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TPM- A KEY STRATEGY FOR PRODUCTIVITY IMPROVEMENT IN PROCESS INDUSTRY

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Abstract

During high growth era companies are making technical progress in automation and centralization of the plants, which needs large amount of manual work to maintain the automation systems. The strategy of maintaining the equipment of a plant is crucial for the effectiveness of manufacturing. Total productive maintenance (TPM) is a maintenance program, which involves concepts for maintaining plant and equipments effectively. In this paper detailed implementation of TPM in the cold rolling plant is discussed. Results achieved are quite encouraging in terms of motivated employees, improvement in overall equipment effectiveness (OEE) and reduction in no. of accidents on shop floor.

Keywords: TPM, Kobetsu kaizen, Jishu hozen, OEE.

1. Introduction

Efficiency and effectiveness of equipment plays a dominant role in modern manufacturing industry to determine the performance of the organizational production function as well as the level of success achieved in the organization. Total productive maintenance (TPM) is a methodology that aims to increase the availability of existing equipment hence reducing the need for further capital investment [1,2]. Because of increased competency levels and demand of quality products at lower costs, companies needs a comprehensive system to achieve optimum output from the equipment/ machine. TPM is a plan, which concentrates on total involvement of everyone from top management to all employees to implement a comprehensive maintenance program for all equipment throughout its life. This plan results in maximum effectiveness of equipment, tidier, neat and

Abbreviations

CR	Cold rolling
FI	Focused improvement
HPH	High performance hydrogen
JIPM	Japan institute of plant maintenance
OEE	Overall equipment effectiveness
PM	Preventive maintenance
TPM	Total productive maintenance

clean work place and morally boosted employees [3,4]. TPM has been recognized as one of the significant operation strategy to regain the production losses due to equipment inefficiency. TPM is a unique Japanese system of maintenance, which has developed by the Japan Institute of Plant Maintenance (JIPM). It has been very important tool for equipment intensive manufacturing sectors; it is a key means for increasing machine availability [5]. The value of deploying TPM is widely recognized, particularly in current market scenario where economy is in recession, installed capacity is greater than demand, quality is basic, growing competition, and selling price is dictated by the market, diverse equipment, centralized control and few operators in the plant [2,6,7].

In cold rolling plants high level of automation and sophisticated equipment is involved, which is having diverse equipment related problems, high energy consumption, high accidents and pollution, high rework and rejection, and maintenance is not effective due to the continuous nature of production. Due to combination of various units in equipment like pumps, heat exchangers, generation plants, gear boxes, hydraulic and pneumatic drives, compressors, variable drives and programmable logic circuits (PLC), etc., the equipment related problems are diverse in nature. Also there is continuous conflict between maintenance and production department that maintenance people says production people don't know how to handle equipment properly, production complaints that maintenance people don't maintain the equipment properly. By viewing the nature of industry imple-mentation of TPM is decided.

2. Literature Review

TPM is designed to maximize the overall equipment effectiveness. It involves all departments that plan, use and maintain equipment, involves all employees from top management to front line workers [8]. The concept of TPM was developed in Denso, A tier one automotive supplier in the Toyota group of suppliers, during 1960s and 70s in Japan. The central thrust of the programme was the complete elimination of the "six major equipment losses". The key concept behind effective improvements was autonomous maintenance. The concept of overall equipment effectiveness (OEE) and focused improvement were found to be quite encouraging for success of TPM [5]. The aim of the TPM is to improve the labor productivity and to reduce the maintenance cost. The work of the Japanese consultant Koichi in Nissan Motors were acknowledged as 10% reduction in maintenance cost, 30% reduction in manpower and 140% increase in labor productivity were reported [9]. Author reported that labor productivity increases by 140%-150% and maintenance cost decreases by 15%. Customers claim that poor quality reduces

by 20%-25% and machine breakdowns by 98% [10]. TPM aims to develop both the company and its employees individually. It aims to bring equipment to peak operating condition by eliminating the losses that hamper plant effectiveness. That is to achieve zero breakdowns, zero defects and zero accidents [4].

TPM concepts involve commitments to long-range planning, especially on the part of senior management. Typically, TPM is initiated as a "top-down" exercise, but only implemented successfully via "bottom-up" participation. However, consensus building may take about three years, from the planning phase, for sustainability to be achieved in a large organization [11]. TPM is a manufacturing-led initiative that emphasizes the importance of (i) people with a 'can do' and continual improvement attitude and (ii) production and maintenance personnel working together in unison. TPM combines the best features of productive and preventive maintenance (PM) procedures with innovative management strategies and encourages total employee involvement [3].TPM does not provide a quick or easy solution. It usually requires changes in employees' attitudes and values, which take time to imbibe. Quick and company-wide performance gains should not be expected during the initial phase. TPM helps organize maintenance activities by applying the following actions

- Cultivate a sense of ownership in the operator by introducing autonomous maintenance – the operator takes responsibility for the primary care of his/her plant.
- Use cross-functional teams consisting of operators, maintainers, engineers and managers to improve individual employee and equipment performances.
- Establish an optimal schedule of clean-up and PM to extend the plant's lifespan and maximize its uptime [12].

TPM brings maintenance into focus as a necessary and vitally important part of the business: maintenance should no longer be regarded as a non-profit-making activity. The goal is to minimize the frequency and magnitudes of emergency and unscheduled maintenance interruptions. In all, TPM implementation will involve design, operation, maintenance, engineering and sales activities, and may require hiring or appointing a TPM coordinator whose responsibility is to advocate through an educational programme the TPM concepts to the workforce, and check that they are being implemented. Each person becomes a "stakeholder" in the process and is encouraged to do his or her best to contribute to the success of the team [13]. TPM requires a drastic change in the traditional mindset of work culture and maintenance approaches. For this active top management support is crucial to overcome resistance of employees, especially during the transition period [14].

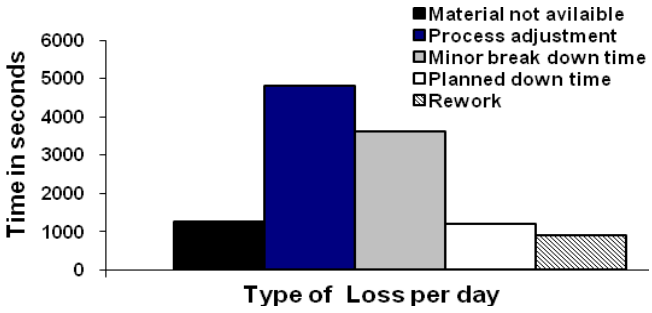
A positive strategic outcome of TPM implementations is the reduced occurrence of unexpected machine breakdowns, which ultimately results in enhanced profits in the organization [15]. The results of the analyses indicate that TPM controls manufacturing cost, quality, and delivery time. TPM can be a strong contributor to the strength of the organization and has the ability to improve MP (Manufacturing performance) [16]. With competition in manufacturing industries rising relentlessly, TPM can be the maintenance philosophy prevents the failure of an organization. It is a maintenance programme that works with TQM and lean management. The willingness of employees within

an organization to accept "change" for the better is an essential prerequisite for successfully implementing TPM [17].

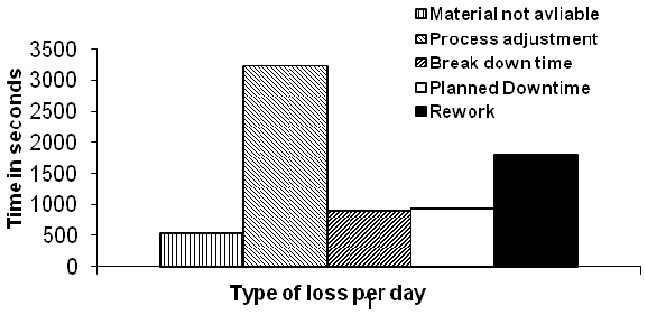
Form the above literature it is clear that TPM shall enhance the organizational profitability by changing the mindset of people involved and led to continuous improvement in the organization. Thus by looking on the competition and cost cutting problems with the steel industry it was decided to implement TPM on cold rolling plant.

3. Problem Statement

First of all out of the whole plant process equipments two main bottleneck equipments were identified and was decided to consider only these two for TPM implementation study. Major losses during the production on these equipments were pointed out using a time study approach as mentioned in Fig. 1. The study was carried out in all three shifts for two continuous hours in each shift. Two persons standing on either side of the line with the stop watches noted down whenever there was a stop or any other situation occurring, which led to idle or stoppage time on equipment. Three days continuously the study was conducted and finally average of all these readings were calculated in order to decide the final values of various losses on respective equipments. In every shift 'process adjustment' emerged as the biggest problem, both in frequency and also the duration.



(a) Rolling Machine



(b) HPH Annealing

Fig. 1. Time Loss per Day.

According to study, small interruptions were the biggest contributors to the time losses. So looking into the type of losses it seems that there is lot of scope for improvement in the profitability after implementation of TPM.

4. Proposed Implementation Plan for TPM

On the basis of surveyed literature following points were considered to implement during TPM implementation programme in the cold rolling unit (CR unit) and adopted in the system step by step;

- Focused improvement (Kobetsu Kaizen),
- Autonomous Maintenance (Jishu Hozen),
- Education & Training,
- Planned maintenance,
- Overall Equipment effectiveness

4.1. TPM development program

The ten TPM development programme steps were taken as described in Table 1 below.

Table 1. Ten TPM Development Programme Steps.

Step	Key point
1. Formally announce decision to introduce TPM	Top management announcement at in house meeting publish in any company magazine.
2. Conduct TPM introductory education & group training for specific employees.	Senior management level.
3. Create a TPM promotion organization, committee and specialist sub committees.	Steering TPM promotion Office.
4. Establish basic TPM policies and goals	Set baseline and targets.
5. Draft a master plan for implementing TPM from preparation stage to application	Forecast effects.
6. Kick off TPM initiatives	Invite customers, affiliates& subcontractors
7. Build a corporate constitution designed pursue the ultimate in production effectiveness to maximize production effectiveness.	Conduct Focused improvement activities, Project-team activities and workplace small group activities, Establish and deploy autonomous maintenance proceed Step by step, with audits and pass certificates.
8. Implement planned maintenance, corrective, shutdown, and predictive maintenance. Conduct operation and maintenance group education.	Training to members by identifying their needs through skill evaluation form.
9. Build an early management system.	Develop equipments/products that are easy to use.
10. Build a quality maintenance system.	Establish, maintain and control conditions for zero defects, zero accidents.

4.2. Creation of a TPM promotion organization

TPM is promoted through a structure of overlapping small groups; in this system leaders of small group at each organizational level are members of small group at the next higher level. TPM small group activities are not voluntary but a part of peoples daily work unlike QC – circle activities. This top-to-bottom integration is accomplished through overlapping small groups.

In this employee of various departments like production, engineering, operations and marketing were overlapped as shown in Fig. 2. As the leaders are the link in the chain they act as linchpins, facilitating horizontal and vertical communication. The structure was made in order to go for effective communication in the whole organization and also to ensure the intimacy of interdepartmental people.

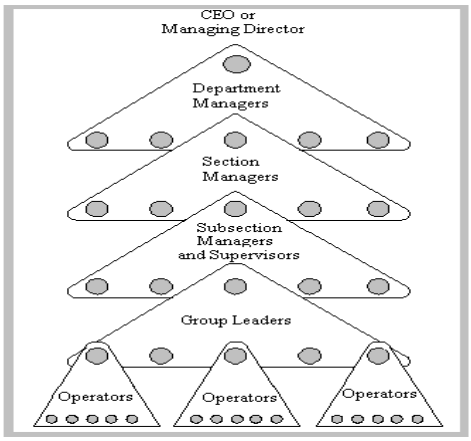


Fig. 2. TPM Small Group Structure.

5. Focused improvement (Kobetsu Kaizen)

Focused improvement includes all activities that maximize the overall effectiveness of equipment, processes and plants through uncompromising elimination of losses. Teams were made from every level of organization, mangers, engineers, staff, technicians, line workers. The principal behind is that "a large number of small improvements are important than a few improvement of large value".

5.1. Step by step procedure for focused improvement

Following steps, shown in Table 2, were followed in the CR unit in order to motivate the employee for adoption of focused improvement strategy.

Table 2. Step by Step Procedure for Focused Improvement.

Step	Activity	Detailed action plan
1.	Select Improvement topic	Select and register topic on topic registration form. Form project team. Plan activity.
2.	Understand situation	Identify bottleneck processes. Measure failures, defects and other losses. Use base lines to set targets.
3.	Expose and eliminate abnormalities	Painstakingly expose all abnormalities. Restore deterioration and correct minor flaws. Establish basic equipment conditions.
4.	Analyze causes	Stratify and analyze losses. Apply analytical technique (why-why analysis, FTA, P-M analysis).
5.	Plan Improvement	Draft improvement proposals and prepare drawings. Compare cost effectiveness of alternate proposals and compile budget Provide instructions on improved equipment, operating methods etc.
6.	Implement improvement	Carry out improvement plan. Practice early management (perform test operation and formal acceptance)
7.	Check Results	Evaluate results with time as improvement project proceeds
8.	Consolidate gain	Draw up control standards to sustain results. Formulate work standards and manuals Feed information back to maintenance prevention programme
9.	Rewards for Kaizen	Spot award given for every kaizen submitted, implemented will be rewarded 10% of the annual saving made by that improvement after implementation. Good KAIZENS rewarded and addressed at common forums by ED/Department/Unit heads to boost the morale of employees.

5.2. Kaizen results and discussions after implementation

For giving suggestion by various employees of the organization a procedure was adopted. In this regards two forms i.e. topic registration form in Fig. 3 and focused improvement (FI) reporting form in Fig. 4 were designed.

The Performa for topic registration in kaizen is to be filled by individual employee and submit it to chairman of FI committee. This Performa will highlight the person suggesting improvement.

This Performa will help in analyzing the improvement in terms of its profitability after incorporation of the respective suggestion. Figures 5 and 6 are graphical representations of number of suggestions submitted by production and maintenance in two years on rolling and annealing.

TO CHAIRMAN FI COMMITTEE	LEADER NAME/ SIGN_____
DATE_____	DEPARTMENT_____
TOPIC_____	
RESPONSIBLE EMPLOYEE_____	
HELP REQUIRED_____	
PLANNED DURATION_____	

Fig. 3. Topic Registration Form.

Name…….. **Date & Month……**
Deptt…….. **Group……**

S. No	Existing Situation	Description of improvement	Personal role played	Help received	Date of implementation	Result after two month	Remarks

Signature of Group leader ……

Fig. 4. Focused Improvement Reporting Form.

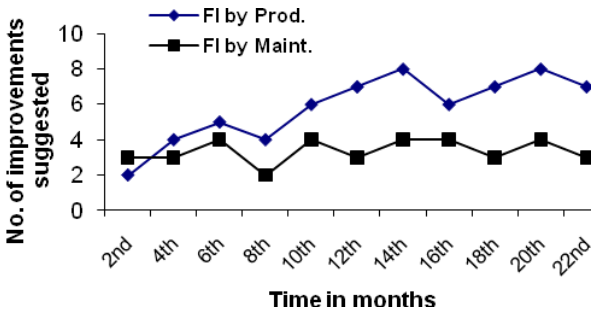


Fig. 5. Focused Improvement Trend on Rolling Mill.

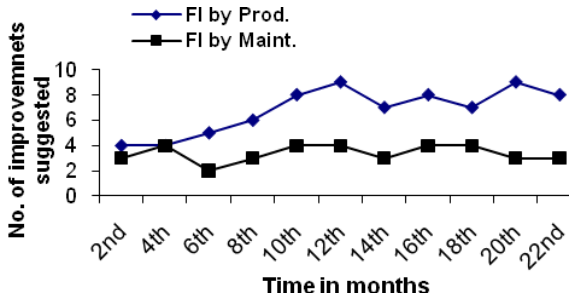


Fig. 6. Focused Improvement on HPH Annealing.

Form these graphs it is quite evident that number of suggestions given by both the departments is improving with passage of time improving, which is indirect indication that employees are motivated to participate in the improvement process. Further figure indicates that number suggestions submitted by production department are higher as compared to maintenance. Thus we can conclude here that the all the employees of the organization are motivated to participate in the activity of enhancing profitability of the company. In particular the ownership concept is being imbibed in the employees of the Production department. This is encouraging factor for implementation of autonomous maintenance.

6. Autonomous Maintenance (Jishu Hozen)

Once we are having motivated employees in the organization thus next step is to go for autonomous maintenance. In this main aim is to develop operators to be able to take care of the small maintenance. Japanese name of autonomous maintenance is "Jishu Hozen" is one of the most important basic building blocks in any TPM programme. Autonomous maintenance includes any activity performed by the production department that has a maintenance function. During the implementation stage at the CR unit in order to increase the effectiveness of autonomous maintenance, maintenance tasks at the equipment were specifically defined and allocated between maintenance and production departments very clearly as shown in Fig.7. For which production operators were trained for handling the basic tasks of maintenance on the equipment through a specialized training programme on the basis of equipment configuration. In autonomous maintenance production people involve themselves in following ways:

- Preventing deterioration,
- Measuring deterioration,
- Predicting deterioration.

After the successful training of the workers for one month, workers were able to identify problems on the equipment before they led to equipment breakdown/ failure. Following problems were observed due to which the down time occurs needs due consideration on 6-HI rolling mill and HPH annealing.

- Malfunctioning of Rotaseal,
- Sealing of the hydraulic cylinders,
- Sealing of the hydraulic cylinders,
- Oil leakage from pinch roll and hold down rolls Cylinders,
- Malfunctioning of the impeller in annealing,
- Leakage from the sealing in hydraulic line.

Which further lead to improvement in the availability of the equipments and reduction in the downtime.

Education and training in TPM

First of all on the basis of equipment configuration training needs of the employees were identified particularly in case of production people. Following

areas were identified on which production operator needs to be trained like trouble shooting of pumps, ignition system, belt drives, gear boxes, air-conditioning units, bolts, seals, bearings, electric motors with variable drives. Training was totally a need based and was focused to generate a equipment competent operator. Keeping in view the equipment technology and workers level lesson plans were developed on identified areas. A part from this the work instructions on all the equipment were designed. By this training programme the operator were feeling confident of handling the routine check up on the equipment, minor repairs, primary cleaning, lubrication and nut bolt tightening on the various equipments.

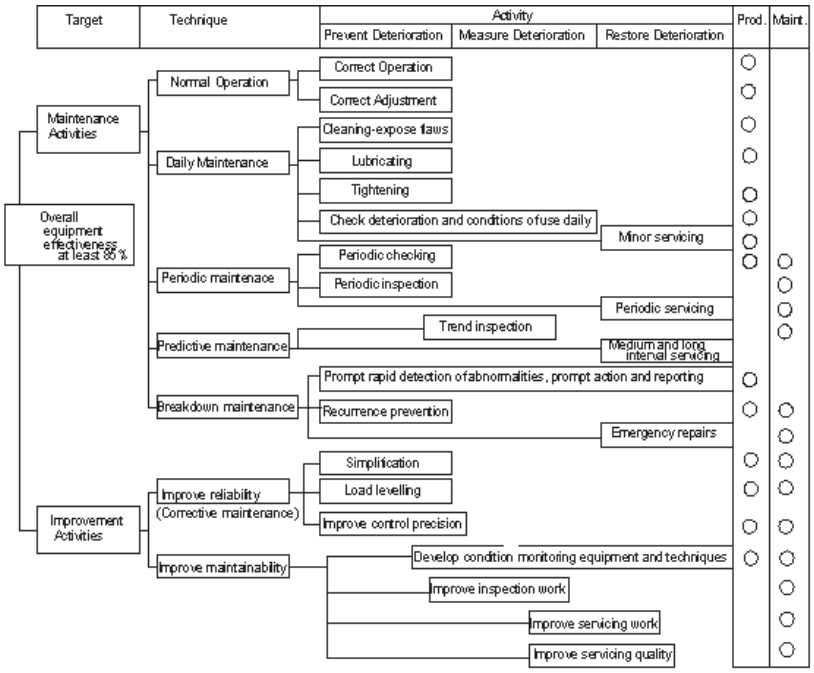


Fig. 7. Allocation of Maintenance Tasks between Production and Maintenance Department.

7. Overall equipment Effectiveness (OEE)

Finally to evaluate the effectiveness of TPM implementation steps OEE on both the equipments were calculated and analyzed after every two months of time. In process industry it is very much essential to maximize the production effectiveness; the effectiveness of a plants production depends on the effectiveness with which it uses equipment materials people and methods. This is done by examining the inputs to the production process and identifying, eliminating the losses associated with each to maximize the production. Eight major plant losses were identified:

- Shut Down (planned maintenance),
- Production adjustment,
- Equipment failure,
- Process failure,
- Normal production loss,
- Abnormal production loss,
- Quality defects,
- Reprocessing.

OEE=Availability × Performance efficiency × Rate of quality

In the study two main equipments rolling Mill and (HPH) High Performance Hydrogen Annealing were considered for study. Data for the two years were collected and OEE of individual equipments with respect of time was analyzed. The operation is based upon three shifts per day and every shift is of eight hrs. Planned down time per month is 8-10hrs.

7.1. Data analysis on rolling mill

A complete data and calculations of overall equipment effectiveness (OEE) are shown in *Appendix A*.

Figure 8 is a graphical representation of the OEE for two years of time; from the graph it is quite evident that the value of OEE is showing an increasing trend with respect to time. This means that availability is increasing, rework and rejection is decreasing and performance efficiency is increasing. The world class OEE is 85-90% and from the graphical representation it is quite evident that equipment is heading towards 80% OEE value, but the time period is around 18-20 months of implementation. Thus it is clear that for successful implementation one needs a two or more years of effective time [5,12].

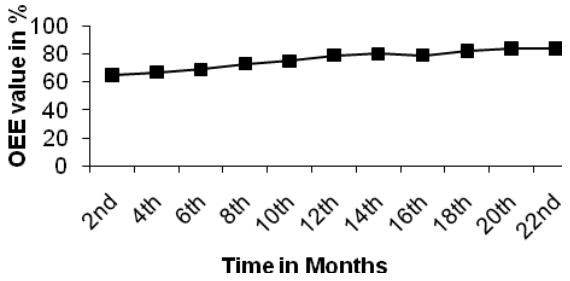


Fig. 8. OEE Trend on Rolling Mill.

7.2. Data analysis on HPH- Annealing

OEE for HPH was calculated in the same manner as discussed in 7.1 and *Appendix A*, which is OEE = 83.95%.

Figure 9 is a graphical representation of the OEE on HPH annealing for two years of time, from the graph it is quite evident that the value of OEE is showing

an increasing trend with respect to time. That means that availability is increasing, rework and rejection is decreasing and performance efficiency is increasing. The effective rise in OEE of HPH annealing in comparison to rolling is high, which is due to the inherent process characteristics of the equipment as the down time before implementation was also less in case of annealing than the rolling.

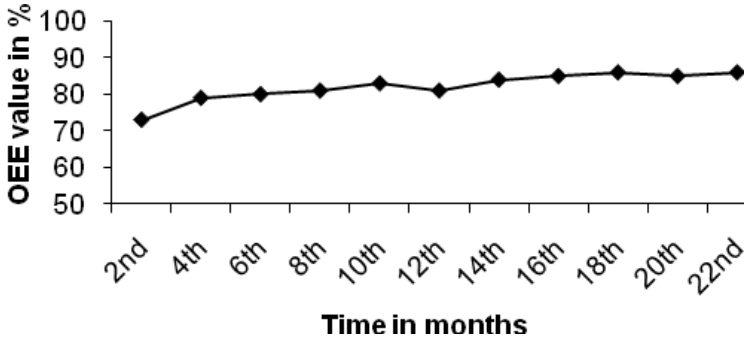


Fig. 9. OEE Trend on HPH Annealing.

8. Discussion of Maintenance Cost and Safety

TPM provides a comprehensive company-wide approach to maintenance management, thus it is necessary to analyze the maintenance cost in terms of production. In Fig. 10 mechanical maintenance cost in Rs. per Metric ton of steel rolled is plotted. Figure 10 is a graphical representation of mechanical maintenance cost which is showing a decreasing trend with respect to time. This is due to the successful adoption of the autonomous maintenance by the production employees. Due to which the abnormalities in the equipment are identified during working itself before converting into a breakdown, which ultimately led to reduction in maintenance cost. This reduction is quite evident after 12^{th} month of implementation. So it is clear that effective result of improvement comes after a year's time, which agrees well with the recommendations of other authors [5,11].

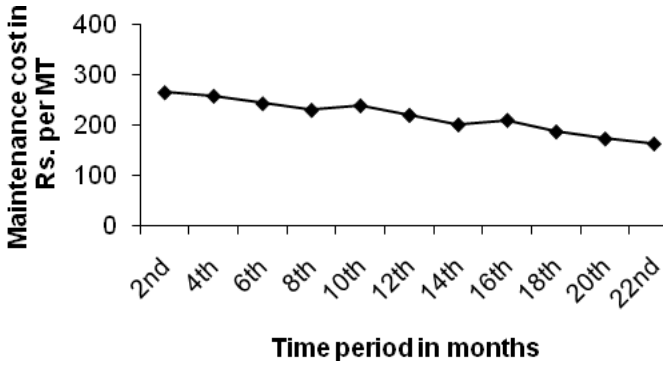


Fig. 10. Maintenance Cost vs. Time.

Another important feature after implementation is to account for the safety aspect on the shop floor, for which it was decided to analyze the number of accidents with respect to time. In Fig. 11 number of accidents on rolling and annealing is plotted with respect to number of months.

Figure 11 is a graphical representation of number of accidents (minor and major accidents both) occurred on equipments, Form this graph it is quite evident that number accidents reducing and approaching towards nearly zero in 20th month of implementation. This is good sign of safer environment and will increase the employee's morale for using the equipment effectively [5].

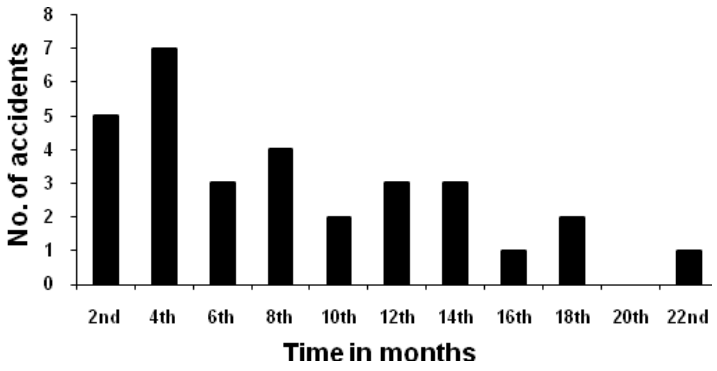


Fig. 11. Number of Accidents on Rolling and Annealing.

9. Conclusions

TPM small group activity has imbibed the habit of better communication among the different departments at all levels, which has lead to increase in the team working spirit of the employees and healthy organizational environment. With implementation of Kaizens employees are contributing fully at all levels in order to improve the system effectiveness, further this strategy of Kaizens has led to motivated employees at all level. It is seen that during all data analysis (OEE, Maintenance cost, Number of accidents etc.) the results are improving effectively only after a years time of implementation. It is clear that employees need a time to adopt TPM system in the organization. Hence Management has to be patience enough to motivate the employees and watch for the results with passage of time. Autonomous maintenance concept has helped to reduce the mechanical maintenance cost which is showing a down trend continuously and lead to saving of Rs.100 per metric ton (MT) of production and further contributed for the increase in profitability of the system, side by side this concept has helped in imbibing the ownership concept about the equipment in the production operators. This has in turn leaded to equipment competent operators.

Further it is seen that OEE on HPH annealing has shown a progressive growth, which is an indication of increase in equipment availability, decrease in rework, rejection and increase in rate of performance. On other hand the increase in OEE at rolling mill is comparatively low in reference to HPH annealing, which

was previously plagued with the breakdowns and was considered to be a bottleneck area. But the growth rate of OEE at rolling is still encouraging and with the passage of time results will be quite good and may reach a world class OEE value of 85%-90%. Number of accidents on both the equipments has been reduced and approaching towards zero value. In general adoption of TPM system in the cold Rolling plant has not only provided a comprehensive maintenance system but also motivated the employees for maximum involvement in order to achieve the common organizations goal.

It is recommended that one can consider customer satisfaction, and lifecycle costing of the equipment for implementation of TPM in any of the relevant organization. TPM can be implemented at any department in the organization like administration, purchase, stores, marketing etc.

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Appendix A

Calculation of OEE

Working days in a month =	30 × 24 hrs
Planned down time in a month =	10 hrs
Setup adjustment losses per day = (which includes material not available, Job setting, rework)	1.75 hrs
Setup adjustment losses per month =	52.5 hrs
Breakdown time Hrs per day =	1 hrs
Breakdown time per month =	30 hrs

Total down time per month =
(Planned down time + setup adjustment losses + breakdown time)/month =

$$10 + 52.5 + 30 = 92.5 \text{ hrs/month}$$

Operating time per month = Running Time - Total down time

$$= 720 \text{ hrs} - 92.5 \text{ hrs} = 627.5 \text{ hrs}$$

Availability = (loading Time – Down Time)/Loading time

$$= (720-92.5)/720 = 87.15\%$$

Performance efficiency (PE) is calculated as

PE = ((TCT×PA)/OT)×100

where

TCT - theoretical cycle time,
PA - processed amount, and
OT - operating time

Targeted capacity of rolling mill is 22 MT/hr, Theoretical cycle time is 2.72 min./MT and Processed Amount (PA) 11000 MT/ month (approx.)

Performance efficiency (PE) = 2.72 × 11000/627.5 × 100
= 79.4%

PE = Speed efficiency × Rate efficiency

where

Speed efficiency = ICT /ACT
ICT - Ideal cycle time and
ACT - Actual cycle time

Rate efficiency = (PA × AT) /OT,

where AT is Actual time.

These losses occur due to machine running at slower speed than the designed speed because of vibration and improper maintenance, also due to idle and minor stoppage etc.

Rate of Quality products = ((PA-DA) /PA) × 100
= (11000-440)/11000 × 100 = 96%.

Defected Amount = 4% of PA = 440 MT (app) (Out of which 3% is Rework and rest 1% amount is Rejection)

OEE on Rolling Mill = Availability × Performance Efficiency × Rate of Quality

= 0.8715 × 0.794 × 0.96 = **66.4%**