Total Productive Maintenance (TPM) Implementation – A Review

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Abstract— Maintenance costs can account for 15 to 40 % of total manufacturing costs. These costs can be minimized by the proper maintenance management. Quality and Maintenance of manufacturing systems are closely related functions of any organization. Today's competitive environment requires much more effective equipment management. Total productive maintenance (TPM) and Total Quality Management (TQM) are the new approaches along with other concepts to achieve World Class Manufacturing system. The goal of the any TPM program is to improve productivity and quality along with increased employee morale and job satisfaction. In this paper experience of implementing Total Productive Maintenance is shared and investigated for an industry's particular part known as Bright Bar shop. Overall Equipment Effectiveness is used as the measure of success of TPM implementation. The various losses linked with the overall equipment effectiveness are determined. The TPM pillars are implemented in order to eliminate losses and to improve productivity. The study found that focused TPM implementation over a sensible time period can advantageously contribute towards understanding of significant manufacturing performance improvements.

Key words: Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE), Pillars of TPM, Quality, Bright Bar Shop

I. INTRODUCTION

In manufacturing industry the total manufacturing cost consists of 15 to 40 % of maintenance costs. Most of equipment cost or system life costs are attributed to maintenance and operational activities and these affects product cost. These costs can be primarily determined by the decisions made during the planning and early design stage. Now manufacturers are realizing that maintenance organization & management and design for reliability and maintainability are the main factor of success.

Today's increasing competitive environment has showing the need for more effective equipment management. Today's requirement is highly automated and sophisticated equipment that is failure free and capable of producing zero defects. It is also important to have maintenance and operations personnel skilled in maintaining the optimal performance of the equipment.

In today's industrial scenario huge losses/wastage occur in the manufacturing shop floor. This waste is due to operators, maintenance personal, process, tooling problems and non-availability of components in time etc. Other forms of waste includes idle machines, idle manpower, break down machine, rejected parts etc. are all examples of waste. Zero oriented concepts such as zero tolerance for waste, defects, break down and zero accidents are becoming a pre-requisite in the manufacturing and assembly industry. In this situation, a revolutionary concept of Total Productive Maintenance (TPM) has been adopted in many industries across the world to address the above said problem.

TPM is a maintenance program that involves a newly defined concept for maintaining plants and equipment. The development of TPM emphasizes several necessities. It is accompanied by a change in the way employees think. First of all TPM is applied in Japanese car industry in 1970s. It was developed at Nippondenso, a major supplier of Toyota Car Company, as a necessary element of the newly developed Toyota Production System. TPM is an operations improvement process (machine efficiency and reliability) involving all affected employees with a view to getting as close to zero breakdowns and zero defects as possible.

TPM provides a comprehensive, life-cycle approach to equipment management that minimises equipment failures, production defects, and accidents. It involves everyone in the organisation, from top-level management to production mechanics, and production support groups to outside suppliers (Ahuja and Khamba, 2008a). It encompasses all departments including maintenance, operations, facilities, design engineering, project engineering, construction engineering, inventory and stores, purchasing, accounting and finance, and plant and site management. TPM is intended to bring both functions (production and maintenance) together by a combination of good working practices, team working, and continuous improvement. It is necessary to implement TPM in order to satisfy global customer, to improve productivity and quality, to make work simpler and safer and to maintain competitive state. TPM also helps to ensure more effective use of human resource through training and multi- tasking.

II. LITERATURE SURVEY

Some the previous works have been reviewed in order to collect the information about the implementation of TPM in different industries over past periods and to know the effectiveness of the TPM.

S. Nakajima,[1] is also known as the godfather of TPM. His book introduction to TPM explains that maintenance techniques are held responsible for completing maintenance tasks within a scheduled time-frame while still meeting production constraint.

Kathleen E. Mc Kone, Roger G. Schroeder and Kristy O. Cua, [2] shows a contextual view of total productive maintenance (TPM). They explain that what type of companies have adopted TPM programs. The results indicate that while environmental contextual factors, such as country, help to explain differences in TPM implementation, managerial contextual factors, which are under the direction of plant management, are more important to the execution of TPM programs.

F. Ireland & B.G. Dale, [3] mention the study of total productive maintenance (TPM) implementation of three companies by following Nakajima's seven steps of autonomous maintenance, but adopting different pillars among them common pillars are improvements, education and training, safety, and quality maintenance.

I. P. S. Ahuja & J. S. Khamba, [4] reveals the important issues in total productive maintenance ranging from maintenance techniques, framework of TPM, overall equipment effectiveness (OEE), TPM implementation practices, barriers and success factors in TPM implementation, etc.

I.P.S. Ahuja & Pankaj Kumar, [5] reviewed and studied the total productive maintenance (TPM) implementation at precision tube mills. This approach is directed towards the justification of TPM implementation for its support to competitive manufacturing in Indian industries.

Osama Taisir R. Almeanazel, [6] provides the goals and benefits of implementing total productive maintenance (TPM), and also focused on calculation of overall equipment effectiveness (OEE), and it also discuss what called the big six losses in any industry (the quality, availability and speed). Set of techniques like Single minute exchange die, computer maintenance management system, and production planning were suggested to the industry after calculating the OEE to improve their maintenance procedures and improve the productivity.

Manu Dogra, Vsihal S. Sharma, Anish Sachdeva, J.S. Dureja [7] suggested TPM as a key strategy for productivity improvement in process industry, by discussing detailed implementation of TPM in the cold rolling plant. After the study they found motivated employees, improvement in overall equipment effectiveness (OEE) and reduction in no. of accidents on shop floor.

By Pradeep Kumar, Dr. K. V. M. Varambally, Dr. Lewlyn L.R. Rodrigues [8] empirical study was conducted about the high end Printing press machines &Packaging machines based on real time data and analysis was done to obtain achievable results. Finally questionnaires were distributed to assess information on successful implementation of TPM in the industry. Results obtained through the empirical study reveals the varying trends in the Overall Equipment Effectiveness (OEE) and Total Productivity of the machines taken up for the study.

Amit Kumar Gupta & Dr. R. K. Garg, [9] works on OEE improvement by TPM implementation in an automobile manufacturing organisation. Through the case study of TPM implementation the increase in efficiency and productivity of machines in terms of overall equipment effectiveness are discussed.

Melesse Workneh Wakjira & Ajit Pal Singh, [10] apply TPM in a manufacturing industry and evaluate the correlations between various TPM implementation dimensions and manufacturing improvements and validate them by employing overall equipment effectiveness (OEE) in boiler plant. In this work the TPM initiatives have been evaluated and critical TPM success factors are identified for enhancing the effectiveness of TPM.

Jagtar Singh, Vikas Rastogi and Richa Sharma, [11] reviews all the Total Productive Maintenance (TPM) Pillars, TPM Implementation methodology and the contribution of TPM towards improving manufacturing performance.

Kadiya Pinjal Navinchandra,[12] provides a review of the goals and benefits of implementing Total Productive Maintenance, and also focusing on calculating the overall equipment effectiveness in one of Steel Company in India, and it also discuss the big six losses in any industry.

Ranteshwar Singh, Ashish M Gohil, Dhaval B Shah, Sanjay Desai, [13] explains the implementation of TPM in a machine shop and identifies the loss associated with equipment effectiveness. All the pillars of TPM are implemented in a phased manner eliminating the losses and thus improving the utilization of CNC machines.

Chetan S Sethia, et al [14]focusing on calculating the overall equipment effectiveness in Rolling Mill, and it also discuss what called the big six losses in any industry (the quality, availability and speed). After calculating the OEE of the company a result company achieved 93.48% in quality factor of overall equipment effectiveness equation and 70.90% in availability where in performance it got 90.03% and the result is compared with the World class OEE.

Raffaele Iannone and Maria Elena Nenni, [15] gives the introduction to the fundamental of OEE, and also some interesting issues concerning the way to implement the index are investigated.

M. Vijayananthan, [16] performs TPM and total process control in heat treatment industry and as a result the company achieved 99% in quality factor of overall equipment effectiveness equation and 76% in availability where in performance it got 72%. Set of techniques like Single minute exchange die, computer maintenance management system, and production planning were suggested to the industry after calculating the OEE to improve their maintenance procedures and to improve the productivity.

III. EVALUATION OF EQUIPMENT MANAGEMENT

The maintenance function is also known as physical asset management. Equipment management has gone through many phases. The progresses of maintenance concept over years are explained below:

1) Breakdown Maintenance (BM):-In this type of maintenance the plant or equipment are run until they fail and they brought into running condition again by repairing them. It is based on emergency.
2) Preventive Maintenance (PM):- In this the preventive actions are apply to the plant or equipment in order to prevent or minimize the breakdown.
3) Predictive Maintenance (PdM):- As the name implies it simply means predicting the failure before it occurs by identifying the root cause and symptoms and eliminating that cause before they result in extensive damage of the equipment.
4) Corrective Maintenance (CM):-This type of maintenance is based on restoring a failed unit or equipment. It consists of typical adjustment to redesigning of the equipment.
5) Routine Maintenance (RM):- This is simplest form of planned maintenance. In this the small maintenance jobs such as cleaning, lubrication, inspection etc. are carried out at regular intervals.
6) Reliability Centred Maintenance (RCM):- It is a process to ensure that assets continue to do the

intended work in their present operating situation. Successful implementation of RCM will lead to increase cost effectiveness, machine uptime and a greater understanding of the organisation's level of risk.

7) Condition Based Maintenance (CBM): - in this method the condition of the equipment or some critical parts of the equipment are continuously monitored using sophisticated monitoring instruments so that the failure may be predicted well before it occurs and correct them.

IV. PILLARS OF TPM

TPM covers the way for excellent planning, organising, monitoring and controlling practices through its unique eight-pillar methodology involving:

A. 5S

TPM starts with 5S which is considered as the base or Foundation of TPM. 5S denotes five terms naming Seiri, Seiton, Seisio, Seiketsu, and Shitsuke.

– Seiri (sort out): sort out unnecessary items from the workplace and remove them.
– Seiton (Set in order/Configure): Arrange necessary items in good order so that they can be easily picked up for use.
– Seisio (Shine/Clean and check): Clean the workplace completely to make it free from dust, dirt and clutter.
– Seiketsu (Standardize/Conformity): Maintain high standard of housekeeping and workplace organization.
– Shitsuke (Sustain/Custom and practice): Train and motivate people to follow good housekeeping disciplines autonomously.

B. Autonomous Maintenance

This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activity and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating. By use of this pillar, the aim is to maintain the machine in new condition. The activities involved are very simple nature. This includes cleaning, lubricating, visual inspection, tightening of loosened bolts etc.

C. Focused Improvement

Focused improvement includes all activities that maximize the overall effectiveness of equipment, processes, and plants through uncompromising elimination of losses and improvement of performance (Suzuki 1994). Kaizen in Japanese context simply means change (kai) for the better (zen). Kaizen is implemented by lower management and workers but relies heavily on support from senior management. This pillar focuses on that "A very large number of small improvements are more effective in an organizational environment than a few improvements of large value."

D. Planned Maintenance

It is aimed to have trouble free machines and equipment's producing defect free products for total customer satisfaction. This breaks maintenance down into four "families" or groups, viz., preventive maintenance, breakdown maintenance, corrective maintenance, and maintenance prevention.

E. Quality Maintenance

It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like focused improvement. We gain understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, and then move to potential quality concerns. Transition is from reactive to proactive (quality control to quality assurance).

F. Education and Training

It is aimed to have multi-skilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill. It is not sufficient know only "Know-How" by they should also learn "Know-Why". By experience they gain, "Know-How" to overcome a problem what to be done.

G. Safety, Health and Environment

In this area focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis. Safety, health and environment target are zero accident, zero health damage, and zero fires.

H. Office TPM

Office TPM should be started after activating four other pillars of TPM (AM, Kaizen, PM, and QM).Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation.

I. Development Management

Minimal problems and running in time on new equipment, Utilize learning from existing systems to new systems and Maintenance improvement initiatives.

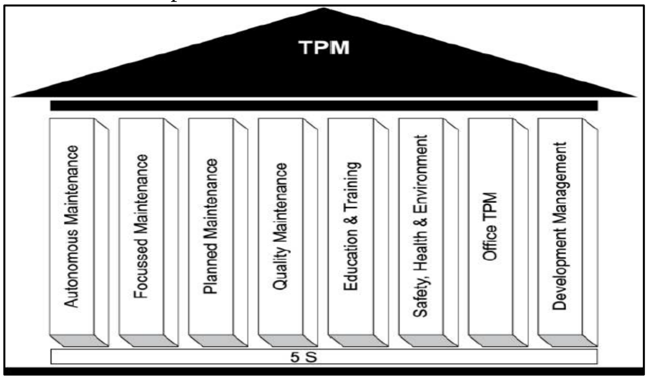

Fig. 1: Eight Pillars of TPM [4]

V. SIX BIG LOSSES

One of the most important objectives of TPM is to minimize or eliminate the six big losses of the industry that causes efficiency loss in manufacturing.

Following are the six big losses occur during production process:

1) Breakdown losses- This type of losses is occur due to the failure of parts, which causes stop of production.
2) Setup and adjustment time losses- This type of losses occurs during to change in production process such as change of section, change operating condition, start of different shift, change of product.
3) Speed losses- When the output is smaller than the output at reference speed, then it is called speed losses. These losses are due to reduction in speed of the equipment.
4) Minor stoppage losses- Minor stoppage occurs due to jamming, machine idling.
5) Quality or defect losses- These losses are due to the defective product produced during the production process and therefore rework has to be done to remove the defects.
6) Yield losses- These losses are due to wasted raw material.

VI. Overall Equipment Effectiveness (OEE)

A well-known way of measuring the effectiveness is the Overall Equipment Efficiency (OEE) index. It has been firstly developed by the Japan Institute for Plant Maintenance (JIPM) and it is widely used in many industries. Overall equipment efficiency or effectiveness (OEE) is a hierarchy of metrics proposed by Seiichi Nakajima [1] to measure the performance of the equipment in a factory. OEE is a powerful tool that can be used to perform diagnostics as well as to compare production units in differing industries.

The traditional vision of TMP referred to Overall Equipment Efficiency while now it is generally recognized as Overall Equipment Effectiveness. The difference between efficiency and effectiveness is that effectiveness is the actual output over the reference output and efficiency is the actual input over the reference input. The Equipment Efficiency refers thus to ability to perform well at the lowest overall cost.

OEE can be defined as the ratio of the actual output of the equipment to the maximum output of the equipment under the best performance condition.

VII. OEE Calculation

The OEE can be calculated by using formula

$$\text{OEE} = \frac{\text{Valuable Operating Time}}{\text{Loading Time}} \qquad (1)$$

Where:

Valuable Operating Time is the net time during which the equipment actually produces an acceptable product;

Loading Time is the actual number of hours that the equipment is expected to work in a specific period (year, month, week, or day).

The formula indicates how much the equipment is doing what it is supposed to do and it captures the degree of conforming to output requirements. It is clearly a measure of effectiveness.

Now in other way

$$\text{Availability (A)} = \frac{\text{Operating Time}}{\text{Loading Time}}$$

Where,

Operating Time = Loading Time –Down Time

$$\text{Performance (P)} = \frac{\text{Net Operating Time}}{\text{Operating Time}}$$

Where,

Net Operating Time = Design Cycle Time × Output

And

$$\text{Quality (Q)} = \frac{\text{Valuable Operating Time}}{\text{Net Operating Time}}$$

Where,

Valuable Operating Time = Productive Operating Time- Defective Operating Time

So from eq. (1) above formula the OEE can be calculated by

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality} \qquad (2)$$

So through a bottom-up approach based on the Six Big Losses model, OEE breaks the performance of equipment into three separate and measurable components: Availability, Performance and Quality.

1) Availability indicates the problem caused by down time losses.
2) Performance indicates the losses caused by speed losses.
3) Quality indicates the scrap and rework losses.

VIII. Conclusion/Summary

By the implementation of TPM we can have following benefits:

1) Various types of loss can be minimized
2) Overall equipment effectiveness can be increased
3) Deterioration of equipment can be minimized
4) TPM can also be adapted in construction, building maintenance, transportation, and other different situations.
5) Equipment breakdown can become zero.
6) Skill level of workers can be higher.

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