TPM-A BOON FOR MANUFACTURING SECTOR- A REVIEW

Abstract

This paper explains the Total Productive Maintenance (TPM) concepts and the interrelationship existing between TPM, Total Quality Management (TQM) and Lean manufacturing. It also explains various pillars of TPM and significance of each pillar in TPM implementation. Here an attempt was made to discuss the previous literature related to TPM. This review was based on a wide range of journals published in last 15 years, specifically related to TPM and its implementation in manufacturing industries. It explains how TPM can be effectively implemented in improving productivity, profitability and Overall Equipment Effectiveness (OEE) in any manufacturing industry. Most of the literature discusses the OEE improvement which is found to be the main objective of TPM implementation. The paper also explains computation of OEE, major losses associated with it and stages in TPM introduction. In the final sections of this paper, obstacles that hamper successful TPM implementation and gaps in implementing TPM in Indian industries are discussed.

Keywords: TPM, OEE, TQM, Lean production, Availability, Performance Rate, Quality Rate.

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I. INTRODUCTION

Nowadays, an effective maintenance system is very essential and critical factor to improve productivity and quality in manufacturing industries. Failure of any machinery not only affects the quality of the products, but also affects safety, health, customer satisfaction and competitiveness. Maintenance is found to be very important function in industries which involve huge investments [1]. Effective maintenance system increases the profitability and productivity of any business organization [2]. It maximizes the system availability and minimizes the output loss due to breakdowns at the minimum cost [3].

TPM is an innovative Japanese philosophy and it was first introduced by M/s Nippondenso Co. Ltd., a supplier of Toyota Motor Company in the year 1971. It became the first company to obtain TPM certification. TPM is an innovative approach to maintenance that optimizes effectiveness of the equipment, eliminates failures, and promotes autonomous maintenance by operators through day-to-day activities [4]. TPM has been developed based on proactive maintenance methodologies and seeks the knowledge and cooperation of top management to shop floor personnel, equipment vendors, technical and support personnel to optimize machine performance. It results in the elimination of equipment failures, reduction in unscheduled and scheduled downtimes, improved equipment utilization, higher output, and better product quality by reducing operating and maintenance costs and enhancing equipment life. The main objective of TPM is to promote and achieve zero breakdowns, zero defects, zero accidents and zero wastes [4] [5]. It supports TQM and lean manufacturing system and establishes a thorough Preventive maintenance system for the entire life span of the equipment [4]. Interrelationship between three approaches of manufacturing namely TQM, TPM and Lean manufacturing is shown in figure 1.

II. PILLARS OF TPM

TPM includes 8 pillars [6] which are shown in figure 2. These pillars are briefly described below:

1. **5S** – Seiri (Organiing), Seiton (Tidiness), Seiso (Cleaning), Seiketsu (Standardization) and Shitsuke (Discipline).

2. **Jishu Hozen (Autonomous Maintenance)** – Operators are responsible for upkeep of their equipment and prevent it from breakdowns. It includes preparation of employees, initial clean up, fixing tentative standards, general and autonomous inspection, standardization and autonomous maintenance.

3. **Kobetsu Kaizen (Continuous Improvement)** – Small improvements carried out on a continual basis involving all people in the organization. The main target of this pillar is to achieve zero losses.

4. **Planned Maintenance** – Aimed to have fault free machines with greater availability producing defect free products. It is a movement from a reactive to proactive method and use maintenance staff to train operators for continuous upkeep of their equipment.

5. **Quality Maintenance** – It is aimed towards customer satisfaction through highest quality which can be achieved through defect free manufacturing.

6. **Education & Training** – It is aimed to have multi-skilled, energetic employees having high morale and eager to perform all required functions effectively and independently. Education is given to operators to upgrade their skills, knowledge and attitude.

7. **Office TPM** – It must be followed to improve productivity and efficiency in the administrative functions and also to identify and eliminate losses. The main aim is to move towards increased office automation.

8. **Safety, Health And Environment Control** – Here the focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. Its target is to achieve zero accident, zero health damage and zero fires. This pillar will play an active role in each of the other pillars on a regular basis.

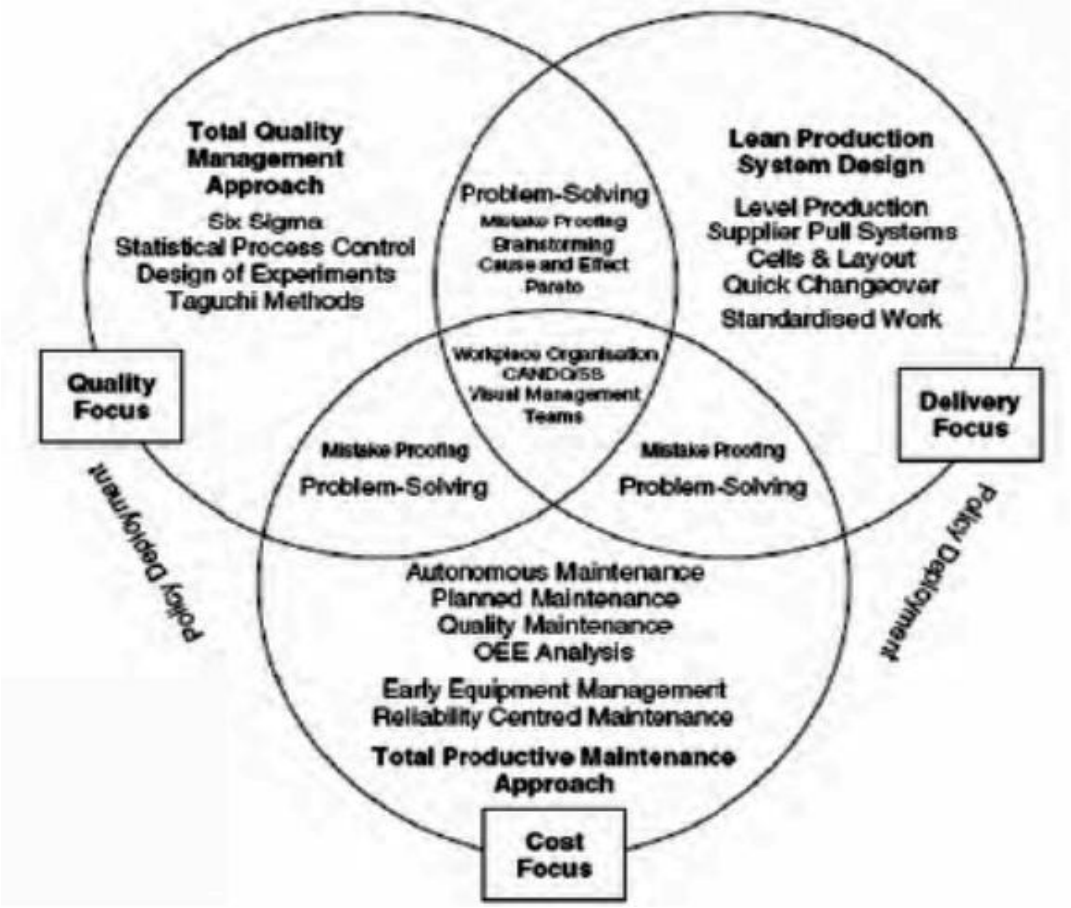

Figure 1: Interrelationships between TQM, TPM and Lean Manufacturing
[Source: Paul Ciprian Patic, et. al., pp. 237, 2010]

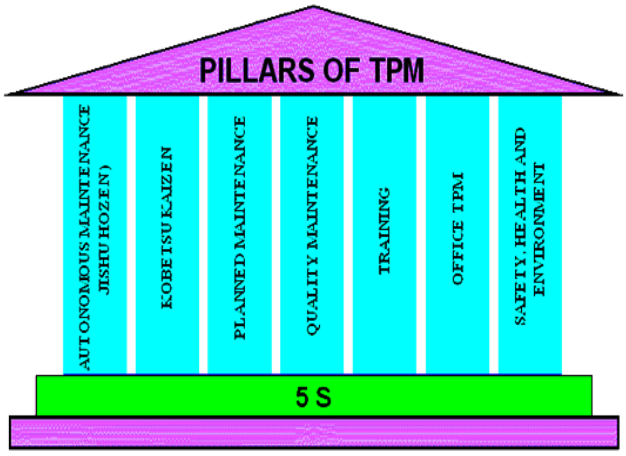

Figure 2: Pillars of TPM
[Source: www.plant-maintenance.com/articles/tpm-intro.shtml]

III. TPM & OEE

Any equipment, however carefully designed, cannot be operated at its maximum capacity all the time. Failures are quite common and these failures deviate the actual performance of the machine from its desired performance. The main aim of TPM is to improve the availability of the machine by reducing downtime, wastages, scraps and rework. TPM collaborates and coordinates the people at all levels in any organization for ensuring the continual improvements in performance. It also improves morale of the employees, enhances the output quality, increases the safety of the workers against hazards and accidents and reduces maintenance and operating costs.

OEE is an important and effective tool used as a Key Performance Indicator in TPM and Lean manufacturing for performance measurement. This general concept of OEE can be applied to equipments such as in water treatment plants as well as in manufacturing, pharmaceutical, telecommunication, refinery processes, etc. It provides a means to measure the effectiveness of operations in any manufacturing process. It helps in bringing together the technical aspects of the equipment, maintenance and operations in order to trace out and eradicate the major causes for poor performance. OEE identifies the unused capacity in any manufacturing process, triggers root cause analysis and helps in prioritizing the improvement activities. OEE can normally be expressed as a percentage which helps in identifying the improved or reduced equipment effectiveness over a time period. OEE of the equipment can be effectively improved by TPM implementation [7]. In any manufacturing industry, an overall 85% OEE is normally considered as the benchmark for world-class performance [7]. OEE is the product of three elements or metrics namely availability, performance rate and quality rate. They can be calculated as follows:

Availability= [(planned time-downtime) ÷planned time] ×100 (1)

Performance Rate = [(std. time per unit x units produced) ÷ operating time] x 100 (2)

Where, operating time = planned time – downtime (3)

Quality Rate = [(units produced - defective units) ÷ units produced] x100 (4)

OEE is mainly affected by three sets or six major losses [8] (figure 3) namely,

1. Downtime losses (include Breakdown losses and Set-up and adjustment losses) which are used in availability calculations.
2. Speed losses (include Idling and minor stop losses and Reduced speed losses) which are used in performance rate calculations.
3. Defect losses (include Start-up losses and losses due to quality defects and rework) which are used in quality rate calculations.

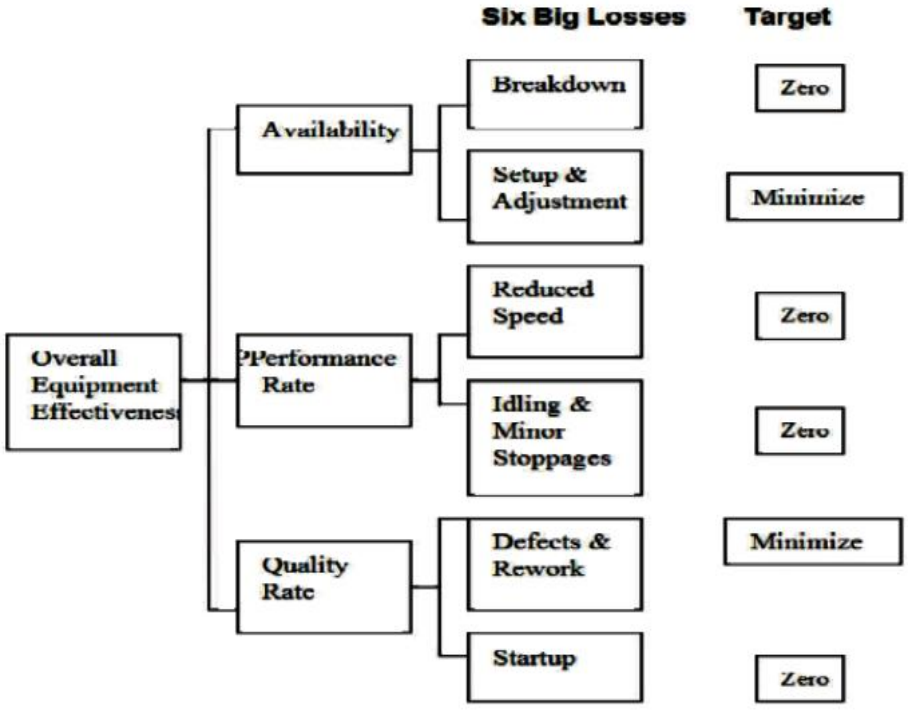

Figure 3: OEE model showing major losses
(Source: Charles Chikwendu Okpala, et.al, pp.199, 2016)

IV. TPM INTRODUCTION

TPM considers maintenance as a necessary and important part of any industry. According to TPM maintenance is no longer considered as a non-profit activity. TPM introduction [6] in any organization includes the following steps:

Step 1: Preparatory Stage Which Includes Following Sub-Steps

- Announcement by the management to all about the introduction of TPM in the organization.
- Initial education and propaganda for TPM
- Setting up TPM and departmental committees
- Establishing the TPM working system and target
- Setting a master plan for institutionalizing the TPM

Step 2: Introduction Stage: It is a ceremony to which everyone will be invited including suppliers, related and affiliated companies, sister concerns and other customers.

Step 3: Tpm Implementation: Eight pillars or activities which are already discussed above are carried out in this stage.

Step 4: Institutionalizing Stage: Above three stages activities bring any organization to a maturity stage in TPM. This is the last stage in TPM which makes the organization to think about taking TPM to higher and much more challenging levels.

V. DISCUSSIONS

The following discussions reveal the wide range of manufacturing industries which implemented TPM and the benefits achieved. Literatures reveal that most of the industries have implemented TPM for improving OEE and also OEE was used as a tool for measuring the performance.

TPM programme in an Indian Auto Industry [9] has produced positive results in a very short span of four months after its implementation. Data were collected 4 months before and after TPM implementation. It was observed that major causes of breakdown were reduced after the implementation of TPM resulting in reduced downtime and improved quality performance of the products.

TPM along with lean production yields improved performance of the equipments. When TPM was introduced on lean implemented textile industries in Sri Lanka [10], it was found that TPM has significant impact on improving cost effectiveness, product quality, on-time delivery and volume flexibility. A self-administered questionnaire was the tool for data collection during the survey. Totally 236 usable responses were collected from 30 textile and apparel firms (78% response rate) and SPSS software was used to perform correlation and regression analysis to determine the TPM effect on manufacturing performance. It was observed that all the 8 TPM pillars have a positive relationship with the above mentioned performance indicators.

TPM can be easily recommended to improve the existing maintenance system of an organization. An investigation on the performance of Limoncello production line [11] has revealed the need for improvement in the existing maintenance policy. Failure details of the limoncello production line were collected for a period of 8 months. The OEE of the production line was calculated by finding availability, performance efficiency and quality rate and was found low. Lower performance efficiency and lower quality rate were responsible for the lower OEE. It was suggested to implement TPM program in order to improve OEE.

TPM model can be effectively designed to improve the existing maintenance programme in a chemical industry. Existing maintenance system was assessed at a chemical manufacturing industry in Zambia to identify key performance indicators [12]. Data collection was done through questionnaires, interviews, direct observations and records available at the company. It was found that only 14% operator involvement was seen in maintenance activities, with 78% of the time the operators were not involved in maintenance activities. OEE was found to be 37% which was very much less than the world class OEE. 52% of the equipment breakdown was caused by shortage of spares, 32% by shortage of raw

materials, 8% due to power problems. They found that 70.5% of the employees were aware of TPM, out of which only 14.7% were sure of TPM improving current maintenance system. Based on these facts it was decided to design a TPM model for effective implementation in order to improve the performance of the company.

OEE can be effectively used as a tool for performance measurement. A study on performance measurement using OEE and its practical application in chemical and packaging industries [13] revealed that OEE provides information on the sources of lost time and lost production. It optimizes the performance of existing capacity. It was observed that OEE reduces overtime expenses, changeover times and improves the performance of the operator. It helps to improve the performance of the company resulting in increased profits. It was found that accuracy of OEE totally depends on the accuracy of the performance data collected.

TPM, TQM and operational performance are interrelated concepts. An empirical study carried out to examine the relationship between them [14] in an Indian pharmaceutical industry has shown that TPM strongly influences operational performance. TQM is supported by TPM in achieving operational performance. A survey was conducted in 410 pharmaceutical plants and 254 responses were considered for the analysis. Factor analysis, path model and structural equation modeling were used in the analysis. It was also concluded that TPM results in less defective products and reduced scrap thereby reducing the cost of quality goods.

The maintenance system of Indian industries can be made effective and efficient by implementing TPM [15]. TPM is a continuous process and it needs few years to find its positive effects. It leads to the overall development of an individual in terms of his knowledge, skills and behavior. Success of TPM depends upon its pillars. Positive effects of TPM can be observed within six months, but an effective TPM implementation for the manufacturing industries may take few years to obtain the desired results. Equipment effectiveness (E) could be proposed as an alternative to OEE due to imperfections in applying OEE with reference to time base and rate efficiency and also due to lack of proper framework [16]. A study was conducted to investigate the influence of utilization, downtime and rework on OEE and Equipment effectiveness in a semiconductor manufacturing industry. Equipment effectiveness is considered with reference to availability, speed losses and quality losses. Equipment effectiveness is a measurement of performance for stand-alone equipment which is isolated from the environment. Unlike OEE, which uses total time as the basis for measurement, equipment effectiveness uses the available effective time. Equipment effectiveness gives the influence of rework and downtime, whereas OEE does not. Also, equipment effectiveness does not depend on the utilization of the equipment whereas OEE does. OEE includes the effect of both equipment as well as its environment whereas the equipment effectiveness includes the effect of equipment itself.

An effective maintenance system like TPM greatly influences the productivity and profitability of a manufacturing process. A case study at a Swedish paper mill [2] showed that a machine can generate extra profit of at least 7.8 million Swedish kronor (SEK) (approximately US$ 0.975 million) per year, if it avoids all unplanned stoppages and poor quality production due to maintenance-related issues. Maintenance can be treated as a profit generating function rather than a cost centre.

TPM prevents organization failures and works better with the TQM and Lean concepts. The main prerequisite for the successful TPM implementation would be the people's acceptance for the change to do something better. TPM success depends on the time allotted for training and to monitor the success or failure of the improvement initiatives. The models and strategies proposed [1] for the implementation of TPM in Nigerian manufacturing industries suggested that there is a need to shift from traditional reactive maintenance procedures to more proactive TPM procedures. The Nigerian industries need to recalibrate and benchmark themselves with the world class organizations for the TPM implementation and for achieving sustainability.

TPM together with proper root cause analysis of the failures yield positive results in reducing the breakdowns. Root cause analysis would help in finding possible causes of breakdown and necessary actions to be taken. A study on the implementation of TPM together with proper root cause analysis in an Indian Label Manufacturing industry [17] resulted in reduced breakdown time during machining from 320 minutes to 170 minutes.

Improvements in OEE, productivity and production cost may result in increased manufacturing performance in terms of sales volume. An empirical study conducted to improve the OEE of 50 machines belonging to light machine shop of Indian based tractor manufacturing company situated in Punjab [18]. Three month's average OEE was evaluated for all 50 machines and it was found that 42 machines were having less than 85% OEE. TPM was implemented and it resulted in improvement of OEE of all 42 machines above 85%. An overall 39% improvement in OEE was observed in about five year period. TPM implementation resulted in the productivity improvement upto 74%. Production cost was reduced from 9.26 to 6.4% (percentage of total cost) in about 6 years. This improvement in OEE, productivity and production cost helped in optimizing the sales volume of the company form 27,423 tractors in 2008 to 78,765 in 2014. The growth in sales volume brought a considerable improvement in market share of the company from 9.1 to 12.8%.

The main objective of TPM is to improve OEE with the involvement of each and every employee in the organization. TPM implementation results in waste elimination and increased plant efficiency [31]. TPM focuses on maximizing the OEE with the involvement of each and everyone in the organization. A lot of researchers have studied the OEE improvement by the implementation of TPM in different manufacturing industries across the world. Implementation of TPM on carding machine in a cotton spinning plant [19] has improved the availability, quality rate, performance efficiency and OEE by 2.2768%, 0.4678%, 0.6989% and 2.4748% respectively. Implementation of TPM on shot peening machine in an Indian manufacturing industry [20] [28] has improved the OEE from 66.4% to 85%. When TPM was implemented in the machine shop of an automobile manufacturing industry [21], OEE of broaching machine increased 59% to 70%, cylindrical grinding machine from 53% to 67% and surface grinding machine from 50% to 65% respectively. OEE of the wire cut CNC machine has improved from 43% to 65% [22] due to the implementation of TPM and resulted in increased annual savings. Implementation of TPM resulted in the OEE improvement from 52.71% to 75.08% in a PC connector manufacturing company located in China [23]. OEE improvement from 63% to 79% indicated the improvement in productivity and quality in the machine shop of an automotive manufacturing industry having CNC turning centres [24] [28]. Table 1 gives a brief summary of the few case studies on TPM implementation and its benefits in different industries.

Table 1: Case Studies on TPM Implementation and Its Benefits in Different Industries

Sl. No.	Case Study	TPM Implementation	Benefits
1.	Paper Industry [2]	TPM implementation in the manufacturing process	• TPM greatly influences the productivity and profitability of a manufacturing process
2.	Auto Industry [9]	Produced positive results in a very short span of four months after TPM implementation	• Major causes of breakdown were reduced • Reduced downtime • Improved quality performance of the products
3.	Textile Industry [10]	TPM along with lean production	• Improved performance of the equipments • TPM has significant impact on improving cost effectiveness, product quality, on-time delivery and volume flexibility.
4.	Chemical and Packaging Industry [13]	OEE as a tool for performance measurement in TPM implementation	• Provides information on the sources of lost time and lost production. • Optimizes the performance of existing capacity. • Reduces overtime expenses, changeover times and improves the performance of the operator. • Helps to improve the performance of the company resulting in increased profits.
5.	Pharmaceutical Industry [14]	Examine the relationship between TPM, TQM and Operational performance	• TQM is supported by TPM in achieving operational performance. • TPM results in less defective products and reduced scrap thereby reducing the cost of quality goods.
6.	Semiconductor Manufacturing Industry [16]	Examine the influence of utilization, downtime and rework on OEE and equipment effectiveness	• Equipment effectiveness is considered with reference to availability, speed losses and quality losses. • Equipment effectiveness is a measurement of performance for stand-alone equipment which is isolated from the environment. • OEE uses total time as the basis for measurement, whereas equipment effectiveness uses the available effective time.

			• Equipment effectiveness gives the influence of rework and downtime, whereas OEE does not. • Equipment effectiveness does not depend on the utilization of the equipment whereas OEE does. • OEE includes the effect of both equipment as well as its environment whereas the equipment effectiveness includes the effect of equipment itself.
7.	Label Manufacturing Industry [17]	Implementation of TPM together with proper root cause analysis	• Reduced breakdown time during machining
8.	Tractor Manufacturing Industry [18]	TPM implementation to improve the OEE of machines belonging to light machine shop	• Improvement in OEE of all the machines in about five year period • Productivity improvement • Reduction in the production cost • Growth in sales volume of the tractors • Improvement in the market share of the industry.
9.	Cotton Spinning Industry [19]	Implementation of TPM on carding machine	• Improvement in the availability, quality rate, performance efficiency and OEE
10.	Manufacturing Industry [20]	Implementation of TPM on shot peening machine	• Improvement in the availability, quality rate, performance efficiency and OEE
11.	PC Connector Manufacturing Industry [23]	Implementation of TPM	• Improvement in the availability, quality rate, performance efficiency and OEE
12.	Automotive Manufacturing Industry [24, 28]	TPM implementation in the machine shop having CNC turning centers	• OEE improvement • Improvement in productivity and quality

VI. BARRIERS TO TPM IMPLEMENTATION

Even though TPM results in several benefits, there are many obstacles or barriers in the successful implementation of TPM. If these barriers are not suitably resolved, TPM implementation will be a tedious job for any manufacturing industry [8]. Proper identification of these barriers is very important to establish and develop a solid TPM implementation programme. There are several methods to identify these barriers. A survey may be conducted using a structured questionnaire and responses from the survey may be used in identification of these barriers. Detailed interviews and formal or informal conversations with the employees can be analyzed to identify these barriers [25]. Some of the researchers classify these barriers into behavioural, organizational, cultural, techno-logical, departmental,

operational and financial barriers [26]. Few barriers of TPM [8] [25] [26] [27] are listed below:

- Lack of top management support for TPM
- Lack of TPM knowledge
- Lack of motivation to employees to develop new skills
- Resistance of the employees for change
- Organization resistance for change
- Faulty machines and equipments
- Carrying huge amount of inventory
- Inadequate training and education to employees
- Inability to attain total employee involvement
- Improper incentive and reward systems in the organization
- Ambiguity in roles and responsibilities
- Failing to convey the goals and objectives of the organization to the employees
- Increased set up and change over times
- Lack of proper maintenance management system and diagnostic facilities
- Lack of coordination between maintenance and production departments

VII. CONCLUSION

The main aim of TPM is to achieve zero breakdowns, zero defects, zero accidents and zero wastes. TPM eliminates equipment failures, improves equipment utilization and increases product quality by reducing operating and maintenance costs. TPM brings together maintenance and production department of the organization. Success of TPM depends on its pillars. There is no need to implement all the TPM pillars on a machine. One or two pillars may be sufficient to improve the overall equipment effectiveness. The above discussion gives a picture of a wide range of manufacturing industries in which TPM implementation has produced positive results in terms of improved OEE, increased productivity and profitability. Apart from the manufacturing industries, TPM can be effectively implemented in service industries like hotels, hospitals, educational institutions, pharmaceutical industries, etc., and similar results can be expected in these industries. On the other side, successful implementation of TPM is not an easy task to accomplish. A lot of challenges, if not addressed properly can hamper the successful TPM implementation. TPM implementation not only needs top management commitment, but also requires involvement of each and every employee in the organization. TPM ensures the presence of well-structured maintenance department in the organization. TPM results can be observed in a very short duration of less than 6 months, but it takes few years for the results to be visible completely. TPM is the corner stone of reliability. TPM improves availability, performance rate and quality rate of any equipment thereby improving its OEE. TPM implementation will be easier in the presence of either preventive or predictive maintenance, otherwise it may be very difficult to implement, but not impossible. TPM, in combination with TQM and Lean manufacturing produce remarkable results for any organization.

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