

A Case Study on Total Productive Maintenance in Rolling Mill

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Abstract - TPM is a technique which helps us in maintaining and improving production system through machine, process, and employee which add a positive value to the organization. TPM has been developed to meet the new maintenance needs by keeping the equipment in top condition so as to avoid breakdown and delay in production. This paper focusing on calculating the overall equipment effectiveness in Rolling Mill, and it also discuss what called the big six losses in any industry (the quality, availability and speed). A case study has been taken in the rolling mill and the main objective of this is to study the manufacturing process and the problem occurs during the production process which causes stoppage. The data taken along fifteen working days. After calculating the OEE of the company a result company achieved 93.48% in quality factor of overall equipment effectiveness equation and 70.90% in availability where in performance it got 90.03% and the result is compared with the World class OEE. Suggestion is given to company so as to improve their maintenance procedures and improve the productivity.

Keywords - Types of Maintenance, Six Big Losses, TPM Pillar, Implementations steps, Benefits of TPM, Case study.

I. INTRODUCTION

In modern day manufacturing and service industries, improved quality of products and services increasingly depend upon the features and conditions of the organization's equipment and facility. In order to survive every industry has to strive for improving productivity in all spheres of activities. Hence it is logical to utilize the resources like machinery, men, and material as optimally as possible. Maintenance of facilities and equipment in good working condition is essential to achieve specified level of quality and reliability and efficient working. Plant maintenance is an important service function of an efficient production system. It helps in maintaining and increasing the operational efficiency of plant facilities and thus contributes to revenue by reducing the operating costs and increasing the effectiveness of production. TPM has been proven to be successful for helping to increase the productivity and overall equipment effectiveness. The concepts of TPM has been introduced and developed by Japanese in 1971. TPM is all about Total plant Maintenance. The Underlying concepts are, if you properly maintain plant machinery there will see a sharp decline in machine breakdowns, safety and quality problems. There is emerging need of TPM implementation in the Indian industry and need to develop TPM Implementation practice and procedures. TPM should promote better team working in the workplace, as the operator will be helping the maintenance team with their task. The aim of the TPM is to bring together management, supervisors and trade union members to take rapid remedial action as and when required. Hence, tpm can be considered as the medical science of machines.

Need of TPM in the contemporary Manufacturing scenario

The following aspects necessitate implementing TPM in the contemporary manufacturing scenario;

- To become world class, satisfy global customers and achieve sustained organizational growth.
- To improve productivity and quality.
- To improve organizations works culture and mindset.
- To make the job simple and safer.
- Need to change and remain competitive.
- Need to critically monitor and regulate work-in-process of manufacturing process.
- Regulating inventory levels and production lead-times for realizing optimal equipment available time.
- Ensuring more effective use of human resource through adequate training and multi-skilling.
- Refining preventive and predictive maintenance activities.

II. LITERATURE REVIEW

Kathleen E. McKone et al. [1] In this paper the author investigate the relationship between TPM and manufacturing performance through structural Equation Modeling (SEM). Manu Dogra et al. [2] In this paper the author discuss the detail implementation of TPM in the cold rolling mill. Harsha G. Hegde et al.[3] The paper reports a case study for improving OEE with the help of TPM and 5s technique using a systematic approach .The result obtained from the TPM approach showed that the OEE was improved from 43% to 72% which indicate the desired level. Ranteshwar Singh et al. [4] In this paper the author implemented a TPM strategy in the machine shop having a CNC turning of different capacity and eliminate the losses, improve the utilization of CNC Machine. OEE is used to measure success of TPM implementation. Jihnsaha P Acharya et al.[5] in this paper the author present the literature review of TPM and is used to solve the manufacturing problem, this paper also explain the overview of TPM pillar. Nitish Mundhada et al.[6] In this the researcher uses a lean which aim is to diagnosing the production process , removing/reducing process waste , cleaning the production environment , improving plant layout and organization workstation by

using a 5s. Sarang Katkamwar et al.[7] In this the author study and overview of TPM implementation in Indian spinning Industries and uses a JH-check sheet, PM-Check Sheet, OPL in order to improve the OEE and proper implementation of TPM. Ajit pal singh , Melesse Wakajiran et al.[8] this the author focus on significant contribution of TPM implementation process and also focus on the TPM pillar for success and also it carried out a case study in power plant industry to find out the OEE before and after TPM and is compared with world standards. Prof. pradeep Kumar et al.[9] In this a researcher uses a TPM technique which aimed at maximizing the effectiveness of facility and also carried out a successful implementation of work literature reviews was done and carried a study at printing press machine and packaging based on real time data and analysis was done to obtain achievable results and calculate OEE and solve problem to increases OEE. G . Ananth, DR. B.K Vinayagam et al.[10] In this researcher aim is to maximize the availability and Overall Equipment effectiveness of the steam power and thermal efficiency of a plant by implementing of TPM. Mr. ranjeet M. Jadhav et al.[11] In this the researcher study the implementation of TPM program in an Indian history using JH Check sheet , PM Check sheet , OPL for proper implementation of the TPM and after implementing both direct and indirect benefits are shown. Osama Taisir R. Almeanazel et al.[12] In this a team is formed to find out the benefits of formation of a team from different dept. To eliminate any boundaries between a dept. and make maintenance process more effectively and also adopt the autonomous maintenance and also suggest to implement TPM to improve their maintenance procedure and productivity after calculation of the OEE. I.P.S Ahuja et al.[13] The purpose of this paper is to review the literature on TPM implementation practices adopted by the manufacturing organization. It also focus seeks to success factors for eliminating barrier in successful TPM implementation.

Types of Maintenance

1. **Planned Maintenance** - It is an organized maintenance work carried out as per recorded procedures having control.
2. **Breakdown Maintenance** - It is an emergency based policy in which the plant or equipment is operated until it fails and then it is brought back into running condition by repair. The maintenance staffs locate any mechanical, electrical or any other fault to correct it immediately.
3. **Corrective Maintenance** - This is an organized maintenance work intended to restore a failed unit. It includes different types of action like typical adjustments to redesign of equipments. It is a one time job and each corrective maintenance activity undertaken should be completed fully. Each corrective maintenance job may differ from the other. The emphasis in corrective maintenance is on obtaining full information of all breakdowns and their causes. Efforts are made to identify and eliminate the cause by activities such as improving maintenance practices, changing frequency of maintenances services and improving process control procedures.
4. **Opportunistic Maintenance** - When an equipment or system is taken down for maintenance of one or few worn parts, the opportunity can be utilized for changing/ maintaining other parts which are wearing out even though they have not yet failed.
5. **Routine maintenance** - It is a simplest form of planned maintenance, which is very essential. Routine maintenance means carrying out minor maintenance jobs at regular intervals. It involves minor jobs such as cleaning, lubrication, inspection and minor adjustment.
6. **Preventive Maintenance** - Preventive maintenance is a planned maintenance of plants and equipments in order to prevent or minimize the breakdown.
7. **Predictive Maintenance** - Predictive Maintenance as the name implies simply means predicting the failure before it occurs, identifying the root causes for those failures symptoms and eliminating that cause before they result in extensive damage of the equipment.
8. **Condition based maintenance** - In this method, the condition of the equipment or some critical parts of the equipment are continuously monitored using sophisticated monitoring instruments so that failure may be predicted well before it occurs and corrective steps are taken to prevent failure.
9. **Reliability Centered Maintenance** - It is a process to ensure that assets continue to do what their users require in their present operating context. It is generally used to achieve improvement in fields such as the establishment of safe minimum levels of maintenance, change in operating procedures and strategies and establishment of capitals maintenance regimes and plans. Successful implementation of RCM will lead to increase in cost effectiveness, machine uptime, and a greater understating of level of risk that the organization is managing.
10. **Design-out Maintenance** - It is a design oriented curative means aimed at rectifying a design defect originated from improper method of installation or poor choice of materials etc. It call for the strong design and maintenance interface.

Six Big losses

One of the major goals of TPM and OEE programs is to reduce and/or eliminate what are called the **Six Big Losses** – the most common causes of efficiency loss in manufacturing. Following are the six big losses which occurs during the production process which are as follows,

1. Breakdown losses: -This type of losses is occurs due to the failure of parts, which causes stop of production.
2. Setup and adjustment losses: - This type of losses occurs during to change in production process such as change of section, change operating condition, start of different shift, change of product.
3. Minor stoppages losses: - Minor stoppage occurs due to jamming, machine idling.
4. Speed losses: - These losses are due to reduction in speed of the equipment.
5. Quality defect and rework losses: - These losses are due to the defective product produced during the production process and therefore rework has to be done to remove the defects.
6. Yield losses: - These losses are due to wasted raw material.

TPM Pillars

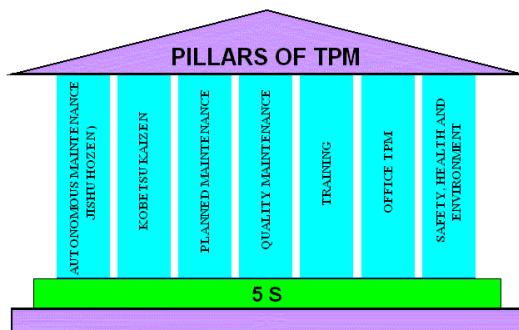


Figure 1:- Shows the TPM Eight Pillar

Pillar 1

5S:-It's a systematic process of housekeeping to achieve a good environment or a clean and clear in the workplace. Following are the component of 5s.

Terms	Features
Sort	Sort out unnecessary items from the shop floor and remove them.
Set in order	Arrange necessary items in good order so that they can be easily picked up for use.
Shine and check	Clean the workplace completely to make it free from dust.
Standardize	Maintain high standard of work place.
Sustain	Train and motivate people to follow good housekeeping disciplines autonomously.

PILLAR 2 Autonomous Maintenance

Autonomous Maintenance means maintain one's own equipment by one self. In this the operator are responsible to upkeep their equipment on daily basis so as to prevent it from deteriorating. The abnormalities are eliminated by using the technique such as abnormality sheet, CLITA, OPL, Inspection, and Lubrication Sheets.

PILLAR 3- Planned Maintenance

This pillar aimed toward to have a trouble free machine and equipments for improving the reliability and maintainability and also for total customer satisfaction for the products.

Benefits:

- a. Optimum maintenance cost.
- b. Reduce spares inventory.
- c. Improve Reliability and maintainability.

PILLAR 3 Kaizen

In this KAI means “change” and ZEN means “good”. Generally kaizen is for small improvement and it involves all people from the organization. The principle behind kaizen is that “a very large number of small improvement is more effective in an organization than a few improvement of large value.

PILLAR 4 – Quality Maintenance

This pillar aimed toward achieving the customer requirement through highest Quality through defect free manufacturing through focused improvement, defect the process after identifying the parameters of machine which mainly affect the products. Transition is from Quality control to Quality Assurance.

PILLAR 5- Training and education

This pillar aimed toward developing multiskill employees whose morale is high and who has eager to come to work and perform all required function effectively. In this an operator is educate as per required. So that he/she will be able to solve the problem.

PILLAR 6- Office TPM

This pillar should be started after its successful activating of four pillar of tpm which are JH, KK, QM, PM office tpm must be followed to improve productivity and efficiency of the administrative functions. Due analyzing process and procedures towards increasing in the office automation.

PILLAR 7- Safety, Health and Environment

This pillar focuses towards to create a safe workplace and a surrounding area so that our process does not damaged that area.

III. IMPLEMENTATION STEPS

- Step 1. Announcement of TPM- Top management needs to create an environment that will support the introduction of TPM.
- Step 2. Launch a formal Education Program- This program will inform and educate everyone in the organization.
- Step 3. Create an Organizational support structure- This group will promote and sustain TPM activities once they began and include members from every level of the organization.
- Step 4. Establish basic TPM policies and quantifiable goals- Analyze the existing conditions and set goals that are specific, Measurable, Attainable, Realistic and Time-based.
- Step 5. Outline a detailed master deployment plan- This plan will identify what resources will be needed and when for training, equipment restoration and improvements, maintenance management system and new technologies.
- Step 6. TPM kick-off- Implementation will begin at this stage.
- Step 7. Improve the effectiveness of each piece of equipment- Project teams will analyze each piece of equipment and make necessary improvement.
- Step 8. Develop an autonomous maintenance program for operators- Operators routine cleaning and inspection will help stabilize conditions and stop accelerated deterioration.
- Step 9. Develop a preventive maintenance program- create a schedule for preventive maintenance on each piece of equipment.
- Step 10. Conduct training to improve operation and maintenance skills- The maintenance department will take on the role of teachers and guides to provide training, advice and equipment information to the teams.
- Step 11. Develop an early equipment management program- Apply preventive maintenance principles during the design process of equipment.
- Step 12. Continuous improvement- As in any lean initiative, the organization needs to develop a continuous improvement mind-set.

IV. OVERALL EQUIPMENT EFFICIENCY

TPM employs OEE as a quantitative metric for measuring the performance of a productive system. OEE is a core metric for measuring the success of TPM implementation program. The overall goal of TPM is to raise the overall equipment efficiency. OEE is calculated by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products.

$$\text{Overall Equipment Efficiency} = \text{Availability} \times \text{Performance efficiency} \times \text{Rate of Quality.}$$

Where,

Availability: - Available Time required to produce a finish product.

$$\text{Availability} = (\text{Required availability} - \text{Downtime}) / (\text{Required availability}) * 100.$$

Performance: - It can be defined as the design cycle time to produce the item multiply by the output of the equipment and then divided by the operating time.

$$\text{Performance} = (\text{design cycle time} * \text{output}) / (\text{operating time}) * 100$$

Quality = It is the ratio of production output to the production input.

$$\text{Quality} = \text{output/input.}$$

V. BENEFITS OF TOTAL PRODUCTIVE MAINTENANCE

- Productivity Improvement - Productivity is improved through fewer losses in the company.
- Quality Improvement - Quality is improved as a result, that the failures and malfunctions is reduced.
- Cost Reduction – The cost is reduced because the losses and other not value added work is reduced.
- Employee Ownership - Ownership of equipment by operators through Autonomous Maintenance
- Employee Confidence - "Zero failure", "zero defect" and "zero accident" conditions builds employee self-confidence.
- Improved working environment - Clean working conditions provides a good working environment.
- Increased Plant Reliability.
- Customer Satisfaction - TPM leads to high delivery performance and customer satisfaction.

VI. A CASE STUDY

A case study has been conducted in one of the leading manufacturing of the TMT Bar in the Rolling mill industry. The company is an integrated plant with a facility to produce Sponge Iron, Power, Billet and Structural Steel (TMT Bars). It is the large scale industry which has set up modern production facilities to meet the customer requirements for quality structural (Thermo Mechanically Treated) TMT bar is rolled out in one of the most modern and fully automatic Rolling Mills and further processed in the world's proven "Thermex®" technology. The Thermex® TMT process involves 3 stages of treatment for imparting the superior strength and quality to the ribbed bars - Quenching, Self-tempering and Atmospheric Cooling. The study conducted along the 15 days, the company produces different size of TMT bar and uses different size of billet as per requirement. Finally, the aim of this case study is to measure the overall equipment efficiency of the company and find out the bottleneck which causes stoppage of production. There are some of the standard from the industry:

- Three shift each shift eight hours and timing per shift is shift A 6:00-2:00, shift B 2:00-10:00, shift C 20:00-6:00
- The target for production of TMT Bar for each day is 400 ton and for each shift is equal to 133.33 tons.
- The product time process, the production line can operate at speed of 16.75 tons per hour, this speed is theoretical speed.

Problem Identify

Major industry losses were identify which are shut down, production adjustment, equipment failure, process failure, normal production loss, abnormal production loss, quality defect and reprocessing. Following are some of the losses listed which occurs during the production process:

1. Miss roll of TMT Bar.
2. Cooling Bed jam.
3. Tool break of crop and cobble shear system.
4. Jamming of material in the furnace.
5. Reduction Gear Box Problem (due to, oil contamination, low oil level, teeth damage).
6. Section change problem.
7. Wear of Roller.
8. Ejector jam.
9. Sprocket and chain fails.
10. V belts fail.
11. Pulley.
12. Guiding and transportation system.

VII. DATA COLLECTION

Table A: - The Total Downtime and the amount of Scrap, Batch size and production/day for 15 operating days in the March 2014

DAYS	DOWNTIME (MIN)	SCRAP (TON)	BATCH SIZE (TON)	PRODUCTION/DAY(TON)
1	300	16.34	344.55	328.21
2	240	17.67	364.59	346.92
3	300	17	348.98	331.68
4	420	12.3	172.49	160.19
5	540	15.79	238.83	223.04
6	360	19.14	315.66	296.52
7	240	16.71	357.59	340.88
8	510	16.44	287.73	271.29
9	765	11.31	231.36	220.05
10	300	16.7	255.88	239.18
11	750	15.19	252.84	237.65
12	390	56.07	215.46	159.39
13	75	3.95	74.55	70.6
14	450	15.81	319.28	303.47
15	260	19.07	359.05	339.98

Table B: - Shows the Summation of Downtime, Scrap, Batch size, Production/day of all 15 operating days

TOTAL DOWNTIME (MIN)	5900
TOTAL SCRAP (TON)	269.49
TOTAL BATCH SIZE (TON)	4138.54
PRODUCTION (TON)	3869.05

In Table A the data taken direct from the production line for shift A , shift B and shift C, the batch size is the amount of tons the company starts the production with, the amount of scrap is the amount of defective steel caused by breakdown or malfunction failure. The Table B shows the summation of the Down time, Scrap , Batch size, Production/day of all 15 operating days.

VIII. CALCULATING THE OVERALL EQUIPMENT EFFICIENCY

After collecting the data, we needed to measure the OEE which will gives an indication of where we may find the error or the weakness point. The study was taking during 15 days in March 2014 all the days was normal working days because there is no holiday consider.

As there are 3 shifts/day with 8 working hours per shift

There was a stoppage of 30 min for each shift, which gives in total 22.30 hours , $360-22.30=337.30$ hours

Therefore, Available operating time = 15 days * 3 shift/day * 8 hours/shift = 360 hours.

As we know that the target for production of TMT Bar for each day is 400 ton and for each shift is equal to 133.33 tons.

Availability factors

Now the total time needed to produce the whole batch for 15 days is

$$= (\text{available operating time} - \text{downtime})$$

$$= 337.30-98.33$$

$$= 239.17 \text{ hours}$$

Therefore, the valuable operating time is 239.17 hours.

$$\begin{aligned}\text{Availability} &= \text{valuable operating time} / \text{available operating time} \\ &= 239.17 / 337.30 \\ &= 0.7090\end{aligned}$$

Availability factor = 70.90%

Performance factors

To calculate this we need to main factors Designed cycle time = 17.77 ton / hour

Total output = 3869.05 ton

$$\begin{aligned}\text{Performance rate} &= [(\text{design cycle time} * \text{output}) / \text{operating time}] \\ &= [(60 \text{ min} / 17.77 \text{ ton}) * 3869.05] / (239.17 * 60) \\ &= 0.9103\end{aligned}$$

Performance factors = 91.03 %

Quality factors

For calculating the quality factors we need

Total amount of defect = 269.49 ton

Production input i.e. Total batch size = 4138.54 ton

$$\begin{aligned}\text{Quality rate} &= (\text{production input} - \text{quality defects}) / (\text{production input}) \\ &= (4138.54 - 269.49) / 4138.54 \\ &= 0.9348\end{aligned}$$

Quality rate = 93.48 %

The Overall equipment effectiveness

$$\begin{aligned}\text{OEE} &= \text{Availability} * \text{Performance rate} * \text{Quality rate} \\ &= 0.7090 * 0.9103 * 0.9348 \\ &= 0.6033\end{aligned}$$

Therefore, the Overall equipment effectiveness of Rolling Mill is 60.33 %

IX. COMPARISON OF OEE WITH WORLD CLASS

Its can seen from the table C that the performance of the company as overall equipment effectiveness is 60.33%, where the availability of the line was 70.90% of the production time and the performance was 91.03% while the quality factor is 93.48%.

Table C: - Shows the comparison between WCM and the company

	OEE Company	OEE world class
Availability	70.90%	90%
Performance	91.03%	95%
Quality	93.48%	99%

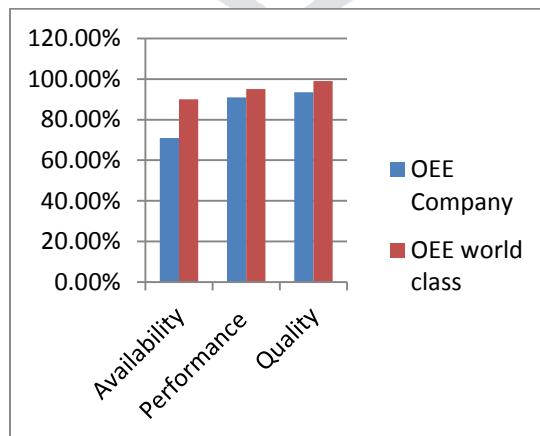


Figure 2:-shows the comparison between the OEE of company and the World standard

X. SUGGESTION

- By Implementing the TPM strategy we can eliminate most of the waste.

- Operator should be skilled in their particular working area, so Training the operator is very much important.
- Launch of Reliability Centered Maintenance:- In this , the operator will gain the knowledge about the machine in the rolling a mill, if any failure occurs he would know how to repair that machine.
- There should be flexibility in pinch roll machine, so that miss guide of the billet is reduced.
- Proper setup and adjustment of the section change is needed. For this, a good Engineer along with the worker who do this job in needed for proper guiding of each activity.
- There should be proper linearity in the guiding system i.e. through which the hot billet is passed if this done properly then the problem of the miss roll is minimize and automatically the breakdown is reduced and the efficiency of the plant is increase.
- As the section changes according to the customer order for (8, 10, 12, 20,32mm) this should be minimize by producing bar and kept in a stock so that no disturbance will occurs in the system and if this is done a downtime is also reduced to some extents.

XI. CONCLUSIONS

- A Manufacturing Process and the Resources available for producing TMT Bar have been studied and also the breakdown such as mechanical, electrical and other which occur during operation have been analyzed.
- From the calculation of overall equipment effectiveness it is seen that the performance of the Rolling Mill come to be 60.33% in which the availability of the line is 70.90% of the production time and the performance rate is 91.03% while the quality rate comes to be 93.48%.
- When this i.e. (A, P, Q) of the Rolling Mill is compared with the World Class Measurement it come to be very less, According to the World Class Manufacturing OEE should be 85% and the Rolling Mill Equipment Efficiency is reduced by 25%.
- Therefore it is necessary / very much important to implement the TPM in Rolling Mill so as to improve the productivity and Efficiency of the Equipment of the Rolling Mill by eliminating most of the waste.

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