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Case Study

Total Productive Maintenance Review: A Case Study in Automobile Manufacturing Industry

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Abstract

This paper will review all the Total Productive Maintenance (TPM) Pillars, TPM Implementation methodology and the contribution of TPM towards improving manufacturing performance.. It will also focus on calculating the Overall Equipment Effectiveness (OEE) in one of the two wheeler automobile Industry in India. The relationship between various TPM implementation dimensions and manufacturing performance improvements have been evaluated by applying OEE. The study establishes that focused TPM implementation over a reasonable time period can strategically contribute towards realization of significant manufacturing performance enhancements. Set of various techniques like Single Minute Exchange Die (SMED), computer maintenance management system, production planning were suggested to the industry after calculating the overall equipment effectiveness to improve their maintenance procedures and improve the productivity.

Keywords: *Total Productive Maintenance, Overall Equipment Effectiveness, Availability, Performance Efficiency.*

1. Introduction

TPM is a unique Japanese philosophy which has been developed based on the productive maintenance concepts and methodologies. Total Productive Maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce (Bhadury, 2000). TPM is a production driven improvement methodology that enhance the equipment reliability and ensure effectual management of plant assets using employee involvement and empowerment, by linking maintenance, manufacturing and engineering functions (Ahuja and Khamba. 2008). The key objective of an effective TPM initiative is to bring critical maintenance skilled trades and production workers together (A.W. Labib,1999) with its three ultimate goals: Zero breakdown, Zero defects and Zero accidents (P. Willmott. 1994), (M.Noon *et al* 2000). Another US advocate of TPM, (Wireman 1991) suggests that TPM is maintenance that involves all employees in the organization and accordingly includes everyone from top management to the line employee and indicates:

it encompasses all departments including, maintenance, operations, facilities, design engineering, project engineering, instruction engineering, inventory and stores, purchasing, accounting finances, plant /site management

There are many different definitions for TPM and the reason behind this diversity in definition is found in the way of adoption this strategy, some industries focus on the group working more than equipment management, and other focus on equipment effectiveness, this diversity shows how important implementing TPM in company that it is covers all factors may affect the production process (D.Hutchins. 1998)

This paper is organized in following sections: section two presents Pillars of TPM , section three presents the implementing the TPM methodology, section four represents the contribution of TPM towards improving manufacturing performance, section five describe the Overall Equipment Effectiveness, section six presents the case study in an Automobile Manufacturing Organization and conclusion is discussed in section seven.

2. TPM Pillars

Total Productive Maintenance (TPM) is classified into eight pillars, all of which are supported by 5S include Autonomous Maintenance, Focused Improvement, Planned Maintenance, Quality Maintenance, Education & Training, Office TPM Pillar, Safety Health & Environment and Development Management Pillar. (Ireland & Dale, 2001; Shamsuddin *et al*, 2005)

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5S Concept

TPM starts with 5S. It is a systematic process of housekeeping to achieve a serene environment in the work place involving the employees with a commitment to sincerely implement and practice housekeeping. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement. 5S is a foundation program before the implementation of TPM..

5S is the name of a workplace organization method that uses a list of five Japanese words: *seiri, seiton, seiso, seiketsu,* and *shitsuke.* There are five primary 5S phases: sorting, set in order, systematic cleaning, standardizing, and sustaining. Refer to the Figure 1 for 5S meaning

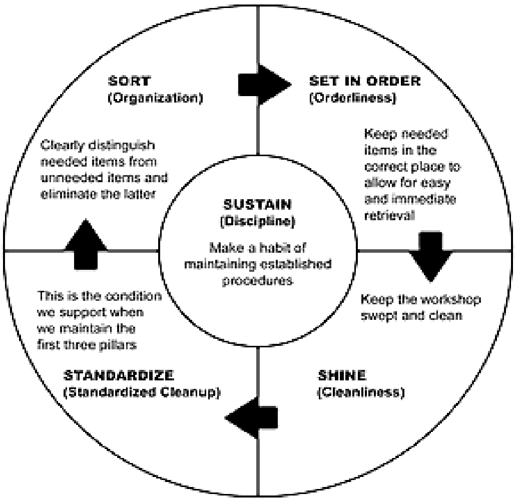


Figure 1: 5S Meaning

Pillar1. Autonomous Maintenance

Autonomous Maintenance follows a structured approach to increase the skill levels of personnel so that they can understand, manage and improve their equipment and processes. The goal is to change operators from being reactive to working in a more proactive way, to achieve optimal conditions that eliminate minor equipment stops as well as reducing defects and breakdowns. The Autonomous Maintenance pillar activity is broken down into three phases and is owned by the team who use the equipment on a daily basis.

The first phase establishes and maintains basic equipment conditions through restoration and eliminating causes of forced deterioration and sources of contamination. Standards are introduced for cleaning, inspection, tightening and lubrication to ensure the conditions are sustained.

The second phase increases the capabilities of the team by training them in the detailed operating principles of the equipment and then improving the standard basic condition.

During the third phase, the operators take total ownership of the equipment as self-directed teams, continuously improving equipment condition and performance to further reduce losses.

Pillar 2: 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.The objective of Focused Improvement is for equipment to perform as well every day as it does on its best day. The better our machines run, the more productive our shop floor, andthe more successful our business. The driving concept behind Focused Improvement is Zero Losses. Maximizing equipment effectiveness requires the complete elimination of failures, defects, and other negative phenomena – in other words, the wastes and losses incurred in equipment operation.(Nakajima 1988). Overall Equipment Effectiveness (OEE) is the key metric of Focused Improvement. Focused Improvement is characterized by a drive for Zero Losses, meaning a continuous improvement effort to eliminate any effectiveness loss. Equipment losses may be either chronic (the recurring gap between the equipment'sactual effectiveness and its optimal value) or sporadic (the sudden or unusual variation or increase in efficiency loss beyond the typical and expected range), (Tajiri and Gotoh 1992)

Pillar 3: Planned Maintenance

Planned Maintenance aims to achieve zero breakdowns. It follows a structured approach to establish a management system that extends the equipment reliability at optimum cost.

It is aimed to have trouble free machines and equipment producing defects free products for total customer satisfaction. The Planned Maintenance pillar activities are normally led by the maintenance team. The initial phase prioritises equipment and involves evaluating current maintenance performance and costs to set the focus for the pillar activity. Support is provided to the Autonomous Maintenance pillar to establish a sustainable standard basic condition and the team focusses on eliminating the causes of breakdowns

Pillar 4: Quality Maintenance

Quality Maintenance aims to assure zero defect conditions. It does this by understanding and controlling the process interactions between manpower, material, machines and methods that could enable defects to occur. The key is to prevent defects from being produced in the first place, rather than installing rigorous inspection systems to detect the defect after it has been produced. Quality Maintenance is implemented in two phases. The first phase aims to eliminate quality issues by analysing the defects, so that optimum conditions can be defined that prevent defects occurring. Then, the current state is investigated and improvements are implemented. The second phase ensures that quality is sustained, by standardising the parameters and methods to achieve a zero defect system.

Pillar 5: Early Management

Early Management is the fifth pillar of TPM and aims to implement new products and processes with vertical ramp up and minimized development lead time. It is usually deployed after the first four pillars as it builds on the learning captured from other pillar teams, incorporating improvements into the next generation of product and equipment design. There are two parts to the Early Management pillar: Early Equipment Management and Early Product Management. Both approaches focus on using the lessons from previous experiences to eliminate the potential for losses through the planning, development and design stages.

For Early Equipment Management, the goal is to introduce a loss and defect free process so that equipment downtime is minimal (zero breakdowns), and maintenance costs are all considered and optimized, from commissioning onwards.

Early Product Management aims to shorten development lead times, with teams working on simultaneous activities so that vertical start up can be achieved with zero quality loss (zero defects).

Pillar 6: 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. This they do without knowing the root cause of the problem and why they are doing so. Hence it become necessary to train them on knowing Know-why. The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phase of skills are:-

1. Do not Know
2. Know the theory but cannot do
3. Can do but cannot teach
4. Can do and also teach

Pillar 7: Office TPM

Office TPM should be started after activating four other pillars of TPM (Autonomous Maintenance, Focused Improvement, Planned Maintenance and Quality Maintenance).Office TPM concentrates on all areas that provide administrative and support functions in the organization. The pillar applies the key TPM principles in eliminating waste and losses from these departments. The pillar ensures that all processes support the optimisation of manufacturing processes and that they are completed at optimal cost. Office TPM benefits organizations by eliminating losses in the administrative systems across the whole organization and into the extended supply chain. This delivers cost reductions in the organisation's overheads as well as supporting improvement and sustainability of the manufacturing process efficiency.

Pillar 8: Safety, Health and Environment

Safety, Health and Environment (SHE) implements a methodology to drive towards the achievement of zero accidents. It is important to note that this is not just safety related but covers zero accidents, zero overburden (physical and mental stress and strain on employees) and zero pollution. SHE pillar activities aim to reactively eliminate the root causes of incidents that have occurred, to prevent reoccurrence, and proactively reduce the risk of future potential incidents by targeting near misses and potential hazards. The pillar team target three key areas: people's behaviours, machine conditions and the management system. All SHE pillar activities should be aligned to relevant external quality standards and certifications. The immediate benefits of implementing the SHE pillar are to prevent reoccurrence of lost time accidents and reduce the number of minor accidents as well as preventing environmental system failure. This has a direct financial saving in the cost of containment, investigation and compensation as well as reputational impact.

3. TPM Implementation Methodology

In a non-TPM organization, a lot of changes are invited in order to have a full-blown TPM system. So, it cannot be attained overnight. Depending on the size of the organization in terms of number of equipment, complexity of equipment handling, and availability of skilled manpower, it takes 1-3 years to create a „total" TPM organization. However, a strategic plan is required for its proper implementation. The major elements of its implementation in order are the understanding and development of awareness about TPM, identification and classification of problems, development of human resources and formation of small groups, collection of data on losses and flow of information, identification of engineering methods for their minimization, implementation of those methods and evaluation by statistical analysis and interpretation, documentation, and measures for further improvement. Following are the twelve steps for the implementation of TPM:-

Step 1: Announcement of TPM - Top management needs to create an environment that will support the introduction of TPM. Without the support of management, skepticism and resistance will kill the initiative.

Step 2: Launch a formal education program. This program will inform and educate everyone in the organization about TPM activities, benefits, and the importance of contribution from everyone.

Step 3: Create an organizational support structure. This group will promote and sustain TPM activities once they begin. Team-based activities are essential to a TPM effort. This group needs to include members from every level of the organization from management to the shop floor. This structure will promote communication and will guarantee everyone is working toward the same goals.

Step 4: Establish basic TPM policies and quantifiable goals. Analyze the existing conditions and set goals that are SMART: Specific, Measurable, Attainable, Realistic, and Time-based.

Step 5: Outline a detailed master deployment plan. This plan will identify what resources will be needed and when for training, equipment restoration and improvements, maintenance management systems and new technologies.

Step 6: TPM kick-off. Implementation will begin at this stage.

Step 7: Improve effectiveness of each piece of equipment. Project Teams will analyze each piece of equipment and make the necessary improvements.

Step 8: Develop an autonomous maintenance program for operators. Operators routine cleaning and inspection will help stabilize conditions and stop accelerated deterioration.

Step 9: Develop a planned or preventive maintenance program. Create a schedule for preventive maintenance on each piece of equipment.

Step 10: Conduct training to improve operation and maintenance skills. Maintenance department will take on the role of teachers and guides to provide training, advice, and equipment information to the teams.

Step 11: Develop an early equipment management program. Apply preventive maintenance principles during the design process of equipment.

Step 12: Continuous Improvement - As in any Lean initiative the organization needs to develop a continuous improvement mindset

4. Contributions Of TPM Towards Improving Manufacturing Performance

Manufacturing is considered to be an important element in a firm's endeavor to improve firm Performance(Skinner, 1982; Hayes & Wheelwright,1984). TPM is a highly structured approach, which uses a number of tools and techniques to achieve highly effective plants and machinery. With competition in manufacturing industries rising relentlessly TPM has proved to be the maintenance improvement philosophy preventing the failure of an organization (Eti et al., 2006). Today, an effective TPM strategy and programs are needed, which can cope with the dynamic needs and discover the hidden but unused or under utilized resources (human brainpower, man-hours, machine-hours). TPM methodology has the potential to meet the current demands. A well conceived TPM implementation program not only improve the equipment efficiency and effectiveness but also brings appreciable improvements in other areas of the manufacturing enterprise.

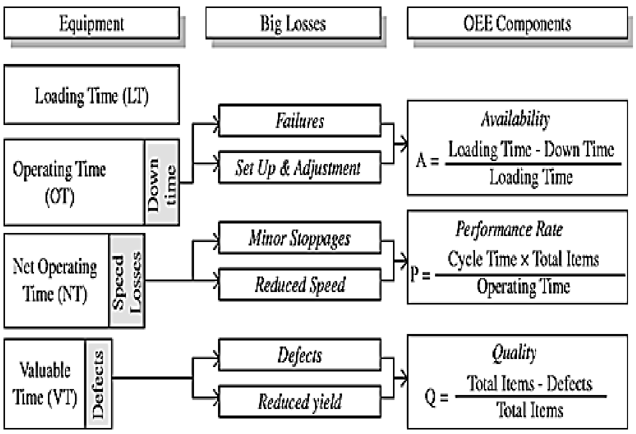
Kutucuoglu et al. (2001) have stated that equipment is the major contributor to the performance and profitability of manufacturing systems. (Seth & Tripathi 2005) have investigated the strategic implications of TQM and TPM in an Indian manufacturing set-up. (Thun 2006) has described the dynamic implications of TPM by working out interrelations between various pillars of TPM to analyze the fundamental structures and identifies the most appropriate strategy for the implementation of TPM considering the interplay of different pillars of this maintenance approach. (Ahuja & Khamba 2008a) have investigated the significant contributions of TPM implementation success factors like top management leadership and involvement, traditional maintenance practices and holistic TPM implementation initiatives towards affecting improvements in manufacturing performance in the Indian industry.

5. Overall Equipment Effectiveness

The goal of the TPM is to maximize equipment effectiveness. OEE provides an effective way of measuring and analyzing the efficiency of a single machine/cell or an integrated manufacturing system. The six major losses that can result from faulty equipment or operation, whose elimination is the major objective of the TPM, are as shown in Table 1, can results in a dramatic improvement in the Overall Equipment Efficiency (OEE). The calculation of OEE is performed by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products.

OEE= Availability (A) x Performance Efficiency (P) x Rate of Quality

Table 1: Big Equipment Losses and OEE



It provides a systematic method for establishing production targets, and incorporates practical management tools and techniques in order to achieve a balanced view of process availability, performance efficiency and rate of quality .As stated earlier that an overall 85 percent benchmark OEE is considered as world-class performance. However, it is desirable to find the gaps between the existing performance levels and desired performance levels. Calculating the OEE following mathematical models (Sohal et.al. 2010) is adopted. The high level of effectiveness OEE will be achieved only, when all the three indexes are very high. OEE is calculated by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products expressed by (Jostes and Helms 1994):

5.1.1 Availability

The available time can be defined as the time of production to operate the equipment minus the other planned downtime like breaks, meetings etc. The down time can be defined as the actual time for which the equipment is down for repairs or changeovers. This time is also sometimes known as the breakdown time. The output of this formula gives the true availability of the equipment. This value is used also in the overall equipment effectiveness formula to measure the effectiveness of the equipment. The availability is calculated as the required available time minus the downtime and then divided by the required available time. This can be written in the form of formula as (Almeanazel, 2010 and Afefy, 2012):-

$$\text{Availability} = \frac{\text{Total Loading time} - \text{Total downtime} \times 100}{\text{Total Loading Time}}$$

5.1.2 Performance Efficiency

The performance efficiency can be defined as the ideal or design cycle time to produce the item multiplied by the output of the equipment and then divided by the operating time. This will give the performance efficiency rate of the equipment. The formula to calculate the performance rate can be expressed as (Gomaa, 2003):

$$\text{PE} = \frac{\text{Total Actual Amount of Product} \times 100}{\text{Target amount of Product}}$$

5.1.3 Quality Rate

The quality rate can be expressed as the process quantity minus the volume or number of defective quantity then divided by processed quantity. The quality rate can be expressed in a formula as [24] (Chana et al., 2005):

$$\text{Quality Rate} = \text{Processed Quantity} - \text{Defective Quantity} \times 100/\text{Processed Quantity}$$

Where, the quality defects mean the amount of products which are below the quality standards i.e. the rejected items after the production process. This formula is very helpful to calculate the quality problems in the production process (Mobley, 2002).

5.1.4 World Class OEE

Table 2: Percentage of World Class OEE

OEE Factors	OEE World Class
A%	90.0
PE%	95.0
QR%	99.9
OEE%	85.0

World class OEE is a standard which is used to compare the OEE of the firm. The percentage of World Class OEE is given in Table I (Kailas, 2009).

6. Case Study in Automobile Manufacturing Organization

In this section, the TPM implementation is demonstrated through a case study in an automobile manufacturing organization. Section 6.1 gives a brief review of case organization and then the TPM implementation procedure is discussed in section 6.2

6.1 Automobile Manufacturing Organization

The case study reported in this paper has been conducted at an automobile manufacturing two wheeler plant in SIDCUL, Haridwar. The management of the company observed that maintenance costs increased for 30-40 percent of the production costs and emergency repairs were three times more expensive then the same job done in pre-planned manner. Since the plant facilities and manufacturing processes were extremely equipment intensive and the data collection and analysis process revealed that the total idle time for the critical process equipment was observed to be extremely high which was not at all acceptable under the prevailing circumstances. Thus, the need for fostering an efficient TPM implementation program was felt fundamentally necessary

6.2 TPM Implementation in Automobile Manufacturing

TPM implementation started with the selection of key model machines and measurement of TPM effectiveness with initiation of four activities – 5S Implementation, Autonomous Maintenance, focused improvement, planned maintenance and OEE have been implemented. A maintenance plan have also been prepared.

(i)Selection of Machines

The first step of this work is selection of machines on which the study is carried out. To start with TPM, a few machines have been selected for implementation of TPM, which is known as TPM model machine. In that Organization, there are seven shops. Four machines have been selected from Light Machine Shop (LMS) i.e. 2 Broaching machines, 1 Cylindrical Grinder and 1 Surface Grinder for TPM implementation. This section was named as TPM model section in Light Machine Shop. Shop. These machines are used in production of components like bull gear, shafts for power transmission etc. A code is assigned to each machine for ease of identification. Each machine is studied thoroughly to identify each part and to understand the working of every component.. OEE is calculated for all the machines before and after implementation as shown in Table 3, 4 and Table 5.

OEE for Broaching Machine I

Table 3: OEE for Broaching Machine I Before TPM Implementation

Before TPM Implementation		
A	Shift Time (General)	450
B	Planned Downtime	60
C	Running Time (A-B)	390
D	Running Time Losses	78
E	Operating Time (C-D)	312
F	**Availability (E/C)x 100**	80%
G	Output	180
H	Machine Speed(No. of Components per year	0.75
I	Expected Output (H x E)	234
J	**Efficiency (Gx 100)/I**	76.9%
K	Rejection	8
L	**Quality (G-K x 100)/G**	95.5%
OEE= Availability x Performance Efficiency x Quality Rate 80% x 76.9% x 95.5% 58.7%		

Table 4: OEE for Broaching Machine I After TPM Implementation

After TPM Implementation		
A	Shift Time (General)	450
B	Planned Downtime	60
C	Running Time (A-B)	390
D	Running Time Losses	58
E	Operating Time (C-D)	332
F	**Availability (E/C)x 100**	85.1%
G	Output	207
H	Machine Speed(No. of Components per year	0.75
I	Expected Output (H x E)	249
J	**Efficiency (Gx 100)/I**	83.1%
K	Rejection	2
L	**Quality (G-K x 100)/G**	99%
OEE= Availability x Performance Efficiency x Quality Rate 85.1% x 83.1% x 99 % = 70%		

Similarly OEE is calculated for rest of the machines at LMS section of the Machine Shop Floor as shown in Table 5

Table 5: OEE Improvement Before and After TPM Implementation

Name of Machine	OEE %	
	Before	After
Broaching Machine I	59	70
Broaching Machine I	60	69
Cylindrical Grinder	53	67
Surface Grinder	50	65

Conclusion

It can be seen that OEE has shown a progressive growth as shown in Table 5, which is an indication of increase in equipment availability, decrease in rework, rejection and increase in rate of performance. Today, with competition in industry at an all time high, TPM may be the only thing that stands between success and total failure for some companies TPM can be adapted to work not only in industrial plants, but also in construction, building maintenance, transportation, and in variety of other situations. Employees must be educated and convinced that TPM is not just another program of the month and that management is totally committed to the program and the extended time frame is necessary for full implementation. If everyone involved in a TPM program does his or her part, a usually high rate of return compared to resources invested may be expected. TPM success requires strong and active support from management, clear organizational goals and objectives for TPM implementation.

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