Selecting Best Maintenance Policy for Getting Quality Products with Least Cost

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***Abstract* - For any company the main aim is to produce the quality products with lowest possible cost. Nowadays companies are recognizing the importance of maintenance. But still a lot more improvement is necessary in maintenance area. Most of the companies are still thinking maintenance as a separate additional department. This paper outlines different maintenance policies with their benefits and limitations. It also defines the relationship between maintenance and quality by emphasizing the importance of Condition Based Maintenance (CBM) and e-maintenance. This paper also elaborates how Total Productive maintenance (TPM) changes the company culture. It also explains how Overall Equipment Effectiveness (OEE) is used to calculate machine performance efficiency.**

***Index Terms* - Maintenance, TPM , OEE , CBM , product , quality , customer , cost**

I. INTRODUCTION

Nowadays there is increasing awareness about maintenance. Companies are now understand that if they want to achieve their production goal then their machines with full working condition should be available throughout the production. So the relationship between production and maintenance has been acknowledged by industry. But still there is not much awareness about the relationship between quality and maintenance. Only availability of machines doesn't mean that all the finished goods will have good quality. This paper explains how the maintenance helps to get quality products. Quality means Fitness for purpose. It can also be defined as manufacturing the products which can satisfy the functional requirement of that part. To get good quality product, well maintained machines should be available throughout the production. Depending upon the company's strategy, company selects the best maintenance policy which satisfies their requirement. Before selecting maintenance policy, company should take into account all the parameters related with the maintenance, their goals. Sometimes maintenance strategy is selected only by considering cost factor. Most of the times this strategy proved wrong by getting heavy losses in production at the end.

II. MAINTENANCE POLICIES

Typically there are four maintenance policies. These are as follows [1]:

- Breakdown (Reactive) maintenance
- Preventive Maintenance
- Predictive Maintenance
- Proactive Maintenance

Breakdown (Reactive) maintenance

This policy is based on the principle 'Run the equipment till it breaks". This is the traditional policy. Here there is no specific maintenance approach. When the equipment fails, maintenance person repairs the equipment. The only benefit of this policy is it doesn't have initial cost. But the disadvantages are plenty. If any equipment of the production line fails then whole production line stops which is a very heavy loss to the company. Till the repair of that equipment labors sit idle which is another loss to the company. Also company has to store spare parts inventory irrespective of their requirement. So another disadvantage is having high inventory cost[1].

Preventive Maintenance

As compared to reactive maintenance, Preventive maintenance policy is much better policy. It is based on periodic inspection of the machines. It is done on regular basis. The major advantage of this policy is periodic inspection of the machines helps to prevent future breakdown or it will remove the causes of future breakdown. Most of the Indian industries are using preventive maintenance policy. The major drawback of this policy is that preventive maintenance is done irrespective of the condition of the machine. e.g. If the condition of machine is good (It means that there is no need of doing maintenance) , still maintenance will be carried out as per the schedule. By doing unnecessary maintenance it will reduce the valuable production time[1].

Condition-Based Maintenance [CBM]

CBM can be defined as "Maintenance carried out in response to a significant deterioration in a unit as indicated by a change in a monitored parameter of the unit condition or performance, is called condition based maintenance" [5]. One of the major differences between CBM and Preventive maintenance is that former takes into account the condition of machine while latter will not take into account the condition of machine. So CBM will decide whether the machine requires the maintenance or not depending upon the machine condition. Vibration-based CBM is the most usual example of CBM. First it identifies the important parameter for machine monitoring. After that it defines specific limit for that parameter. That limit is used for prediction of future life of the machine. If the parameter value crosses that limit then it means machine degradation starts. So maintenance person will come and carry out the maintenance. Although initial cost of implementing CBM is more costly as compared to preventive maintenance. But once it is implemented then benefits of CBM are much greater than preventive maintenance.

Proactive Maintenance

It is also called **as root-cause failure analysis**. One of the major drawbacks of preventive maintenance as well as CBM is that it will not go to the root cause of failure so after some time again that failure occurs. Even if preventive and predictive maintenance remove the failures but these repetitive failures (or causes of failures) results in degradation of machine performance. Also these repetitive failures reduce machine life. Proactive maintenance takes care of the machine life by removing the root causes. Once the root cause is removed then these failures will not happen again. Every industry should go for proactive maintenance. But to implement proactive maintenance, maintenance person should have complete knowledge about the machines. So that he can easily identify the root causes [1].

III. RELIABILITY CENTERED MAINTENANCE (RCM)

RCM main objective is to increase the life of equipment by improving the reliability. It can be defined as a process used to determine the maintenance requirements of any physical asset in its operating context It uses a failure mode theory. In the equipment all the parts are not equally important. Some parts are more critical (important) than other parts. RCM concentrates on these parts and analyzes the risk associated with them by using failure mode theory[2].

Components of RCM

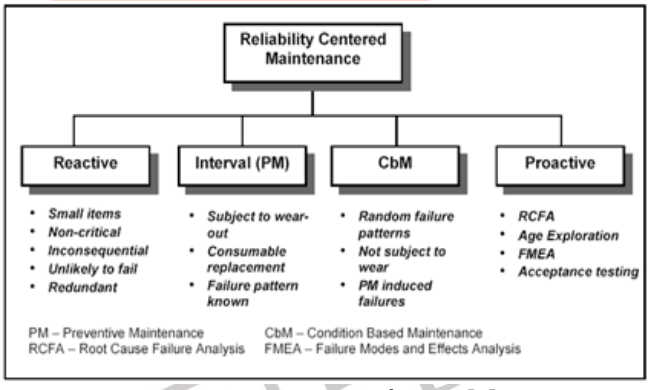

Fig. 1 Components of RCM [2]

As explained earlier for non critical parts RCM uses reactive maintenance policy. Failure of these non critical parts will not prevent the machines to perform effectively. RCM also uses Preventive maintenance policy for the parts whose failure pattern is already known to the maintenance person. It means he knows the life span of that part so after the specific period maintenance person changes the parts. For more critical parts, RCM uses Condition Based Maintenance. It uses sensors and communication technology to monitor the parts. Once the parts performance deviates from expected performance it gives signal to maintenance person for necessary maintenance. RCM uses Failure Mode Effect Analysis (FMEA) theory for very critical parts. Based on the outcome of FMEA, it will decide whether maintenance is required on that part or not [2].

Procedure for RCM

1. Select important parts: Before applying to RCM, first find out what are the important parts of the equipment. Select all these parts.
2. Identify functions: After finding the important parts of the equipment. Then find out what are the functions these parts have to do. What type of performance is expected from these parts? Is there any difference between actual performance and anticipated performance?[1]

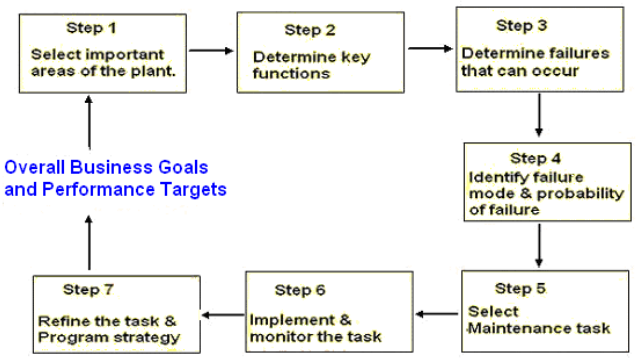

Fig.2. RCM Procedure [1]

3. Functional failures: Defect or failure always prevents part to perform effectively. A functional failure is the inability of any asset to fulfill a function to a standard of performance which is acceptable to the user. Analyze the causes for these failures and whether these causes are related to each other or not. In which circumstances these failures occur. Go to the root cause of the problem.
4. Identify failure mode and probability of failure: A Failure mode is any event which is likely to cause an asset to fail. Maintenance manager should find out the events which causes the failure. Record all these events. Check whether these events are already happened before or they are the new ones. What is the most likely reason for this failure? How many times these failures occurred before in other words what is the probability of failure?
5. Selection of the maintenance task: This is the important step. Here the maintenance task is selected to prevent the failure. But before selecting maintenance task, prepare the priority list of the task. Which part of the equipment will get first maintenance priority? What type of maintenance policy has to be used? All these work is done in this step.[1]
6. Implement and monitor the task: Here selected maintenance policy is implemented. But implementation doesn't mean the completion of work. Sometimes selected maintenance policy doesn't work or give full benefits. For this it is always useful to monitor the progress.
7. Refine the task and program strategy: This is the last step. Here all the evaluation of task is done. Then the progress report is made. If the selected maintenance policy gives the anticipated benefits then RCM may use this policy for future work or otherwise may select another policy in case of getting more benefits.

Benefits of the RCM

- The main purpose of the RCM is to give an optimum maintenance program to the equipment. This helps to maximize equipments availability. It helps to increase the life of the equipment.
- Each maintenance policy has its own advantages and disadvantages. RCM uses the suitable maintenance policy for each task. It helps to give effective maintenance programs.
- RCM minimizes the cost by avoiding unscheduled maintenance and break down of machines, avoiding unnecessary inventory etc.
- As RCM clearly focuses on every activity related to the maintenance so it helps to ensure that time, money spent on these activities are used to its maximum efficiency.
- RCM focuses maintenance activities on critical parts of the equipment so it avoids unnecessary maintenance inspection on other less important part.

IV. TOTAL PRODUCTIVE MAINTENANCE (TPM)

TPM stands for Total Productive Maintenance. It is originated from Japan. TPM is an approach to equipment management. Equipment management is the set of activities that prevents quality defects and breakdowns, eliminates the need for equipment adjustments, and makes the work easier and safer for equipment operators. The word '**Total**' means involvement of all the employees of the company. '**Productive**' means how to increase the production efficiency. '**Maintenance**' shows that production efficiency increases by well-maintained machines [1].

Necessity of TPM

Every company has different departments such as production, research and development, maintenance etc. Even though these departments works with their full efficiency still sometimes companies fails to achieve the anticipated production efficiency or product quality because of the lack of the coordination between different departments. But TPM removes this drawback[1]

One of the most important things in TPM implementation is commitment required from all levels of organization. Without this TPM cannot give anticipated benefits to the company. It is necessary to change the mindset of workers towards the TPM concept. Earlier it was assumed that maintenance (production) department has the whole responsibility for implementation of TPM. But it is not true. Everyone in the organization has to attend the TPM meetings. Top management should actively participate in the implementation of TPM. They should give their views towards implementation of TPM. They should actively participate in systematic planning of TPM. Supervisors and shop floor operators should be aware of the importance of TPM because, they are the

main people who are responsible for success of TPM. In TPM most importance is given on continuous improvement. For this it is necessary to regularly check the plan and procedure. It is the duty of supervisor to check whether all the things are going according to the plan or is there any need to change the plan.

The main objective of TPM is to achieve zero defects and zero breakdown, increase the production efficiency and quality. Often there is confusion between TPM and TQM. Although there are some similarities between these two but there are some major differences. Commitment of all the employees and long term planning are the similarities between these two. But the main difference is, in TQM all the importance is given to quality and in TPM most focus is given on equipment maintenance and its relation to the production efficiency and quality.

TPM Pillars

Autonomous maintenance: The main idea of this is to train the new inexperienced operators so that they can do small maintenance work and give free time to maintenance worker to do more valuable task. For this experienced worker has to set policy how they will train the operators.

Kaizen: The word Kaizen is split up into "KAI" means change and "ZEN" means good. Kaizen stands for continuous improvement. With kaizen every employee is motivated for improvement. For this employee should have an aim such as Zero breakdown, Zero defects etc [3].

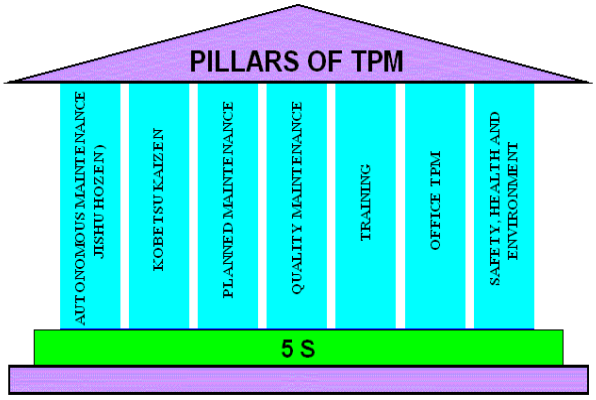

Fig.3. TPM Pillars [3]

Planned Maintenance: Here the main emphasis is given on proactive maintenance. Employee has to work on some important issues such as how to achieve proactive maintenance, how to reduce inventory etc.

Quality Maintenance: One of the TPM goals is to improve the product quality. Employee has to prepare a plan and criteria for improving the quality. Each product should be then checked by these criteria.

Training: Each new worker must get sufficient training for TPM. Training always helps to do the work faster and correctly.

Office TPM: There should be a committee having one person from each department. The main functions of this committee are to increase awareness of TPM into the employees, setting the goals of TPM etc.

Safety, Health and Environment: - Care should be taken for safety of the employees. Employee should have aim of zero accidents it will help to improve the safety of worker. Environment in the company must be healthy so that every employee can work with his maximum efficiency. Management must always give the importance with regard to the environment of the company [3].

TPM Benefits

If TPM is implemented in a right way then company can get great benefits in every work area, such as:

- TPM helps to reduce the defects related to machinery. Also well-maintained machines help to increase the productivity efficiency.
- Better coordination: - As TPM gives more emphasis on team work. It helps to improve the coordination of the workers.
- As TPM has aims like zero defects, zero breakdown it results in continuous improvement.
- TPM has the goal of overall equipment effectiveness. It increases the awareness about the machinery related aspects.

V. OVERALL EQUIPMENT EFFECTIVENESS (OEE)

One of the major tools TPM uses is the Overall Equipment Effectiveness (OEE). It takes into account different manufacturing process and analyzes the data received from these manufacturing processes. OEE gives the result in terms of percentage (%). OEE result is useful for understanding machine performance efficiency.[4]

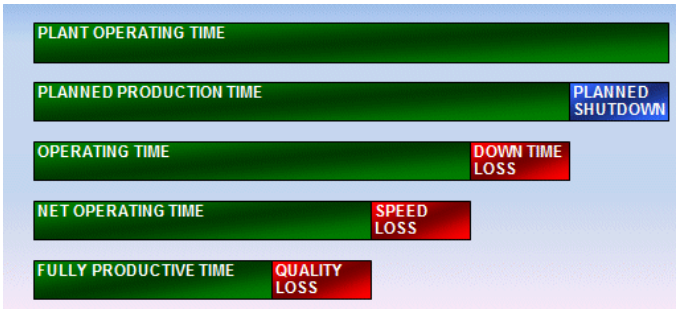

Fig.4. Overall Equipment Effectiveness (OEE) [6]

OEE = Availability x Performance x Quality

Availability: Every machine is expected to run throughout the shift but most of the time machine didn't run throughout the production because of sudden breakdown, setup adjustments etc. Availability rate takes into account machine failures, downtime losses. So availability rate is calculated below:

Availability Rate = Operating Time –Downtime/Total Operating Time

Performance rate: It uses all factors that cause the production rate to operate at less than the maximum possible speed when running. It is calculated as the ratio of Net Operating Time to Operating Time. In practice, it is calculated as:

(Ideal Cycle Time x Total Pieces) / Operating Time

Ideal Cycle Time is the theoretical fastest possible time to manufacture one piece. Therefore, when it is multiplied by Total Pieces the result is Net Operating Time – the theoretical fastest possible time to manufacture the total quantity of pieces.

Quality: Most of the times 100% quality products cannot be manufactured because of sudden machine breakdown , faulty machines. Quality considers this as **Quality Loss.** It separates out defective (rejected) pieces including pieces that require rework from good pieces. It is calculated as the ratio of Fully Productive Time (fastest possible time for Good Pieces) to Net Operating Time (fastest possible time for Total Pieces). It is calculated as: ***Good Pieces / Total Pieces***

OEE Benchmarks: Generally company should know the standard OEE score so that if their OEE score is less than the standard score then company can take corrective action to get the standard score.

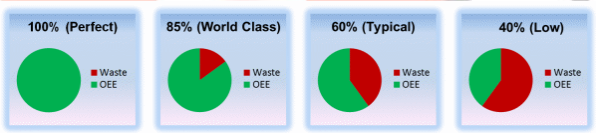

Fig.5. Overall Equipment Effectiveness (OEE) Benchmark [6]

- An OEE score of 100% is perfect production: manufacturing only good parts, as fast as possible, with no down time.
- An OEE score of 85% is considered world class for discrete manufacturers. For many companies, it is a suitable long-term goal.
- An OEE score of 60% is fairly typical for discrete manufacturers, but it also indicates there is substantial room for improvement.
- An OEE score of 40% is a low score and in most cases can be easily improved by doing the analysis.

How to improve OEE?

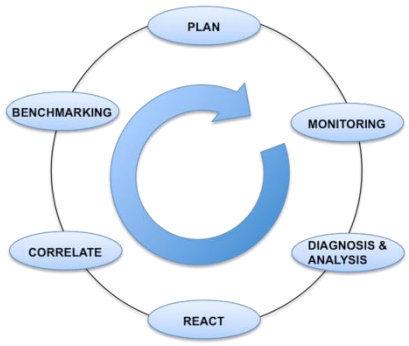

Fig.6. OEE improvement cycle. [4]

If company's OEE score is less than the expected score then company has to set the procedure to improve the OEE score.

- Plan : Find out the important machinnery , their part for analysis.
- Monitor : Use the advanced technology (CBM , E-maintenance) to monitor the performamce of these machineries. The main goal is to reduce the breakdown of these machines.

- Diagnosis and analysis : Data received from sensors should be used for analysis purpose. Proper analysis will give the root cause of the problems (losses).
- React : Once maintenance person identifies the root cause then he will take the corrective action against it. Implement this corrective action.
- Benchmarking : After implementation of the corrrective action again OEE score has to be calculate and compared against the benchmark score. If the actual score deviates from benchmark score then repeat the above cycle [4].

Benefits of OE

OEE results help to understand heavy losses. Once maintenance person analyses the root causes of these heavy losses then it will be easy to take corrective actions against them so that they will not occur in the future. Below are some of the heavy losses on which maintenance person has to work:

- **Breakdown:** First find out the breakdown frequency. Then find out the reasons behind these breakdowns. Eliminating breakdown is critical for improving OEE. Without eliminating breakdown, other OEE factors cannot be improved.
- **Set-up and adjustments:** Find out set up time required for every machine. Do the brainstorming on how to reduce the set up time. The most common approach to reduce this time is the Single Minute Exchange of Dies program (SMED) [4].
- **Minor stoppages and reduced speed:** Cycle time analysis is used to overcome these losses. The manufacturing process (automated) are very fast and it will not give sufficient time for manual data recording so cycle time analysis should use automated data recording. Once we compare actual cycle time with theoretical cycle time then we will understand the reason for deviation of actual cycle time from theoretical cycle time. Maintenance person has to work on the reasons which cause deviation.
- **Quality losses and reduced yield:** For every organization **'zero – defect'** must be the aim. Any rejected products are considered as quality loss. It also includes the repair products as company needs to spend additional resources (Men, Machine & Material etc.) for repairing these products. Six Sigma is effective tool for reducing rejection as its aim is 3.4 defects per million opportunities.

VI. CONCLUSION

The above paper describes different maintenance policies with their benefits and limitations. For every company the main goal is to produce the parts with zero rejection and with least cost. To achieve this first maintenance and quality relationship should be understood. Well maintained machine always helps to get quality products. Root causes of the breakdowns should be removed completely so that aim of zero breakdown can be achieved. OEE is one of the important tool for the company to measure the performamce efficiency of their machines. Nowadays CBM is the most effective maintenance policy which helps company to reduce breakdowns. Although initial cost of implementing CBM is high but after implementation of CBM, company can get huge benefits. TPM is also good maintenance policy but insufficient training , no motivation of the workers and lack of management support are the biggest obstacles for implementation of TPM.

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