Zarządzanie Przedsiębiorstwem. Enterprise Management
Volume 22 • Number 2 • June 2019 • pp. 2–6
DOI: 10.25961/ent.manag.22.02.01

ANALYSIS OF THE EFFICIENCY OF MACHINE USE ON THE PRODUCTION LINE OF INTERIOR DOORS

Karolina Czerwińska, Andrzej Pacana

Rzeszow University of Technology, The Faculty of Mechanical Engineering and Aeronautics, Poland

Corresponding author:
Karolina Czerwińska
Rzeszow University of Technology
The Faculty of Mechanical Engineering and Aeronautics
al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland
phone: (+48) 730520095
e-mail: ktczerwinska@vp.pl

Abstract
The first part of this article presents methodological assumptions for the construction of the overall equipment effectiveness index (oee). Further, the shortened technological process of the product is presented and the analysis of losses in the context of the causes of machine downtime and the type of non-conformity of the products is made. The last part presents the results of the diagnosis in the scope of monitoring and analysis of the total efficiency index of equipment (oee) carried out on an exemplary production line of doors and proposes comprehensive improvement actions in order to improve the unsatisfactory condition of the machinery stock use efficiency.

Keywords
Indicator of Overall Equipment Effectiveness (OEE), Total Productive Maintenance (TPM), Single Minute Exchange of Die (SMED), quality control, quality management tools.

1. Introduction

Hundreds of billions of tons of different products are produced every year in the world. Technological and organizational progress is noticeable in every industry. There is an impressive development of both production and trade. Constantly growing competition of a global character and the requirements set by customers make the timely execution of production orders and the reduction of production costs the key elements influencing the competitive position of the company on the market [10, 19]. For this reason, companies are forced to constantly search for production reserves, increase efficiency and effectiveness of production, and consequently – reduce production costs [8, 9, 23].

For every manufacturing company, failures and unplanned machine and plant downtime are the source of avoidable costs. It is their reliability that has a direct impact on the business productivity. The more frequent breakdowns and downtime are, the fewer finished products are produced, which translates into the financial result of the organization. More and more companies see the need to monitor the effectiveness of machinery stock use, which makes it possible to identify waste in the implemented technological processes and existing production reserves [1, 18, 20]. The target state, at which all enterprises should aim, is 100% use of the possessed machinery, and at the same time no shortage of production realized with the efficiency corresponding to the nominal efficiency of possessed equipment and technological machines [7, 11, 17].

2. Indicator of Overall Equipment Effectiveness (OEE)

One of the parameters enabling the assessment of the efficiency of the use of the available machinery is the Overall Equipment Effectiveness (OEE) indicator. Its main task is to identify the causes of wastefulness, thanks to which it is possible to plan appropriate actions, which will aim to improve the course of production processes and ways of manufacturing products. The practical utility of this indicator means that it is used in maintenance improvement actions and is one of the elements used in the philosophy of lean manufacturing (Lean Manufacturing) [2, 3, 5, 12].

The OEE indicator consists of three elements that can be used as an independent indicator in an enterprise, and each element is divided into individual components that increase or decrease its value [13, 14, 16]. The components of OEE are (Fig. 1):

- Availability Loss – this is the percentage value reflecting the availability of the object to carry out the tasks entrusted to it. Availability is expressed as the ratio of working time (time spent on the production of products) (Fig. 1, value B) to net operating time, including working shift time less planned downtime (Fig. 1, value A);
- Performance Loss – the ability of machines to maintain a standard work rate. The value is expressed as the ratio of the actual production (number of manufactured products) (Fig. 1, value D) to the target production (number of products that could be man-

ufactured with the assumption of maximum working speed of machines) (Fig. 1, value C).

- Quality Loss – defines the ratio of the number of good pieces to all pieces produced. Quality is expressed as the ratio of good production (products meeting the quality assumptions) (Fig. 1, value of F) to actual production (Fig. 1, value of E). This is the simplest component of OEE.

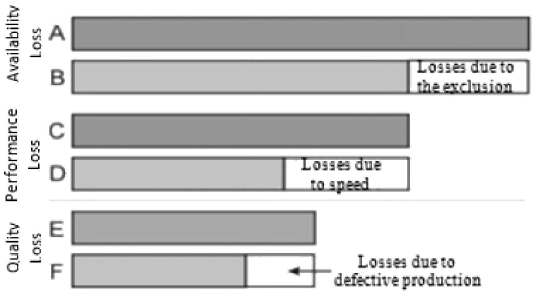

Fig. 1. Components of the indicator OEE [6, 20].

Multiplying the productivity by the availability and by the quality, a total effectiveness of the equipment which is a percentage expression is received. OEE gives us a complete picture of the actual condition of machines and equipment. It shows how quickly good products were made when the equipment was technically efficient. This is extremely important when considering how many factors influence the equipment operation [4, 6, 15]. One such factor may be a person who can perform his duties properly or cause machine breakdowns.

With regard to Fig. 1, the OEE indicator can be calculated from the following formula:

$$\mathrm{OEE} = \frac{\mathrm{B}}{\mathrm{A}} \cdot \frac{\mathrm{D}}{\mathrm{C}} \cdot \frac{\mathrm{F}}{\mathrm{E}} \cdot 100\%. \tag{1}$$

The last step in the performance analysis, which is both the essence and purpose of the method, is the interpretation of the obtained result. The calculation of the OEE index is a starting point for taking improvement measures aimed at increasing the efficiency of individual machines in the production line or technological nest. Depending on the result obtained, either general actions or specific actions to improve the various components of the indicator can be taken. It should be remembered that the introduction of improvement measures is an objective of the use of the OEE indicator, while the results obtained are a signpost for further action [21, 22].

3. Description and presentation of the Stile technology

The Stile technology is characterized by wrapping the flat surface and door rim with CPL laminate 0.2 mm thick, with a significant level of resistance to scratches and abrasion. This laminate has many important technical advantages. It is characterized by: high resistance to abrasion, impact, scratches and high temperatures and UV radiation. The use of this type of material makes it possible to use the door in so called “difficult” rooms – exposed to higher temperatures, humidity or above-average operation (Table 1).

Table 1
Design features of Stile doors.

Constructional feature	Profile
Construction	stiles made of mdf board covered with foil greko or cpl
Filling	stiles made of mdf board covered with foil greko or cpl
Fittings	stiles made of mdf board covered with foil greko or cpl
Glaziery	toughened milk glass or laminated glass vsg 221 milk safety glass, smooth on both sides
Available leaf widths	60, 70, 80, 90, 100

Table 2
Shortened technological process.

Lp	Name of operation	Device/workstation	Steps
10	Cutting plates	Rover C6	– cutting of MDF boards
20	Fabrication of components (machining)	Mounting station	– production of frame elements, slats, bands and quarters of shafts, – machining of vertical and horizontal frames
30	Gluing	Edge bander Stefani	– double-sided wrapping of MDF boards, – wrapping of shoulder straps
40	Fixing the metal fittings	Mounting station	– door leaf fittings
50	Drilling	Askla drilling machine	– drilling of holes for locks, pins and hinges
60	Spiling	Tenoning machine Askla	– spilling the vertical and horizontal frames
70	Assembly	Mounting station	– installation of fittings, – selection of appropriate accessories, – installation of the door leaf
80	Application of foil	Edge bander Stemas	– application of touchwood film on vertical frames
90	Shortening	Askla saw	– shortening of vertical and horizontal frames
100	Ironing	Diaphragm press	– final pressure on the door leaf
110	Control	Control station	– final control

Stiles technology is a solid alternative to plate technology. Unlike classic constructional solutions, it offers much more durable construction of doors. The technology guarantees an exceptionally strong construction, because the door elements are made of solid MDF material (frame and crosspiece). Table 2 presents a shortened technological process – technological operations in which there is a change in shape, physicochemical properties, external appearance of the processed material or a permanent change in the location of individual parts of the product.

4. The company's maintenance system

The characteristics of the machine maintenance system in the company were prepared on the basis of an interview with employees (operators and mechanics). The maintenance system is not formally described. In the analyzed company, machine operators and mechanics are responsible for maintenance. Their task is to select production parameters in an appropriate way so as not to expose the machine to extreme conditions.

Depending on the type of failure, the person responsible for repairing the machine is the operator or a mechanic employed in the company. Minor breakdowns, e.g. film jamming or twisting, are eliminated on a current basis by the machine operator. Elimination of this type of failure must be immediate, as it has a significant impact on the quality of the products and the performance of the machine. A mechanic is called upon to repair serious failures that prevent the machines from operating.

After the machine has been repaired, the causes of the malfunction are analysed in order to avoid similar situations in the future. The method of failure analysis is not formalized, it is a discussion between the mechanic and the machine operator. The results of analyses are not recorded or reported to superiors.

5. Loss analysis

The effectiveness of the technical infrastructure management process in a pre-branch company largely depends on the type and amount of information collected about machines. If we are not aware of the existence of problems and where they occur, we are unable to prevent or eliminate them. Gathering useful information on the basis of right decisions made at the right time as well as ensuring targeted action and appropriate response is a constant challenge for the information system in enterprises.

The fundamental group of information that should be recorded in companies is information on machine downtime. The specified types of downtime are referred to as: P1 – machinery failures, P2 – changeover, P3 – planned downtime (e. g. maintenance, overhaul), P4 – lack of material, P5 – lack of tooling, P6 – absence of the operator, P7 – other. The research shows that the most frequent downtimes are machine breakdowns and downtimes caused by the need for changeover (Fig. 2). The data for analysis were collected in the period from January to December 2018. In an enterprise, data collection for the purpose of calculating the OEE index and its components is carried out by filling in the loss sheets by employees using a dedicated software.

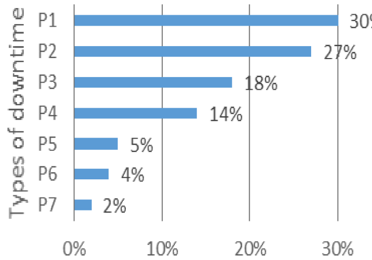

Fig. 2. Types of stoppage occurring during the period under examination.

Another group of registered information is data on the quality of products. The analysis of internal door discrepancies was made on the basis of data collected during the production of the product from the tested period. The types and number of discrepancies were read from the order processing card. 12 categories of product noncompliance were identified during the period considered, such as N1 – incompatibilities concerning the veneer (blisters, waviness, thickening, scratches, discoloration), N2 – incompatibilities related to accessories (faulty, improperly selected accessories, bad fitting), N3 – incompatibility of the pane (scratches, cracks), N4 – distortion of the door leaf, N5 – dimensional inconsistency (incorrect door leaf dimensions, inadequate adjustment of the frames), N6 – inconsistencies related to the gasket (incorrect positioning of the gasket, wrong fixing) N7 – deformation of the door leaf above 4 mm, N8 – other (Fig. 3).

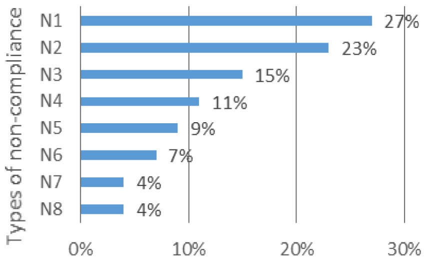

Fig. 3. Types of non-conformity of products occurring during the period under examination.

The research shows that the most frequent nonconformities of the product are non-conformities related to the veneer (blisters, waviness, thickening, scratches, discoloration) and non-conformities related to accessories (faulty, improperly selected accessories, bad fitting).

6. Evaluation of machine performance

A performance indicator, qualities and availabilities being used to calculate the OEE rate were used for the

Table 3
Values of OEE indices of individual machines for I and II shifts.

Machine	Month												Average
	01	02	03	04	05	06	07	08	09	10	11	12	
Values OEE [%] – I shift													
Rover C6	47	52	51	47	52	57	51	49	44	53	55	49	51
Edge bander Stefani	64	68	64	30	79	67	63	62	67	36	71	51	60
Askla drilling machine	56	46	68	53	68	60	40	46	58	53	60	65	56
Tenoning machine Askla	69	73	76	68	68	78	70	80	62	79	69	60	71
Edge bander Stemas	78	74	81	70	78	77	83	85	74	81	77	83	78
Askla saw	60	75	60	56	74	65	74	65	73	65	59	60	66
Diaphragm press	65	75	69	61	68	60	68	68	75	65	67	54	66
Values OEE [%] – II shift													
Rover C6	49	51	54	46	50	58	48	52	47	55	52	44	51
Edge bander Stefani	60	71	35	70	78	64	68	68	63	70	68	64	65
Askla drilling machine	61	47	65	57	65	58	56	48	57	55	58	67	58
Tenoning machine Askla	72	71	78	70	65	76	73	78	62	78	70	62	71
Edge bander Stemas	76	75	83	72	79	76	82	85	77	83	78	81	79
Askla saw	64	76	62	55	72	63	75	65	70	69	64	62	66
Diaphragm press	63	74	68	63	70	65	71	68	72	64	68	67	68

evaluation of the effectiveness. In order to determine the value of OEE indicators, the following data were collected: the use of machines, the number of products produced, the number of non-compliant products and planned and unplanned downtime. Data from the following months of 2018 were used to calculate individual OEE indicators. Table 3 contains received values of OEE indicators for individual machines.

In practice, it is assumed that the value of the OEE ratio above 85% is a very good result. In the example analysed, none of the machines achieved such a result. The machines on the interior door production line reached between 79% and 51%, which means that the machines have effectively worked between 51% and 79% of the time they would have been able to work in a non-failure situation, if changeovers are made in the planned time and the machines are running without shortages or loss of productivity.

7. Improvement proposals

The first improvement proposal is further monitoring and analyzing the achieved indicators. The lack of constant analysis of the relations between production processes may result in the condition that the improvement of a single workstation may not be reflected in the improvement of the management of the whole process.

The factor that can cause a breakdown is the man, the way of management and, above all, the defectiveness of the machines. Consequently, a number of actions, which may have a positive impact on the improvement of the company's performance, should be taken. It is necessary to carry out periodic training of employees and constantly monitor the operation of the machines, which will allow to indicate errors occurring on them. These actions should be carried out in the first place on the stations "Rover C6" and "Askla drilling machine". The OEE index for these stations was the lowest in the period considered and did not exceed 60.

Due to the fact that relatively low OEE values are related to the technical condition of the machinery stock, one of the Lean Management methods, i. e. Total Productive Maintenance (TPM), should be implemented in the area of the entire production line. Preventive actions should be carried out in two areas: human and machine. In the first area, the task of TPM will be to increase the level of efficiency of employees by increasing their knowledge and skills – which will mean an increase in the degree of their responsibility. According to the assumptions, employees will become more involved in their work, will acquire the ability to interpret situations within their workstation and thus, will be able to make appropriate decisions on their own. On the other hand, from the machinery perspective, the activities of employees should focus on maintaining machines in a state of high availability, so that the maintenance department obtains information from operators on the current condition of the machinery stock in order to plan their activities on an ongoing basis. Thanks to the knowledge of the machines used, production workers, maintenance staff and technicians can design improvements to facilitate maintenance or improve machines (e. g. Kaizen ideas). In turn, maintenance service units change their attitude from reactionary interventions into predictive operation of machines, which will contribute to increased availability of machines and their reliability, which directly reduces production costs and thus increases the profits of the company.

Additionally, in order to shorten set-up times, it is necessary to implement SMED methodology, which is a set of techniques and tools enabling shortening set-up times of machines, devices and production processes in the company. In the case of the workstations "Rover C6", "Askla drilling machine" and "Edge bander Stefani", relatively long changeover time is associated with inadequate workspace planning and frequent lack of instruments necessary to carry out specific operations of the production process. The elimination of organisational incompatibilities is essential to optimise changeover times.

8. Summary

Continuous improvement of the machinery stock management process allows increasing production efficiency, eliminate losses and, consequently, generate higher revenues. In order to streamline the company's infrastructure management process, it is important to carry out appropriate measurements, their effectiveness and efficiency, which may contribute to the improvement of the quality of manufactured products. The improvement process should be based on the use of appropriate tools and methods to increase the efficiency of the entire system.

The OEE index contains information on machine availability, use and production quality. On the basis of the results obtained, it can be concluded that the machines analysed show significant reserves in the area of overall efficiency in terms of performance, quality and, above all, availability. The state of use of the machinery stock is unsatisfactory, especially in relation to world standards.

Appropriate action should be taken to improve the values of both sub-indicators and the total OEE indicator. The proposed solution assumes further monitoring of the machine utilization efficiency ratio, implementation of the TPM strategy and SMED methodology, as well as periodic training for employees.

References

[1] Antosz K., Ciecińska B., *Podstawy zarządzania parkiem maszynowym w przedsiębiorstwie*, Oficyna Wyd. Politechniki Rzeszowskiej, Rzeszów, 2011.

[2] Antosz K., Pacana A., Stadnicka D., Zielecki W., *Lean Manufacturing. Doskonalenie produkcji*, Oficyna Wyd. Politechniki Rzeszowskiej, Rzeszów, 2015.

[3] Antosz K., Pacana A., Stadnicka D., Zielecki W., *Narzędzia Lean Manufacturing*, Oficyna Wyd. Politechniki Rzeszowskiej, Rzeszów, 2013.

[4] Chabowski P., Żywicki K., *Wpływ organizacji przezbrojeń na efektywność zasobów technicznych*, Inżynieria Maszyn, pp. 60–70, 1/2013.

[5] Czerska J., *Podstawowe narzędzia Lean Manufacturing*, LeanQTeam, Gdańsk, 2014.

[6] Elevli S., Eleveli B., *Performance measurement of mining equipments by utilizing OEE*, Acta Montanistica Slovaca, Slovak Republic, 15, 95–101, 2010.

[7] Furman J., *Wdrażanie wybranych narzędzi koncepcji Lean Manufacturing w przedsiębiorstwie produkcyjnym*, [in:] R. Knosala [Ed.] Innowacje w zarządzaniu i inżynierii produkcji, Oficyna Wyd. Polskiego Towarzystwa Zarządzania Produkcją, Opole, pp. 247–256, 2014.

[8] Gola A., Economic Aspects of Manufacturing Systems Design, Actual Problems of Economics, 6, 156, pp. 205-212, 2014.

[9] Gola A., *Sterowanie przepływem produkcji w zautomatyzowanych systemach produkcyjnych*, [in:] Szatkowski K. [Ed.] Nowoczesne zarządzanie produkcją. Ujęcie procesowe, Wyd. PWN, Warszawa ss. 406-440, 2014.

[10] Gola A., Świć A., *Directions of Manufacturing Systems' Evolution from the Flexiblity Level Point of View*, [in:] R. Knosala [Ed.] Innovations in Management and Production Engineering, Oficyna Wyd. Polskiego Towarzystwa Zarządzania Produkcją, Opole, pp. 226–238, 2012.

[11] Kornicki L., Kubik S. [Ed.], *OEE dla Operatorów. Całkowita efektywność wyposażenia*, Wyd. Prod-Press.com, Wrocław, 2009.

[12] Kruczek M., Żebrucki Z., *Koncepcja lean management w procesie ciągłego doskonalenia przepływów*, Logistyka, 2, 425–432, 2015.

[13] Loska A., *Bazy danych we wspomaganiu zarządzania eksploatacją maszyn i urządzeń*, Rozprawa doktorska, Gliwice, 2002.

[14] Lungberg O., *Measurement of overall equipment effectiveness as a basic for TPM activities*, International Journal of Operations and Production Management, 18, 5, 495–507, 1998.

[15] Muchiri P., Pintelon L., *Performance measurement using OEE: Literature review and practical application discussion*, International Journal of Production Research, 46, 13, 2008.

[16] Oechsner R., Pfeffer M., Pfitzner L., Binder H., Muller E., Vonderstrass T., *From overall equipment efficiency(OEE) to overall Fab effectiveness (OFE)*, Materials Science in Semiconductor Processing, 5, 333–339, 2003.

[17] Pacana A., *Metoda 5S*, Oficyna Wydawnicza Stowarzyszenia Menedżerów Jakości i Produkcji, Częstochowa, 2016.

[18] Świć A., Gola A., *Elements of Design of Production Systems – Methodology of Machine Tool Selection in Casing-Class FMS*, Management and Production Engineering Review, 1, 2, 73–81, 2010.

[19] Walczak M., *System utrzymania ruchu czynnikiem przewagi konkurencyjnej przedsiębiorstwa*, Uniwersytet Ekonomiczny w Krakowie, 2015.

[20] Werpachowski W., *Podstawy zarządzania w przedsiębiorstwie*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 2011.

[21] Wirkus M., Kukułka A., *Obliczanie składowej jakości OEE przy wielu operacjach technologicznych*, Zarządzanie Przedsiębiorstwem, 2, 40–47, 2015.

[22] Wirkus M., Węsierski T., Chmielarz A., *Marnotrawstwo pracy maszyn na placu budowy*, Budownictwo i Inżynieria Środowiska, 4, 699–708, 2011.

[23] Woźnicka K., Sikora K., *Model utrzymania sprawności produkcyjnej maszyn, jako kluczowy czynnik rozwoju przedsiębiorstwa produkcyjnego*, Konferencja Innowacje w Zarządzaniu i Inżynierii Produkcji, Tom II Część XI Zarządzanie utrzymaniem ruchu, ss. 725–736, 2014.