks. These meters are characterized by stability, reliability and accuracy, high class of measurement and mechanical resistance, EMC resistance and resistance to strong magnetic fields of neodymium magnets. The materials needed for the production of these meters are i.a.: integrated circuits, SMD units, multi-layer printed circuit board and fireproof polycarbonate case. The company also produces data communications systems for measurement, recording, analysis, presentation and billing of accounting sizes. The company has a lot of patents and utility models, as well as the quality management system according to ISO 9001:2008.

9.3 ANALYSIS OF MACHINES EFFECTIVENESS WITH USING OEE COEFFICIENT

To evaluate the current state of technical objects, Overall Equipment Effectiveness OEE coefficient is used [1-7]. This coefficient is a measure of machine work effectiveness, which is calculated on the basis of its performance: availability (in a sense of active machine work), performance (in a sense of planned percentage load), quality of products made by a particular machine. OEE coefficient can be attributed to particular machines, production workplace or whole assembly lines.

An analysis of machines work effectiveness [1-6], using Overall Equipment Effectiveness OEE coefficient was made in research company during 12 months, on the machines which are used in manufacturing process of electronic meter of electric energy - surface mount assembly machine and wave soldering machine.

The company has a Japanese surface mount assembly machine, which ensures high effectiveness. This machine is equipped with two video heads and complex optical systems, guaranteeing very high precision alignment of elements. Surface mount device components are packed in special strips or trays. This machine has also the precise buckets and feeders that charge the elements from strips and put these items on the printed circuit board in places covered with solder paste. The assembly process is fully automated, computer-controlled with production software and supervised by highly qualified staff.

Wave soldering is a machine in which above the "wave" hot, liquid tin is moved printed circuit board with elements, during being a few seconds contact between printed circuit board and wave a soldering process of many trough-hole components at the same time is followed. Unit for wave soldering has a microprocessor temperature control in each zone and allows for lead-free soldering. Tab. 9.2 shows the number of days in the month in which surface mount assembly machine and wave soldering machine worked.

Tab. 9.2 The number of days in the month in which surface mount assembly machine and wave soldering machine worked

Month Machine	1	2	3	4	5	6	7	8	9	10	11	12
Surface mount assembly machine	20	18	21	17	17	19	18	20	21	22	21	19
Wave soldering machine	21	19	21	18	18	20	19	20	20	21	21	19

Source: own elaboration

Tab. 9.3 presents summary of research results of the effectiveness of the surface mount assembly machine. The graphic interpretation of selected coefficients is showed in Fig. 9.1.

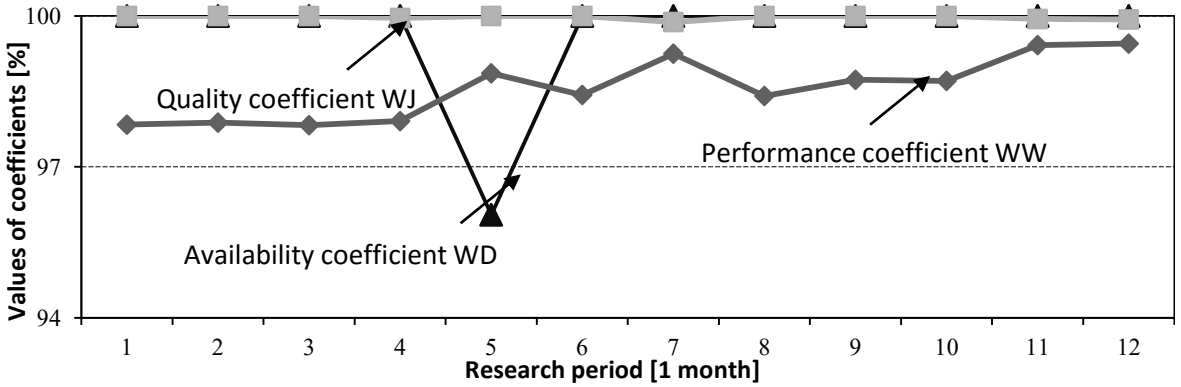

Fig. 9.1 Graphic interpretation of the availability coefficient, performance coefficient and quality coefficient in research period for surface mount assembly machine

Source: own elaboration

From the data presented in Tab. 9.3 and Fig. 9.1 it can be concluded that the availability coefficient, the performance coefficient and the quality coefficient are at high level, exceeding 90%. The availability coefficient amounts to 100% for all months except the month 5, where there were unplanned stops the machine. Performance coefficient for all

months on the level above 90% and quality coefficient is 100% for all months expect 4, 7, 11 and 12 month, where were slight nonconformities in production.

Tab. 9.3 Analysis of efficiency of the surface mount assembly machine during 12 months

Research period [month]	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 coefficient [%]	Production [unit]	Ideal time per unit [h\unit]	Actual time per unit [h\unit]	WPD. Speed working coefficient [%]	WW. Performance coefficient [%]	Number of failures [unit]	WJ. Quality coefficient [%]	OEE. Overall Equipment Effectiveness [%]
1	280	1	279	0	279	100.00	6500	0.042	0.044	95.45	97.84	0	100.00	97.84
2	252	1	251	0	251	100.00	5850	0.042	0.044	95.45	97.88	0	100.00	97.88
3	294	1	293	0	293	100.00	6825	0.042	0.044	95.45	97.83	0	100.00	97.83
4	238	1	237	0	237	100.00	5525	0.042	0.044	95.45	97.91	2	99.96	97.87
5	204	1	203	8	195	96.05	4590	0.042	0.043	97.67	98.86	0	100.00	94.95
6	228	1	227	0	227	100.00	5320	0.042	0.043	97.67	98.43	0	100.00	98.43
7	180	1	179	0	179	100.00	4230	0.042	0.043	97.67	99.25	5	99.88	99.13
8	240	1	239	0	239	100.00	5600	0.042	0.043	97.67	98.41	0	100.00	98.41
9	336	1	335	0	335	100.00	7875	0.042	0.045	93.33	98.73	0	100.00	98.73
10	352	1	351	0	351	100.00	8250	0.042	0.045	93.33	98.71	0	100.00	98.71
11	378	1	377	0	377	100.00	8925	0.042	0.046	91.30	99.42	5	99.94	99.36
12	342	1	341	0	341	100.00	8075	0.042	0.046	91.30	99.45	5	99.93	99.38

Source: own elaboration

The next Fig. 9.2 presents a graphical interpretation of the Overall Equipment Effectiveness coefficient for the surface mount assembly machine.

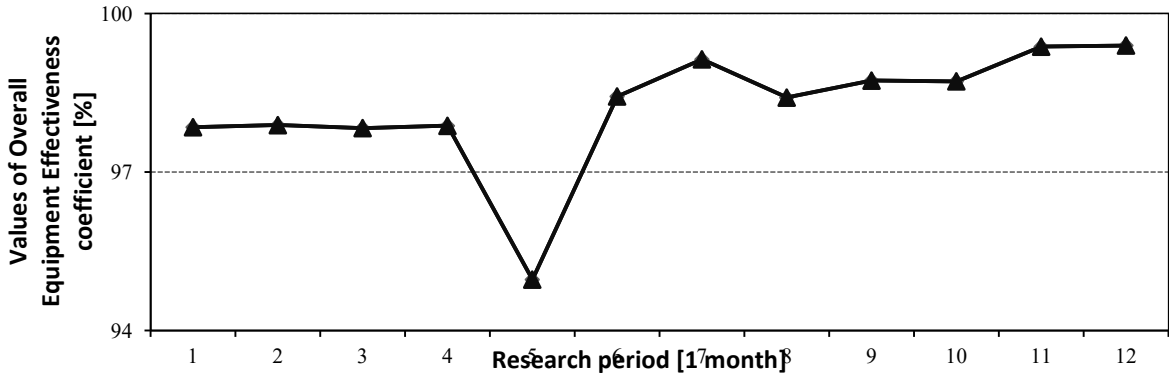

Fig. 9.2 Graphic interpretation of the Overall Equipment Effectiveness coefficient for surface mount assembly machine

Source: own elaboration

Overall Equipment Effectiveness coefficient OEE is at a very high level, which exceeds 90%. The OEE decline in 5 month was caused by unplanned stops the surface mount assembly machine. Tab. 9.4 presents summary of research results of the effectiveness of the wave soldering. The graphic interpretation of selected coefficients is showed in Fig. 9.3.

From the data presented in Tab. 9.4 and Fig. 9.3 it can be concluded that, as in the case of surface mount assembly machine the availability coefficient, the performance coefficient and the quality coefficient for wave soldering machine are at high level, exceeding 90%. The availability coefficient, except 9 month, where there were unplanned shutdowns machine, is for the remaining months on the level of 100%. Performance coefficient for all months is at a level higher than 95% for all months, while the quality coefficient is 100% for 1, 3, 5, 7, 9 and 11 months. In 2, 4, 6, 8, 10 and 12 month, this coefficient is on the level above 99%m because of the slight nonconformities in production. Fig. 9.4 shows a graphic interpretation of the Overall Equipment Effectiveness coefficient for the wave soldering machine. Overall Equipment Effectiveness coefficient OEE is at a very high level, which exceeds 90%. The OEE decline in 9 month was caused by unplanned stops the wave soldering machine.

Tab. 9.4 Analysis of efficiency of the wave soldering machine during 12 months

Research period [month]	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 coefficient [%]	Production [unit]	Ideal time per unit [h\unit]	Actual time per unit [h\unit]	WPD. Speed working coefficient [%]	WW. Performance coefficient [%]	Number of failures [unit]	WJ. Quality coefficient [%]	OEE. Overall Equipment Effectiveness [%]
1	252	4	248	0	248	100.00	7245	0.033	0.036	91.67	96.40	0	100.00	96.40
2	228	2	226	0	226	100.00	6555	0.033	0.036	91.67	95.71	4	99.93	95.64
3	210	2	208	0	208	100.00	6300	0.033	0.036	91.67	99.95	0	100.00	99.95
4	198	2	196	0	196	100.00	5850	0.033	0.035	94.28	98.49	5	99.91	98.40
5	198	2	196	0	196	100.00	5760	0.033	0.036	91.67	96.97	0	100.00	96.97
6	220	2	218	0	218	100.00	6500	0.033	0.036	91.67	98.39	3	99.95	98.34
7	152	2	150	0	150	100.00	4465	0.033	0.034	97.06	98.23	0	100.00	98.23
8	160	2	158	0	158	100.00	4700	0.033	0.034	97.06	98.16	6	99.87	98.03
9	240	2	238	16	222	93.27	6500	0.033	0.036	91.67	96.62	0	100.00	90.11
10	252	2	250	0	250	100.00	7350	0.033	0.036	91.67	97.02	7	99.90	94.98
11	336	2	334	0	334	100.00	9975	0.033	0.036	91.67	98.55	0	100.00	98.55
12	304	2	302	0	302	100.00	9025	0.033	0.036	91.67	98.61	7	99.92	98.53

Source: own elaboration

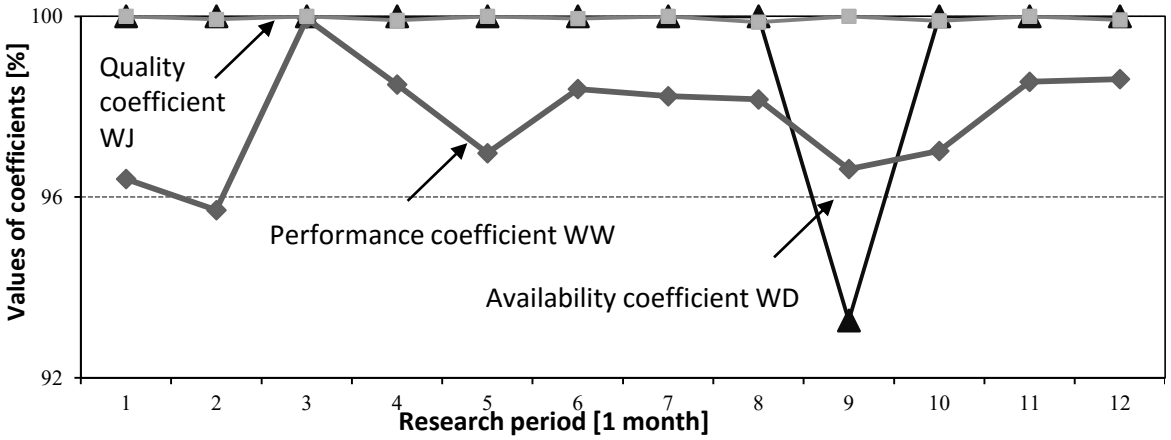

Fig. 9.3 Graphic interpretation of the availability coefficient, performance coefficient and quality coefficient in research period for wave soldering machine

Source: own elaboration

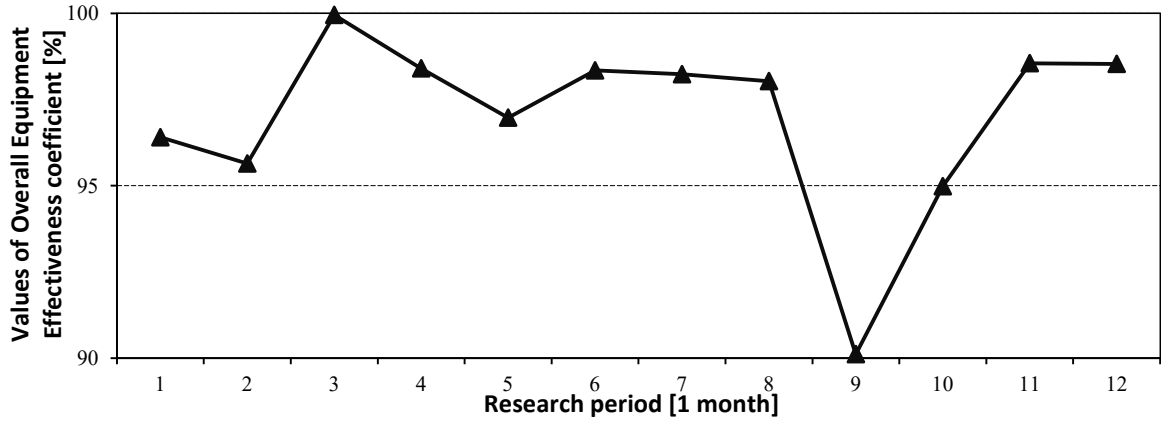

Fig.9.4 Graphic interpretation of the Overall Equipment Effectiveness coefficient for wave soldering machine

Source: own elaboration

CONCLUSIONS

To calculate the effectiveness of using of time of machines work in the analyzed company Overall Equipment Effectiveness OEE coefficient was used. Two machines needed in the manufacturing process of electronic meters of electric energy - surface mount assembly machine and wave soldering machine were analyzed. These devices represent global technology standards of assembly and calibration of electronic meters of electric energy.

Using the TPM coefficients for machines needed in the manufacturing process of electronic meters of electric energy allowed to evaluate their current state, their "condition", as well as to draw conclusions on further activities related to the maintenance of these machines and activities related to the improvement. After analysis it can be seen that both in the case of surface mount assembly machine and wave soldering machine the coefficient of the Overall Equipment Effectiveness OEE is very high (above 90%). This proves the high availability of machines, high quality coefficient and a small number of deficiencies in each test machine. During the months, where there were unplan-

ned shutdowns of machines, this coefficient was slightly lower, but in the months, where there were gaps in the production, it is considered lower quality coefficient.

To minimize, or even eliminate machine breakdowns, necessary to have close co-operation between workers from maintenance department and operators. It is the operator, through the work of the machine and its practical knowledge, can predict many failures and prevent them. Worker from maintenance department has knowledge of the technology of machine, works with operators, teaching them, among others, OS machines.

In the research company, after the evaluation of the current state of machines, introduced an improved system of maintenance machines, within which held, among others, the initial steps of cleaning and control, elimination of pollution sources, providing access to all the elements, training on the machine control. Also used visual management in the form of clear instructions and posters located on the machines.

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ANALYSIS OF MACHINES EFFECTIVENESS IN THE COMPANY WHICH PRODUCES ELECTRONIC EQUIPMENT

Abstract: *This article presents the issues in the field of maintenance systems. They are characterized four major generations of maintenance systems. Assumptions, goals and history of the Total Productive Maintenance TPM are presented. This article presents also the company located in the Silesian Voivodeship, which produces electronic devices: electronic meters of electric energy and data communications systems for measurement, recording, analysis, presentation and billing of accounting sizes. In the research part an analysis of the machines effectiveness, which are used in manufacturing process of electronic meter of electric energy - surface mount assembly machine and wave soldering machine, using TPM coefficients was presented. Application of these coefficients allowed to the evaluation of current state of machines, which were analyzed and conclusions regarding to the further maintenance of these machines.*

Key words: *electronic meters of electric energy, TPM, Overall Equipment Effectiveness*

ANALIZA EFEKTYWNOŚCI MASZYN W PRZEDSIĘBIORSTWIE PRODUKUJĄCYM SPRZĘT ELEKTRONICZNY

Streszczenie: *Artykuł prezentuje zagadnienia z zakresu systemów utrzymania ruchu. Scharakteryzowane są cztery, główne generacje systemów utrzymania ruchu. Przedstawione są również założenia, cele oraz historia Kompleksowego Utrzymania Maszyn TPM. Przedstawiono przedsiębiorstwo zlokalizowane w województwie śląskim, zajmujące się produkcją urządzeń elektronicznych: elektronicznych liczników energii elektrycznej i teleinformatycznych systemów pomiarów, rejestracji, analizy, prezentacji i billingu wielkości rozliczeniowych. W części badawczej zaprezentowano analizę efektywności maszyn niezbędnych w procesie wytwórczym elektronicznego licznika energii elektrycznej - automatu do montażu powierzchniowego i fali lutowniczej, przy wykorzystaniu współczynników TPM. Zastosowanie tych współczynników pozwoliło na ocenę stanu istniejącego maszyn poddanych analizie i wyciągnięcie wniosków odnośnie dalszego utrzymania ruchu tych maszyn.*

Słowa kluczowe: *licznik energii elektrycznej, TPM, ogólna efektywność urządzenia*

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