TPM METHOD IN THE ANALYSIS OF FLOW IN THE COLD ROLLING MILL

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Abstract

The fundamental goal of production logistics can thus be formulated as the pursuance of greater delivery capability and reliability with the lowest possible logistic and production cost. Tasks of production logistics include organisation, planning and scheduling of product manufacturing processes, but it is not an objective of logistics to develop new technologies or to improve manufacturing processes. 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. Furthermore, with shorter throughput times the risk of changes being made to orders in progress decreases. However, from the business perspective, it is preferred that the available production equipment is highly utilized and that there is the lowest possible WIP (Work in Process level). The TPM method most commonly employs three indicators: MTTR, MTBF 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 two subsystems, namely the CPA - continuous pickling subsystem and the FHM – four high mill subsystem.

Keywords: cold mill, maintenance, TPM method

1. INTRODUCTION

Most modern enterprises implement the management rules known as lean [10]. Currently, there are numerous methods and tools to improve the efficiency of business [4]. It should be noted, however, that the commonly proposed lean toolboxes [1] tend to have specific applications (e.g. SMED should be deployed in the case of multi-product manufacturing, and the retooling of machines or production lines is as often as several times per shift). 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], [7]. 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 [9], 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]. 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.

The performance of typical equipment systems (serial, parallel, mixed) is most often increased by:
- selecting devices with higher reliability,
- improving the reliability of devices or lines (e.g. resulting from the application of TPM),
- using redundancy, i.e. excess throughout the entire system (the so-called parallelisation of the system - often used in control systems),
- using redundancy, i.e. excess of selected elements in the system (the so-called parallelisation of components),
- placing an additional capacitive element in the system - a buffer, a small warehouse.

2. **THE ESSENCE OF THE TPM METHOD**

The TPM method most commonly uses three indicators: MTTR, MTBF and, most distinctively, OEE. MTTR (Mean Time to Repair) indicates the average time needed to repair a device (in a line).

\[
MTTR = \frac{\sum \text{times to repair}}{\text{number of repairs}} \tag{1}
\]

MTBF (Mean Time Between Failures) indicates the average time between the occurrence of two failures or micro-stoppages.

\[
MTBF = \frac{\sum \text{of times of correct operation}}{\text{number of occurrences of correct operation}} \tag{2}
\]

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 TPM identifies 6 main losses (in three subgroups):

Time losses (availability):
1. Losses due to failure.
2. Losses for exchanges of die and adjustments.

Efficiency losses (efficiency):
3. Losses for dead time and micro-downtime.
4. Losses due to process speed drop.

Losses due to defects (quality):
5. Losses due to occurrence of rejects and corrections.
6. Start-up losses.

The OEE indicator is usually calculated using this simple formula:

\[
OEE = \text{availability} \times \text{performance} \times \text{quality} \times 100 \% \tag{3}
\]

where:
A - availability: practical availability, availability factor,
P - performance: performance effectiveness, performance ratio,
Q - quality: quality factor.

Using another description, the factors of the product can be determined as follows:

\[
A = \frac{A_2}{A_1} = \frac{\text{operation time}}{\text{net operating time}} \tag{4}
\]

\[
P = \frac{P_2}{P_1} = \frac{\text{actual yield}}{\text{target yield}} \tag{5}
\]
Q - quality: \[ Q = \frac{Q_2}{Q_1} = \frac{\text{good yield}(\text{number of good products})}{\text{actual yield}} \]  

Analysis of the losses is the starting point for the whole process of introducing modifications. Based on this analysis, the problem is recognised, and the impact of the individual components (A, P, Q) on the functioning of the object in question is evaluated. Based on the data concerning losses, activities are prioritised and a plan is set up. The TPM method requires a systemic problem solution.

3. IMPLEMENTATION OF THE TPM METHOD IN COLD MILL

A typical rolling mill system is composed of many subsystems [6]:
\[ S_{CRM} = <S_1, S_2 \ldots S_n>, \]  
where \( n \) means most often 8 – 10 subsystems.

There were separated \( n = 8 \) subsystems in the examined system, for example:
- \( S_1 \) - the CPA continuous pickling subsystem,
- \( S_2 \) - the FHM four – high rolling mill subsystem,
- \( S_6 \) – the SCC cross cutting subsystem,
- \( S_8 \) – the SSS subsystem of storing and shipping final products.

The coils of hot – rolled sheets CS are the charge material:
\[ CS = \{ cs_i; \ i = 1\ldots M\}, \]  
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 ready products are made.

The paper discusses some examination results for two subsystems, namely the CPA (\( S_1 \)) continuous pickling subsystem and the FHM (\( S_2 \)) cold rolling subsystem. The diagram of these subsystems is presented in Fig.1.

![Fig. 1 The diagram of subsystems CPA and FHM](image-url)
The elements of the CPA pickling subsystem are:
\[ S_{CPA} = \{M1, UP1, UT1\} \]  \( (9) \)
where: M1 - storage yard of obtained coils, UP1 = \{CPA\} - continuous pickling aggregate, UT1 = \{CR, FE, CA\} - transport facilities,
and: CR = \{(Ci ; i = 1, 2)\} - cranes, FE = \{P1\} - conveyors transporting coils to pickling, CA = \{CA1\} - bay car, transporting a part of pickled coils to the storage yard before rolling.

The elements of the FHM rolling subsystem are:
\[ S_{FHM} = \{M2, UT2, UP2\} \]  \( (10) \)
where: M2 - inter-operational store (before rolling mill), UT2 = \{CR, FE\} - transport facilities, and: CR = \{(Ci ; i = 3, 4)\} - transport cranes, FE = \{Pj ; j = 2, 3\} - conveyors transporting coils, UP2 = \{4HR\} - four-high rolling mill - tandem.

Using a systemic approach to solving the problem of machine downtimes, one can check the influence of other solutions on improving the continuity of flow of materials in manufacturing processes \[ [8] \]. Such improvement should result in an increase in productivity of the manufacturing system. Implementation of the TPM method in one of the metal plants required complex approach to the company activity. Thus, specific TPM structure was accepted, consisting of eight pillars (8 Units), including:
- Planned repair management pillar – PM.
- Quality improvement pillar – PQ.
- Training and education pillar – T&E.
- Lean flow pillar – LF.

Selected results of implementation of the TPM in Cold Rolling Mill is shown in the table 1 and figure 2.

### Table 1 Operation times for the sample coils No 1

<table>
<thead>
<tr>
<th>Process</th>
<th>Operation</th>
<th>Time hh:mm:ss</th>
<th>Score time gg:mm:ss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pickling of coil</td>
<td>1. Transport by crane No 4</td>
<td>00:03:21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Buffer before unrolling</td>
<td>00:25:07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Preparation of metal band</td>
<td>00:02:31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Waiting for the pickling</td>
<td>00:03:23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Welding metal bands</td>
<td>00:01:14</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>6. The continuous pickling</strong></td>
<td><strong>00:11:08</strong></td>
<td><strong>01:03:53</strong></td>
</tr>
<tr>
<td></td>
<td>7. Cut – of band</td>
<td>00:01:16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8. Transfer of coils to storage</td>
<td>00:03:32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9. Buffer before rolling</td>
<td>00:12:21</td>
<td></td>
</tr>
<tr>
<td>Rolling of coil</td>
<td>10. Transport by crane No 9</td>
<td>00:01:16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11. Transport before the mill</td>
<td>00:34:28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12. Preparation of metal band</td>
<td>00:02:11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13. Waiting for the rolling</td>
<td>00:03:11</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>14. Cold rolling</strong></td>
<td><strong>00:06:43</strong></td>
<td><strong>01:18:32</strong></td>
</tr>
<tr>
<td></td>
<td>15. Removing the metal bands</td>
<td>00:00:43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16. Transport outside the mill</td>
<td>00:29:02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17. Transport by crane No 13 to storage</td>
<td>00:00:58</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 2 Times of each operation (from 1 to 17) for the sample coils No 1

Results for CPA CONTINUOUS PICKLING LINE (data for one month):

A - availability: \( A = \frac{A_2}{A_1} = \frac{29800\text{min}}{36790\text{min}} = 0.81 \)

P - performance: \( P = \frac{P_2}{P_1} = \frac{63936\text{Mg}}{73580\text{Mg}} = 0.87 \)

Q - quality: \( Q = \frac{Q_2}{Q_1} = \frac{63861\text{Mg}}{63936\text{Mg}} = 0.99 \)

Overall Equipment Effectiveness: \( \text{OEE}_{\text{CPA}} = A \times P \times Q = 69.8\% \) (world class - good)

Results for FHM FOUR – HIGH ROLLING MILL (data for one month):

A - availability: \( A = \frac{A_2}{A_1} = \frac{22795\text{min}}{34380\text{min}} = 0.66 \)

P - performance: \( P = \frac{P_2}{P_1} = \frac{55399\text{Mg}}{72198\text{Mg}} = 0.76 \)

Q - quality: \( Q = \frac{Q_2}{Q_1} = \frac{55340\text{Mg}}{55399\text{Mg}} = 0.99 \)

Overall Equipment Effectiveness: \( \text{OEE}_{\text{FHM}} = A \times P \times Q = 49.6\% \) (world class - low)
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 by 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. Global research indicates that the average OEE rate in manufacturing plants is approximately 60%. The results on the global level is 85% or more. In this case, the result of 69.8% and 49.6%, thus improving the possibility is very high.

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REFERENCES