Total Productive Maintenance In Automotive Industry: Issues And Effectiveness

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Abstract—Nowadays, consumers expect manufacturers to provide excellent quality, reliable delivery and competitive pricing. This demands that the manufacturer’s machines and processes are highly reliable. In order to possess highly reliable machines to make sure smooth manufacturing process, many organizations have implemented Total Productive Maintenance (TPM) as the enabling tool to maximize the effectiveness of equipment. Overall Equipment Effectiveness (OEE) is used as a measure when evaluating the result of TPM. This paper has found out the difference between before and after the TPM implementation to OEE result. Comparison between before and after the implementation of TPM was carried out to see the difference that TPM can bring to an organization. Elements that constitute the OEE equation have been analyzed and indentified which one that affected OEE result. After identifying, improvement has been made on that element so that OEE result would be improved ultimately. Microsoft Excel was used to analyze data obtained and calculate OEE. Hence, TPM is a useful tool in helping firm to achieve optimal manufacturing process. By being able to achieve this level of maintenance, an organization will be able to reap competitive advantages brought by TPM, thus, producing quality products that manage to satisfy customers and subsequently generating greater profits.

Keywords— automotive industry, overall equipment effectiveness, total productive maintenance

I. INTRODUCTION

Having recognized by some world-class Japanese companies over twenty-five years ago, effective application of modern technology can only be achieved through people – starting with the operators and maintainers of that technology – and not through systems alone. Hence the emergence of Total Productive Maintenance (TPM) as the enabling tool to maximize the effectiveness of equipment by setting and maintaining the optimum relationship between people and their machines. Automotive industry Malaysia is a booming industry which encompasses areas of activities from car manufacturing to dealing auto business with foreign countries. Automotive industry Malaysia is one of principal producers and exporters of vehicle parts, components and accessories, which are widely accepted to most of leading countries of world. Company X Malaysia is a regional branch of the X Group, one of the world’s biggest private industrial corporations. There are a few business divisions in Company X Malaysia, however, only automotive technology will be focused on in this paper.

Modern manufacturing requires that to be successful organizations must be supported by both effective and efficient maintenance. One approach to improving the performance of maintenance activities is to implement and develop a Total Productive Maintenance (TPM) strategy. Measurement is an important requirement of continuous improvement process [1]. It is necessary to establish appropriate metrics for measurement purposes. From generic perspective, TPM can be defined in terms of Overall Equipment Effectiveness (OEE) which in turn can be considered a combination of the operation maintenance, equipment management and available resources [5]. The goal of TPM is to maximize equipment effectiveness, and the OEE is used as a measure. Hence, this paper will focus on the aspect implementation of TPM to OEE. This paper will study the comparison between before and after the TPM implementation to machine performance (OEE) in automotive industry. Comparison of result between before and after the use of TPM will be carried out in order to show the impact that TPM brought. Study on OEE figures will also be conducted as OEE is the indication of machine performance. Identifying the OEE element with the lowest value by comparing the result between OEE obtained to world-class OEE benchmark will be done as it will affect the rate of OEE in TPM implementation. It is to believe that by improving the element’s figure, overall OEE rate will increase, production rate of the factory will increase and thus, bringing higher sales and revenue to organization.

This study is intended to figure out the contributions of TPM in manufacturing industry by comparing between before and after the implementation of TPM to machine performance (OEE). By observing the production process, OEE element that causes low OEE value will be identified, therefore, suggesting resolutions to improve the challenge encountered. A holistic implementation of TPM will provide and promise high machine performance, moving towards to achieve zero breakdowns, to achieve zero defects, and to achieve improved throughputs which ultimately, bringing high production rate. The scope of this study is focused in automotive industry. Besides that, the scope will focus on Overall Equipment Effectiveness (OEE) in order to find out the performance of OEE in the automotive industry. OEE will
be calculated and evaluated so that improvement on the OEE performance can be made.

II. LITERATURE REVIEW

A. Total Productive Maintenance (TPM)
TPM is a methodology and philosophy of strategic equipment management focused on the goal of building product quality by maximizing equipment effectiveness. It embraces the concept of continuous improvement and total participation by all employees and by all departments [9].

B. Overall Equipment Effectiveness (OEE)
Overall Equipment Effectiveness (OEE) is the TPM metric for measuring equipment effectiveness or productivity. Variations for calculating OEE are in use, however, most are consistent in identifying three major elements of OEE, which are availability, performance efficiency, and quality rate. TPM has the standards of 90 per cent availability, 95 per cent performance efficiency and 99 per cent rate of quality [7]. An overall 85 per cent benchmark OEE is considered as world-class performance [4][8].

C. Past Research
[3] have done a study on outlining the factors affecting successful implementation of TPM in United Kingdom (UK) Manufacturing. By viewing these reasons and factors, an organization will know where and how to pay attention to while implementing TPM. [6] have discussed about method to calculate quantitative monetary managerial effects by using OEE. This method has presented the contributions of OEE to management level in a managerial way in order to ease the understanding of managers. [10] has done a case study in adopting the TPM in the food industry and especially in bakery products. The paper aims to develop a methodology for increasing production rate, improving the quality of the products and providing a healthier and safer work environment. Although there are numbers of research done on the TPM and OEE, currently there is no study done on realizing the relationship between TPM implementation and OEE and also identifying the element that affect OEE [2]. Hence, it is necessary to carry out a research in order to study the issues mentioned.

III. METHODOLOGY

A. Research Design
The research design used in this paper is causal research. In causal research, the emphasis is on specific hypotheses about the effects of changes of one variable on another variable.

B. Research Strategy
The strategy used in this research is experimental. Experimental design is a set of procedures for devising an experiment such that a change in a dependent variable may be attributed solely to the change in an independent variable. The independent variable in this experiment is the implementation of TPM while the dependent variable is machine performance (OEE).

C. Measurement of OEE
OEE can be calculated using the formulas shown below [11]:

\[
OEE = \text{Availability (A)} \times \text{Performance Efficiency (P)} \times \text{Rate of Quality (Q)}
\]

where

\[
\text{Availability (A) = Operating Time / Planned Production Time}
\]

\[
\text{Operating Time= Planned Production Time – Down Time}
\]

\[
\text{Planned Production Time = Shift Length – Breaks}
\]

\[
\text{Ideal Cycle Time = Shift Length / Scheduled Number of Products}
\]

\[
\text{Quality Rate (Q) = Good Pieces / Total Pieces}
\]

\[
\text{Good Pieces = Total Pieces – Reject Pieces}
\]

D. Population and Sampling
The population in this study is the Manufacturing Operation and Engineering Department of Company X. Due to this is an experiment, so non-probability sampling is used in collecting data as the data that is going to be collected is just from one organization – Company X only. Non-probability sampling is one in which each element of the population does not have an equal probability of selection. When choosing type of non-probability sampling, purposive or judgmental sampling is chosen as the method of choosing samples. The reason of choosing purposive sampling is the subject to be studied is fixed, which are the machines in the production line. The research sample in this study is the machines available in Manufacturing Operation and Engineering Department. The instrument that is going to be used in this study is observation. Observation is carried out by observing closely the activities of machines and data is recorded. Data recorded will become the input of OEE calculation.

E. Data Analysis Technique
Company X uses Microsoft Excel in analyzing data and when calculating OEE. Besides that, graphic method will be used in order to show a clearer picture of implementation of TPM to OEE and to identify element that affects OEE the most. After conducting analysis on the OEE, improvements will be suggested to Company X and will be launched to see for improvement.

IV. RESULTS AND DISCUSSIONS
A. The analysis and findings on Overall Equipment Effectiveness (OEE)

Data on Availability, Performance, and Quality was obtained through the collection of SMT & AI Hourly Control Form. This form was used to monitor the status of machines in SMT lines and also the quality of products produced. SMT & AI Hourly Control Form for the whole month was collected, wanting to calculate the Overall Equipment Effectiveness (OEE) of every single line in Surface Mounted Technology (SMT) production site. SMT was the name given by Company X to identify its production lines. Below graphs showed the Availability, Performance, and Quality of eight SMT lines.

Fig. 4.1: Availability for all SMT lines at Company X

Fig. 4.2: Performance for all SMT lines at Company X

Fig. 4.3: Quality for all SMT lines at Company X

The table shown was a summary of Availability (A), Performance (P), Quality (Q), and Overall Equipment Effectiveness (OEE) for all the SMT lines. From the table, results obtained were compared to world-class benchmark in order to identify which SMT line possesses result that was not conforming to world-class benchmark. Firstly, the result was compared according to elements. The first to compare was Availability. Out of 8 SMT lines, only SMT 3 and 6 met the target, which was 90%. Next element to compare was Performance. The world-class benchmark was set to be 95% but encouraging enough; all SMT lines exceeded the benchmark. Last element to compare was Quality. World-class benchmark was set to be 99% and SMT 2, 4, 6, and 8 managed to hit the target. From the table, it can be seen that out of three elements that constitute OEE, there were two elements that met world-class benchmark; which were Performance and Quality. Availability was the element that did not achieve the world-class benchmark. For this reason, researcher has decided to take Availability as the element to improve while the other two elements were maintained. By improving percentage of Availability, it was to believe that the OEE would be improved, thus, increasing the number of SMT line that meet world-class benchmark by shortening the distance between current OEE and world-class benchmark.

<table>
<thead>
<tr>
<th>SMT</th>
<th>A</th>
<th>P</th>
<th>Q</th>
<th>OEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82%</td>
<td>100%</td>
<td>97%</td>
<td>79.54%</td>
</tr>
<tr>
<td>2</td>
<td>80%</td>
<td>100%</td>
<td>99%</td>
<td>79.20%</td>
</tr>
<tr>
<td>3</td>
<td>90%</td>
<td>99%</td>
<td>96%</td>
<td>85.54%</td>
</tr>
<tr>
<td>4</td>
<td>87%</td>
<td>100%</td>
<td>100%</td>
<td>87.00%</td>
</tr>
<tr>
<td>5</td>
<td>79%</td>
<td>97%</td>
<td>96%</td>
<td>73.56%</td>
</tr>
<tr>
<td>6</td>
<td>93%</td>
<td>100%</td>
<td>100%</td>
<td>93.00%</td>
</tr>
<tr>
<td>7</td>
<td>86%</td>
<td>99%</td>
<td>98%</td>
<td>83.44%</td>
</tr>
<tr>
<td>8</td>
<td>85%</td>
<td>100%</td>
<td>100%</td>
<td>85.00%</td>
</tr>
<tr>
<td>World-class Benchmark</td>
<td>90%</td>
<td>95%</td>
<td>99%</td>
<td>85.00%</td>
</tr>
</tbody>
</table>
From the above figure, it can be seen that there were four SMT lines which their OEE did not reach world-class benchmark, which was below 85%. Among these four lines, SMT 5 possessed the lowest OEE figure. The four SMT lines that did not meet world-class benchmark would be used as subject to be improved. All the analysis carried out later on would only concentrate on these four lines. The main intention was to improve those four SMT lines from not conforming to conforming world-class benchmark. Other SMT lines including SMT 3, 4, 6, and 8 which their OEE had already met world-class benchmark would be maintained as they are.

B. Pareto Charts
Since there were four SMT lines possessed low OEE that did not follow world-class benchmark, Pareto analysis was performed on them in order to find out causes that led to low Availability (Refer Figure 4.5-4.8). From the Pareto Chart, it was found that these four lines shared some common causes and thus, table above was produced so that a summary of all the Pareto Charts for these four lines could be seen clearly. From the table above, changeover/ part preparation was the cause which these four lines share in common. In other words, changeover was the mostly seen cause that appeared as one of the reasons to low Availability for these four lines.

C. Define, Measure, Analyze, Improve, and Control (DMAIC) Tool

Upon comparing with world-class benchmark, 85%, it was found out that there were four SMT lines which did not conform to the world-class benchmark; SMT 5 possessed the lowest OEE figure, and hence, SMT 5 was chosen as subject to improve. After deciding which line to be improved, observation process was initiated by going to SMT site to observe all the activities carried out so that problems that were hidden or neglected could be realized. In this step, the 6 Why’s approach was used to find out the root cause to low OEE readings. From the approach, it was known that long changeover time was the cause of low OEE situation. In generating idea for improvement, 5W + 1H was used. As a result, Single Minute Exchange of Die (SMED) has been determined as the solution to low OEE. In order to control and make sure change is in the right track, documentation has been made and the steps involved include Step 1: Creating SMED team; Step 2: Select the tool; Step 3: Document every step of the changeover; Step 4: Viewing the changeover; Step 5: Define the target time for changeover; Step 6: Analysis of the elements; and Step 7: Repeating the exercise.

E. Result

Table 4.3: Comparison of result between before and after improvement

<table>
<thead>
<tr>
<th>Changeover</th>
<th>Before Improvement (min)</th>
<th>After Improvement (min)</th>
<th>Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>30</td>
<td>67%</td>
</tr>
<tr>
<td>2</td>
<td>92</td>
<td>20</td>
<td>78%</td>
</tr>
<tr>
<td>3</td>
<td>88</td>
<td>25</td>
<td>72%</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>31</td>
<td>66%</td>
</tr>
<tr>
<td>Average</td>
<td>90</td>
<td>26.5</td>
<td>71%</td>
</tr>
</tbody>
</table>

From the above table, it can be seen that the suggestion implemented has brought improvement of over 50%. Basically, it can be said that the idea was a success as the time used in changeover after improvement has decreased much. Averagely, changeover time has decreased 63.5 minutes, or equivalent to 71%. Below was the graphical result.

![Comparison between Before and After Improvement](image)

Table 4.4: OEE result after improvement for SMT 1, 2, 5 & 7

<table>
<thead>
<tr>
<th>SMT</th>
<th>Old OEE (%)</th>
<th>New OEE (%)</th>
<th>OEE Improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79.54%</td>
<td>90.21%</td>
<td>13%</td>
</tr>
<tr>
<td>2</td>
<td>79.20%</td>
<td>93.06%</td>
<td>18%</td>
</tr>
<tr>
<td>5</td>
<td>73.56%</td>
<td>86.60%</td>
<td>18%</td>
</tr>
<tr>
<td>7</td>
<td>83.44%</td>
<td>90.23%</td>
<td>8%</td>
</tr>
</tbody>
</table>

Table above showed the OEE result after improvement has been made and implemented in SMT production site. Maintaining Performance and Quality, improvements were emphasized on Availability since it has been determined as the element that did not conform to world-class benchmark. As an overall, the OEE results for all four lines have improved.

V. CONCLUSIONS

In conclusion, this study has accomplished the objectives set. Starting from identifying OEE element that does not meet world-class benchmark to proposing suggestions for improvement and until comparing between before and after the improvement, all these have brought a good achievement to objectives set earlier. Accomplishment to the objectives set can be seen through increase of productivity time or so called Availability, via the reduction of downtime of machines. Since changeover is a form of downtime, by reducing the changeover time, Company X’s production lines possess more solid time for production. As a result, productivity time is increased.

Future work should be more focused on broadened scope of study. Concentrating on just a car radio making company currently, it is hoped that future work can be carried out into other companies or fields. Besides that, future researchers can study on the areas out of improving availability as there are still other two elements that form OEE, which are performance and quality.
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REFERENCES


BIOGRAPHY
Dr. Abdul Talib Bon is an Associate Professor in Production and Operations Management in the Faculty of Technology Management and Business at the Universiti Tun Hussein Onn Malaysia since January 2010. He has a PhD in Computer Science, which he obtained from the Universite de La Rochelle, France in the year 2008. His doctoral thesis was on topic Process Quality Improvement on Beltline Moulding Manufacturing. He studied Business Administration at the Universiti Kebangsaan Malaysia for which he was awarded the MBA in the year 1998. He’s bachelor degree and diploma in Mechanical Engineering which his obtained from the Universiti Teknologi Malaysia. He received his postgraduate certificate in Mechatronics and Robotics from Carlisle, United Kingdom in 1997. He had published more 100 International Proceedings and International Journals and 5 books. He is a member of MSORSM, IIF, IEOM, IIE, INFORMS, TAM and MIM.