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ASSESSMENT OF THE EFFECTIVENESS OF MACHINE AND DEVICE OPERATION

In effectively managed companies, the answer to the question of whether employees should be perceived as cost or as investment, is obvious. Investment should be made in human resources as this allows for reducing the cost of company's activities, increasing its effectiveness, efficiency, etc. A similar question can be put for machine operation, but here the answer is not so straightforward. The conflict between production managers and machine maintenance managers still exists; it is usually settled with the production side winning. This paper is an attempt to assess the effectiveness of machine operation and the effectiveness of the whole company based on an analysis of so called OEE (Overall Equipment Effectiveness) index, calculated from a timekeeping study of a big food producing company.

Keywords*: vehicle operation, effectiveness.*

1. Introduction

Machine maintenance in a production company is a key issue; however, in a process approach it is usually classified as an auxiliary process for the production. Meanwhile, the process can have a fundamental effect on the amount and cost of production, quality of the final product, safety of people and the environment. The effectiveness of any actions, including machine maintenance, will be limited without a precise goal and measures used to monitor the degree in which the goals have been achieved. In general, two principles of rational management are correct: the principle of the maximum effect, where the degree of the goal achievement with given resources should be maximized, and the principle of minimum resources, where for an assumed degree of the goal achievement, the resources are minimized. These principles clearly indicate that it is not possible to achieve increasing values of readiness or reliability indexes with simultaneous reduction of sums spent on machine maintenance, inspections, repairs, etc. This truth is frequently missed, which is shown in the so-called conflict of operation managers. The conflict stems from the fact that technical objects participate in two different activities: in their use, oriented towards the product, and their operation, oriented towards the object itself and its value. Therefore, the use of a machine is directly linked to performing a production task, while operation is regarded as an auxiliary process; this is often expressed as "I use the machine (i.e. I produce) while you repair it (you generate costs)". An analysis of Fig. 1 leads to the conclusion that operation decisions should be based on cost calculation which includes the cost of machine operation and the cost of production loss being the result of machine stoppages [11].

An increase in the expenses for machine maintenance beyond the basic actions, including oil and filter replacement and surveys, reduces the loss resulting from unexpected stoppages and reduces the considered cost. The tendency is apparent only until the moment, beyond which the production loss starts to grow, it being the result of excessive stoppages in the operation sub-system. However, it is very important to consider all the operation-related costs, both the direct costs, which are easily measurable, related to labour and material related expenses, and those less obvious, resulting from reducing working speeds as a result of the machine's technical condition. The issue can be visualized as an iceberg (Fig. 2).

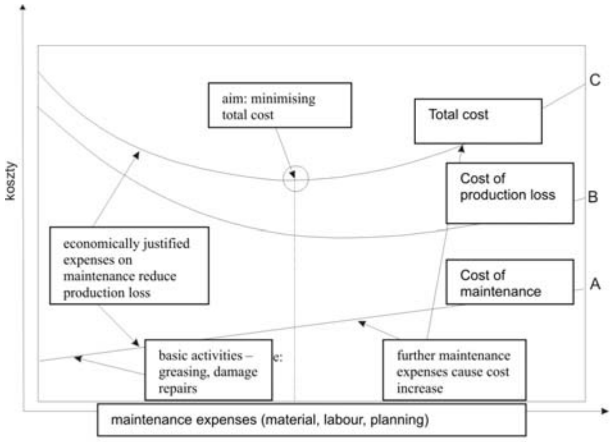

Fig. 1. The relationship between the cost of machine maintenance, cost of production loss and total cost

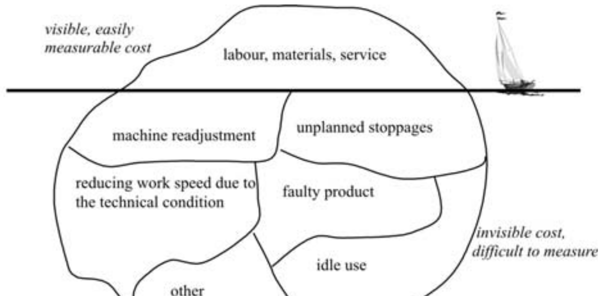

Fig. 2. Maintenance costs as an iceberg

2. OEE

Ideally, machines and devices could work for 100% of assumed work time, with 100% efficiency and with the final product in 100% conformity with the requirements. In reality, there are three categories of losses, which, according to the TPM idea, make up six big losses (Table 1).

Tab. 1. Six big losses according to TPM [11]

category of losses	*Loss*
LOSS IN READINESS (machine switch-off)	*Machine breakdown*
	Adjustments, regulations, replacement the working tool, etc.
LOSS OF EFFECTIVENESS (loss of working speed)	*Idle speed, minor stoppages*
	Reduced working speeds
LOSS OF QUALITY (defects of final products)	*Product defects and their repair*
	Loss (product defects) during the machine start-up

Now that the ISO 9001 series standards have become common (which indicates the need for constant improvement) and modern methods of management are widely applied, it seems that it would be appropriate to adopt an index to show potential for improvement of machine and device maintenance process. Such an index could be the so-called Overall Equipment Effectiveness *(OEE*), whose value embraces all the categories of loss encountered during the process of machine and device use as compared to the ideal conditions. The index is obtained by multiplying three elements:

- the readiness index, which is the percentage of use of the general time of change K_G;
- the productivity index, which is the percentage of the machine productivity during a time unit in relation to the rated value K_W;
- the quality index, which the percentage of the number of products in conformity with the requirements in relation to the overall number of manufactured products K_J.

The *OEE* index can be expressed as the general formula:

$$OEE = K_G\, K_W\, K_J \qquad (1)$$

Table 2 shows the diagram of calculating the OEE index value.

An example of calculating the *OEE*: work for 65% of the planned time, the productivity of 80% of the rated value, 98% conformity of the final product with the requirements; then *OEE* = 0.65 x 0.8 x 0.99 = 0.51.

3. Examining the possibility of applying the OEE index in a production company

The aim of the study was to assess a possibility of applying the *OEE* index in assessment of the effectiveness of a machine maintenance system in a production company [2].

The study object was a production line for vacuum packing of foodstuff – a Multivac R 7000 roll machine.

The timekeeping study was conducted during five days in the first shift lasting from 6.00 a.m. to 2.00 p.m. The adopted duration of the shift was t_z = 8 h – 30 min = 7 h 30 min = 27000 s. The total shift duration should always be reduced by the time which decreases the effective work time fund and are not included in the OEE index. In this example, it is the duration of the planned morning break – 30 minutes. Table 3 shows the forms of the components of the OEE index.

Data for the calculation of the OEE value for the CRAYOWAC VR 8620 packing machine and the calculation results are shown in table 4.

Graphic presentation of the OEE index and its components values as well as the results of the Pareto analysis for the portion of the stoppage times is shown in Fig. 3.

An analysis of the results of timekeeping studies and the calculated values of the productivity, readiness and quality indexes reveals that that the values of productivity and quality indexes are constantly high, while the value of the readiness index is low, which results from a long “no production” time. The length of the time depends on the marketing department, which determines the amount of the packed product. The value is not pre-planned and depends on the orders from customers.

Tab. 2. The diagram of calculating the OEE index value

<table>
<tr><td colspan="6">Total work time</td></tr>
<tr><td rowspan="2">readiness</td><td colspan="4">A work time</td><td>Planned lack of manufacture</td></tr>
<tr><td colspan="3">B manufacture time</td><td>defects, adjustments, tool replacement</td><td rowspan="5"></td></tr>
<tr><td rowspan="2">efficiency</td><td colspan="3">C planned productivity</td><td rowspan="2"></td></tr>
<tr><td colspan="2">D actual productivity</td><td>minor stoppages, reduced speed</td></tr>
<tr><td rowspan="2">quality</td><td colspan="2">E number of product</td><td colspan="2" rowspan="2">LOSS OF THE EFFECTIVENESS OF A MACHINE USE</td></tr>
<tr><td>F number of conforming products</td><td>product defects, their repair, loss during start-up</td></tr>
<tr><td colspan="6">OEE = B/A × D/C × F/E</td></tr>
</table>

Tab. 3. The indexes adopted for calculating the OEE value

Readiness index K_G	Productivity index K_W	Quality index K_J
$K_G = \frac{t_z - p}{t_z}$	$K_W = \frac{l_C - l_0}{l_C}$	$K_J = \frac{l_D - l_N}{l_D}$
t_z – shift duration (27000s) p – breaks [s], time of: product preparation, container preparation, change of product range, production stoppage, failure.	l_c – total number of produced packages, l_o – number of idle movements of the machine – it is the number of unfilled vacuum chambers, with which the machine is equipped.	l_D – the number of produced conforming packages, l_N – the number of non-conforming packages (not airtight)

Tab. 4. Timekeeping data and determined values of the index for CRAYOWAC VR 8620

	day1	day2	day3	day4	day5	mean x	standard deviation
Time of product preparation	1740	2940	2580	3480	1800	2508	746.2
Time of container preparation	0	0	0	0	660	132	295.1
Time of product range change	840	1260	0	1560	1080	948	591.5
Time of production stoppage	9000	16980	13380	16620	8280	12852	4100.5
Time of failure	120	0	0	0	360	96	156.4
Number of idle movements of the machine (l_o)	324	164	294	136	289	241.4	85
Number of non- air-tight packages (l_N)	144	16	18	12	78	53.6	57.4
Number of good packages (l_D)	2244	1276	1885	1180	2385	1794	548.9
Readiness index	0.56	0.22	0.41	0.2	0.55	0.388	0.173
Productivity index	0.88	0.94	0.86	0.9	0.89	0.894	0.0296
Quality index	0.93	0.99	0.99	0.99	0.97	0.974	0.02607681
OEE	0.45	0.20	0.35	0.18	0.47	0.33	0.135830777

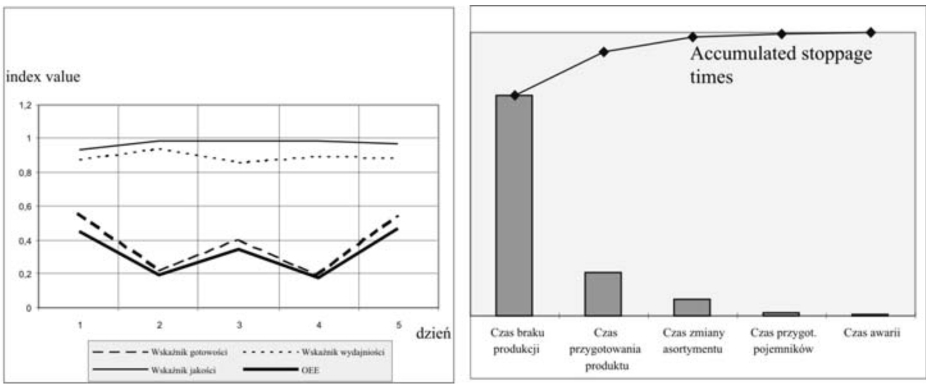

Fig. 3. The values of K_G, K_W, K_J indexes and OEE as well as the Pareto analysis of the CRAYOWAC VR 8620 machine stoppages

The Pareto analysis indicates that the value of the *OEE* index is most affected (due to the effect of the readiness index) by the "no production" time, product preparation time, product range change time, etc., i.e. the times which are not related to the process maintenance.

4. Summary

1. *OEE* is a general measure of the effectiveness of machine use, taking into account the effectiveness of all the parties concerned: machine maintenance department, production department, planning department, marketing and other departments.
2. *OEE* "measures" all the aspects concerning the effectiveness of use of machines and devices, both in terms of quality (performing work correctly) and quantity (performing correct work).
3. *OEE* seems a simple and convenient tool to monitor the processes of machine maintenance and production upkeep and to compare the effectiveness of machine use. The comparisons can be internal and external. The former are conducted in a company in certain intervals for the same machine, device or production line. The aim of the latter is to compare the effectiveness of use of machines in various companies (benchmarking), but in that case it is of particular importance to strictly establish the principles of calculation of the *OEE* values.
4. The *OEE* index should be used with caution. Assuming, for example, that the values of the readiness, productivity and quality indexes for a certain period are equal to 0.95%, 85% and 98%, respectively, and for another - 98%, 85% and 90%, the *OEE* value calculated in each case is the same: 0.79. Analysis of the index only in terms of its total value does not provide a warning about the productivity increasing at the cost of product quality.

5. References

[1] Drożyner P., Veith E.: *Risk Based Inspection Methodology Overview*, Diagnostyka nr 27, 2002.

[2] Kłobukowski M.: *Analiza efektywności systemu utrzymania maszyn w przedsiębiorstwie Indykpol z wykorzystaniem wskaźnika OEE (Całkowita Efektywność Eksploatacji)*, praca magisterska zrealizowana na Wydziale Nauk Technicznych UWM, Olsztyn 2004.

[3] Niziński S.: *Eksploatacja obiektów technicznych.* ITE Radom 2000.

[4] Niziński S.: *Elementy eksploatacji obiektów technicznych*, UWM. Olsztyn 2000.

[5] Niziński S.: Michalski R.: *Diagnostyka obiektów technicznych*. ITE, Radom 2002.

[6] Niziński S.: Żółtowski B.: *Modelowanie procesów eksploatacji maszyn*. MARKAR – BZ, Bydgoszcz- Sulejówek, 2002.

[7] Niziński S.: Żółtowski B.: *Zarządzanie eksploatacją obiektów technicznych za pomocą rachunku kosztów*. ATR , Bydgoszcz, 2003.

[8] PN-EN ISO 9001:2001, Systemy zarządzania jakością - Wymagania.

[9] Żółtowski B.: *Podstawy diagnostyki technicznej*. ATR, Bydgoszcz 1996.

[10] Maintenance – Key Performance Index, dokument TC 319 WI WG6.50 przygotowywany przez Technical Committee CEN/TC 319 "Maintenance" (w przygotowaniu).

[11] Pod red. Nizińskiego S. i Michalskiego R.: *Utrzymanie maszyn i pojazdów*. ITE Radom 2007 – w druku.

[12] Internet websites:
http://www.oeetoolkit.nl/
http://www.udt.gov.pl/
http://www.barringer1.com/
http://www.plant-maintenance.com/

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