IMPROVE PRODUCTIVITY WITH A MULTI-STAGE PRODUCTION OF TRANSFORMER SHEETS

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Abstract

The development of the concept of the supply chain has resulted in a broader view of logistics. The primary goal of production logistics can be formulated as expansion of the capabilities for the implementation and reliability of deliveries with the lowest logistical and production costs. In such an approach production systems are those in which input quantities are temporally and spatially transformed into products. With logistical supply networks at the input and distribution networks at the output of the system, production and logistics are closely linked. The approach proposed within the framework of *Lean enterprises* is interesting. The methods appearing in the literature under the name *Lean toolbox* can be used to improve a company's productivity indices. The article presents parts of research OEE performance indicator for many production lines. The object of the study was the production plant of transformer sheets.

Keywords: productivity, efficiency indicator OEE, sheet production

1. INTRODUCTION

The basic problems considered by industrial logistics are: displacement of materials and information, data storing and processing, problems of integrating the materials flow process, planning and control.

The task of logistics is to ensure a buyer to obtain the proper quality and quantity of a product in due time and place on the minimal cost of delivery [4]. Continuous search of methods improving effects of carried out activity has been characteristic feature for enterprise management in recent years. Currently the following ways are recommended more and more often: lean approach and lean thinking as a countermeasure to eliminate wastage *(muda)* by creating value stream in an enterprise [5]. The essence of lean approach is transformation of wastage *(muda)* into a value, thus determination of value is the first step during lean approach implementation. Whereas, tools supporting the *lean* concept include: VSM (Value Stream Mapping, Five Pillars Method - 5S, Jidoka, Heijunka, TPM - Total Productive Maintenance). The purpose of the TPM is to strive after maintaining continuous work of devices and machines executing specific tasks, which at the same time shows improvement of their functioning effectiveness. Until recently, the TPM was used mainly in production and repair processes. The main goal of TPM [3] is the strive to ensure continuous operation of the equipment and machines performing specific tasks, which also means improving their operational efficiency. The method is based on the use of human resources to analyze the causes of wastage and losses (*muda*) arising in the process and requires a systemic solution to the problems that cause downtime of machinery and equipment [1]. The main objectives for the implementation of the TPM method are: reducing the number of equipment failures, accelerating repair times of a unit or line, elimination of micro-stoppages, reduction of losses. The OEE (*Overall Equipment Effectiveness*) index is the primary measure for the TPM implementation effects [3]. The OEE is either overall equipment effectiveness or general equipment efficiency (machines, devices). This index shows what percent value of theoretically obtainable efficiency is characteristic for an examined device or line. The TPM identifies 6 main losses (in three subgroups) [2]:

- time losses (availability: losses due to failure, losses for exchanges of die and adjustments),
- efficiency losses (performance: losses for dead time and micro-downtime, losses due to process speed drop),
- losses due to defects (quality: losses due to occurrence of rejects and corrections, tart-up losses).

Fig. 1 presents a diagram showing components that allow practically determining effectiveness (efficiency) evaluation index for machine or line used to carry out specific process.

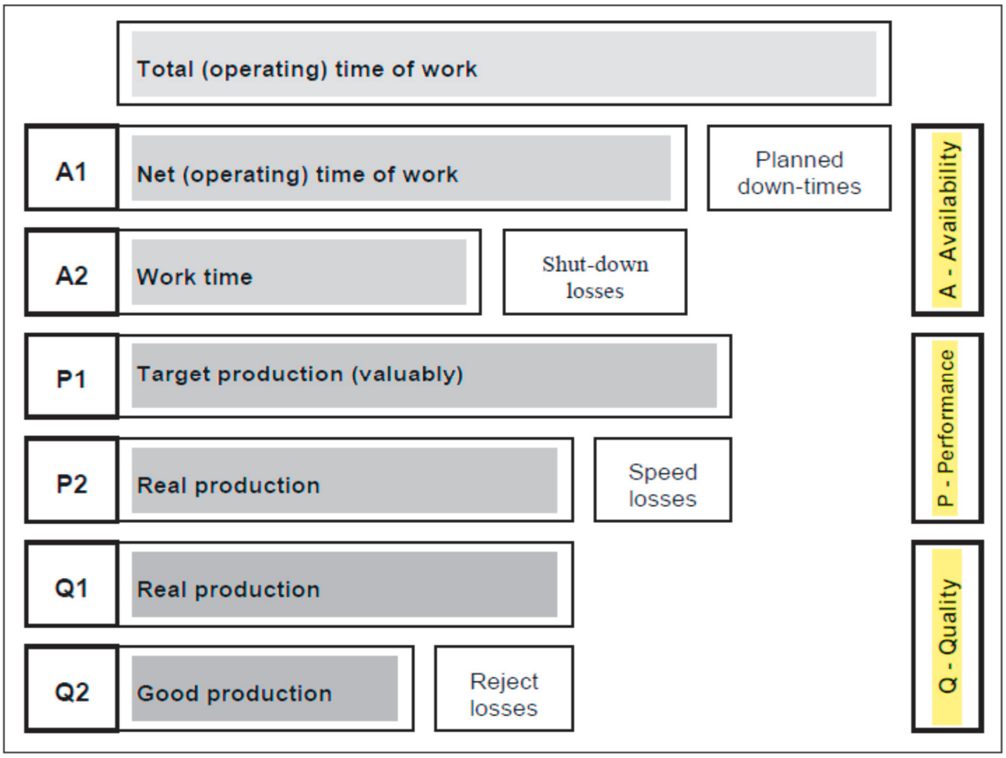

Fig. 1 Components of the OEE index [4]

The OEE index is most often computed using simple formula:

OEE effectiveness index = availability x performance x quality x 100 (%)

$$OEE = A \times P \times Q \times 100 \, (\%) \quad (1)$$

where:
A - availability: practical availability, availability ratio;
P - performance: efficiency of performance, performance ratio;
Q - quality: quality factor.

TPM method has been used to improve productivity in plant production of electrical sheets.

2. TPM IMPLEMENTATION - ANALYSIS OF THE PRODUCTION PROCESS

The final product of the plant is the electrical sheets. All parameters and tolerances are in accordance with EN 10107:2005. Offer plant contains four of the final product thickness: 0.23 mm, 0.27 mm, 0.3 mm and 0.35 mm.

Load (120 000 -140 000 Mg): hot-rolled sheet with a thickness of 2.0 ÷ 2.5 mm and a width of about 1000 mm in the form of rolled coils.

Suppliers: Arcelor Mittal Poland (Krakow), Arcelor Mittal Germany, U.S Steel Czech Republic (Kosice).

A production system SES of electrical (transformers) sheets is composed of many subsystems:

$$S_{SES} = \langle L1, L2, L3 \ldots . L13 \rangle \quad (2)$$

The technological process is carried out on 13 production lines:

L1 - NT: Line of normalizing and pickling - preparing for the cold rolling
L2 - WS1: Line of primary mill - Sendzimir mill

L3 - A, L4 - B1, L5 - B2: Lines of decarburization - reduce the carbon content (up to 12 ppm)
L6 - WS2: Line of final rolling - Sendzimir mill (thickness min. 0.23 mm)
L7 - B3 L8 - B4: Lines of straightening and coating (layer of magnesium oxide MgO)
L9 - LOI, L10 - IPSEN: Lines of annealing (new furnaces: LOI - 20 pcs, old: IPSEN - 10 pcs)
L11 - C1, L12 - C2, L13 - C3: Lines electro-coating layer

In addition, it is possible to cut sheet to another dimension on Lines of cutting (cutting units). Sheet production scheme is shown in **Fig. 2**.

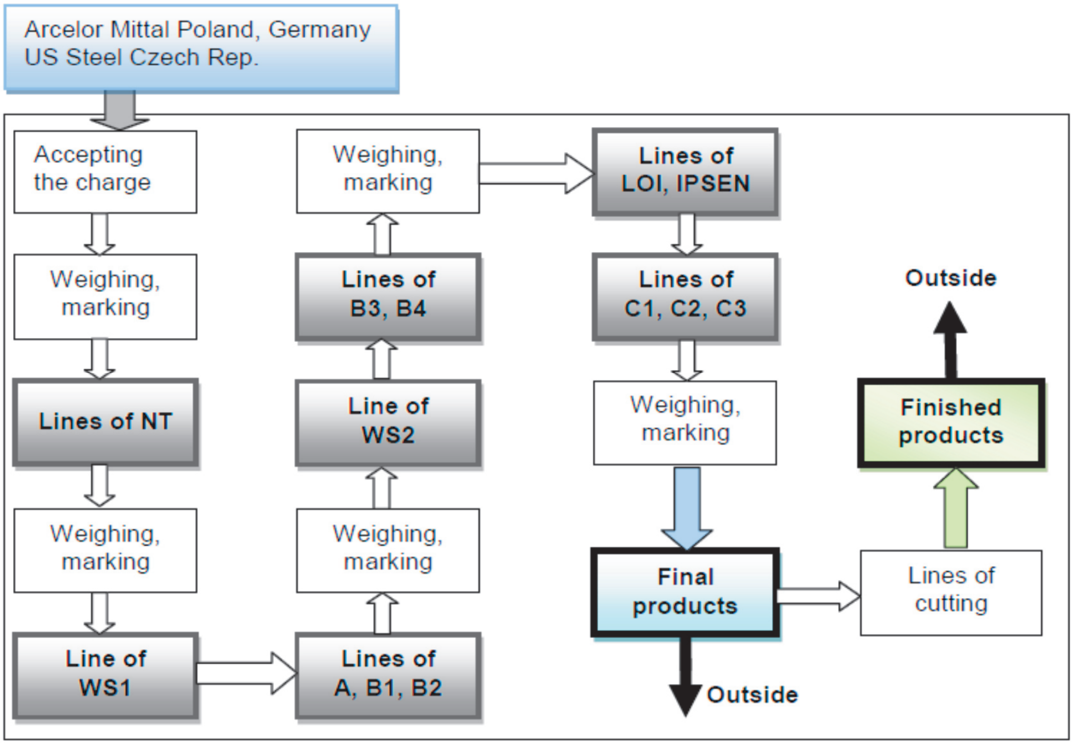

Fig. 2 Scheme of electrical sheets production

For all 13 lines was carried out research performance indicators OEE (Overall Equipment Effectiveness). Presented below are the results for the line L1: Line of normalizing and pickling NT.

OEE analysis for Line NT (data for the six months of operation from ERP-IFS)

Table 1 shows the results of measurements obtained from the IFS system (ERP) for the time line and the stops planned and unplanned. For shutdowns planned works consist necessary to ensure proper operation of the line (replacing the blades, replacement breakers). Identified unplanned shutdowns include problems with the welding and shot peening machines, replacement rollers, breaking plates).

Table 1 Availability

Parameter	Time (h)
Total working time	4416
Planned working time	2715.5
Planned down time	58.2
Shut down unplanned time	133.8

Availability *A*: $$A = \frac{A2}{A1} = \frac{2523.5\ \text{h}}{2715.5\ \text{h}} = 0.9295 = 92.95\ \%$$

Table 2 summarizes the results of calculations to determine the performance index P line NT.

Table 2 Performance

Parameter	Performance (Mg/h)
Average nominal capacity	27.6
Average real capacity	23.2
Parameter	**Time (h)**
Real operating time	2524.2
Calculated operating time	2121.8

Performance *P*: $$P = \frac{P2}{P1} = \frac{2121.8\ \text{h}}{2524.2\ \text{h}} = 0.8417 = 84.17\ \%$$

Table 3 shows the results of calculations relating to the quality indicator Q for NT line operation.

Table 3 Quality

Parameter	Mass (Mg)
Volume of production	59544.2
Waste	1625.6
Finished products	57918.6
Parameter	**Time (h)**
Calculated operating time	2121.8
Real operating time	2051.8

Quality *Q*: $$Q = \frac{Q2}{Q1} = \frac{2051.8\ \text{h}}{2121.8\ \text{h}} = 0.9727 = 97.27\ \%$$

The results of the calculation of OEE are shown in **Fig. 3**.

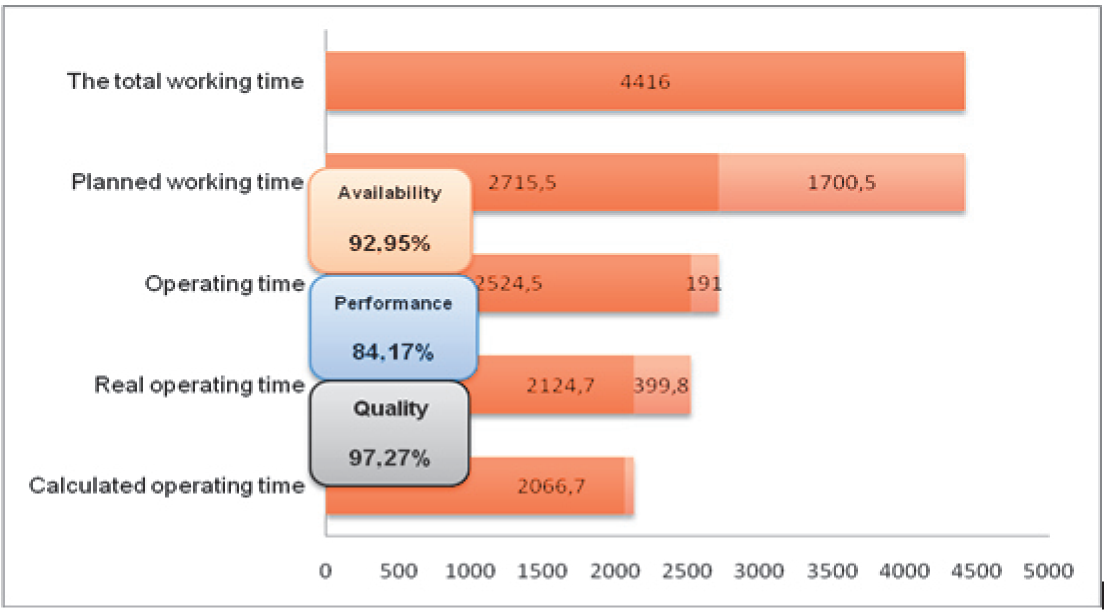

Fig. 3 The results of the OEE calculation for L1 (line NT)

Overall Equipment Effectiveness: $OEE_{NT} = A \times P \times Q =$ **76.11%** (world class - good)

The result OEE = 76.11% is a good global level.

For the next twelve lines was carried out similar research. The test results are shown in **Table 4** and in **Figs 5** and **6**.

Table 4 Indicator OEE for each production line

No.	Line	Availability	Performance	Quality	OEE
L1	NT	92.95	84.17	97.27	76.11
L2	WS1	63.37	43.44	100.00	27.53
L3	A	96.60	88.62	95.28	81.55
L4	B1	88.99	81.81	95.25	69.35
L5	B2	95.87	83.79	95.28	76.62
L6	WS2	73.32	80.00	100.00	58.98
L7	B3	92.53	59.56	99.00	54.56
L8	B4	92.43	60.34	98.96	55.19
L9	LOI	97.52	88.67	100.00	86.47
L10	IPSEN	97.46	87.78	100.00	85.55
L11	C1	87.60	66.10	92.83	53.75
L12	C2	88.08	71.62	92.85	58.57
L13	C3	78.52	80.98	94.77	60.26
				Average OEE	**64.96**

Analysis of variability OEE:

A - Availability: minimum value A_{WS1} = 63.37%; maximum value A_{LOI} =97.52%;
P - Performance: minimum value A_{WS1} = 43.44%; maximum value A_{LOI} =88.67%;
Q - Quality: minimum value A_{C1} = 92.83%; maximum value $A_{WS1,WS2,LOI,IPSEN}$ =100%;

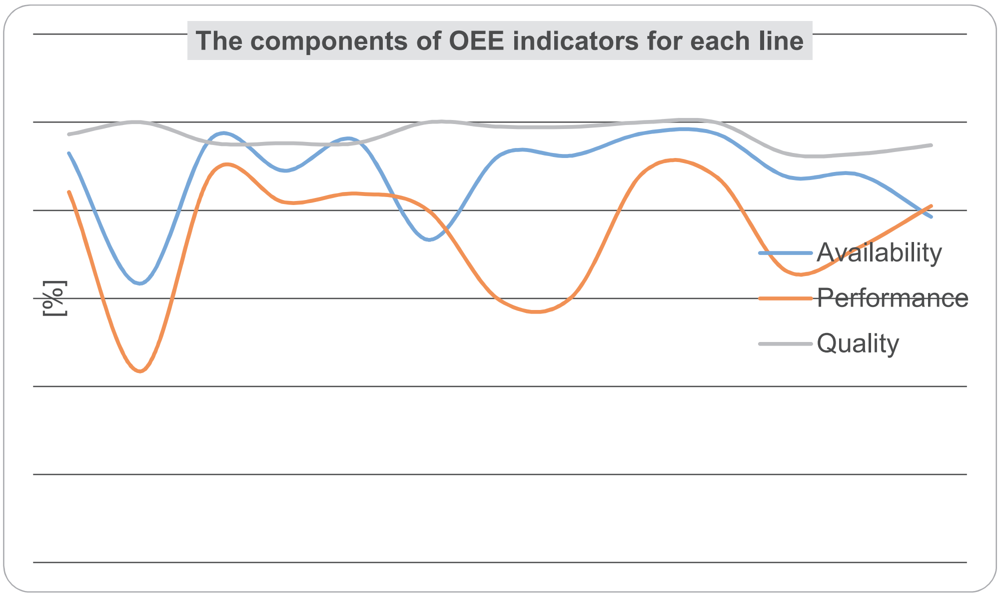

Fig. 5 Charts components of OEE indicators for each line

Summary graph of the total indicator OEE for production of transformers sheets is shown in **Fig. 6**.

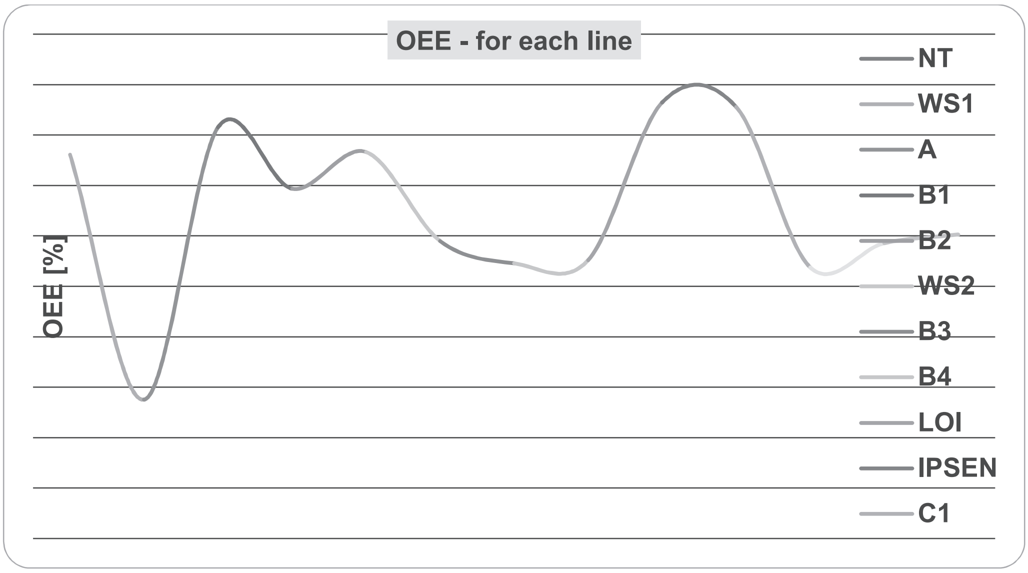

Fig. 6 Summary graph of total indicators OEE

The analysis of the charts shows that the results OEE indicators are very different. The best result was obtained for the line L9 (LOI furnaces) - OEE = 86.47%, while the worst result was obtained the line L2 (Sendzimir mill) - OEE = 27.53%. This is a very bad indicator.

CONCLUSION

Average score index for the whole plant was OEE_{SES} = 64.96%. The OEE coefficient is strongly dependent on the operation of the production line, but its value depends on the method of calculation methods and data collection. In the case of the primary rolling mill (Sendzimir mill WS1) to improve the rolling coefficient OEE_{WS1} = 27.53% would first seek to improve the availability of the index as it has a small value. This is a very bad indicator for immediate improvement. Improving the value of this ratio can be achieved not by eliminating unplanned downtime, but the analysis of the causes of their occurrence and to find the reasons that cause it stops. Also two other lines have bad results (less than 55%). They are: L11 line electro-coating layer OEE_{C1}=53.75% and L7 line of straightening and coating OEE_{B3} =64.56%. For these lines and for lines L8 and L12 proposed improvement program through the establishment of teams TPM. It was assumed that the indicator should be equal to 75%.

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