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Total Productive Maintenance Overview

Eng. Ana ROTARU
University of Pitești

ABSTRACT

Total Productive Maintenance (TPM) is a very important tool for equipment intensive manufacturing sectors. It is a key means for increasing machine availability, and a vital step in linking machines to create better flow. Most companies however have failed to achieve the program's full potential and instead capture only partial benefits. Toyota Motor Corporation has developed its own unique style of TPM actions over the past 30 years that are critical both in terms of supporting its lean production system and delivering industry leading maintenance results.

Keywords: *total productive maintenance, equipment, flow, production system.*

1. Introduction

The essence of TPM was developed in Denso a tier one automotive supplier in the Toyota group of suppliers during the 1960's and 70's in Japan. The central thrust of the program is the complete elimination of what are called the "six major machine losses" i.e. breakdowns, set up time, cycle time losses, minor stoppages, scrap and rework, and yield or start up losses.

While lean thinking strives to eliminate waste in terms of man, machine, material, and method, TPM dives deeper into the specific realm of losses that relate to the "machine" component of manufacturing.

Each letter in the acronym of TPM is subtle yet critical. **Total** implies a comprehensive look at all activities that relate to maintenance of equipment and the impact each has upon availability. **Productive** relates to the end goal of the effort i.e. efficient production not merely efficient maintenance as is often mistakenly assumed. **Maintenance** signifies the directional thrust of the program in ensuring reliable processes and maintaining production.

Often an overlooked component of a lean manufacturing program, proper equipment maintenance is a key to lean manufacturing success. Continuous flow manufacturing will not allow for frequent, unplanned equipment down-time.

TPM (Total Productive Maintenance) is an excellent method for meeting the demands continuous flow manufacturing places on equipment. TPM does the following:

- It increases OEE (Overall Equipment Effectiveness) using improvement activities.
- It establishes an autonomous maintenance program performed by equipment operators.
- It establishes a planned maintenance system.
- It requires training to improve operation and maintenance skills.
- It institutes a system for MP (maintenance prevention) design and early equipment management.

2. Increasing Overall Equipment Effectiveness

OEE is the default scope for a production team. It shows the ratio between the theoretical maximum good output during the loading time vs. the actual good output. The loading time can be less then the operations time since the equipment can be unscheduled during the operations time, thus reducing the loading time. Loading time therefore is the time the equipment was supposed to be running. In cases where several products have been produced, (either sequential or parallel) the Performance part of the OEE is calculated as a weighted

average between the several expected output ranges.

TPM is aimed at eliminating the so-called "six big losses:" The following table lists the Six Big Losses, and shows how they relate to the TPM Loss categories.

Table 1

Six Big Loss Category

Six Big Loss Category	OEE Loss Category	Event Examples	Comment
Breakdowns	Down Time Loss	Tooling Failures Unplanned Maintenance General Breakdowns Equipment Failure	There is flexibility on where to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
Setup and Adjustments	Down Time Loss	Setup/Changeover Material Shortages Operator Shortages Major Adjustments Warm-Up Time	This loss is often addressed through setup time reduction programs.
Small Stops	Speed Loss	Obstructed Product Flow Component Jams Misdeeds Sensor Blocked Delivery Blocked Cleaning/Checking	Typically only includes stops that are under five minutes and that do not require maintenance personnel.
Reduced Speed	Speed Loss	Rough Running Under Nameplate Capacity Under Design Capacity Equipment Wear Operator Inefficiency	Anything that keeps the process from running at its theoretical maximum speed (a.k.a. Ideal Run Rate or Nameplate Capacity).
Startup Rejects	Quality Loss	Scrap Rework In-Process Damage In-Process Expiration Incorrect Assembly	Rejects during warm-up, startup or other early production. May be due to improper setup, warm-up period, etc.
Production Rejects	Quality Loss	Scrap Rework In-Process Damage In-Process Expiration Incorrect Assembly	Rejects during steady-state production.

Overall equipment effectiveness (OEE) is the key metric in determining how well equipment is performing with regards to the big six losses. OEE measures equipment effectiveness in terms of availability, performance, and product quality. Availability tells us what percentage of time the equipment is actually running when we need it.

In addition to the above measures, there are tree underlying metrics that provide understanding as to why and where the OEE and TEEP performance gaps exist.

The measurements are described below:

- **Availability:** The Availability is a percentage number showing how the machine was available when it was needed for production. It looks at the first two of the 6 Big Losses, Breakdowns and Setup/Adjustments. That is the downtime that is measured at the equipment. Usually if the measurements at the equipment/machine are collected manually it is times longer than 5-10 minutes.
- **Performance Efficiency:** The Performance Efficiency takes into account the unrecorded downtime. That is the third and fourth of the 6 Big Losses, all unrecorded

downtime, i.e. short stoppages, usually less than 5-10 minutes and losses due to the difference between ideal cycle time and actual cycle time.

- **Quality rate**: The quality rate captures the last two of the 6 Big Losses; time loss due to the rejected parts during production and the losses from initial startup to process stabilization. The quality rate is calculated by dividing the good parts produced by the total number of parts produced. Good parts are all parts that meet the quality definition the first time. Parts that have to be reworked are counted as scrap.

OEE = AVAILABILITY x PERFORMANCE x QUALITY

Availability is calculated by dividing the Actual Operating Time by the Loading Time. The loading time is given by subtracting the unscheduled time; e.g. no customer demand, nonworking Sundays, etc, during the day from the total available time or calendar time (24 hours in one day).

The actual operating time is the loading time minus the sum of all downtime losses while operating, i.e. breakdowns and changeovers.

Availability = Actual Operating Time/ Loading time
Actual Operating Time = Loading time - Unplanned Downtime
Loading time = Total Available Time - Planned Downtime

To be able to calculate the performance efficiency an ideal cycle time for the job running at the machine is needed. If the ideal cycle time is multiplied with the total parts produced the outcome will be the time it should have taken to produce the parts. To calculate the performance efficiency the time it should have taken is divided by the actual operating time.

*Performance Efficiency = (Total Parts Run *Ideal Cycle Time)/ Actual Operating Time*

The quality rate is calculated by dividing the good parts produced by the total number of parts produced. Good parts are all parts that meet the quality definition the first time. Parts that have to be reworked are counted as scrap.

Quality Rate = (Total Parts Run - Total Defects)/ Total Parts Run

After the OEE are calculated for each piece of equipment, equipment improvement project teams determine which losses have the greatest impact on equipment effectiveness, and then prioritize improvement efforts accordingly.

3. Autonomous Maintenance Program

An autonomous maintenance program stabilizes equipment and halts accelerated deterioration.

The program makes operators responsible for cleaning and inspection, lubrication, precision checks, and other light maintenance tasks. In carrying out these activities, operators learn more about their equipment and become better equipped to detect problems early. To implement such autonomous maintenance, operators are systematically trained in a step-by-step program.

4. Planned Maintenance System

Planned maintenance improvement is led by the maintenance department. The maintenance department will handle all of the planned maintenance tasks that are beyond the scope of the autonomous maintenance program.

These are tasks that require special skills, significant disassembly, special measuring techniques and tools, etc. As equipment operators improve their skills, the maintenance group will perform fewer and fewer planned maintenance activities and will focus their efforts on improvements designed to reduce the maintenance required on equipment.

5. Maintenance Prevention (MP) Design and Early Equipment Management

MP Design involves discovering weak points in currently used equipment and feeding back this information to equipment design engineers. Similar to design for manufacturability, MP design takes the following factors into consideration:

- Ease of autonomous maintenance
- Ease of operation
- Improving quality
- Improving maintainability
- Safety

MP Design can be applied to develop criteria for selecting “off-the-shelf” equipment as well.

Early Equipment Management is a system for dealing with problems that surface during test-running, commissioning, and start-up of new equipment. During this period, production and maintenance engineering people must correct problems caused by poor selection of materials at the design stage, errors occurring during fabrication of the equipment, or installation errors. In an ideal world, Early Equipment Management should not be very complicated (particularly if MP Design is properly applied at the design stage).

6. The steps of TPM implementation

TPM requires effective leadership from the start. That is part of the meaning of "total" in Total Productive Maintenance. Without effective leadership that links TPM efforts to the business and holds people accountable for performing highly specified work, equipment performance and reliability will continue to decline and TPM initiatives will be short-lived. Many of today's business leaders have risen through the ranks when maintenance was only responsible for "fixing things" – not for preventing problems. Viewing maintenance as a non-value-adding support function, they often subject the maintenance department to severe cost-cutting; this usually results in higher costs due to decreased equipment effectiveness.

Companies that have been successful usually follow an implementation plan that includes the following 12 steps:

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.

Maintenance and reliability as a core business strategy is key to a successful TPM implementation. Without the support of top management, TPM will be just another "flavor of the month." Implementing TPM using the above 12 steps will start you on the road to "zero breakdowns" and "zero defects."

It's recommend that the operator collect the daily data about the equipment for use in the TPM. Collecting this data will

- teach the operator about the equipment
- focus the operator's attention on the losses
- grow a feeling of ownership of the equipment

The shift leader or line manager is often the one who will receive the daily operating data from the operator and process it to develop

information about the TPM. Working hands on with the data will;

- give the leader/manager basic facts and figures on the equipment
- help the leader/manager give appropriate feedback to the operators and others involved in equipment improvement
- allow the leader to keep management informed about equipment status and improvement results

7. TPM and Preventive Maintenance

Preventive maintenance is another major area that must be investigated during a TPM development plan. The largest reason for the failure of preventive and predictive maintenance programs is the lack of understanding and support for the program by upper management. Total Productive Maintenance programs ensure this support. Preventive maintenance under a TPM program will be successful if they are properly designed and implemented.

Planned Maintenance Activities are:

- Support Autonomous Maintenance Activities by technical support, breakdown analysis and demarcation between Production & P.M. Systems.
- P-M Analysis for chronic breakdowns.
- Time Based Maintenance items
- Condition Based Maintenance items.

Preventive maintenance takes a proactive approach to storm water management and seeks to prevent problems before they occur. A preventive maintenance program can improve water quality by controlling pollutant discharges to surface water that would result from spills and leaks. Preventive maintenance programs can also save facility money by reducing the likelihood of having a system breakdown and also by reducing the likelihood of funding costly cleanup projects. In addition, a preventive maintenance program can be an effective community relations tool.

The primary limitations of implementing a preventive maintenance program include:

- Cost.
- Availability of trained preventive maintenance staff technicians.
- Management direction and staff motivation in expanding the preventive maintenance program to include storm water considerations.

Elements of a good preventive maintenance program should include the following:

- Identification of equipment or systems that may malfunction and cause spills or leaks, or may otherwise contaminate storm water runoff. Typical equipment to be inspected includes pipes, pumps, storage tanks and bins, pressure vessels, pressure release valves, process and material handling equipment, and storm water management devices.
- Establishment of schedules and procedures for routine inspections.
- Periodic testing of plant equipment for structural soundness.
- Prompt repair or replacement of defective equipment found during inspection and testing.
- Maintenance of a supply of spare parts for equipment that needs frequent repairs.
- Use of an organized record-keeping system to schedule tests and document inspections.
- Commitment to ensure that records are complete and detailed, and that they record test results and follow-up actions.

Preventive maintenance inspection records should be kept with other visual inspection records.

8. Difficulties faced in TPM implementation:

One of the difficulties in implementing TPM as a methodology is that it takes a considerable number of years. The time taken depends on the size of the organization. There is no quick way for implementing TPM. This is contradictory to the traditional management improvement strategies. Following are the other difficulties faced in TPM implementation.

- Typically people show strong resistance to change.
- Many people treat it just another “Program of the month” without paying any focus and also doubt about the effectiveness.
- Not sufficient resources (people, money, time, etc.) and assistance provided
- Insufficient understanding of the methodology and philosophy by middle management
- TPM is not a “quick fix ” approach, it involve cultural change to the ways we do things

- Departmental barrier existing within Business Unit
- Many people considered TPM activities as additional work/threat.

7. Conclusions

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. It has been proven to be a program that works. It can be adapted to work not only in industrial plants, but also in construction, building maintenance, transportation, and in a 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 necessary for full implementation. If everyone involved in a TPM program does his or her part, an unusually high rate of return compared to resources invested may be expected.

Based on the wide spread and diverse understanding and use of TPM, there are several cautions regarding its use:

- TPM aims to maximize equipment effectiveness.
- TPM establishes a thorough system of Preventive Maintenance (PM) for the equipments entire life span.
- TPM is cross-functional, implemented by various departments (engineering, operators, maintenance, and managers).
- TPM involves every single employee.
- TPM is based on the promotion of Preventive Maintenance through the *motivation* of management.

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Vedere de ansamblu asupra Total Productive Maintenance

Rezumat

TPM este un important instrument pentru echipamentele din sectorul producției. Este o soluție destinată creșterii disponibilității echipamentelor și este un pas important în crearea unui flux mai bun. Oricum, cele mai multe compani au eșuat în implemetarea metodei cu beneficii maxime, reușind să obțină numai beneficiu parțiale. Toyota Motors Corporation a dezvoltat un stil propriu unic al acțiunilor TPM care se sprijina pe doi termeni critici: sistemul de producție lean și obținerea celor mai bune rezultate în mentenanță.

Vue d'ensemble sur Total Productive Maintenance

Résumé

TPM est un outil important pour les équipements du secteur de la production. C'est une solution destinée à augmenter la disponibilité des équipements et un pas important dans la création d'un meilleur flux. En tout cas, la plupart des entreprises ont échoué à adopter cette méthode qui présente des bénéfices maximums, en réussissant à obtenir seulement des bénéfices partiels. Toyota Motors Corporation a développé un style à soi, unique, des actions TPM qui ont à base deux termes critiques : le système de production lean et l'obtient des meilleurs résultats en maintenance.