TECHNICAL PAPER

MS02-297

Understanding and Implementing Total Productive Maintenance

author(s)

CHARLES J. ROBINSON
Principal
Total Systems Development, Inc.
Shorewood, Minnesota

abstract

The development of Total Productive Maintenance (TPM) means little without a master plan for implementation and strategic use. Building a master plan is essential in planning resources, securing management buy-in, and establishing aggressive, yet reachable goals for the manufacturing organization. The ultimate goal of TPM is to first establish stability in your manufacturing operation and then to increase plant capacity without capital investment. If TPM is understood and implemented properly, it can increase quality, reduce costs and decrease lead times for any manufacturing operation.

conference

IMTS 2002
September 4-11, 2002
Chicago, Illinois

terms

Maintenance
Reliability
TPM
Lean
Stability
Kaizen

Society of Manufacturing Engineers
2002

Society of Manufacturing Engineers
One SME Drive • P.O. Box 930 • Dearborn, MI 48121
Phone (313) 271-1500
www.sme.org

SME TECHNICAL PAPERS

Understanding and Implementing Total Productive Maintenance

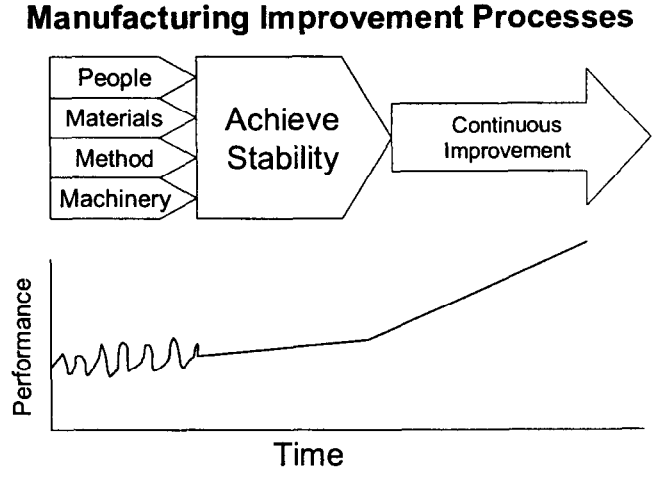
Abstract:

The development of Total Productive Maintenance (TPM) means little without a master plan for implementation and strategic use. Building a master plan is essential in planning resources, securing management buy-in, and establishing aggressive, yet reachable goals for the manufacturing organization. The ultimate goal of TPM is to first establish stability in your manufacturing operation and then to increase plant capacity without capital investment. If TPM is understood and implemented properly, it can increase quality, reduce costs and decrease lead times for any manufacturing operation.

Introduction

There are many modern manufacturing processes which are being advertised as the latest and best method of manufacturing continuous improvement. Whether the process is entitled Lean, Six Sigma, Demand Flow, Kaizen Blitz, TPS, or TQM, there is a common basis of all of the methods that starts with the establishment of a stable manufacturing environment. It does not mean that the environment is the optimum, it just starts with a certain level of stability in people, materials, methods and machinery. Each improvement process has a tool set that is designed to establish stability in these areas. Total Productive Maintenance is a tool set which is designed to establish stability in machinery. Stability for equipment means that the performance of the equipment is predictable. Equipment performance is measured as availability (how often will it break down?), capacity (what rate can it operate safely and efficiently?), and quality rate (can the machine operate to produce a consistent quality rate?).

Figure 1 – Achieve Stability First



Once the stability has been established, the flow of materials and products through the plant can be standardized, measured, and predicted, and as such a basis for improvement can be established. Other parameters can then be improved to improve the performance of the plant. TPM can then go further to improve the performance of the equipment by attacking the seven forms of equipment loss or waste. As equipment is improved, capacity is increased thereby creating additional capacity for the plant without adding capital assets to the company.

TPM Background

TPM was originated in Japan by Nippondenso, a supplier to the automotive industry, in the early 1960's. It was developed and standardized by the Japan Institute of Plant Maintenance (JIPM) in the 1970's. JIPM developed criteria for TPM and established an assessment system which awarded prizes for achievement in TPM. In the mid-1980's, Siiechi Nakajima documented the TPM process in a book entitled Introduction to TPM. It was translated into English and published by Productivity Press in 1984. TPM was recognized as a best practice by several large US Corporations in the early 1990's including Eastman Kodak, Magnavox, Ford, and 3M. JIPM opened an office in Atlanta in the mid-1990's and has been teaching their pure version of TPM within the US since that time.

The classical JIPM TPM process has twelve-steps within three stages as follows:

Figure 2 - The JIPM TPM Process

Stage	Step
Preparatory	1. Announce top management's decision to introduce TPM
	2. Launch an educational campaign to introduce TPM
	3. Create an organizational structure to promote TPM
	4. Establish basic policies and goals of TPM
	5. Form a master plan for implementing TPM
Preliminary Implementation	6. Kick off TPM
TPM Implementation	7. Improve the effectiveness of each critical piece of equipment
	8. Set up and implement autonomous maintenance
	9. Establish a planned maintenance system in the maintenance department
	10. Provide training to improve operator and maintenance skills
	11. Develop an early equipment management program
Stabilization	12. Perfect TPM implementation and raise TPM levels

This process assumes that TPM is being developed as a stand-alone process – not as a part of an overall improvement strategy. As many overall improvement strategies include TPM as the portion of the strategy focused on equipment improvement, the twelve-step TPM process needs to be integrated into the overall improvement strategy. For example, in the preparatory and preliminary implementation phases, much of the effort is in organizing for the implementation of TPM. For an overall improvement process, the preparatory and preliminary activity should be for the overall process which includes TPM, not just focused on TPM.

Understanding TPM

TPM is defined as a plant equipment improvement methodology which enables continuous and rapid improvement through use of employee involvement, employee empowerment, and closed loop measurement of results. The premise is that in order to be the best as a business enterprise which converts raw materials into products, the equipment that supports the conversion must be performing at peak levels and must continue to challenge that performance level for continuous improvement. That means that equipment must improve performance as a function of time. As the equipment gets older and we understand more about it, the performance must improve. Indeed at companies where TPM is perfected, the day that new equipment arrives at the factory is a baseline of performance. Future performance must improve.

This is a simple concept, but it is counterintuitive to our normal thought patterns. Aside from early equipment issues often referred to as "infant mortality", we usually think of equipment performance deteriorating as a function of time. Parts wear which deteriorate performance. Fixes made on the plant floor are not as precise as the original specifications thereby deteriorating performance. TPM says this does not need to be standard practice. We study equipment wear patterns and we take countermeasures. We practice precision repair where we can duplicate and actually improve upon the precision of the equipment manufacturers. We make the equipment easier to repair. We improve the equipment so that it becomes easier to operate. We install visual factory elements to the equipment such that defects are easy to see and control so that we stop and fix equipment before it breaks. This is what TPM is all about. It is possible in all industries. We have practiced it in mission critical industries for years. The last B-52 was manufactured over a quarter century ago, yet they are more reliable, more fuel efficient, and have more range than ever before. The machining equipment installed at the Toyota Georgetown facility in Kentucky had equipment that was over twenty years old and yet it outperformed similar new equipment in Japan. (Toyota shipped the old equipment from Japan to Kentucky because they felt they understood the old equipment and could predict its performance).

Classic TPM consists of five pillars or themes as follows:

- Conduct Planned Maintenance
- Improved Equipment Effectiveness

- Autonomous Maintenance Activities
- Training in Operations and Maintenance
- Early Equipment Management

Conduct Planned Maintenance

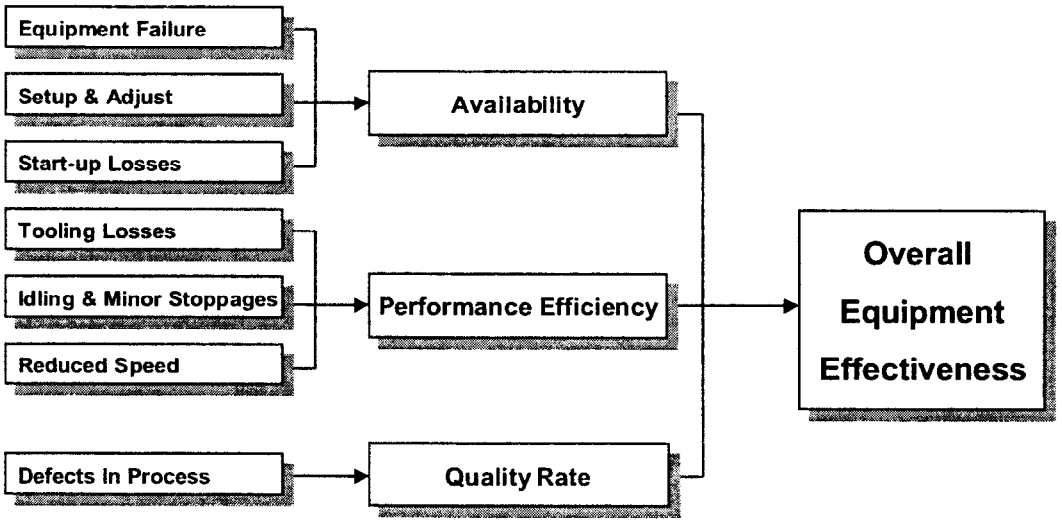
TPM starts with basic equipment maintenance discipline. This includes religiously performing equipment preventive maintenance. PM is scheduled with the same priority as a production schedule and performed according to schedule. It includes the proper training of maintenance mechanics in maintaining the equipment. It includes operators as the first line of defense in the health of the equipment. Spare part quality is continuously checked and never compromised. Cleaning and lubrication of the equipment are taken as seriously as product quality.

Improve Equipment Effectiveness

TPM continues with constant monitoring and improvement of equipment condition and performance. The major performance metric is Overall Equipment Effectiveness (OEE) which measures the effective utilization of the capital asset. OEE is the product of the availability of the equipment, the performance efficiency of the equipment and the quality rate of the output of the equipment. OEE measures the seven losses or wastes of equipment. The seven losses are as follows:

- Downtime due to machine breakdown
- Time required for setup and adjustments
- Time or cycles lost to inefficient startup
- Time or cycles lost due to tooling
- Time or cycles due to minor stoppages
- Operating at less than ideal speed
- Producing defective or off-spec product that is rejected, requires rework, or repair or is sold at a lower price.

Figure 3 – Overall Equipment Effectiveness



OEE = Availability X Performance Efficiency X Quality Rate

Autonomous Maintenance Activities

The focus of any TPM process is the equipment that converts raw material into product. Equipment is cared for as if it were the crown jewels of the plant. To do this, the ownership of the equipment must be shared with both operators and mechanics whether

the equipment is running or shutdown. The equipment care and the dual ownership are promoted through the process of "autonomous maintenance".

The seven levels of autonomous maintenance include the following:

1. Initial cleaning
2. Preventive cleaning measures
3. Development of cleaning and lubrication standards
4. General inspection
5. Autonomous inspection
6. Process discipline
7. Independent autonomous maintenance

Autonomous maintenance when implemented creates an environment where the equipment health is monitored and improved as the result of the increased focus. As the equipment condition improves, it becomes much easier to identify additional equipment defects so that they can be permanently resolved.

Training in Operations and Maintenance

In the TPM process, operators and maintenance mechanics are being asked to perform different roles than in the classic manufacturing operations. If we are to ask operators to take a larger role in the health of the equipment they operate, it is necessary to develop the skills required to assume that new role. If the focus of the maintenance mechanic is now changed to improving equipment performance (up from maintaining equipment performance), then they also will need new skills. Training in operations and maintenance is designed to develop those new skill requirements. TPM training is best performed on the factory floor using actual experience on the equipment that exists in the plant. Most all of the training can be accomplished using a series of small training modules called single point lessons. Single point lessons are concepts that are introduced to small groups of students in ten minutes or less and immediately practiced on the plant floor. Many safety training courses are designed in a similar style, such as ladder safety procedures or spill containment.

Early Equipment Management

Often time we inherit equipment that was purchased and installed by others and we have to make do the best we can with whatever was left to us. A real opportunity to make a difference is when we are specifying and purchasing new equipment for our plants. Early equipment management is the TPM process that insures that we take advantage of our full knowledge base to make the most intelligent business decision when purchasing new equipment. "Buy the best, you only cry once," should be the theme we should all use in

purchasing new equipment. The best does not always imply the most expensive purchase cost.

The cost that is the most important is the Total Life Cycle Cost (LCC) of the equipment. Total LCC includes all of the following costs for the proposed total life of the equipment:

- Purchase Cost
- Installation Cost
- Spare Part Cost (including cost of inventory)
- Operating Labor Cost
- Maintenance Labor Cost
- Utility Cost
- Cost of Downtime
- Disposal Cost of Equipment

When procuring new equipment, the TPM process considers all of these costs in determining the best business decision. In addition, it is important to use the historical data from operating and maintaining similar equipment in an effort to improve the design of the equipment being purchased. This involves reviewing equipment historical data as well as interviewing operators and maintenance mechanics for ideas on making the equipment easier to operate and maintain.

From a maintenance perspective, there are two metrics which simplify calculating the cost of equipment downtime and equipment maintenance labor. These metrics are

Mean Time Between Failure (MTBF) – sometimes referred to as mean cycles between failure. This is the average time the equipment operates without failure. It is calculates as the total operating time divided by the number of failures. The longer the mean time between failures, the better the equipment reliability.

Mean Time to Repair (MTTR) – is the average time it takes to repair an equipment failure ot the difference between the failure time and the return to producing good products. This is a measure of the maintainability of the equipment. The easier it is to repair, the lower the MTTR.

Clearly most of the effort spent in the procurement phase of the equipment life cycle should be spent on minimizing the total life cycle cost and not just the acquisition cost.

Another aspect of early equipment management is the philosophy that equipment warranties are not valuable for the purchasers of the equipment. A warranty only guarantees that a failed component will be replaced with another component of equal probability of failure. It also usually specifies that the equipment vendor will perform the repair on a time frame convenient to the equipment vendor. Most manufacturers cannot wait for the equipment vendors and thus make the repairs themselves. In most cases this

invalidates the warranty. All of this is considered when making the statement that most equipment warranties are worthless. A better plan is to have the equipment vendor act as a partner in continuously improving the equipment. Partnering is facilitated by sharing equipment performance data with the vendor. If the vendor is actively sharing data with all of the users of their equipment then equipment improvements can be accelerated for all of the users.

Developing a TPM Master Plan

The development of a TPM Master Plan is essential for planning of resources and establishment of goals, objectives and milestones for achievement. For overall improvement strategies, the plan should be part of an overall plant. The steps outlined below form the basis for the TPM part of the overall plan.

An outline of typical master plan milestones for implementation of TPM follows. This can be used as a guide in the development of a plant-specific TPM master plan.

Process Milestones

1. Achieve stability in the fundamentals of maintenance management, including preventive maintenance, work order systems, historical data collection, and maintenance planning.

2. Complete a plant feasibility study to establish baseline indicators of Overall Equipment Effectiveness (OEE), employee involvement, and equipment supplier relationships.

3. Complete TPM overview training for plant and union management.

4. Formulate a TPM implementation strategy - training methods, inspirational methods, results measurement (to be included in the overall implementation strategy for improvement for the entire plant).

5. Complete a detailed TPM implementation plan - activity schedules, budget guidelines and authority, roles and responsibilities, and outside resources.

6. Establish a specific set of measurable TPM goals in terms of OEE, employee involvement, manufacturing cycle times, inventories, customer satisfaction, and equipment supplier involvement.

7. Introduce TPM to all plant personnel and launch TPM implementation strategy - overview and OEE training as a part of the overall plant improvement strategy.

8. Complete development of TPM training modules - single-point lessons in both process and technical skills.

9. Complete development of initial cleaning, inspection, and lubrication standards - levels one through three of autonomous maintenance.

10. Complete expanded technical skills training for operators - training to be performed by maintenance craftspeople.

11. Complete expanded failure analysis / root cause analysis - train maintenance trades people in these analytical skills and methods.

12. Establish total life cycle costing as a criteria for new equipment purchases - include collection of data from production groups and vendors to help in this decision support process.

13. Achieve complete autonomous maintenance by operators - complete levels four through seven of the autonomous maintenance process.

14. Celebrate successes achieved - have an outside resource audit the process for achievement of a predetermined level of excellence.

Conclusion

Equipment stability is a prerequisite for implementation of any of the modern manufacturing methods. TPM is an established, well documented, process which can be used to establish a reasonable level of equipment stability. The key to establishing the stability is a disciplined approach to equipment management that involves both operations and maintenance functions working together.

Once equipment stability is established, TPM can proceed to develop additional plant capacity with existing assets. Additional plant capacity is only valuable if it is needed for additional production or if you can reorganize to reduce operating costs.

References

Robinson and Ginder, Introduction To Implementing TPM: The North American Experience: Stock #: IMPTPM-OLC, Productivity Press, 1994

Nakajima, Introduction to TPM : Total Productive Maintenance, Productivity Press; ISBN: 0915299232; (October 1988)

Society of Automotive Engineers, Reliability and Maintainability Guideline for Manufacturing Machinery and Equipment, ISBN Number: 0-7680-0473-X, September 1999.