ANALYSIS OF THE IMPACT OF DOWNTIME ON THE CONTINUOUS PRODUCTION OF SHEETS

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Abstract

Production is concerned with short throughput times and high schedule reliability in order to on the one hand, fulfill customer demands and on the other hand, increase planning reliability. The continuity of the flow of materials and information are influenced by many factors. One of the most important factors is the reliability of the machines and equipment. The TPM method most commonly employs three indicators: MTTR (Mean Time To Repair), MTBF (Mean Time Between Failures) and most typically - OEE. The first two are associated exclusively with technical issues of the examined production line. However, as the basic TPM implementation performance indicator stands OEE (Overall Equipment Effectiveness), which is a global efficiency rate. This indicator represents the percentage of theoretically available effectiveness possessed by a device or production line. The paper discusses some examination results for main subsystems of Cold Rolling Mill.

Keywords: OEE indicator, TPM method, cold rolling mill

1. INTRODUCTION

The task of logistics in a plant is a purposeful shaping, planning and controlling of the flow of materials which come into a plant, produced and distributed by it as well as the information connected with the flow [2], [7]. Currently, there are numerous methods and tools to improve the efficiency of business [1], [5]. The variety of manufacturing systems means that each efficiency improvement system requires serious analysis. One of the major tasks of these systems is to ensure the continuity of the flow of materials in manufacturing processes [2], [6]. One of the methods that can be used in this regard is Total Productive Maintenance (TPM), which can also serve as a basis for other analyses, such as using a capacitive element in the material flow system. As we know [6], the main goal of TPM 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 analyse 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 [3], [4]. The main objectives for the implementation of the TPM method are:

- reducing the number of equipment failures**,**
- accelerating repair times (restoring efficiency) of a unit or line,
- elimination of micro-stoppages,
- reduction of losses.

2. THE ANALYSIS OF SYSTEM OPERATION

Described rolling mill system is composed of many subsystems [5]:
$S_{CRM} = < S_1, S_2 \dots S_n >$,
where n means most often 6 - 10 subsystems.

There were separated $n = 7$ subsystems in the examined system:

S_1 - the CPL continuous pickling line subsystem,
S_2 - the FHM four - high rolling mill subsystem,

S_3 - the SAL annealing line subsystem,
S_4 - the SPL planishing line subsystem,
S_5 - the SCC cross cutting subsystem,
S_6 - the SSC strip cutting subsystem,
S_7 - the SSS subsystem of storing and shipping final products.

The coils of hot - rolled sheets CS are the charge material:
$CS = \{cs_i \,;\, i = 1...M\}$,
where:
$cs_i = (g_i, s_i, m_i, t_i, z_i)$;
M = 23 assortments of charge coils of thickness g_i, width s_i, mass m_i, pickling time t_i, and demand z_i were investigated. Out of these M = 23 charge assortments w = 83 assortments of finished products are made.

Example:

- characteristics of charge material: tickness from 1.4 to 6.0 mm, width from 700 to 1 565 mm, mass of coils from 8 to 30 t,
- characteristics of finished products: tickness from 0.4 to 2.5 mm, width from 700 to 1 565 mm, mass of coils from 5 to 30 t.

Figure 1 shows a scheme of cold-rolled sheet production.

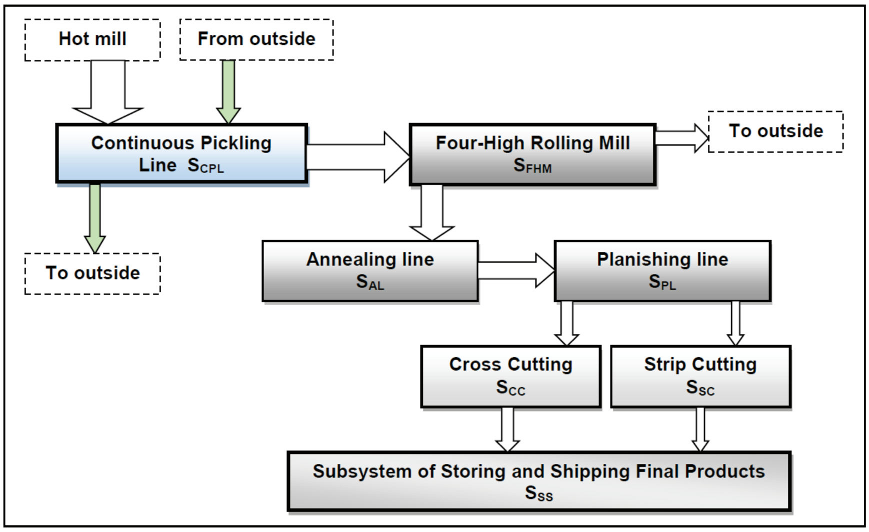

Figure 1 Scheme of cold rolling mill

As a result of changes in global markets, has changed the structure of production (see **Figure 2**). Currently, more than 50 % of the production is sent to another steelworks F. Weight send coils is approx. 25 t. Coils for galvanizing must weigh less than 17 t. It causes that material processing times by the various processes are different. It also requires a change in the planning process - mainly pickling and rolling.To examine the operation of CPL continuous pickling line subsystem (S_1) and the FHM four - high rolling mill subsystem (S_2) a model of coils was developed from the storage yard before pickling line to the feeder after the rolling mill.

The pickling process consists of 9 operations: transport by crane (1), waiting in buffer before unrolling (2), preparation of metal band (3), waiting for the pickling (4), welding metal bands (5), continuous pickling process (6), cutting - of band (7), transfer of coils to storage (8), waiting in buffer before rolling (9).

While the rolling process consists of 8 operations: transport by crane (1), transport before the mill (2), preparation of metal band (3), waiting for the rolling (4), cold rolling process (5), removing the metal bands (6), transport outside the mill (7), transport by crane to storage (8).

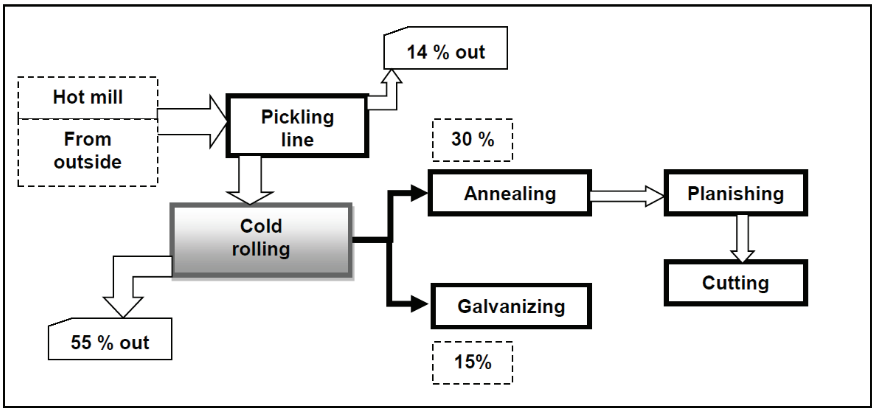

Figure 2 Structure of production after changes

For example:

1. Coil for galvanizing - throughput time is respectively:
   Pickling process - $t_{CPL} = \Sigma\, t_{CPLi} =$ 1h 3 min.; $t_{6\ (pickling)} =$ 11 min. 8 sec.
   Rolling process - $t_{FHM} = \Sigma\, t_{FHMj} =$ 1h 18 min.; $t_{5\ (rolling)} =$ 6 min. 50 sec.

2. Coil for outside plant F - throughput time is respectively:
   Pickling process - $t_{CPL} = \Sigma\, t_{CPLi} =$ 1h 40 min.; $t_{6\ (pickling)} =$ 12 min. 13 sec.
   Rolling process - $t_{FHM} = \Sigma\, t_{FHMj} =$ 1h 56 min.; $t_{5\ (rolling)} =$ 9 min. 3 sec.

Currently, in the rolling mill changed the flow of information related to the implementation of sheet production. The study examined the impact of changes in structure (see **Figure 2**) on the performance indicators. **Figure 3** shows a schematic material and information flows on the performance order.

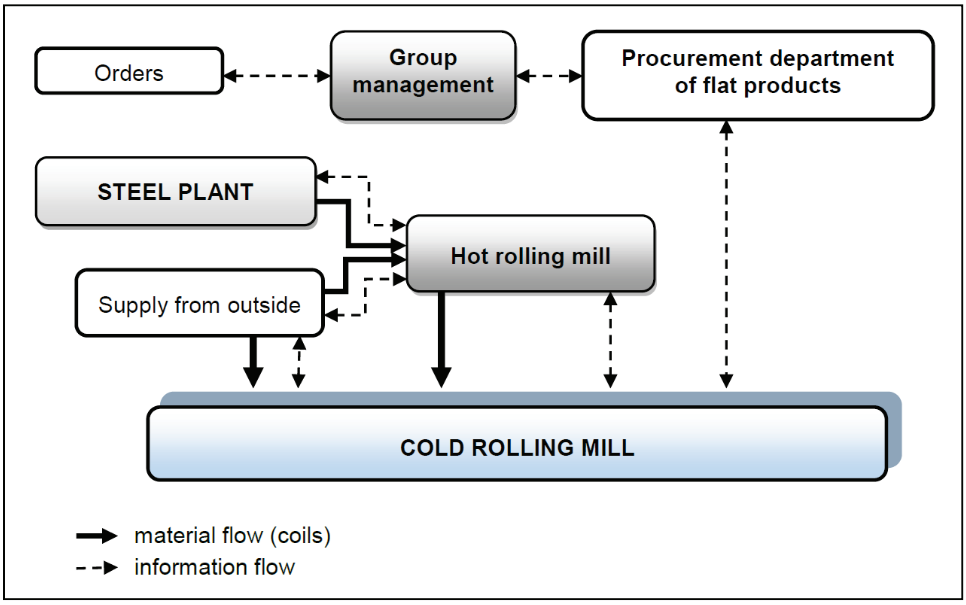

Figure 3 Scheme of material and information flow

In recent years there has been a reduction in the total production of sheet metal.This results in a reduction in the use of machinery and equipment. To determine the quality and quantity of these changes to the TPM method was used.

3. THE TPM METHOD IN COLD ROLLING MILL

The TPM method most commonly uses three indicators: MTTR, MTBF and, most distinctly, OEE. MTTR (*Mean Time to Repair*) indicates the average time needed to repair a device (in a line), MTBF (*Mean Time between Failures*) indicates the average time between the occurrence of two failures or micro-stoppages. The primary measure of the effects of introducing TPM is the OEE indicator (*Overall Equipment Effectiveness*). OEE means the overall efficiency of equipment (machinery, devices). This indicator shows the current percentage of theoretically achievable efficiency for a given device or line.

The OEE indicator is usually calculated using this simple formula:

$$OEE = A \times P \times Q \times 100\ [\%] \tag{1}$$

where:
A - availability: practical availability, availability factor,
P - performance: performance effectiveness, performance ratio,
Q - quality: quality factor.
The calculations included the following indicators:

A - availability: $$A = \frac{A2}{A1} = \frac{operating\ time}{net\ operating\ time} \tag{2}$$

P - performance: $$P = \frac{P2}{P1} = \frac{actual\ yield}{target\ yield} \tag{3}$$

Q - quality: $$Q = \frac{Q2}{Q1} = \frac{good\ \ yield\ \ (number\ \ of\ \ good\ \ products)}{actual\ \ yield\ \ (number\ \ of\ \ products)} \tag{4}$$

Research were five major subsystems: pickling line, cold rolling, planishing line, cross cutting and strip cutting. **Table 1** shows the time needed to calculate the OEE.

Table 1 Performance data for five subsystems (average of year)

No	Time	Pickling line	Four-high rolling mill	Planishing mill	Cross cutting	Strip cutting
1	Total working time t_K	8 400	8 400	8 400	8 400	8 400
2	Planned working time t_P	7 358	6 876	5 236	4 100	3 050
3	Planned shutdowns and repair t_{PP}	1 042	1 524	3 164	4 300	5 350
4	Break and damage t_{PA}	1 398	2 317	1 050	900	675

Selected results of implementation of the TPM in Cold Rolling Mill is shown in **Table 2** and **Figure 4**. This study period was one year. The calculations included the following indicators: *A*, *P*, *Q* and *OEE*.

Table 2 Indicator OEE for each production line

No.	Line	Availability A [%]	Performance P [%]	Quality Q [%]	OEE [%]
S_1	CPL	81.00	86.89	99.98	**70.37**
S_2	FHM	66.30	76.73	99.89	**50.82**
S_4	SPL	79.94	83.30	99.10	**65.99**
S_5	SCC	77.86	83.96	97.80	**63.93**
S_6	SSC	79.94	83.30	97.10	**64.66**
				Average OEE	**63.15**

For example - Overall Equipment Effectiveness for Continuous Pickling Line CPL:

$\boldsymbol{OEE}_{CPL} = A \times P \times Q = 0.81 \times 0.8689 \times 0.9998 \times 100\ \% =$ **70.37 %** (see **Figure 4**).

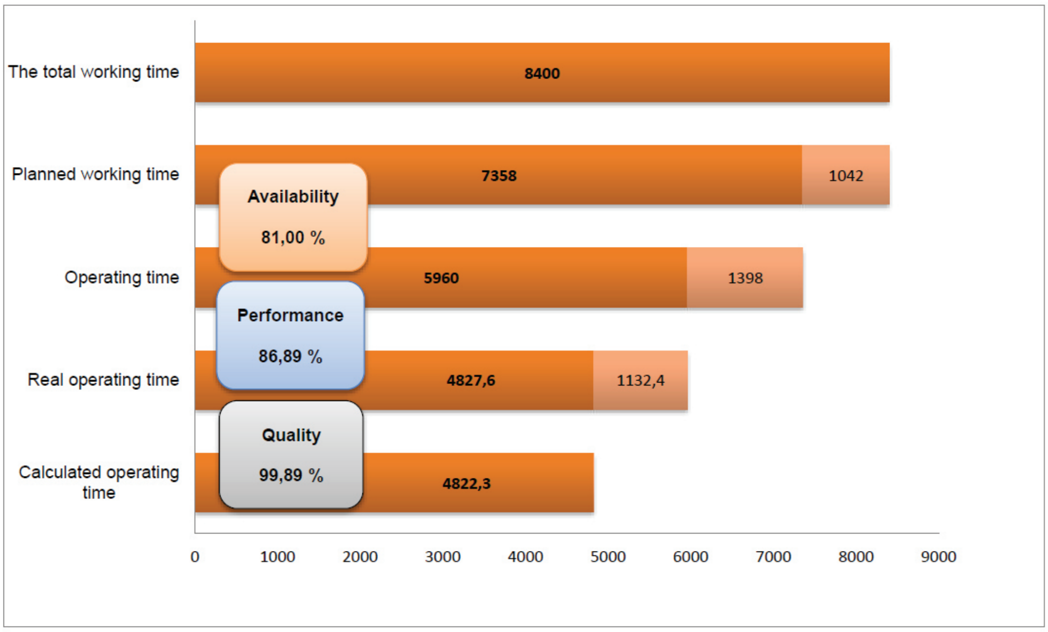

Figure 4 The results of the OEE calculation for CPL

Similarly, other processes have been calculated.The calculation results for five production lines are shown in **Figure 5**.

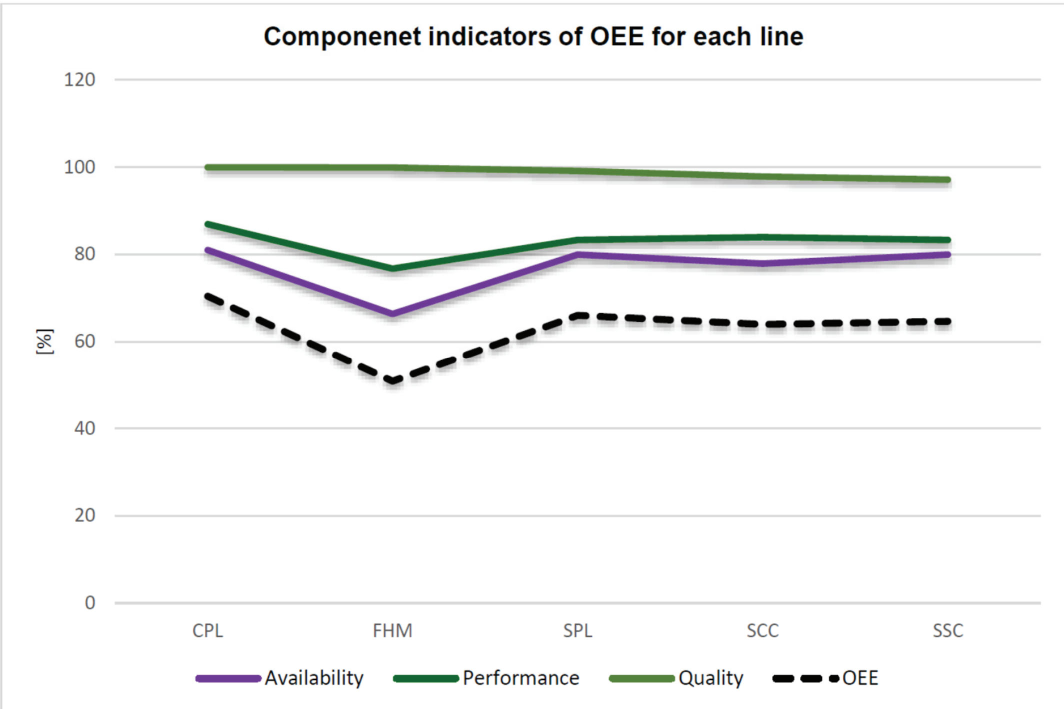

Figure 5 The results of the OEE calculation for five processes

Obtained in mill OEE indicators are relatively low (product quality is very high). To improve OEE (except for higher production) can help better information system. The cold rolling mill has an integrated information system SAP. To improve the flow of information and better production planning further implemented of new computer systems: PTS and LEVEL (ABB Company). The system LEVEL consists of two levels:
LEVEL 1 - device management,
LEVEL 2 - managing product.

4. CONCLUSION

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. Therefore, OEE should be treated as an internal indicator that allows to estimate the improvement or deterioration compared to the situation from a different time period on the same production line. In the case of the pickling process and to improve the rolling coefficient OEE would first seek to improve the availability of the index as it has a small value. 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. The main reasons for the occurrence of unplanned downtime in addition to the rolling process are difficult to predict failure is inadequate planning and production of the pickling process improvement to be found here, because the two processes are closely linked.

Research indicates that the average OEE rate in cold rolling mill is approximately 63 % - the results on the world level are 80 % or more. In this case, the results of indicator OEE for each line: 70.37 % (CPL), 50.82 % (FHM), 65.99 % (SPL), 63.93 % (SCC) and 64.66 % (SSC) show there is a high possibility to improve OEE.

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REFERENCES

[1] BICHENO, J., HOLLWEG, M. *The Lean toolbox: The essential guide to Lean transformation*. Johannesburg: Picsie Books, 2008.

[2] HARRIS, R., HARRIS, Ch., WILSON, E. *Material flow improvement*. Wroclaw: Wroclaw Centre of Technology Transfer, 2005.

[3] KORNICKI, L., KUBIK, SZ. (ed.) *OEE dla operatorów. Całkowita efektywność wyposażenia (OEE for operators. Overall equipment effectiveness)*. Wrocław: ProdPress.com, 2009.

[4] KUBIK SZ. (ed.) *TPM dla każdego operatora (TPM for every operator).* Wrocław: ProdPublishing.com, 2012.

[5] MICHLOWICZ, E. TPM method in the analysis of flow in the cold rolling mill. In *METAL 2013: 22nd International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2013.

[6] NYHUIS, P., WIENDHAL, H-P. *Fundamentals of Production Logistics. Theory, Tools and Applications*. Berlin Heidelberg: Springer - Verlag, 2009.

[7] VOSS, S., PAHL, J., SCHWARZE, S. *Logistik Management.* Heidelberg: Physica-Verlag und Springer Verlag, 2009.