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TOTAL PRODUVCTIVE MAINTENANCE IMPLEMENTATION THROUGH DIFFERENT STRATEGIES: A REVIEW

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Abstract *— Competitive pressures and changing production management paradigms have, in recent years, increased the importance of reliable and consistent production equipment. Whatever the level of competition exists in manufacturing industry the performance greatly affects the survival and prolong life time in industrial scenario.*
In measuring the corresponding level of performance of a particular organization, the term "productivity" becomes vital. the combination of these maintenance practices; called as maintenance function would optimize performance of the applied productivity improvement strategy .Since maintenance also has a strategic dimension, its performance measurement system should be linked to the espoused strategy of the function in order to get the maximum impact.
With regards to Total Productive Maintenance (TPM) implementation, Indian manufacturing organizations have often been plagued with teething problems and challenges.
The developed working system and new responsibilities is explained through Autonomous Maintenance (AM), Preventive Maintenance (PM), and 5S Modeling, with a suggestion for additional working performance indicators.

Keywords-: *Productivity Improvement Strategy, Maintenance Function, Performance Measures, Total Productive Maintenance (TPM)*

I. INTRODUCTION

Total productive maintenance (TPM) is a system of maintaining and improving the integrity of production and quality systems through the machines, equipments, processes and employees that add business value to the organization.
Originally know as Total Productive Maintenance, the words correctly interpreted mean Total (all employees) Productive (creating greater return on investment) Maintenance (by caring for the plant & equipment so as to maximize its performance & output).
TPM has developed significantly over the years since 1970. Originally there were 5 pillars of TPM that are now referred to as first generation TPM. It is focused on improving equipment performance or effectiveness from an equipment focus perspective.
But in late 80s it was realized that even shop floor were committed fully to TPM and the elimination of "six big losses". Hence the development of second generation TPM which focused on the whole production process and incorporated extra pillars of TPM called Support Department Improvement-Production Planning.
Furthermore in most recent times it has been recognized that the whole company can benefit from your equipment operating perfectly resulting in significant improvements in output, quality and safety. Hence the expansion of the support department pillar to include all support areas along with the addition of two further pillars quality and safety to create the third generation TPM, which encompasses 8 pillars of the TPM methodology.

Table 1. Represents the development of TPM pillars.

1st Generation TPM (Equipment Focus)	2nd Generation TPM (Manufacturing Process Focus)	3rd Generation Focus (Company Focus)
1) Improving Equipment Effectiveness 2) Autonomous Maintenance By operators 3) Planned Maintenance 4) Training to improve Operating and Maintenance skills 5) Early Equipment Maintenance	1) Improving Equipment Effectiveness 2) Autonomous Maintenance By operators 3) Planned Maintenance 4) Training to improve Operating and Maintenance skills 5) Early Equipment Maintenance 6) Support Department Improvement	1) Improving Equipment Effectiveness 2) Autonomous Maintenance By operators 3) Planned Maintenance 4) Training to improve Operating and Maintenance skills 5) Early Equipment Maintenance 6) Support Department Improvement 7) TPM in Administration 8) Safety And Environmental Management

In Today's context of the competitive business market the production of product should be a quality product with effectiveness and efficiency. TPM now comprises of eight different sections which have come to be pillars. Each pillar has its own responsibility.

The productivity improvement can be achieved by proper implementation of the following eight pillars indicated in the respectively which are:-

A. Autonomous Maintenance
B. Planned Maintenance
C. Quality Integration
D. Focused Improvement
E. New Equipment Management
F. Training & Education
G. Safety, Healthy & Environment
H. TPM in Administration.

The above are the basic eight different areas to be focused on the proper effective implementation of whole TPM in an organization.

But the base of these eight pillars is the 5s methodology to be firstly properly implemented. With the 5s model implementation only the TPM can be implemented in any organization

II.METHODOLOGIES

2.1 5s methodology:-

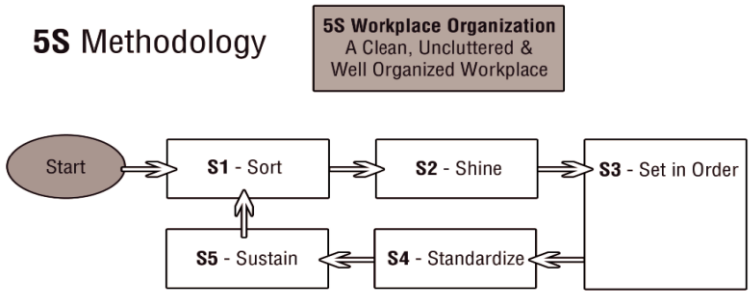

Fig 1.1: 5s Methodology

5S is one of the most widely adopted techniques from the lean manufacturing toolbox. Along with Standard Work and Total Productive Maintenance, 5S is considered a "foundational" lean concept, as it establishes the operational stability required for making and sustaining continuous improvements.

The primary objective of 5S is to create a clean, orderly environment- an environment where there is a place for everything and everything is in its place.

Visual Workplace – also known as Visual Factory or Visual Management – is a concept that emphasizes putting critical information at the point of need.

"**A visual workplace is a work environment that is self-ordering, self-explaining, self-regulating and self-improving – where what is supposed to happen does happen, on time, every time, because of visual solutions.**"

2.1.1. S1 – SORT (SEIRI):-

The first **S** focuses on eliminating unnecessary items from the workplace.

An effective visual method to identify these unneeded items is called red tagging. A red tag is placed on all items not required to complete your job.

The goal is to eliminate nonessential items from the workplace. Items are "red tagged" and stored in a local red tag area for a specific period of time, typically five days. If not reclaimed by the work group, items are then moved to one of the company's central red tag areas. Here everyone can sift through the items to see if there is anything they need.

In order to implement S1-Sort, there are action steps that need to be taken in order to guarantee success.

A. Select a 5S application area and take "before" pictures.

B. Review sorting criteria -recommended criteria are frequency of use, criticality, and quantity needed for production.
C. Create a red tag area – mark off a corner or space to identify it as the local red tag area.
D. Tag, record, and move items to the red tag area – keep records so that the company can track assets.
E. Take "after" pictures of the uncluttered work area and red tag area.
F. Items not reclaimed by the work group within a set amount of days are moved to the company's central red tag area.

2.1.2 S2 – SHINE (SEITON):-

The second **S** focuses on efficient and effective storage methods.

The S2-Shine step includes three primary activities which include getting the workplace clean, maintaining its appearance, and using preventative measures to keep it clean.

Shine the workplace by eliminating dirt, dust, fluids, and other debris. Each team member should be equipped with adequate cleaning supplies that have been tested to make sure the solution will not harm any equipment or work areas.

Treat cleaning as an inspection process. Use it to identify even tiny abnormal and pre-failure conditions. Working in a clean environment enables workers to notice malfunctions in equipment such as leaks, vibrations, breakages, and misalignments.

Follow these action steps to guarantee success.

A. Define "clean" – you may face conflicting definitions for clean within your work area.
B. Find a definition that everyone supports.

C. Get cleaning supplies – be sure to identify appropriate cleaning supplies for your work area.

D. Take "before" pictures – a record of your current state often generates the motivation to keep things clean.

E. Clean the work area – share the work load among the group.

F. Eliminate small imperfections through cleaning and inspecting activity.

G. Take "after" pictures – use photographs to demonstrate your results.

2.1.3 S3 – SET IN ORDER (SEISO):-

It is generally the Planning phase of the 5s methodology.

In S3 Set In Order, team members come together and share the insights they have gained during S1 and S2.

They analyze the work area for additional improvement opportunities and look for ways to reduce sources of waste and error as well as to make the workplace more visually instructive.

The team brainstorms potential solutions, with special emphasis on using visual resources to achieve improvement.

Use the focus points below to guide efforts to redesign the workplace for improved performance:-

2.1.3.1 Facilities/equipment/tools: Focus is on organizing and labelling facilities and equipment.

- Make sure utility pipes, conduits, compressed air hoses, gas cylinders and electrical systems are clearly named and labeled to simplify line tracing.

- Operator tools should be kept near the point of use, organized and labeled.
  \
- Gauges and indicators should be marked so abnormalities can be detected at a glance.

2.1.3.2Safety: Focus is on alerting people to potentially hazardous situations and controlling actions to prevent an unsafe condition.

- Provide hazard warnings and safe work instructions at the point of need.
- Make sure that locations for lockout/tag out devices, eye wash stations, first aid stations, and safety showers, etc., are clearly marked.
- Ensure that the proper personal protection equipment is easy to access and ready for use.

2.1.3.3 Procedures: Focus is on employee's ability to execute job responsibilities within a given workplace.

- Make certain that the latest version of work instructions and job aids are posted.
- Employ visual or auditory signals that alert operators to abnormal conditions.
- Use mistake-proofing devices to prevent human and machine errors.

2.1.3.3 Quality: Focus is on graphically or physically representing quality standards.

- Quality standards should be visually designed and properly displayed.
- Post examples of acceptable and unacceptable outputs in a common area.
- Visually display quality performance trends.

2.1.3.5 Inventory/Material Handling: Focus is on effective identification of production and MRO materials,

2.1.3.6 Storeroom organization, and material movement. Clearly mark:

- Line side inventories (inventory type, max/min quantity, location, etc.).
- Storerooms (shelf, rack and bin labels, restocking indicators, barcoding, etc.).
- Inventory delivery routes and replenishment procedures.

The steps in S3 – Set In Order: Implementation Phase include:

A. Take "before" pictures. This is your last chance to capture the past before you move towards the future.
B. Implement workplace changes. Plan to do…do the plan. Now is the time to implement your changes. Be sure to involve necessary company personnel, such as skilled trades, plant maintenance, engineering, quality, etc.
C. Set locations by creating addresses and applying labels, markings, and colour coding. Verify or create standards for colours and character size before setting in order. See the person in charge of facilities or maintenance for input.
D. Take "after" pictures. Take lots of pictures – they memorialize your success and serve as a valuable company record.

2.1.4 S4 – STANDARDIZE (Seiketsu)

Once the first three of the 5S's have been implemented, you should concentrate on standardizing *best practice* in your work area. Allow your employees to participate in the development and documentation of such standards.

The team identifies ways to establish the improved workplace practices as a standard. The goal of standardization is to create best practices and to get each team member to use the established best practices the same way.

In order to standardize, roles and responsibilities must be clearly and consistently applied. This can be accomplished through visual controls such as color-coding, flow charts, checklists, and labeling to help reinforce a uniformed approach.

Action steps for implementing S4 – Standardize include:

a. Brainstorm ideas for making the 5S changes standard operating procedure. That may mean updating workplace procedures, checklists, job aids, diagrams and the like.

b. Update documentation to reflect the changes. If your company has an ISO Coordinator, get the person involved to assure compliance with ISO requirements.

c. Make sure all stakeholders are aware of the new standard – inform and educate.

2.1.5 S5 – SUSTAIN (Seiketsu):-

This is by far the most difficult **S** to implement and achieve. Human nature is to resist change and more than a few organizations have found themselves with a dirty cluttered shop a few months following their attempt to implement 5S. The tendency is to return to the status quo and the comfort zone of the "old way" of doing things.

Sustain focuses on defining a new status quo and standard of work place organization.

A management auditing process should be put into practice to ensure that employees understand that maintaining the level of workplace organization is a top priority.

Management audits should focus on ensuring that the routines and schedules specified in S4 Standardize are being properly maintained. The audit also provides an excellent opportunity for asking questions and providing suggestions that stimulate further improvements.
Action steps for implementing S5 - Sustain

A. Audit to ensure that processes established during S4– Standardization continue to be maintained.
B. Use the phase 1 work area as a model for other areas to match, and have the original 5S team share their insights and experiences with employees in other work areas.
C. Use newsletters, displays and other communication tools to publicize successes and reward strong efforts with recognition.
D. Evaluate 5S effectiveness and continue to improve. Conduct regular review meetings to identify additional 5S opportunities.

III PURPOSE OF OVERALL EQUIPMENT EFFICEINCY (OEE):-

Firstly, the OEE measure can be a benchmark for measuring the initial performance of a manufacturing plant in its entirety.
Secondly, an OEE value, calculated for one manufacturing line, may be used to compare line performance across the factory, thereby highlighting any poor line performance.
Lastly, if machines process work individually, an OEE measure can identify which machine performance is worst and therefore indicate where to focus TPM resources.

OEE = Availability x Rate x Quality

$$\text{Availabilty} = \frac{Required\ Production\ Time - All\ recorded\ tme}{Required\ Prduction\ Time}$$

$$\text{Rate} = \frac{Actual\ Rate}{Ideal\ Rate}\ x \frac{Processed\ Amount}{Reported\ Operating\ Time\ x\ Actual\ Rate}$$

$$Quality = \frac{\text{Good Output Produced}}{\text{Processed Amount}}$$

Therefore In general we can say that

$$OEE = \frac{\text{Good Output Produced}}{\text{Required Prduction Time x Ideal Rate}}$$

As such we have developed a balanced scorecard type approach, which looks like at a range of measures that also act as a counter-balance to OEE to ensure a balanced behaviour pattern is established in the workplace.
These complimentary measures are:

A. Safety
B. Quality to customer
C. Delivery Performance
D. Productivity
E. Cost
F. Morale

IV HYPOTHESES

As shown in Fig.1.2, our framework considers the Relationship among the environmental, organizational, and managerial factors, and the autonomous and planned TPM elements.

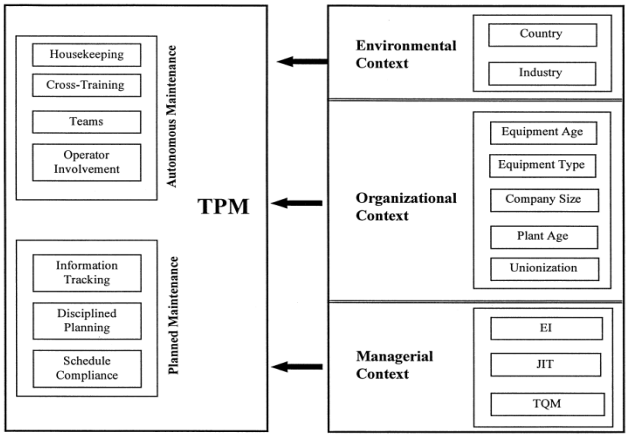

Fig 1.2 Framework Of TPM Hypothes

Industry can also be an important factor in equipment maintenance since the type of equipment, customer demands and strategic uncertainty can differ significantly from industry to industry.

H1: Environmental factors—country and industry— explain a significant portion of variation in TPM implementation levels.

H2: Organizational factors—equipment age, equipment type, company size, plant age, and unionization —significantly add to the explanation of variation in TPM implementation levels.

H3: Managerial contextual factors—the use of JIT, TQM, and EI—significantly add to the explanation of variation in TPM implementation levels.

V. EIGHT PILLARS OF TPM:-

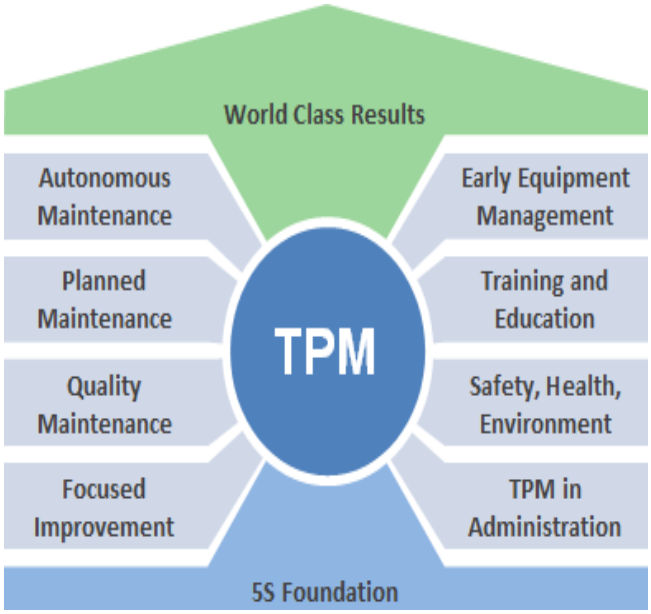

Fig 1.3 Eight Pillars Of TPM

Fig 1.3 Represents the Eight Pillars Of the Total productive Maintenance (TPM)

5.1 Autonomous Maintenance

It aims to create a scenario where all operators look after own equipment, carrying out routine checks, oiling and greasing, replacing parts, doing repairs, spotting problems at an early stage, checking precision and so on. The most important skill required of an operator is the ability to identify abnormalities and notice immediately when something is not quite right with the quality or the equipment. This skill requires three abilities

A. The ability to set conditions.
B. The ability to sustain
C. The ability to take corrective action and affect repairs

Seven step of implementation of Jishu Hozen pillar.

Step 0: Safety
Step 1: Initial Cleaning
Step 2: Eliminate sources of contamination and inaccessible.
Step: 3 Creation and Maintenance of cleaning and lubrication Standard.
Step: 4 General inspections.
Step: 5 Autonomous inspections
Step: 6 Standardization.
Step: 7 fully implemented autonomous maintenance pillar

5.2 Kobetsu Kaizen

Various "kaizen" activities to accomplish maximum efficiencies of individual facilities, equipment and manufacturing processes, as well as entire plants, by thoroughly elimination losses and improving performance.Kaizen Realize the zero loss situation in such as an equipment failure and product defect & that affect ultimate production efficiency situation.

5.3 Planned Maintenance

When we want to implement equipment maintenance in line with the business objectives, factory-wide maintenance orientation must be proactively changed from breakdown maintenance to preventive and predictive maintenance. Factories need this because they aim to minimize cost and maximize production.

The purpose of Planned Maintenance is to ensure the equipment conditions at their best with the minimum maintenance cost, enabling equipment to unction at an optimal level whenever operation is required.

In order to achieve this purpose, both the production department and the maintenance department must carry out their roles of equipment maintenance properly. In addition, other activities such as Kobetsu Kaizen (Individual Improvement, Focused Improvement) and MP (maintenance prevention) activities must be coordinated to realize ultimate aim of minimum cost production.

5.4 Quality Maintenance

The purpose of Quality Maintenance is to produce defect free products to maintain the product quality through eliminating non-conformance to satisfy the demand of the customer. The Japanese Institute Of Plant maintenances define Quality Maintenance as activities that are to set equipment conditions that preclude quality defects, based on the basic concept of maintaining perfect equipment to maintain perfect quality of products.

The conditions are checked and measured in time series to verify that measured values are within standard values to prevent defects. The transition of measured values watched to predict possibilities of defects occurring and to take counter measures before hand.

5.5 Training and Education

All shop-floor training should be based on a clear understanding of the human resource development systems and policies laid out by the company's personnel and training departments. Prospective trainees are selected, and their training needs assessed. This assessment may be based on past work performance evaluations, daily observation, or the individual's own stated wish for training. Once these training needs have been established, a training plan is drafted.

Training may implemented by day-to-day teaching and coaching, informal chats, and assistance with self-study. Off-the-job-training is another effective method worth considering.

5.6 Safety, Health and Environment

The basic principle of safety, health and environment is to minimize the number of accidents, health problems and damage to the environment. This pillar plays a great role in the other pillars that addresses workplace organization and discipline, regular inspections and servicing, and standardization of work procedures.

5.7 Office TPM

Companies must map out a clear strategy to respond to this change and dramatically shorten their product time-to-market. At the same time, they must distinguish themselves from their competitors in both quality and cost. These are the most important challenges facing managers today.

Eighty percent of a product's quality and cost is already determined at the development, design, and production stages. Development, design, and all other staff departments must cooperate determinedly to ensure that the production department does not produce useless or wasteful products. Meanwhile, companies must set up manufacturing plants in a way that enables the production department to fill orders on time, at the quality and cost that the development and engineering departments prescribe. This is not the responsibility of the production department alone – it requires a TPM program that embraces the entire company, including the administrative and support departments.

TPM activities in administrative and support departments do not involve production equipment. Rather, these departments increase their productivity by documenting administrative systems and reducing waste and loss. They can help raise production-systems effectiveness by improving every type of organized activity that supports production. Their contributions to the smooth running of the business should be measurable.

VI. BARRIERS IN IMPLEMENTATION OF TPM

TPM implementation though easy on paper, is difficult to achieve and this is mainly due to reluctance by the organization to understand and implement the concepts of TPM and failure to realize the benefits obtained by implementation of TPM. Let us look at the various factors:

6.1] Lack of top management commitment:

TPM programs can be effective if and only if the top management is totally committed and involved. The top management drives TPM. It is the responsibility of the top management to distill the benefits of TPM down the organizational levels.

6.2] Organization resistance to change:

This is a direct off-shoot from the lack of top management commitment. An organization changes if and only if its top management is willing to change.

To adopt a complex ideology, the organization needs to be fearless and should be able to adapt and change as per the environment. In this world of cut-throat competition and globalization, to stay ahead, innovation is the key.

A majority of the organizations once set in a particular path, believes it to be too risky to alter its course and hence finds it difficult to implement TPM.

6.3] Unwillingness to commit resources:

TPM implementation requires investment by the top management in terms of resources (man, materials, money and time).

In majority of the cases, management considers TPM as an unnecessary expenditure and drain on its resources, thereby resisting calls for implementation of the same and finding out ways and means not to allocate budget for its implementation. They fail to see the larger picture and the effect of TPM in improving profits.

TPM implementation takes time and the top management should be willing to show patience in achieving the desired results.

6.4] Work culture:

"Keep the distance" is practiced in many organizations. Boundaries between management and non-management staff impede flow of communication and foster indifference among employees. Departments of the organization. For example – maintenance does not fully trust operations to carry out autonomous maintenance.

6.5] Resistance by employees:

A common comment in Indian organizations is "This is not my job". When the work culture promotes distinction and boundaries, All employees should be involved in the decision making process. The same is true among the various employees view themselves as belonging to the departments in which they work and not to the organization that employ them.

A narrow sense of vision hinders growth of an organization. It is the task of the management to align employees to the organization's vision and goals.

6.6] Long term commitment of management and employees:

Human resource assets are to be treated with care and management should go the extra distance to make them feel at home. Remuneration and employee benefits and facilities should be at par with global levels.

6.7] Manpower costs:

Organizations opt for minimum manpower to cut costs. Manpower recruitment has to be done in line with the requirements the processes demand.

Unfortunately, as TPM implementation is not considered a core requirement, it is not considered when manpower allocation is carried out.

6.8] Non-Involvement of non-management staff:

All organizations in India have unionized staff of appreciable strength. The actual job of running the machines is done by the operators who belong to the workers union.

To get TPM started, management must find time to sit with the union, take them into confidence and convince them about the benefits of TPM. The operators and lower level workers are key constituents of TPM programs. Without their involvement, TPM implementation will definitely fail.

6.9] Lack of a suitable reward mechanism:

TPM implementation is unlike the normal routine activities carried out by the employees of an organization. It is a specialized job demanding specific skill sets.

Employees whole heartedly invest their time and knowledge for a successful implementation and for this reason they should be publicly appreciated by the management for their efforts.

A suitable reward mechanism should be instated to encourage a sense of inclusiveness to the employees.

6.10] Lack of knowledge of TPM:

Many organizations are not able to successfully implement TPM due to insufficient knowledge on TPM. Before announcing and implementing TPM programs, it is imperative that organizations send senior personnel to industries where.

TPM has been successfully implemented to learn the nuts and bolts of TPM implementation. The failure of organizations to successfully institutionalize effective TPM implementation program is due to lack of support system to facilitate learning and transform learning into effective diffusion of the practices of TPM.

6.11] Improper constitution of teams:

Teams are integral to TPM implementation strategy. The "Team" concept on which TPM is based on should involve all departments including engineering, operations and maintenance.

6.12] Attitude towards manufacturing / production process:

This is directly related to work culture in an organization where-in frequent breakdowns are tolerated and not analyzed, processes are inefficient, product quality is not checked and customer feedback not monitored.

Operators have to become involved in routine maintenance and improvement activities that halt accelerated deterioration, control contamination and help prevent equipment problems ***(Suzuki T., 1994)***.

6.13] Repair driven maintenance:

This is an offshoot of attitude towards manufacturing process. In a large number of organizations, instead of carrying out maintenance jobs to avoid failure and repair, focus is on carrying out immediate repair and bringing the machine back on line as fast as possible. The focus should really be on reliability centered maintenance which implies that the function must concentrate on assuring maximum reliability in production equipment and not on quick repair time (***R. Moore, 1997***).

6.14] Maintenance management process:

To implement TPM, management and employees should embrace technology. Maintenance management process should be computerized to have ready access to the schedules and failure analysis reports, which should be uploaded on to the organization's Local Area Network.

Organizations should develop preventive, predictive and corrective maintenance programs to achieve the goal of maintenance prevention.

6.15] Issues in design modification:

There is a general feeling that the design given by the Original Equipment Manufacturer (OEM) is considered sacrosanct.

This need not always be the case. The design would be suited for a particular process but when the process is changed to enhance efficiency and productivity, the original design need to be modified to suit the new requirement.

6.16] Non-availability of Standard Operating Procedures:

SOP is a set of clearly written down instructions that document any activity followed by an organization. They document the way activities are to be performed to facilitate consistent conformance to technical and quality system requirements and assist an organization to maintain quality control and quality assurance processes (***United States Environmental Protection Agency, 2007***).

6.17] Tools and instruments:

Organizations should invest in latest state-of-the-art tools and measuring instruments for faster identification and rectification of problems arising in manufacturing processes. This will help in considerably reducing failures and breakdowns of equipments and machines.

6.18] Holding large inventory:

In order to ensure that processes do not get affected due to unavailability of resources and raw materials, organizations hold enormous inventory leading to large holding and storage costs which adversely affects profits. Production planning should be done in a manner that the raw materials are available just-in-time for the process and a ready customer is available for the products.

VII. COCNCLUSION

The main aims of study of this paper understand TPM methodology and tools of TPM. Implementation of TPM is not overnight. It is day-to-day activity with involvement of all employees. It needs top management commitment.

TPM implementation is not easy. But its payoff is huge. Management has to invest in time, money and resources for a successful implementation. The organization as a whole should be dedicated and committed to TPM. This requires transformation of work culture from ―It's not my job but yours‖ to ―It's our job‖.

There should be free flow of communication and information both horizontally and vertically transcending all levels within an organization. Processes need to standardize and maintenance need to be planned. Routine maintenance activities require to be carried out by operators to allow maintenance personnel to schedule modification and maintenance programs.

Total productive maintenance is one of the best tools for making our industries competitive and effective in the field of maintenance .TPM may be the only thing that stands between success and total failure for some companies.

Total productive maintenance is successfully gives the improvement in the availability, performance efficiency and the quality rate, results in improvement of the overall equipment effectiveness of the equipment.

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