

Equipment maintenance policies from two different perspectives.

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1 Abstract

The evolution of maintenance management has been changing with time starting from the concept of Breakdown maintenance, Preventive maintenance, Condition Based Maintenance, the recent, Total Productive Maintenance (TPM) and Reliability Centered Maintenance (RCM). In today's competitive market, many industries are enhancing their competitive advantage by adopting new operating and maintenance philosophies to reduce their operation and maintenance costs. Maintenance has evolved from a non-issue into an essential strategic element to accomplish business objectives because machine breakdown due to unplanned maintenance will increase the repair cost and

machine downtime. Total Productive Maintenance and Reliability Centered Maintenance have been implemented at different industries to enhance the competitiveness. There are success and failure histories in each of the maintenance systems. The objective of this paper is to review the two approaches of maintenance system, identify the weakness of the systems using literature and propose a solution for improving the maintenance system. Finally it is found that RCM is machine oriented while TPM is management system and human oriented; and by taking some of the elements from both systems, a new approach can be achieved which fills the gap of individual maintenance system.

Key Words: - Maintenance, Reliability Centered Maintenance, Total Productive Maintenance, Failure Mode and Effect Analysis.

2. Introduction

Equipment and machinery maintenance evolved from traditional breakdown maintenance practice to planned preventive maintenance around 1960s and then to condition-based maintenance in 1970s. The relatively recent evolutionary development in maintenance strategies include Reliability-centered Maintenance (RCM) in 1980s and Total Productive Maintenance (TPM) in 1990s. (Rose,2006). During the two last decades of the 20th century, there has been a renewed focus on maintenance, mainly due to the pressures on operating margins and the need for continuously lowering down-times. (Moubray ,1997). Interest in maintenance has shown a rapid increase due to the need for improving effectiveness, safety and environmental compatibility of production systems and services. The maintenance management has undergone a paradigm shift; maintenance is no longer seen as a necessary evil, but as an integral part of the business process that creates value for the organization (Peach et al, 2016). Additionally maintenance people are having to adopt completely new way of thinking and acting as engineers and as managers. According to Prabhakar and Raj (2014), maintenance management strategies have been evolving over time and starting from the concept of breakdown maintenance, varied strategies like Condition Based Maintenance, Total Productive Maintenance (TPM) and Reliability

Centered Maintenance (RCM). Reliability Centered Maintenance was developed over a period of thirty years, one of the principal milestones in its development was a report commissioned by the United States Department of Defense from United Airlines and prepared by Stanley Nowlan and Howard Heap in 1978, the report provided a comprehensive description of the development and application of (RCM) by the civil aviation industry, Mowbray (1997). The main focus of (RCM) is on equipment reliability.

Total productive maintenance (TPM) originated in the assembly line industry, and is focused on improving the quality of people and processes, Suzuki (1992). The trial version of Total Productive Maintenance was used in the Japanese automotive component manufacturer Nippondenso in 1961 by taking only one of the basic pillars which was involvement of all employ, taking some additional years for further improvement and development of TPM. It was implemented in Japan within the automotive industry, particularly within Toyota and their associated component suppliers. Nissan and Mazda soon followed Toyota in implementing TPM in, at least, some of their manufacturing sites, Robinson and Ginder (1995). TPM has been defined by different authors. Lawrence (1999) defines TPM as the general movement on the part of businesses to try to do more with less. TPM is an integrated life-cycle approach to factory maintenance and support (Blanchard, 1997). It is defined also as a program that “addresses equipment maintenance

through a comprehensive productive-maintenance delivery system covering the entire life of the equipment and involving all employees from production and maintenance personnel to top management (McCone, Schroeder et al. (1999, p. 123). The Society of manufacturing Engineers (1995) and Robinson and Ginder (1995), Cooke (2000) mention that TPM is a methodology and philosophy of strategic equipment management focused on the goal of building product quality by maximizing equipment effectiveness. It embraces the concept of continuous improvement and total participation by all employees and by all departments. It is a set of structured activities that can lead to improved management of plant assets when properly performed by individuals and teams to bring change.

3. RCM (Machine Centered) and TPM (System focused)

RCM is a logical approach to quantitatively evaluate and optimize the performance of preventive maintenance tasks and to eliminate non-value adding maintenance actions (Hoseinie et al, (2016). RCM realizes the inherent reliability capabilities of the equipment for which they are designed, and to do so at minimum cost. It provides considerable cost savings due to optimum maintenance effort, increased safety and productivity. Each scheduled-maintenance task in an RCM program is generated for an identifiable and explicit reason. RCM has been applied with sizable success for more than twenty years; first among the air craft industry, and later within the military forces, the nuclear power industry, the offshore oil and gas industry, and many different industries

(Naik et al, (2016). However lifetime Reliability (2007) claim that RCM fails in general industry because inherent problems in the business design of most organizations are prevented in the airline industry with business processes imposed by legal regulation. The aircraft industry does RCM differently to other industries. Similarly several industries face difficulties and fail to implement RCM because of managerial obstacles (Backland, 2003). In this context there are success and failure history on different industry depends on the internal factors of the company. RCM is fully successful in Aviation and Nuclear industry because it is supported by strong organizational regulations. There is thus an indication that RCM needs additional management effort for its success.

Reliability-Centered Maintenance (RCM) is the optimum mix of reactive, time or interval-based, condition-based, and proactive maintenance strategies (Afefy, 2010). A study by International Atomic Energy Agency in 2008 indicated that RCM is a decision making tool. Therefore operations and maintenance programmers can benefit both the processes involved in the decision-making benefits and the outcomes that result in the changes to maintenance and operations programmers, such as, the act of performing the RCM decision-making process provides a benefit in promoting better co-operation among all of those involved in the process. The process demands that all established tasks are challenged with the objective of justifying continued use or removing/replacing them with other tasks, in doing so it promotes a healthy questioning attitude and the

process raises awareness of the functions of the systems involved, the consequences of failure of those functions and the economics of operating and maintaining them.

These principal maintenance strategies, rather than being applied independently, are integrated to take advantage of their respective strengths in order to maximize facility and equipment reliability while minimizing life-cycle costs. The main focus of RCM is on the system functions, and not on the system hardware. (Rausand, 1998) Its main objective is to reduce the maintenance cost by focusing on the most important functions of the system by avoiding or removing maintenance actions that are not strictly necessary. RCM is a systematic approach to determine the maintenance requirements of plant and equipment in its operating condition (Dexey, 1993). An RCM analysis basically provides answers to the following seven questions (Rausand, 1998, Moubray, 1997)

1. What are the functions and associated performance standards of the equipment in its present operating context?
2. In what ways does it fail to fulfill its functions?
3. What is the cause of each functional failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What can be done to prevent each failure?

7. What should be done if a suitable preventive task cannot be found?

The above seven questions can be summarized in five steps, i.e., function, functional failure, failure mode, failure effects and failure consequences (Naik et al, 2016); Moubray,1997).

Function: - a state of performance level, a machine or a system , at which it continues to do whatever its users want to do. The first step of the RCM analysis is to define the function of each chosen system. It is also important to determine the failure and maintenance strategy of machinery and equipment.

Functional failure: - occurs when the system is unable to fulfill its function to an acceptable level of performance set by the user. This includes both potential and functional failure.

Failure mode:- is related to any event which causes a functional failure. It is the analysis process to identify all kinds of reasonable causes that can cause or make a functional failure happen.

Failure effects:- it describes what happens when each failure mode occurs. This step is in close relationship with the next step and it should support the analyst in what way failure affects safety or the environment, production or operations and physical damage.

Failure Consequences: - RCM processes have four categories of failure consequences:

- Safety and environmental consequences
- Operational consequences.
- Hidden failure consequences.
- Non-operational consequences.

Preventive, Proactive and Reactive Strategy are integrated optimally in RCM, together with their respective advantages, in order to achieve the highest level of reliability in the equipment and thus that in the components of the whole facility. In addition, it reduces the cost of the equipment's lifecycle, by reducing the amount spent on unnecessary maintenance programs. The main aim of the RCM method is to enhance the reliability of the physical asset by identifying the failure modes of the items and components of a system, and ranking the consequence of each failure mode. Preventive action is then performed if the consequences of failure are safety related or hidden to the operators.

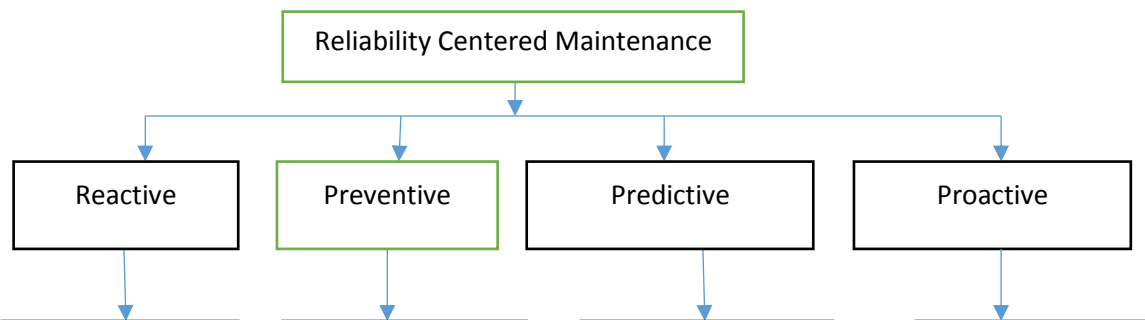


Figure-1, RCM Components: source (Afefy, 2010); Albarkoly, and Park, 2015)

The implementation of RCM starts with defining the function of the equipment and its performance standard. The different functional failure, failure mode, failure effect, failure consequence through a failure management policy selection method can be addressed with a Failure Mode , Effect and Critical Analysis (FMECA). The consequences of each failure possibility can be evaluated, and the failures are then classified according to the severity of their consequences. Then for all significant items, those whose failure involves operating safety or has major economic consequences are evaluated according to specific criteria of applicability and effectiveness of the proposed tasks. The resulting scheduled-maintenance program thus includes all the tasks necessary to

protect safety and operating reliability that will accomplish this objective, Prabhakar & Raj (2015). All the concerns starting from the beginning up to the end of the process focus on the machinery only that miss other management elements. Failure mode and effect critical analysis will be done for component, aggregate, assembly system and plant based on the priority of the critical elements.

4. Comparison of TPM and RCM.

In case of Total productive maintenance, in an effort to increase industrial competitiveness, companies use an improvement systems such as Just-in-Time (JIT) and Total Quality Management (TQM). However, advantages from these programs have often been limited because of unreliable or inflexible equipment (Mckone, 1999), the name ‘total productive maintenance’ (TPM) was adopted for Total quality management approach. The focus of TPM is to develop quality maintenance workers and adopt a zero defect, zero loss, and zero failure approach towards maintenance management. TPM is often viewed as a people-centered approach to maintenance, and is therefore an approach or philosophy for all workers in the business enterprise, and in this case prioritization of criticality of equipment and machinery is not strong as that of RCM (Mungani & Visser, 2013). A main feature of TPM is to eliminate all

machine losses to maximize overall equipment effectiveness (OEE). Another main feature is the use of small work groups to investigate and solve recurring problems and failures in the plant. The role of total productive maintenance implementation in any organization involves to maximize overall equipment effectiveness; establish a thorough system of preventive maintenance for the equipment's entire life span; implement TPM by involving all departments (e.g. Engineering, operations, maintenance); also involve every single employee, from top management to workers on the floor and finally promote TPM through motivational management (autonomous small group activities) (Ngaich et al, 2015). TPM implementation procedure follows effective Japanese principles such as eliminating the six big losses, reaching zero defects, developing autonomous maintenance, promoting small group activities under the eight pillars shown in Figure 2.

Most of the pillars focus on creating a paradigm shift on working culture and organizational behaviors from departmental thinking (production, maintenance and quality control) to an integral entity that works in harmony, responsibly and cooperatively. Such approach improves the awareness of each employee about failures and about what to do to prevent them.

TPM is expressed by its pillars (Singh et al, 2013); Ngaich et al, 2015); Hafiz et al, 2012)

Pillar1. 5 S:-5S is the foundation stone of TPM implementation. It is a Japanese way of housekeeping. Problems cannot be recognized if the work place is unorganized. Cleaning and organizing the workplace helps us to pop up the problems. Making problems visible being seen to the people gives an opportunity of improvement. Meaning of each 'S'

Sort (eliminate anything that is not truly needed in the work area)

Set in Order (organize the remaining items)

Shine (clean and inspect the work area)

Standardize (create standards for performing the above three activities)

Sustain (ensure the standards are regularly applied). If this 5S is not taken up seriously, then it leads to 5D i.e. Delays, Defects, Dissatisfied customers, Declining profits and Demoralized employees.

Pillar2. Autonomous Maintenance: Operators are given training by engineers on shop floor in charge in daily maintenance. The operators are responsible to upkeep their equipment on daily basis to prevent it from deteriorating. The maintenance activities performed by operators are simple nature like cleaning, lubricating, visual inspection, tightening of loosened bolts and so on. Maintenance department will be responsible to give training for the operators and to solve complex maintenance problems.

Pillar3. Planned Maintenance:- it is aimed to have trouble free machines and equipment producing defect free products for total customer satisfaction. It can be used either of the maintenance strategy

Pillar4. KAIZEN “Kai” means change, and “Zen” means good (for the better). Basically kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. The principle behind is that "a very large number of small improvements are more effective in an organizational environment than a few improvements of large value. This pillar is aimed at reducing losses in the workplace.

Pillar5. Quality Maintenance: It is geared towards achieving customer satisfaction through delivery of highest quality product, through focused process improvement by eliminating any defects after identifying the parameter of machine which affects the product quality.

Pillar6. Training: - Education is given to operators to upgrade their skill. It is not enough to know only “Know-How”, they should also learn “Know why”. Continuous improvement is possible only through continuous improvement in knowledge and skill of the people at different levels. The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phases of skills are: Phase 1: Do not know, Phase 2: Know the theory but cannot do, Phase 3: Can do but cannot teach, Phase 4: Can do and also teach.

Pillar7 Office TPM: Office TPM improves synergy between various business functions, remove procedural hassles by focusing on addressing cost-related issues as well applying 5S in office and working areas.

Pillar8 - Safety, Health and Environment: it is about creating a safe workplace and a surrounding area that is not damaged by the process or procedures. This pillar will play an active role in each of the other pillars on a regular basis. The targets of this pillar are:-zero accident, zero health damage and zero fires.

As far as technical subject is concerned, TPM leverages on the ability of expert maintainers and technicians to train low level maintainers and even operators, especially through one points lessons, in such situation, the level of responsibility on maintenance can create conflict unless it is clearly specified for both departments.

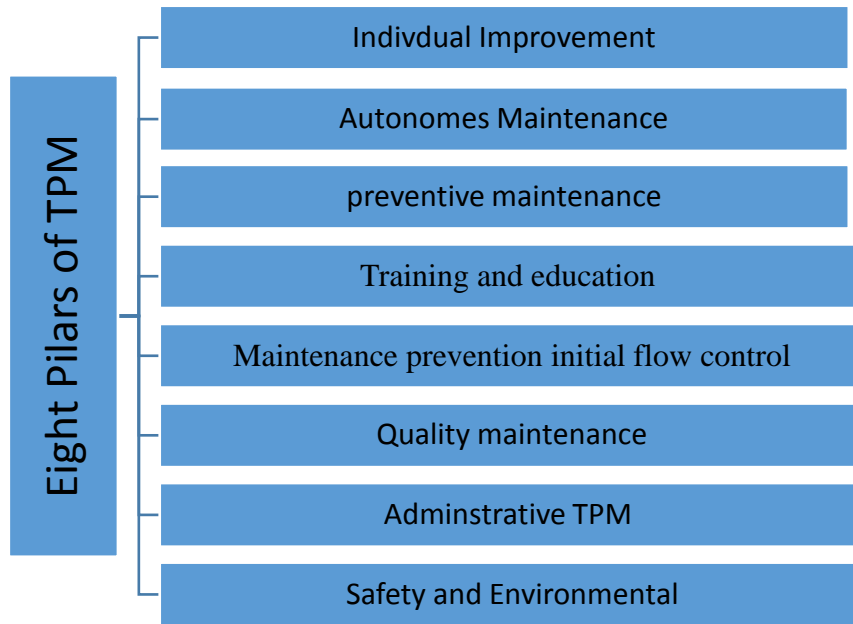


Figure 2, the eight pillars of total productive Maintenance

It is important to see some of the pillars to take care of small maintenance tasks and eliminate the defects at source through active employee participation, such as daily inspection, lubrication, minor repair, parts replacement, trouble shooting and accuracy checks to prevent it from deterioration. The other pillar is education and training providing and developing multi skilling employees whose morale is high and who are eager to come to work and perform all required functions effectively and independently. Employees will be trained to address the problems by finding the root cause and eliminating them. Similarly the other pillars focus on changing the management system, organizational behavior and changing the working culture of the organization.

Table 1. Basic differences of TPM and RCM.

Parameters	TPM	RCM
Main Value	Cultural change	Failure Prevention
Focus of Implementation	Planning for different Condition.	Coverage of all possible failure modes.
Program Initiation	Top management announcement ,launch training program	Assembling team training
Program support	Creation of organizational support structure, policies and activities	Post training implementation can begin immediately
Presumed existing system	Planned Preventive maintenance	Preventive Maintenance based on FMECA
Process Changes	Autonomous maintenance by training operators.	No change to the maintenance process ,plan generation based on RCM outcome
Maintenance Activity	Preventive maintenance operator level monitoring.	Predictive ,Preventive where predictive does not work and design change where both fail
Performance Measurement	Overall Equipment effectiveness	Mean Time Between Failures (MTBF).

The other key difference between RCM and TPM is that RCM is promoted as a maintenance improvement strategy whereas TPM recognizes that the maintenance function alone cannot improve reliability. There are other important factors such as experience of operator, basic equipment conditions, skill and handling of operators, and adverse equipment loading due change in processes. All have contribution to the states of reliability of machineries. Without the involvement of all the workers in the organization, the need to eliminate or reduce all losses and to focus in defect avoidance or early defect identification and elimination of failure will never be cost effective. RCM is dependent on the results of failure mode, effect and critical analysis that prioritize the effect and consequence of failure of a system or a component.

5. Conclusion

RCM and TPM are the recent equipment maintenance philosophies. They have been contributing a lot for the improvement of production system at different industries, to improve productivity, quality and competitiveness by enhancing availability and reliability of machineries and equipments with the optimum cost. However, RCM is mostly dominant in nuclear station and Aviation industries (Naik et al,2016). RCM provides the

optimal maintenance program with the least maintenance costs for low operational risk and high equipment reliability. It is recognized it fails to work often in general industry. It is necessary to explore what happens in general industries that are not present in the airline industry and nuclear stations. The advantage of this method is determination of the interval of potential failure (starting point failure) and the functional failure (final failure) that includes determination of the states (maximum and tolerable) performance standard of each aggregate and component needs decision. The aviation industry and nuclear stations have a strong failure mode effect analysis because the safety and environmental failure consequences. The other drawback when compared to TPM is that RCM is the focus on equipment prevention, protection and inspection through failure mode and effect analysis. Such inclination has negative impact on the other elements such as skill of operator and technicians, organizational culture and maintenance management system.

TPM unlike RCM all the pillars focus on human and organizational elements such as organizational culture, skill and knowledge and skill of operators and maintenance management system, priority of maintenance for aggregates and equipment is not clear as that of RCM. Even though the two policies have different perspectives and approaches their overall object is to achieve reliability and availability of industrial machine as well as the production system at reasonable cost and resources. The

reliability and availability factors are directly related to competitiveness, product quality, and productivity of an organization.

Integrating the two policies (RCM and TPM) can create a balanced System which can fill the gaps of each other, taking some of the pillars from TPM and harmonizing with elements of RCM. For Example, failure mode and effect analysis can be taken as alternative way to avail the drawbacks TPM in order to prioritize the criticality of the system and components. In RCM continues improvement and involvement of all workers are missed and TPM is human focused. Thus the two approaches, human focused (TPM) and machine focused (RCM) can be taken as complementary systems to increase the effectiveness and efficiency of maintenance system.

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