

Practical Aspects of OEE in Automotive Company – Case Study

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Abstract— Measure is initial and basic step in taking actions striving for excellence in an organization. To maintain competitive advantage in the market, enterprises use various tools enabling measuring efficiency. In the paper the most often cited in literature and implemented in practice measure of efficiency of manufacturing equipment utilization called Overall Equipment Effectiveness is presented.

Keywords- Overall Equipment Effectiveness (OEE); availability; automotive industry

I. INTRODUCTION

The commonly applied standard and to some extent principle in the context of management is the often cited and paraphrased sentence by Peter Drucker “when an organization can measure its own performance then it can be managed”. Measure increases curiosity and discussion on measurement results provide understanding of processes, their capacity [1], allows to focus on important characteristics, problems [2] and builds reliability [3, 4, 5]. Campbell and Jardine [6] gave the commonly-classified maintenance performance indicators as measures of:

- equipment performance, such as its availability, reliability and overall equipment effectiveness (OEE),
- process performance, such as the ratio of planned to unplanned work or scheduled compliance,
- cost performance, such as the costs for labor, material and maintenance.

The goal of the hereby paper is to analyze the Overall Equipment Effectiveness in the automotive industry company. The paper is composed of five chapters and starting with introduction. The second chapter includes analysis of the literature on the subject of measuring efficiency of production equipment use. The next chapter provides presentation of the company and OEE measurement methodology. The subject of the next chapter is analysis of results of the research conducted and discussion on positive and negative aspects of customize model of OEE measurement. The fifth chapter is the summary of the work and conclusion.

II. LITERATURA REVIEW

One important metric to ascertain the productivity of individual equipment, called overall equipment effectiveness (OEE) was devised by [7] under the Total Productive

Maintenance (TPM) umbrella. The author defines the losses which reduce the effectiveness of the equipment, classifies it into six major categories (TABLE I) and proves that OEE measurement is an effective way of analyzing the efficiency of a single machine in the manufacturing system.

TABLE I. CLASSIFICATION OF LOSSES ACCORDING [7]

Category	Big losses
Downtime losses	Equipment failure - losses due to failures. Failure types include sporadic function stopping failures and function – reduction failures in which the function of the equipment drops below the normal level
	Set-up and adjustment losses result from downtime and defective products that occur when production of one item ends and the equipment is adjusted to meet the requirements of another item
Speed losses	Idling and minor stoppage losses occur when the equipment temporarily stops or idles due to sensor actuation or jamming of the work. The equipment will then operate normally through simple measures (removal of the work and resetting)
	Reduced speed losses refer to the difference between equipment design speed and actual operating speed
Quality losses	Quality defects and rework are losses in quality caused by malfunctioning production equipment
	Start-up losses are yield losses that occur during the early stages of production, from machine start-up to stabilization

Equipment	Losses	Computation of OEE
<div>Loading Time (LT)</div> <div>(Total Possible Time – Scheduled not-production Time)</div>	Equipment failure	Availability efficiency = operating time/loading time
	Setup & Adjustment	
Operating Time (OT)	Idling and minor stoppage	Performance efficiency = net operating time/operating time
	Reduced speed	
Net Operating Time (NT)	Defects in process	Quality efficiency = valuable operating time/net operating time
	Reduced yield	
Valuable Operating Time (VT)		
OEE = Availability efficiency x Performance efficiency x Quality efficiency		

OEE, by identifying and quantifying losses, enabled professionals to address their problems and measurably improve performance, making it a popular metric. Analytically, OEE can be expressed as the ratio between what was actually manufactured and what could be ideally

manufactured or, alternatively, as the fraction of time in which an equipment works at its full operating capacity. The concept of OEE is variously used in industry with modifications to suit the particular industry and the objective of measurement. Dal et al. [8] suggest that OEE can be used for example as a benchmark on many various levels of manufacturing environment: enterprises as a whole, production line or isolated machine and referred to future values of OEE and define levels of improvements to be made. The analysis of the literature proves that generally differences in the definition of OEE are mostly the result of:

- The approach to losses definition ([7], [9], [10]),
- The intended implementation area, e.g. single machine, production line, entire company ([11], [12], [13], [14], [15], [16], [17], [18], [19], [20]),
- Specific characteristics of an industry ([21], [22], [23], [24], [25]).

Although OEE originated as a part of TPM, it has also been used extensively outside the maintenance paradigm [19]. The Scopus search delivers 114 documents (20.07.2016). The figure 1 shows a short Scopus analysis. The pie chart shows the document allocation by subject areas and the line chart displays the trend of the documents by time which includes the keyword "overall equipment effectiveness (OEE)".

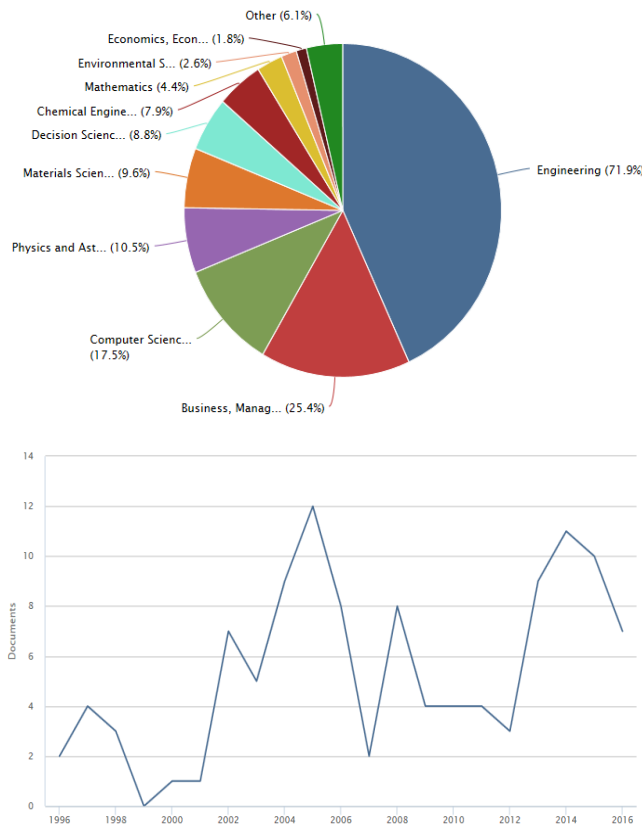


Figure 1. Documents by subject areas and time.

The database does not index all published documents. However, even that reference proves that the OEE is the

measure popular both among academic researchers and business practitioners.

III. CHARACTERISTICS OF RESEARCH OBJECT AND MODEL OF OEE ASSESSMENT

Company Presentation

The company, which is the subject of the study, is a leader in the production of die casting of aluminum alloy, precision machining of aluminum and iron castings for the automotive industry. The company specializes in the production of parts for turbochargers and brake systems. For several years, the company has been benefiting from the concept of Lean Manufacturing, which in its scope covers all departments of production as well as the non-productive departments. Within the system, tools such as 5S, SMED, Kaizen Events are implemented, and from nearly a year the company has been implementing the concept of Total Productive Maintenance. The result of applying Lean concepts are the standards of implementation of production processes (procedures and instructions for the operators) and performance measuring system for the production area developed in the enterprise.

Making the decision to improve maintenance area in accordance with the concept of TPM was another project by the management towards building competitive advantage. One of the steps taken for the implementation of the concept was development of OEE measurement model.

Previous actions implemented in the framework of Lean and data on the machine (data on MTBF and MTTR indicators) and their role in the process enabled assessing the criticality of machines and nominating the group of machines for which the OEE measure is to be carried out first. Classification of machines and devices due to their influence on safety, quality and continuity of production process was carried out with the help of a decision tree and a matrix developed by the technical department of the company. Machinery and equipment were allocated to three groups A, B and C. The company identified 32 strategic machines (CNC machines and casting machines), which are classified as the group A (for them OEE assessment is to be conducted in the first place), 72 machines have been qualified as the group B, the other machines and devices 112 as the group C.

OEE model

The following section provides the formulae for each element of the OEE calculation in the company. The first of these elements is machine availability. The availability element of the OEE measure is concerned with the total stoppage time resulting from unscheduled downtime, process set-up and changeovers, and other unplanned stoppages. In simple terms, it is the ratio of actual operating time to the planned operating time (Eq. 1).

$$\text{Availability} = \frac{\text{Operating time}}{\text{Planned operating time}} = \frac{O_t}{P_t} \quad (1)$$

Planned operating time is calculated by subtracting from the Theoretical production time the scheduled break for employees (TFO - 15 min), the setup time (TPZ - 20 min) and the additional break for employees (Tp - 15 min) resulting from the fact that the company employ people with disabilities. Operating time (O_t) is obtained by subtracting downtime from planned operating time. Loss of time is analyzed in four categories (TABLE II): losses related to machine (PR), losses related to tool (TT), non-productive intervals (PP) and new releases (NBR)

TABLE II. CATEGORIES OF LOSSES FOR "AVAILABILITY RATE"

Source	Losses	Description
PR	1.1	Planned maintenance (operator is involved)
	1.2	Short downtime – problem eliminated by the operator
	1.3	Large failure
TT	2.1	Tool failure (mold failure, emergency mold cleaning)
	2.2	Changeover
	2.3	Tool servicing (planned cleaning, seals replacement)
	2.4	Setups - mold exchange or processing (casting department)
NBR	3.1	New releases production
PP	4.1	Unplanned cleaning, lack of materials
	4.2	Leaving the department (others)
	4.3	Launching production (after downtime)
	4.4	Employee's training quality. improvement, initial training)

Data is manually collected in the computer system. The formula for calculating "Availability rate" implemented in the company is presented in the TABLE III

TABLE III. "AVAILABILITY" OF A CNC MACHINE FOR 3 SHIFTS

Shift	P _t [min] planned production time				P _t	Downtime [min]												O _t	A	
	T _d	T _p	T _{pz}	T _{fo}		PR			TT			NBR		PP						
						1.1	1.2	1.3	2.1	2.2	2.3	2.4	3.1	4.1	4.2	4.3	4.4			
I	480		20	15	445										10				435	0,98
II	480		20	15	445					27									418	0,94
III	240		20	15	205									22					183	0,89

The second element of the OEE calculation is "P - performance rate". The indicator is calculated according to the formula presented below (Eq. 2):

$$\text{Performance} = \frac{\text{Net operating time}}{\text{Operating time}} = \frac{O_{nt}}{O_t} \quad (2)$$

Net operating time is calculated as the ratio of the number of goods produced on the machine by theoretical time of the operation performed (Ct). Ct parameter is usually associated with how fast a machine runs. In practice, it is necessary to define the Ct parameter taking into consideration actual conditions the machine is to work in and parameters of products that are to be processed. Hence, calculation of performance requires definition of Ct standards for every product. The formula for calculating "Performance" indicator implemented in the company is presented in the TABLE IV.

TABLE IV. "PERFORMANCE" OF A CNC MACHINE FOR 3 SHIFTE

Shift	P _t [min] planned production time				P _t	O _t	Output [pcs]		C _t	O _{nt}	P
	T _d	T _p	T _{pz}	T _{fo}			O _{pt}	R _{pt}			
I	480		20	15	445	435	474	29	1,15	412,2	95
II	480		20	15	445	418	456	7	1,15	396,5	95
III	240		20	15	205	183	64	23	1,15	55,65	30

The third and final element of the OEE calculation is the "Q - quality rate". Quality is calculated by subtracting the output during running time by rejects (including reworks) and then dividing by the output (Eq. 3). The number of products that do not meet quality specification is calculated by the operator after completing each shift.

$$\text{Quality} = \frac{\text{Actual output} - \text{Rejects}}{\text{Actual output}} = \frac{O_{pt} - R_{pt}}{O_{pt}} \quad (3)$$

For the moment, the plant has a data collection and analysis tool named QMS (OEE basis), designed by the consulting firm. It is developed in SQL Server 2014: the data collection remains in the form of manual entry while the analysis of different losses is an automated process.

IV. USING THE TEMPLATE

The period of the first month after development of OEE model and its components is validation of the model. The data entered to the system on each shift and each day was observed (TABLE V).

TABLE V. OEE OF A CNC MACHINE FOR ONE DAY

Shift	OEE zmianowe						OEE dzienne								
	P _t	O _t	A	P	Q	OEE	P _t	O _t	Output		O _{ut}	A	P	Q	OEE
	min	min	%	%	%	%	min	min	O _{pt}	R _{pt}	min	%	%	%	%
									pcs	pcs					
I	445	435	98	95	93,88	87	1 095	1 036	935	994	864	95	83	94	74
II	445	418	94	95	98,46	88									
III	205	183	89	30	64,06	17									

Most of the problems in this period was primarily the result of the erroneous data input into the system and the

regularity of data recording. Analysis of the data and the information obtained during meetings with production and maintenance department staff led to developing a training plan. Trainings were focused mostly on creating the habit of entering data into the system and on proper allocation of data (assigning events to the appropriate category of losses). The result of the trainings was development of standards for data entering into the system by operators and maintenance staff.

After half a year period after training sessions, another comprehensive analysis of OEE and its components for all strategic machines (casting machines and CNC) was conducted. Its aim was to answer the following questions: Is the equipment effective? If poor performance exists, where does it come from? What are the principal losses? Which actions should be taken to solve the problems and to improve the performance? The sample graphs presenting OEE and its components (A- availability, P – Performance, Q – quality) for all the casting machines (KPZ), for a selected casting machine (STO1094) are shown in Figure 2 and MTTR indicators for the casting machine STO1094 are shown in the Figure 3.

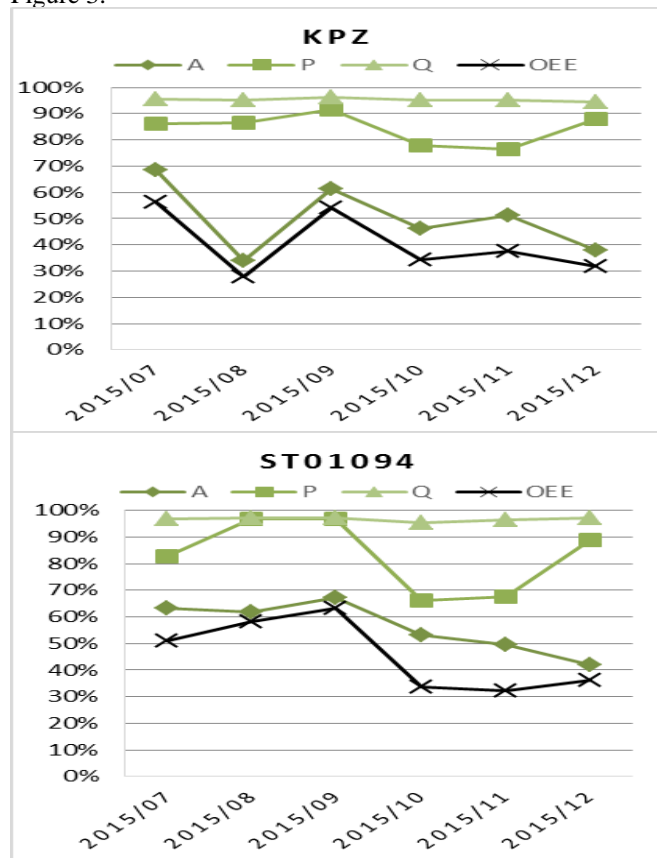


Figure 2. OEE measure distribution in time for all the casting machines (KZT) and for the one selected (STO1094)

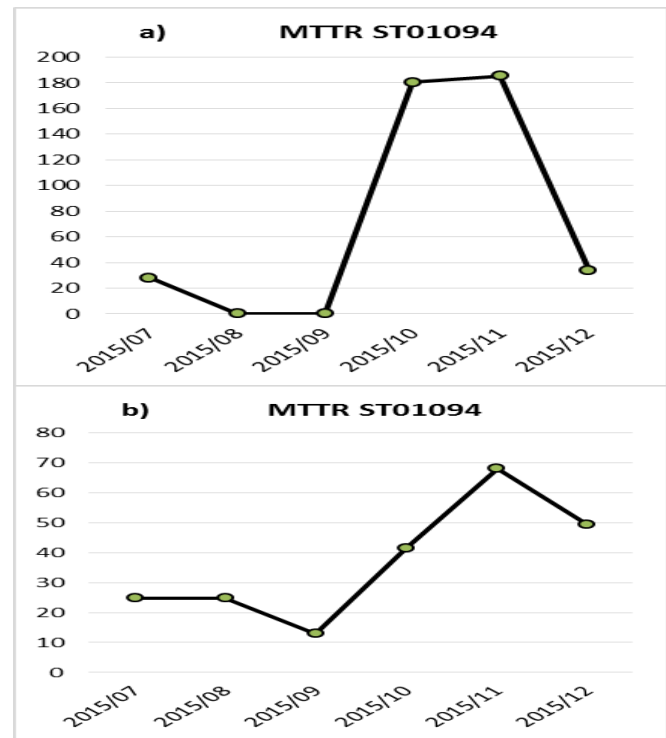


Figure 3. MTTR for a casting machine a) monthly, b) cumulative graph

According to the assumptions take, implementation of OEE should lead to identification of areas of operational improvement of activities for both production and maintenance staff. Analysis of Figure 2 highlights the very high value of Quality rate for all the casting machines, which is good news. In contrast, the value of Availability rate is disturbing. It is the main cause of low value OEE.

The first step of the research was analysis of losses (TABLE II), records in the computer system, and executive instructions for operators and interviews with operators. In order to effectively use the OEE, the data required for calculation must be clearly defined, and well structured (clearly assigned to the appropriate category of losses), to be credible, and so the staff recording the data need to understand what they do and have a real the opportunity to do this. As the result of the activities carried out it was found that the primary problem is the incorrect data entered into the system by operators, lack of performance standards for the maintenance work carried out on the machine by operators, improper organization of work and the lack of employee awareness (what is it for?) - The employees do not see the interdependences. Thus, the improvement must go towards the standardization of the operators work and building awareness and motivation to comply with the rules and standards developed.

In the next step the relationship between the "Availability rate" and values MTTR, MTBF and MTTF were sought for. These indicators were measured in a company for a long time and were input to the maintenance activities schedules

and to evaluation of the effectiveness of these actions. The impact of MTTR indicator on "Availability rate" and thus on the value of the OEE is obvious. The calculation of this ratio in a cumulative way enables determination of the trend, but its precision is very limited. However, the analysis of the indicator has led to the conclusion that such large losses of availability are not the result of negligence of maintenance staff. The author did not manage to find the links with other indicators (e.g. MTBF, MTTF), which would allow accurate determination of trends and implementation of appropriate measures for the planning and scheduling maintenance work. Moreover, conclusion on a single machine made on the basis of the whole group has not produced the expected results (no correlation). Therefore, the calculated value of the OEE for all the casting machines can only be used as the internal benchmark.

Hence, the summary of the research from the perspective of the activities of maintenance shows that the OEE model developed does not provide clear and precise information to enable appropriate control of processes on specified machines, so monitoring of several indicators (MTTR, OEE, MTBF, MTTF) seems to be the right step, and in combination with the knowledge base SUR (base designed for the needs of enterprise to collect and analyze data on machine operation) enables the development of effective maintenance plans.

V. CONCLUSION

OEE is a "best practices" way to monitor and improve the effectiveness of processes (i.e. machines, manufacturing cells, assembly lines). The OEE tool evaluates equipment performance, which could provide a basis for further improvement. It maps out the "losses landscape"; speed loss, machine breakdown and minor stoppages, defect loss, and so on. All those details are integrated into the single tool. This article highlights three important issues related to the OEE measure. Firstly, the multiplicity of approaches for determining losses and corresponding models for calculating OEE (Chapter 2) was shown. Although this situation may cause some confusion, it reflects the potential of this measure in relation to the assessment of efficiency of production equipment of various businesses and industries. Secondly, OEE can be used not only to monitor losses. Its real value is providing information concerning opportunities for improvement. OEE is a useful guide for production processes managers striving for improving and building internal cooperation with other functional areas of the company, e.g. production, maintenance, logistics. Another, third aspect resulting from the case study presented is the issue of availability and reliability of the data necessary to calculate the OEE. According to Muchiri and Pintelon [26], the validity and usefulness of the OEE measure are highly dependent on the data collection and accuracy. Without reliable data, the different losses cannot be measured and identified. It is therefore important to invest time and money to improve data collection. For this reason some

manufacturing companies have automated their collection of OEE-related data to guarantee the data accuracy.

It is also important to know that the OEE provides an excellent perspective of a comprehensive improvement achievement, but e.g. in the area of maintenance should be strengthened indicators such as MTBF, MTTF and MTTR.

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