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The Application of Tools and Techniques of Total Productive Maintenance in Manufacturing

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Abstract:
The quest toachieve optimal equipment maintenance has over the years constituted a myriad of problems to manufacturing companies, as equipment losses, setup and adjustment, idling and minor stoppages, reduced machine speed, defective products, and reduced yield has adversely affected their desire to attain world class manufacturing. Hence, the need for a distinct manufacturing approach that will offer the much needed relief. This paper examined the concept of Total Productive Maintenance (TPM) - a manufacturing approach that blends maintenance and productivity, and reinforces the fact that good care and up-keep of equipment will result in higher productivity and competitive advantage. The applications as well as the attendant benefits of the various tools and techniques of TPM which include Pareto Analysis, One Point Lessons (OPL), 5S Practice, Kaizen (Continuous Improvement), Autonomous Maintenance, PokaYoke, and Overall Equipment Effectiveness (OEE) were discussed in details. The OEE and the eight pillars of successful tools and techniques of TPM implementation which leads to the reduction and possible elimination of the six big losses were fully analysed, before it was concluded that the successful application of the various tools and techniques has enabled many manufacturing firms to achieve better product quality, enhancement of through put and profitability, as well as the elimination of equipment breakdowns, thereby enabling them to attain world class manufacturing.

Keywords: Overall Equipment Effectiveness, tools and techniques of TPM, Pareto analysis, kaizen, six big losses, poka yoke, 5S practice, world class manufacturing, pillars of TPM

I. INTRODUCTION

In today's dynamic environment, a reliable production system is a critical factor for excellence, as poor organizational competencies in managing the maintenance function effectively can severely affect a company's profitability by reducing throughput, increase inventory and also lead to poor due-date performance. This is because an improvement in manufacturing processes is necessary so as to maintain the competitiveness of a business in order to enhance productivity, profitability, and control of excess inventory. Ahuja, Khamba, and Rajesh(2006), observed that manufacturing industry has experienced an unprecedented degree of change in the last decade, which involves drastic changes in management approaches, product and process technologies, customer's expectations, supplier attitude as well as competitive behaviour. The contemporary business environment has become considerably complex and challenging, resulting to a variety of factors that influence the manufacturing organization's ability to compete effectively. Modern manufacturing approach requires that firms that wish to be successful and also intend to achieve world-class manufacturing must possess both effective and efficient maintenance strategy. One approach to improve the performance of maintenance activities is to implement Total Productive Maintenance (TPM) system of manufacturing. Okpala and Egwuagu (2016),explained that TPM "is a philosophy of machine maintenance that entails active participation of employees to ensure the improvement of the general effectiveness of a plant, by eliminating or reducing resources and time wastage through the incorporation of the skills of the workforce." TPM builds a close relationship between maintenance and productivity, showing that good care and up-keep of equipment will result in higher productivity. However, Madu (2000),noted that TPM tools and techniques have been realized and well accepted by manufacturing companies, as the equipment maintenance and reliability are important strategies that can considerably influence an organization's ability to compete effectively. It is a philosophy of continuous improvement that creates a sense of ownership in the operators of each machine, as well as the supervisors, and also a process of maintenance management that empowers the organization with a progressive, continuous philosophy of enabling all manpower resources to work together to accomplish the mutual goal of manufacturing efficiency. According to Nakajima (1988),the application of tools and techniques of TPM has been accepted as the most promising strategy for improving maintenance performance in order to succeed in a highly demanding market arena. This is because it provides organizations with a guide to primarilychange their working place by incorporating technology, organizational culture, and manufacturing processes.

1. Toolsand Techniques of TPM

A variety of tools and techniques are applied by manufacturing companies to assist in the deployment of TPM programmes and activities. Some of the tools employed to analyse and solve equipment and process related problems include but not limited to the following: Pareto Analysis, One Point Lessons (OPL), 5S Practice, Kaizen (Continuous Improvement), Autonomous Maintenance, PokaYoke, and Overall Equipment Effectiveness.

Pareto Analysis: Pareto Analysis is a statistical tool that is usedin decision-making, and for the selection of a limited number of tasks that produce significant overall effect. It uses the Pareto Principle (also known as the 80/20 rule), the idea is that by achieving 20% of the work one can generate 80% of the benefit of doing the entire job. Take quality improvement for example, a vast majority of problems (80%) are produced by a few key causes (20%). This TPM tool and technique is also called the vital few and the trivial many, as the 20% of a systems defects can cause 80% of its problems. After the identification of the defects, TPM applies the root cause effect to correct the defects. As a lean tool the Root cause analysis is used to identify the root causes of problems so that the problems can be eliminated at their base level. Root causes of equipment breakdowns can be analysed when it has been detected and corrective measures can be suggested, so as to reduce or eliminate the root causes (which could be very minor at that level). If root causes are eliminated, breakdowns of equipment wouldreduceleading to the reduction of the downtime of machine, and ultimately increase the Overall Equipment Effectiveness (OEE).

One Point Lessons (OPL): An OPL is a five to ten minutes self-study lesson which is visual in nature, drawn up by team members and covers a single aspect of equipment or machine structure, function, or method of inspection. One point lessons are one of the most powerful tools for transferring skills. The teaching technique helps employees to learn a specific skill or concept in a short period of time through the extensive use of visual images. The skill being taught, is typically presented, demonstrated, discussed, reinforced, practiced, and documented in thirty minutes or less. Robinson and Ginder(1995),noted that Single-point lessons are especially effective in transferring the technical skills required for a production operator to assume minor maintenance responsibilities. They explained that team activities in TPM are usually conducted by teams known as small group activity (SGA). A small group is any cross-functional work team charged with working together to improve plant performance by solving problems and managing specific plant areas, machines, or processes. TPM SGA's do not operate independently, but rather perform TPM activity consistent with the overall TPM plan.

5S Practice

5S practice which is based on Japanese method of establishing and maintaining an organized and effective workplace is often used during plant cleaning activities. It is a systematic method to organize, order, clean, and standardize a workplace. The elements of 5S practice are:

- Seiri (sort)
- Seiton (set in order)
- Seiso (shine)
- Seiketsu (standardize) and
- Shitsuke (sustain).

Table 1depicts the key activities of 5S practice.

Table .1. Key Activities for Effective 5S Implementation. Source: Ahuja, and Khamba(2008)

Japanese term	English 5S	English 5C	Features
Seiri	Sort	Clear	Sort out unnecessary items from the Workplace and remove them
Seiton	Set in order	Configure	Put necessary items in a good order so that they can be easily picked up when needed
Seiso	Shine	Clean and check	Clean the shop floor thoroughly to make it free from dust, dirt and oil spillage
Seiketsu	Standardize	Conformity	Maintain high standard of shop floor and workplace organization
Shitsuke	Sustain	Custom and practice	Train and motivate people to follow good housekeeping disciplines autonomously

Kaizen (Continuous Improvement)

Also known as continuous improvement, Kaizen translated from Japanese language mean good change. It is a systematic TPM tool and technique that seeks to achieve small and gradual change in manufacturing process so as to improve efficiency and quality.

Autonomous Maintenance:

Autonomous Maintenance (AM) which usually is the first step in TPM implementation by manufacturers have the capacity for equipment improvement, as it leads to the stoppage of unnecessary equipment breakdown. Asan extraction of 5S activities of the production team, it helps to prevent sudden breakdown by the machine and give the operators a sense of ownership of production equipment.

Poka Yoke (Error Proofing)

As errors and mistakes are bound to happen in the shop floor, poka yoke which are simple and inexpensive devices are applied to checkmate the occurrence of such mistakes which lead to the manufacturing of defective products. Benhabib (2003), explained that poke yoke involves the use of devices and procedure that would prevent the assembly of wrong components and subassemblies. With its application the operators are able to do self-checking when production is on-going, by stopping production processes whenever an error is detected, thereby ensuring that a defective product does not pass through. This ensures the attainment of one of the goals of TPM which is defect free production. Table 2 illustrates some of the tools and techniques of TPM that are applied to improve quality and productivity and also reduce equipment breakdown.

Table. 2. Toolsand Techniques of TPM.   Source: Strategosin (2017)

TMP Tools	Purpose	Description
5S Practice	Reduces time wastage and motion level	Organized approach to housekeeping that ensures tools, parts and other objects are in known, optimum locations.
Poka yoke	Prevents the occurrence of mistakes or defects.	Uses a wide variety of ingenious devices to prevent mistakes. An example is an automotive gasoline tank cap that has an attachment that prevents the cap from being lost.
One Point Lesson	To provide immediate, visual information that enables people to make correct decisions and manage their work and activities.	One point lesson uses a wide variety of signs, signals and controls, to manage people and processes.
Autonomous Maintenance	To provide personal care of equipment by the operator.	The operator of the equipment haven understood the functions of the equipment, does activities like cleaning, lubricating, dusting and inspection. This helps to prevent sudden breakdown of the machine and also give the operators the sense of ownership of the equipment.
Root Cause Analysis	Tacklesproduction problems at the base level.	When root causes are eliminated, breakdowns of equipment are reduced, which would reduce the downtime of machine and ultimately increase the Overall Equipment Effectiveness (OEE).
Kaizen(Continuous Improvement)	Institutionalizes the practice of achieving small daily improvements and improvement of overall efficiency.	Continuous Improvement refers to the idea that a large number of small improvements in processes are easier to implement than major improvements that have a large cumulative effect.

Overall Equipment Effectiveness: Overall Equipment Effectiveness is an effective way of analysing equipment performance which takes into account the major six big losses (Downtime Losses, Equipment Failures, Setup and Adjustments, Speed Losses, Idling and Minor Stoppages and Defect Losses). It is a function of Availability, Performance rate and Quality, which actually measures equipment losses. The best way to increase the performance of equipment is to identify and eliminate the losses that are hindering performance.OEE is arguable the most important tool and technique in the TPM improvement strategy.Okpala and Anozie (2018), noted that OEE is often regarded as one of the best measurements of Total Productive Maintenance,as it is a technique applied for the measurement of major production features which include performance efficiency, rate of quality and availability. It aims at speed increment, and the reduction of defective products, machines stoppages (downtime), and poor quality products by machines, as well as improving the capacity of machines and equipment that work below their production capacity. The OEE model that comprises of equipment timing, six big losses, and perspectives areshown below in figure 1.

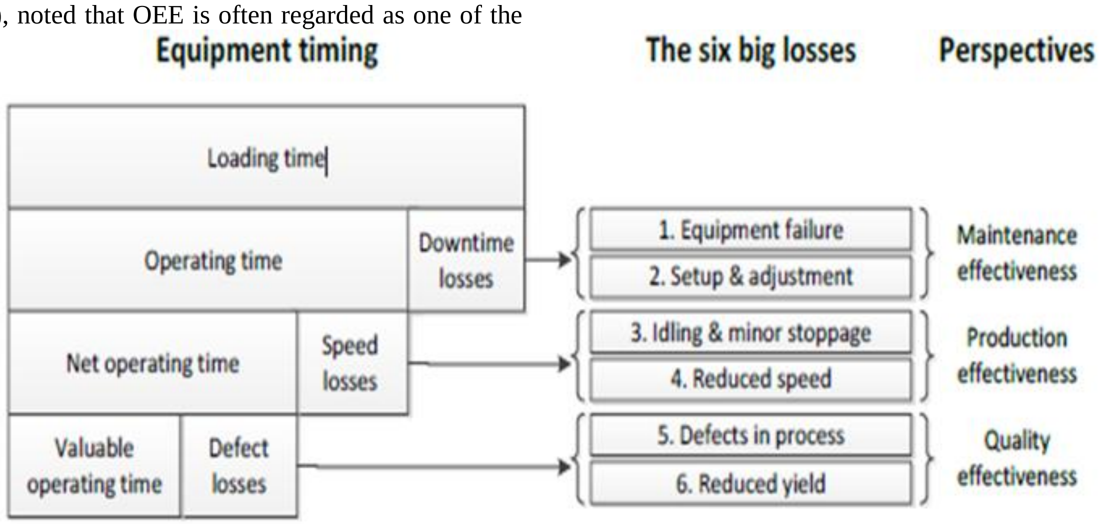

Figure.1. The OEE Model and the Six Big Losses.

OEE can be calculated using the following formulae:

OEE (in percentage)=Availability(A)xPerformance efficiency (P) x Quality Rate (Q)

Equipment availability (A) $=\frac{loadingtime\ \ -downtime}{loadingtime}\times 100$

Performance efficiency (p)$=\frac{processedamount\ \ \times cycle\ time}{operatingtime}\times 100$

Quality Rate (Q) $=\frac{processedamount\ \ -defectamount}{processedamount}\times 100$

Availability: This is the time a machine is creating value, and functioning. In a continuous manufacturing firm, the equipment should be working 24 hours per day. The availability of a machine can be determined by equipment break downs, loss of throughput(which is caused by equipment malfunction), and set-up and adjustment time which is as a result of equipment change over from one product to another.

Performance rate: Often referred to as the run rate or machine capability, the performance rate is the measure of when the machine is not running according to the design speed of the machine, which is as a result of idling or minor stoppages and reduced speed, it takes speed losses into account.

Quality: Also known as yield, Quality takes into account quality losses; they reduce and possibly eliminate products that do not meet specified standards by focusing on defect free manufacturing. Table 3 shows theOverall equipment effectiveness, the recommended six big loss and the traditional six biglosses.

Table.3. OEE and the Traditional Six Big Losses

Overall Equipment Effectiveness	Recommended Six Big Losses	Traditional Six Big Losses
Availability Loss	Unplanned Stops	Equipment Failure
	Planned Stops	Setup and Adjustments
Performance Loss	Small Stops	Idling and Minor Stops
	Slow Cycles	Reduced Speed
Quality Loss	Production Rejects	Process Defects
	Startup Rejects	Reduced Yield
OEE	Fully Productive Time	Valuable Operating Time

The Six Big Losses

Equipment Failure – Equipment failures are sudden, unplanned and unexpected breakdown or failure of the machine. Equipment breakdown or temporary machine stoppages affect productivity, and can be tackled with Autonomous Maintenance.

Set-up and Adjustment – Also referred to as planned stops, this is the point where the machine requires adjustments (tool changing), repairs, lubricating, and changeover (from one product to another).

Idling and minor stoppages –These are not fault stoppage or breakdowns, but are intentional stoppages by the operator for correction of minor detected problems. This stop or idling can be caused by jamming of products, wrong setting, deviation of set standards, and quick checks.

Reduced speed –When a machine is not working at the stipulated design of the manufacturer, it can be regarded as reduced speed or speed losses, and could be caused by a faulty equipment, wrong usage of tools, insufficient lubrication, accumulation of dust particles, inexperienced operator, and out-dated equipment.

Quality defects – Quality defects also known as defect in process or rework process are losses by malfunctioning of production equipment where the product is not meeting up to the set standard of quality. This leads toadditional cost to the manufacturing firm, and can be tackled by the poke yoke device.

Reduced yield –These are losses due to start–up of the equipment until it comes to a point of stabilization. Sometimes the equipment takes time, before it comes up to a point of stabilized level for efficient production.

2. The Pillars of TPM

The pillarsof TPM which guarantees efficient application of the tools and techniques comprise of 5S practice as the foundation, and eight pillars which are geared towards effective maintenance approach. The implementation is based on clear approach and should not be handled disorderly, to ensure that the effects are felt in the production system. The pillars which when properly implemented and understood by the entire work force can reduce breakdowns and also improve equipment effectiveness. Imants BVBA (2004), proposedthat the eight pillars involve the cooperation of the equipment and process support personnel, equipment operator and equipment supplier. They work together to eliminate equipment breakdowns, reduced scheduled downtime and also maximize utilization, throughput and quality. Figure 2depicts the model of TPM pillars and the 5S principle, while Table 3 illustratesthe pillars, its targets, duties and proper actions that leads to success application of the tools and techniques.

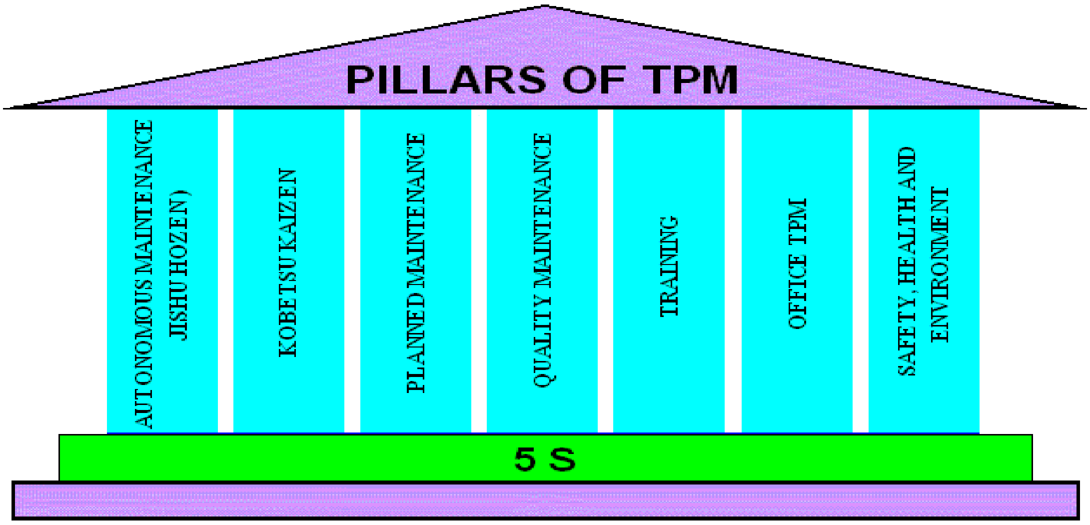

Figure.2. the model of TPM pillars

Table.3. the Eight Pillars of TPM Source: JIPM (2009)

Pillars of TPM	Targets	Duties	Actions
1. Focused Improvement	• Eliminate breakdowns, quality defects and every other kind of loss. • Achieve the ultimate in production effectiveness	• technical staff • Line leaders	• Identifies the 16 losses • Calculates and set target for OEE and unit resources consumptions • Analyse problems and review possible causes • Ruthlessly pursue the ultimate in equipment and production system
2.Autonomous Maintenance	• Develop equipment competent operators • Empower operators to look after their equipment	• Operators • Line leaders	Implement the 7 jishuhozen steps: • Initial cleaning • Remove contamination • Provisional standards • General inspection • Autonomous inspection • Standardisation • Full self- management
3. Planned Maintenance	• Improve the effectiveness of the maintenance department to the point where the big 8 losses are no longer generated	• Staff, team leaders, and personnel from maintenance department	• Day to day action • Preventive maintenance • Improvement to extend equipment life • Spare parts management • Failure analysis and recurrence prevention • Lubrication management
4.Training and Education	• Boost the expertise of operators and maintenance personnel	• Operators • Maintenance personnel	• Basic maintenance • Fitting of nuts and bolts • Key fitting • Axle maintenance • Maintenance of transmission components • Leak prevention • Maintenance of hydraulic and pneumatic equipment
5.Early Management	• Reduce product development and prototyping lead	• Research staff and development staff	• Set development and design targets • Utilise for MP design

	times • Reduce equipment development design and fabrication lead times • Achieve stable commissioning	• Production engineering staff maintenances	• Life-cycle costing • Eliminate problems at design, drawing, prototyping, fabrication, test-running and start up states • Perform design reviews
6.Quality Maintenance	• Achieve zero quality defects by sustaining correct equipment condition	• Quality assurance staff • Line leaders	• Check quality characteristics and standards, investigate existing quality defect phenomenon and results • Check quality assurance conditions prevailing in processes,raw materials,equipment and methods • Identify, analyse and improve unsatisfactory conditions • Set observable standards and monitor trends
7.Office TPM	• Achieve zero functional losses • create highly efficient offices • provide effective services and support to production department	• Team leaders and team members in sales and other indirect department	• JishuHozen for office, like initial cleaning of immediate surroundings and implementing standards • Do specific project based improvement such as reduce lead time for finalising accounts, etc
Safety, Health and Environment (SHE)	• Achieve and sustain zero accidents • Create healthy, rewarding and pleasant workplace.	• SHE managers and committee members • SHE staff	• Make equipment safer • Make work safer • Improve working environments • reduce pollution • improve employees health • promote wholesome actives

3. BENEFITS OF APPLICATION OF TOOLS AND TECHNIQUES OF TPM

The benefits of successful application of tools and techniques of TPM cannot be over-emphasized, as it can be direct and indirect. Some of the direct benefits are improved productivity, better quality of products, reduction of sudden breakdowns, and cost of maintenance. The indirect benefits are continuous improvement(kaizen) approach, and team culture. Carannante (1995), pointed out that successful implementation of TPM Tools and techniques lead to significant intangible benefits such as continuous improvement of workforce skills and knowledge, fostering employee motivation through adequate empowerment, clarification of roles and responsibilities for employees. Others are a system for continuously maintaining and controlling equipment, enhanced quality of work life, reduced absenteeism and enhanced communication in the workplace. Since the introduction of TPM tools in manufacturing companies, it has led to better quality, increase in throughput, elimination of equipment breakdowns, and reduction in the six big losses, which has enabled many production firms to attain world class manufacturing.

4. CONCLUSION

For an effective maintenance in manufacturing firms, the tools and techniques of TPM must be understood and properly utilized. The adoption of tools of TPM enables firms to achieve the overall goal of TPM, which are zero defects, zero accidents and zero breakdowns. In practice, manufacturing firms may noteasily attain the one hundred percent level of the goals, but through continuous improvement can reduce the losses to their barest minimum levels. However, the various tools and techniques will not yield the expected dividends if they are not properly applied, and this explains why the management of manufacturing companies must support the production strategy, and also provide adequate training to their entire staff for optimal performance.

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