OEE - A Tool to Measure the Effectiveness of TPM Implementation in Industries - A Review

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Abstract

This paper aims to study the measurement of effectiveness of TPM implementation in manufacturing and service industries. Here an attempt was made to discuss the previous literature related to the TPM implementation and OEE measurement. The review was done based on a range of journals related to TPM, published in last 10 years, specifically related to TPM implementation and OEE improvement. These TPM papers were studied for the improvement in performance of the equipment by TPM implementation. In this review, OEE is found to be an effective tool for measuring the effectiveness of TPM implementation in most of the industries. It was found that improving Overall Equipment Effectiveness (OEE) is one of the main benefits in TPM implementation and it has been discussed in most of the literature. Improvement in OEE can be observed through the improvement in the availability, performance rate and quality rate as a result of TPM implementation. The review revealed that OEE improvement can be achieved by TPM implementation.

Keywords- Total productive maintenance (TPM), effectiveness, implementation, Overall Equipment Effectiveness, availability, performance rate, quality rate

I. INTRODUCTION

The manufacturing and service industries have experienced an exceptional degree of change in the past few decades. In the recent years, remarkable developments have taken place in the maintenance management of the production systems to reduce the wastage of energy and resources. Maintenance is considered as an integral part of the business process as it provides an additional value to the machines and equipments. It is very much essential for any organization to introduce a maintenance management system to improve its quality and productivity. Currently various innovative management and maintenance practices such as Total Productive Maintenance (TPM), Total Quality Management (TQM), Lean Manufacturing and Just-In-Time (JIT), etc. are becoming very popular among the manufacturing and service industries.

TPM is an innovative Japanese concept and was first introduced in the year 1971 by M/s Nippon Denso Co. Ltd., a supplier of Toyota Motor Company, Japan. The concept of TPM originated initially with the aim of eliminating production losses due to limitations in the Just-In-Time (JIT) process for production operations. Seiichi Nakajima, Vice chairman of the Japanese Institute of Plant Engineers (JIPE) promoted TPM through Japan and was known as father of TPM. TPM can be considered as collaboration between production and maintenance function to improve product quality, reduce manufacturing cost and waste [20]. TPM is an innovative maintenance strategy to optimize equipment effectiveness, eliminate breakdowns and encourage autonomous maintenance by involving all employees [8]. TPM establishes a thorough system of PM for the equipment's entire life span. TPM is based on the promotion of preventive maintenance through motivation management. Success of TPM depends on various pillars like 5S, Autonomous maintenance, Continuous improvement, Planned Maintenance, Quality maintenance, Education and Training, Office TPM and Safety, Health and Environment [9]. The key factors for this implementation are workers involvement and top management support. TPM can be implemented not only in industrial plants, but also in construction, building maintenance, transportation and in variety of other situations [5].

II. KEY PERFORMANCE INDICATORS (KPIS)

Performance measurement is very important in any organization as it identifies the gap between current performance and desired performance. It provides an indication of progress leading to the closure of this gap [17]. It also provides general basic information that can be used in decision making, for management as well as for employees. It is the key decision support tool for continuous improvement program. Hence it is necessary to establish appropriate metrics for performance measurement purposes. Key Performance Indicator (KPI) is used for the measurement of performance of any system or process. It measures the gap between current environmental situation and the desired or target situation [3]. These indicators vary among organizations and among individual processes [17]. When properly utilized, these performance indicators always highlight the opportunities for improvement within the organizations. These performance indicators sometimes referred as performance drivers [3]. Carefully selected KPIs identify precisely where to take action to improve the performance of a system or process. Typical KPIs for manufacturing and maintenance include- operational availability (OA), return on investment (ROI), operating cost, asset availability, Overall Equipment Effectiveness (OEE) and asset utilization [17].

III. OVERALL EQUIPMENT EFFECTIVENESS

OEE of a machine plays an important role in present industrial scenario where customers are more concerned with timely delivery and quality of the product or service [12]. OEE provides a way to measure the effectiveness of manufacturing operations from a single piece of equipment to an entire manufacturing [1]. OEE is an effective tool used in TPM and Lean Manufacturing as a Key Performance Indicator and measures the performance by comparing the manufacturing units in different industries [19].

OEE concept is very easy to grasp, can be easily understood and interpreted by the technicians and maintenance management personnel and is widely used tool of performance measurement. OEE concept can be applied to manufacturing, petrochemical, mobile, pharmaceutical processes and equipments such as in water treatment plant, air handlers, etc. OEE can be represented in two different formats namely OEE data and OEE percentage. OEE data are quantified loss reasons categorized by specific equipment related loss types. The OEE percentage calculated is used to track the improvement or downfall in equipment effectiveness over a period of time [21]. Maintenance activities alone cannot improve OEE. OEE provides the basis for setting improvement priorities, helps in starting root cause analysis, points out unexploited capacity in a manufacturing process and ensures a balanced flow. OEE also plays its vital role in developing collaboration between operations, maintenance and equipment engineering to identify and eliminate the major reasons for poor performance [21].

IV. OEE METRICS AND SIX MAJOR LOSSES

OEE is a measurement used to determine how efficiently a machine is running. OEE is comprised of 6 metrics [19]. These are often referred to as the 'hierarchy of metrics'. They are:

1) OEE itself - a method of measuring the operational performance of a unit, in comparison to the desired performance.
2) Total Effective Equipment Performance (TEEP) - measures the OEE set against time, in other words, 24 hours a day, over 365 days.
3) Loading - part of the TEEP representing the amount of time that units are actually operational.
4) Availability or uptime – time during which the equipment is available to operate.
5) Performance- speed at which a manufacturing unit operates as a percentage of the capacity of unit.
6) Quality - the number of good or perfect items that are produced without any defects.

The OEE calculation is quite general and can be applied to any manufacturing industry [22]. The OEE formula measures availability, performance rate and the quality rate which can be given by:

OEE = Availability x Performance rate x Quality rate, where

Availability= [(planned time-downtime) ÷planned time] ×100;

Performance Rate = [(std. time per unit x units produced) ÷ operating time] x 100;

Where, operating time = planned time – downtime;

Quality Rate = [(units produced - defective units) ÷ units produced] x100.

OEE combines the operation, maintenance and management of manufacturing equipment and resources. The six major losses which affect the overall performance of the equipment are:

1) Breakdown losses: These are the time and quantity losses caused by defective products.
2) Set-up and adjustment losses: These are the time losses resulting from downtime and defective outputs that occur when production of one item ends and the machine is adjusted to meet the requirements of another item.
3) The above two losses are termed as down time losses and they are used to calculate availability of a machine.
4) Idling and minor stop losses: They occur when a machine is idling or the production is interrupted by a temporary malfunction.
5) Reduced speed losses: It is the difference between designed speed of the machine and actual operating speed.
6) The third and fourth loses are termed as are speed losses and they are used to calculate the performance rate.
7) Start-up losses: These losses occur from machine start up stage to stabilization stage.

8) Quality defects and reworks: These are the quality losses due to the malfunctioning of production machine.

The fifth and sixth losses are considered to be losses due to defects in the products. OEE is measured in terms of these six losses, which is the function of availability, performance rate and quality rate of the machine.

V. TPM AND OEE

In any industry, it is not possible to operate any equipment 100% of the time at its maximum capacity to get 100% quality output. Losses are quite common, bringing out the difference between actual and desired performance. TPM ensures that machinery and equipment's are always available for manufacture without any downtime, wastes and rework. TPM is one of the best in class manufacturing improvement process. TPM enables continuous and rapid improvement of the manufacturing process through the involvement of employees at all levels [17]. It is always possible to measure the effectiveness of TPM implementation in terms of OEE of the system.

OEE is the core metric or an important KPI for measuring the success of TPM implementation. A TPM program uses OEE as a quantitative parameter for measuring the performance of a production system [24]. The OEE measure is central to the formulation and execution of a TPM improvement strategy [12]. Improving the OEE is the main goal of TPM. Also, TPM and OEE need more cooperative and collaborative teamwork. Apart from raising the morale of employees, TPM maximizes equipment effectiveness by improving quality, increasing safety and reducing costs [21]. OEE measurement is essential for every organization that is committed to eliminate wastes and losses through the implementation of TPM, Lean manufacturing and other maintenance strategies [17]. An overall 85% benchmark OEE is considered as world-class performance [7].

VI. DISCUSSIONS

OEE improvement is one of the main benefits in TPM implementation. According to Aditya Parida et al. [3], OEE figure is one of the most important and effective key performance indicators (KPIs) in the performance measurement. Arunraj K et al. [6] have shown that TPM increases the availability, performance rate and the quality rate, thereby improving the OEE. According to Chetan S. Senthia et al. [9], TPM implementation results in waste elimination and increased plant efficiency. TPM focuses on maximizing the OEE with the involvement of each and everyone in the organization. Jain A et al. [15] have pointed out that there is no need to implement all eight TPM pillars simultaneously; implementation of one or more pillars can also improve OEE in small industries.

OEE must be used as a tool to assess the current situation of the machine and to note the starting point for the improvement during the TPM implementation in a manufacturing industry. Hemant Singh Rajput et al. [13] have shown that TPM implementation has improved the OEE of the Shot Peening Machine from 66.4% to 85%. R. Raguram [19] shown that OEE of a CNC machine has increased from 75% to 79% by the implementation of TPM tools in an Indian based fastener company which uses powder metallurgy process for the production of components that are used in transmission systems. OEE can be improved by the reduction in downtime which can be achieved by carrying out the preventive maintenance at regular intervals.

Harsha G Hegde et al. [12] have shown that OEE of a bottleneck machine in an Indian manufacturing industry has increased from 43% to 72% as a result of TPM implementation which was reflected in a total annual savings of Rs.5 lakhs. The availability, performance rate and quality rate must increase individually in order to get an increase in OEE. Improved production rates and delivery time can be achieved as a result of increase in OEE of the machine. S. D. Kalpande [21] highlighted that OEE gives the ability to analyze the machines for productivity improvements. OEE is a process to analyze the efficiency of a machine and it can help to improve the quality as well as productivity, with the help of TPM implementation.

Amit Kumar Gupta et al. [5] have shown in their study that the TPM implementation has increased the OEE of broaching machine from 59% to 70%, cylindrical grinding machine from 53% to 67% and surface grinding machine from 50% to 65% in the machine shop of an automobile manufacturing organization. Amit Bajaj et al. [4] have shown TPM implementation has raised OEE of the machine from 60% to 82% at a small scale manufacturing unit in an agricultural industry. S. R. Vijayakumar et al. [22] have shown that OEE of the injection moulding machine in an Indian based automobile manufacturing sector has increased from 61% to 81% through the implementation of TPM. Disha M Nayak et al. [10] have shown that lower performance rate of 68.67% was responsible for a lower OEE of 53% in an insulation unit of a cable organization located at Bangalore. The performance rate can be improved by reducing mainly speed losses, quality losses and downtime losses. This can be achieved by reducing the non-productive events by implementing new techniques and tools, standardized speed for running the line, skilled labours, and special purpose machinery without affecting the shop floor environment.

Abhijit Chakraborty et al. [2] have observed OEE of the boiler plant in India has improved from 70.35% to 80.23% in duration of 6 months. Pradeep Kumar et al. [18] have shown that successful implementation of TPM in Manipal Packaging Solutions has improved the OEE of the printing, punching, gluer and lamination machines. E. Sivaselvam et al. [11] have shown that lesser availability and lower performance rate were responsible for lower OEE values of five bottleneck machines in a Chennai based plastic company. An efficient data collection is very important for the meaningful OEE calculation. OEE helps to determine the current situation of the production system, effectiveness of the maintenance system, conditions of the machines,

worker's skill and utilization of the machines. Nazim Baluch et al. [17] have highlighted that OEE measurements can be applied to individual work center level or rolled up to department level or plant levels. OEE is an important measure of efficiency and improvements in OEE have a direct positive impact on the bottom line, to get a greater return on the investment (ROI). OEE also give businesses a valid comparative measurement across own plant and potentially against competitors.

T. Ahmed et al. [23] have discussed OEE of a pharmaceutical industry is influenced by eight major equipment related losses-equipment failure, set-up and adjustment, cutting blade change, start-up, minor stoppage and idling, speed, defect and rework and equipment shutdown. William M. Goriwondo et al. [25] have shown that OEE and utilization of the critical machine will improve as a result of TPM implementation in a pharmaceutical company plant located in Zimbabwe. ABC analysis establishes the critical equipment that requires 20% attention to produce 80% results and TPM pillars root out major losses in the plant. Proper training and education plays a great role in achieving the OEE improvement and machine utilization.

Vinayak Suryawanshi et al. [24] have shown TPM approach applied on the Wire cut CNC machine has improved the OEE from 43% to 65%, resulting in the total saving per annum of around Rs 4 lakhs. Liu Yong et al. [16] have highlighted that OEE has improved from 52.71% to 75.08% in a China based PC connector manufacturing company due to the implementation of TPM. OEE is a tool to analyze and diagnose the causes and deficiency, whereas OEE improvement needs the organization to take different measures suitable to themselves to improve the situation. Improvement in OEE due to TPM implementation ensures the accurate delivery of orders, high product quality, savings in labor and materials costs, reduced maintenance expenditures and wastes, energy and resource economization, maximized return on investment (ROI).

Ignatio Madanhire et al. [14] have discussed that TPM is an integrated management system which includes technicians and operators into one body and can result in great improvements in productivity and OEE. OEE is a comprehensive indicator of a plant condition that takes into account operating time, performance and quality. A. Bangar et al.[1] have shown that implementation of Kaizen methodology of TPM has improved the OEE of the parabolic and eye rolling machine from 89% to 95% in an automobile suspension parts manufacturing industry.

VII. CONCLUSIONS

The review reveals that today TPM may be the only program that stands between success and total failure for many companies. OEE calculations provide the useful data necessary to identify exactly what percentage of production time is truly productive and help to identify the causes of lost productivity. TPM increases the availability, performance rate and the quality rate and thereby results in the improvement of the overall equipment effectiveness of the equipment. OEE is an effective tool to benchmark, analyze and improve the production system. The OEE tool gives the ability to measure the productivity improvements of the machines. It is a bottom-up approach where an integrated workforce strives to achieve overall equipment effectiveness by eliminating the six big losses. A truly comprehensive OEE solution will provide operators and production managers with continual line notification and control so that actions can be taken to prevent issues that can result in downtime, speed losses and poor product quality. OEE is a good beginning for many organizations to find out where are the root causes for failures and losses.

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