The improvement of Overall Equipment Effectiveness of machines using TPM study in a small scale industry

(A case study on Milling Machine and Chasing Machine used in a CTC roller sharpening industry)

Subhankur Dutta
PG Scholar
Department of Mechanical Engineering
Jorhat Engineering College
Jorhat, Assam, India

Ajoy Krishna Dutta
Assistant Professor
Department of Mechanical Engineering
Jorhat Engineering College
Jorhat, Assam, India

Abstract—*In this project, a CTC roller sharpening enterprise under small scale industry of Golaghat district of Assam is chosen. The roller sharpening action in the enterprise is accomplished through a set of three milling machines and a chasing machine. This case study aims at determining the OEE of the four machines and suggesting steps to improve it using TPM tools. Improvement in OEE is indirectly the improvement of its parameters viz. availability, performance and quality. First and foremost, the general working conditions and parameters of all the machines are noted down and the initial OEE values are noted down. Later a ten week survey is conducted to determine the actual downtime, theoretical cycle time and number of defective rollers produced on a weekly basis on the four machines and average OEE is calculated.Ishikawa fishbone diagram is used to analyze the cause of downtime loss, defective rollers, roller costs, high cycle time and reduced OEE.Pareto Analysis is used to single out the most influencing cause leading to the aforesaid effects. A detailed literature survey on a number of research papers is done to study the effects of TPM on OEE.Two significant research papers are taken from the lot and their average improvement in availability and performance is taken as a base for the improvement of the aforesaid parameters of this project. However for quality improvement, a TPM team is formed with a theme of total employee participation and creating enthusiastic work environment. Finally the target values obtained are found to be higher than the initially noted values of OEE.This improvement in OEE using TPM is shown to the personnel's of the industry and provided them the freedom and confidence to implement TPM in near future.*

Keywords—CTC; OEE; Availabiilty; Performance; Quality; TPM

I. INTRODUCTION

In the present scenario of world class manufacturing, effectiveness and efficiency of machines play a vital part for the commercial benefit of any industrial organization. Overall Equipment Effectiveness analysis is a procedure to determine how effectively a manufacturing operation is utilized. To boost the manufacturing system, Total Productive Maintenance is incorporated with Overall Equipment Effectiveness. Various TPM programmes are suggested by the researchers to improve OEE.This case study aims at determination, calculation, analysis and improvement of Overall Equipment Effectiveness of four machines used in a CTC rolling sharpening industry using TPM.

A. *Objective of the research*

- To meaure the Overall Equipment Effectiveness of machines utilised in a small scale industry.
- Analyze the contributors of OEE for improvement.

B. *Enterprise of the project undertaken*

Hydron Engineering Works, an enterprise under small scale industry located in Dergaon, Golaghat, Assam is the chosen place for the project undertaken. The industry is primarily involved in the sharpening action of CTC rollers used in tea industries. The sharpened products are supplied to the tea manufacturing units located in Golaghat, Jorhat and Nagaon districts of Assam.

C. *CTC Rollers*

Crush, Tear, Curl is a technique of manufacturing tea in where the tea leaves go through a series of cylindrical rollers with sharp teeth. They crush, tear and curl the tea into small, hard pellets. The rollers possess two types of grooves a milling and a chasing, both of which needs resharpening using suitable cutting tools. Rollers in batches of 6-8 arrive from various sources. Thread cutting operations are performed in the milling machines at a rate of 8 tpi-10tpi depending upon the length and diameter of the rollers.

II. METHODOLOGY

A. *Steps followed for OEE calculation*

a) Data collection, Machine history study.

b) Identification of the problems in the machine.

c) Determine the OEE of four machines over a period of 10 weeks and make a comparative study.

d) Analyze the three OEE parameters and their role in effecting the overall effectiveness of the production system.

e) Listing the causes of reduced downtime and defective products with the help of Ishikawa Fishbone diagram.

f) Making a Pareto Analysis of all the root causes and finding out the one most affecting the aforesaid parameters.

g) Detailed literature survey is conducted to determine the improved values of Availability and Performance by the influence of TPM.

h) Creating a TPM team to improve the values of Quality.

i) Finally improved OEE values are calculated using TPM and suggested to the enterprise for futuristic implementation.

B. *Oee calculation from data given by the machine incharge in the visited industry*

Working days in a week = 6 days

Working hours per day = 10 hours

Working hours per week = 6*10 = 60 hours

Downtime per day (includes material not available, job setting, rework, meal break) = 1.5 hours

Total down time per week = 1.5*6 = 9 hours

Operating time per month = Running Time - Total down time = 60 hrs. - 9hrs. = 51 hrs.

Calculation of Availability

The operating time for all the 3 machines is approximately equal.

Now, Availability = Operating Time/ Planned Production Time

Planned Production Time = 60 hours

Operating Time = 51 hours

So Availability = 51 hours/ 60 hours

= 0.85 * 100%

= 85%

Calculation of Performance

Performance = {Processed Numbers/ (Operating Time/ Theoretical Cycle Time)}

a) Milling M/c 1

Targeted Numbers = 15 rollers/ week

Theoretical Cycle Time = 4 hours/roller

Processed Numbers = 1.5 rollers/ day

= 9 rollers/week

Performance = [9/ {51/4}]

= 0.706 * 100%

= 70.5 %

b) Milling M/c 2

Targeted Numbers = 15 rollers/ week

Theoretical Cycle Time = 4 hours/roller

Processed Numbers = 1 rollers/ day

= 6 rollers/ week

Performance = [6/ {51/4}]

= 0.470 * 100%

= 47 %

c) Chasing M/c

Targeted Numbers = 3 rollers/ 8 hours

= 22.5 rollers/ week

Theoretical Cycle Time = 2.67 hours / roller

Processed Numbers = 2 rollers/ 8hours

= 15 rollers/ week

Performance = [15/ {51/2.67}]

= 0.785 * 100%

=78.5 %

Calculation of Quality

Quality = (Processed Numbers-Defect Numbers)/ Processed Numbers

Defective numbers (DN) = 1/week (approx.)

a) Milling M/c 1

Quality = {9-1/9}

= 0.88 * 100%

= 88.0%

b) Milling M/c 2

Quality = {6-1/6}

= 0 .8333 * 100%

= 83.33%

c) Chasing M/c

Processed numbers/week = 15/ week

Defective number/week = 3/week (approx)

Quality = {15-3/15}

= 0 .80 * 100%

= 80.0%

Calculation of Overall Equipment Effectiveness

OEE = Availability*Performance *Quality

a)Milling M/c 1

OEE = 0.85 * 0.706 * 0.88

= 0.5280 * 100%

= 52.80 %

b) Milling M/c 2

OEE = 0.85 * 0.470 *0.8333

= 0.332 *100%

= 33.2 %

c) Chasing M/C

OEE = 0.85 * 0.785 *0.80

= 0.5338 * 100%

= 53.38 %

C. Tables for weekly calculation of OEE over ten weeks of all four machines after undergoing survey

Estimation of Milling Machine 1

a) Considering 6 days/week:

Planned Production Time = 60 hrs

Downtime = 12.25 hrs

Operating Time = 47.75 hrs

Availability = .80

Targeted Numbers = 15

Processed Numbers = 9

Theoretical Cycle Time = 240 min

Performance = .705

Defective Rollers varies from week to week ranging from 1 to 4.

So Quality varies accordingly.

b) Considering 5 days/week:

Planned Production Time = 60 hrs

Downtime = 20.22 hrs

Operating Time = 39.78 hrs

Availability = .663

Targeted Numbers = 15

Processed Numbers = 7.5

Theoretical Cycle Time = 200 min

Performance = .588

Defective Rollers varies from week to week ranging from 1 to 4.So Quality varies accordingly.

The estimation is shown in Table I

TABLE I: Estimation of OEE of Milling M/c 1

Duration (weekly)	Availability	Perfor mance	Processed Numbers	Defective Numbers	Quality	OEE
Oct1-Oct7	0.663	0.628	7.5	1	0.867	0.361
Oct8-Oct14	0.800	0.753	9	2	0.778	0.469
Oct15-Oct21	0.800	0.753	9	1	0.889	0.535
Oct22-Oct28	0.663	0.628	7.5	2	0.733	0.305
Oct29-Nov4	0.800	0.753	9	1	0.889	0.535
Nov5-Nov11	0.800	0.753	9	3	0.667	0.402
Nov12-Nov18	0.800	0.753	9	1	0.889	0.535
Nov19-Nov25	0.663	0.628	7.5	1	0.867	0.361
Nov26-Dec2	0.800	0.753	9	4	0.555	0.334
Dec3-Dec9	0.800	0.753	9	2	0.778	0.469

Estimation of Milling Machine 2

a) Considering 6 days/week:

Planned Production Time = 60 hrs

Downtime = 9 hrs

Operating Time = 51 hrs

Availability = .85

Targeted Numbers =15

Processed Numbers = 6

Theoretical Cycle Time = 240 min

Performance = .470

Defective Rollers varies from week to week ranging from 1 to 4.

So Quality varies accordingly.

b) Considering 5 days/week:

Planned Production Time = 60 hrs

Downtime = 17.5 hrs

Operating Time = 42.5 hrs

Availability = .708

Targeted Numbers = 15

Processed Numbers = 5

Theoretical Cycle Time = 200 min

Performance = .392

Defective Rollers varies from week to week ranging from 1 to 4.

So Quality varies accordingly.

Estimation of Chasing Machine

a) Considering 6 days/week:

Planned Production Time = 60 hrs

Downtime =18.75 hrs

Operating Time = 41.25 hrs

Availability = .688

Targeted Numbers = 22.5

Processed Numbers = 15

Theoretical Cycle Time = 160 min

Performance = .784

Defective Rollers varies from week to week ranging from 1 to 4.

So Quality varies accordingly.

b) Considering 5 days/week:

Planned Production Time = 60 hrs

Downtime = 25.64 hrs

Operating Time = 34.36 hrs

Availability = .573

Targeted Numbers = 22.5

Processed Numbers = 12.5

Theoretical Cycle Time = 133.3 min

Performance = .653

Defective Rollers varies from week to week ranging from 1 to 4.

So Quality varies accordingly.

The estimation of Overall equipment effectiveness of Milling M/c 2 is shown in Table II.

TABLE II: Estimation of OEE of Milling M/c 2

Duration (weekly)	Availability	Perfor mance	Processed Numbers	Defective Numbers	Quality	OEE
Oct1-Oct7	0.708	0.392	5	1	0.800	0.222
Oct8-Oct14	0.850	0.470	6	1	0.833	0.332
Oct15-Oct21	0.850	0.470	6	1	0.833	0.332
Oct22-Oct28	0.708	0.392	5	2	0.600	0.166
Oct29-Nov4	0.850	0.470	6	2	0.667	0.266
Nov5-Nov11	0.850	0.470	6	1	0.833	0.332
Nov12-Nov18	0.850	0.470	6	1	0.833	0.332
Nov19-Nov25	0.708	0.392	5	1	0.800	0.222
Nov26-Dec2	0.850	0.470	6	1	0.833	0.332
Dec3-Dec9	0.850	0.470	6	1	0.833	0.332

The estimation of Overall Equipment effectiveness of Chasing M/c is done. These estimations are shown in Table III below.

TABLE III: Estimation of OEE of Chasing M/c

Duration (weekly)	Availability	Performance	Processed Numbers	Defective Numbers	Quality	OEE
Oct1-Oct7	0.573	0.808	12.5	2	0.840	0.389
Oct8-Oct14	0.688	0.969	15	2	0.866	0.577
Oct15-Oct21	0.688	0.969	15	4	0.733	0.395
Oct22-Oct28	0.573	0.808	12.5	3	0.760	0.352
Oct29-Nov4	0.688	0.969	15	2	0.866	0.577
Nov5-Nov11	0.688	0.969	15	1	0.933	0.622
Nov12-Nov18	0.688	0.969	15	3	0.800	0.533
Nov19-Nov25	0.573	0.808	12.5	2	0.840	0.389
Nov26-Dec2	0.688	0.969	15	2	0.866	0.577
Dec3-Dec9	0.688	0.969	15	4	0.733	0.489

The average OEE of the three machines over ten weeks is plotted in Table IV below.

TABLE IV: Average OEE of the three machines over ten weeks

Machine	OEE(Average)
Milling Machine 1	43.06%
Milling Machine 2	28.68%
Chasing Machine	49.00%

D. Pareto Analysis of Downtime Loss, Defective Rollers and Roller Costs

Ishikawa fishbone diagram is used to analyse the cause and effects of downtime loss, defective rollers and roller costs.

The causes of downtime loss of all four machines are classified below.

1) Load Time

2) Unload Time

3) Operational Motion Loss

4) Speed Loss

5) No Manpower

6) Sudden Power Failure

7) Shift Change

8) Filling Bulk Stock out

9) Tool Regrinding Time

10) Defect and Rework

11) Tool Replacement Time

The downtime analysis of all the three machines is done using Pareto analysis. These are shown in tables.

Downtime analysis of Milling M/c 1&2 is shown in Tables V and VI respectively below.

TABLE V: Causes of downtime loss in Milling M/c 1

Sr. No	Downtime loss	Frequency (min)	Cumulative Frequency	Percentage
1	Load Time	198	198	26.94%
2	Unload Time	180	378	51.43%
9	Tool Regrinding Time	90	468	63.67%
6	Sudden Power Failure	72	540	73.47%
5	No Manpower	45	585	79.59%
8	Filling Bulk Stockout	42	627	85.31%
7	Shift Change	36	663	90.20%
10	Defect and Rework	27	690	93.88%
3	Operational Motion Loss	18	708	96.33%
11	Tool Replacement Time	17	725	98.64%
4	Speed Loss	10	735	100%

TABLE VI: Causes of downtime loss in Milling M/c 2

Sr. No	Downtime loss	Frequency (min)	Cumulative Frequency	Percentage
1	Load Time	132	132	24.44%
2	Unload Time	120	252	46.67%
9	Tool Regrinding Time	90	342	63.33%
6	Sudden Power Failure	48	390	72.22%
8	Filling Bulk Stock out	42	432	80.00%
5	No Manpower	30	462	85.56%
7	Shift Change	24	486	90.00%
10	Defect and Rework	20	506	93.70%
3	Operational Motion Loss	18	524	97.04%
11	Tool Replacement Time	10	534	98.89%
4	Speed Loss	6	540	100.00%

Downtime analysis of Chasing M/c is shown in Table VII.

TABLE VII: Causes of downtime loss in Chasing M/c

Sr. No	Downtime loss	Frequency (min)	Cumulative Frequency	Percentage
1	Load Time	330	330	29.33%
2	Unload Time	300	630	56.00%
6	Sudden Power Failure	120	750	66.67%
9	Tool Regrinding Time	90	840	74.67%
5	No Manpower	75	915	81.33%
7	Shift Change	60	975	86.67%
8	Filling Bulk Stock out	42	1017	90.40%
3	Operational Motion Loss	38	1055	93.78%
10	Defect and Rework	33	1088	96.71%
4	Speed Loss	22	1110	98.67%
11	Tool Replacement Time	15	1125	100.00%

E. Pareto Analysis of the Defective Rollers produced by the 3 Machines

During the CTC thread cutting operation, a certain number of defective rollers are also produced by the milling machines and chasing machine. A roller can be designated as a defective one if it does not fulfil certain quality criteria thereby influencing the quality rate of production. A number of quality defects are detected and also are their subsequent causes. These are arranged in a table by retaining the most vital one at the topmost position and the least one at the bottom.

The defects found in the produced rollers are:

1) Rough Surface

2) Scratch Marks

3) Poor Cuts

4) Low Precision Cuts

5) Dimensional Shift

6) Low Roller Life

The causes of defects found in the produced rollers are:

1) High Feed Rate

2) High Spindle Speed

3) High Depth of Cut

4) High Cutting Speed

5) Chatter Vibrations

6) Dull Cutter

7) Delay in Regrinding

8) Unsecured Work piece

9) High Cutting Temperature

10) Worker carelessness and ignorance

The Pareto analysis of defects is shown in Table VIII and the Pareto analysis of causes of defects is shown in Table IX.

TABLE VIII: Pareto Analysis of Defects

Sr. No	Defects	Frequency (No)	Cumulative Frequency	Percentage
1	Rough Surface	21	21	30.43%
2	Scratch Marks	18	39	56.52%
4	Low Precision Cuts	15	54	78.26%
3	Poor Cuts	9	63	91.30%
5	Dimensional Shift	4	67	97.10%
6	Low Roller Life	2	69	100.00%

TABLE IX: Pareto Analysis of Causes of Defects

Sr. No	Causes of Defects	Frequency (No)	Cumulative Frequency	Percentage
4	High Cutting Speed	50	50	21.74%
1	High Feed Rate	39	89	38.70%
2	High Spindle Speed	39	128	55.65%
3	High Depth of Cut	31	159	69.13%
5	Chatter Vibrations	26	185	80.43%
6	Dull Cutter	16	201	87.39%
10	Worker carelessness and Ignorance	13	214	93.04%
7	Delay in Regrinding	10	224	97.39%
8	Unsecured Work piece	4	228	99.13%
9	High Cutting Temperature	2	230	100.00%

F. Pareto Analysis of Roller Costs

Finally another Pareto Analysis is carried out on the cost factor effecting the roller production. The three primary costs influencing the roller production are Tooling Cost, Material Cost, and Production Cost. These costs can again be classified into a number of other costs which are directly related to the system.

So we can determine the various costs and their individual influence on the overall cost and create a rank for each of these costs.

The productivity rate of the industry depends on bringing the cost factor to its nadir. So by Pareto Analysis we determine the most dominant cost and subsequently try to lessen it.

The costs influencing the industry are found to be:

1) Total Cost of Milling/Chasing Cutters
2) Total Cost of Bearing
3) Total Cost of Pinion
4) Miscellaneous Cost of Sudden Equipment Failure
5) Roller Transportation Cost
6) Electricity Bill
7) Manpower Expenses
8) Total Roller Cost(one time purchase)
9) Coolant Expenses
10) Motor Maintenance Cost
11) Production Loss Cost due to Downtime
12) Safety Related Cost
13) Tool Regrinding Cost including Cutter Cost
14) Grinder Machine Maintenance Cost
15) Defect and Rework Cost

TABLE X: Pareto Analysis of Cost Factors of Milling M/c 1 over ten weeks

Sr. No	Cost Factors	Frequency (Rs.)	Cumulative Frequency	Percentage
8	Total Roller Cost (one time purchase)	401000	401000	67.56%
7	Manpower Expenses	107500	508500	85.67%
11	Production Loss Cost due to Downtime	19500	528000	88.96%
1	Total cost of Milling Cutters	18000	546000	91.99%
15	Defect and Rework Cost	15000	561000	94.52%
6	Electricity Bill	12500	573500	96.63%
5	Roller transportation cost	10125	583625	98.33%
4	Miscellaneous cost for sudden equipment failure	2000	585625	98.67%
10	Motor Maintenance Cost	2000	587625	99.01%
2	Total cost of Bearing	1500	589125	99.26%
13	Tool Regrinding Cost including Cutter Cost	1200	590325	99.46%
3	Total cost of Pinion	1050	591375	99.64%
9	Coolant Expenses	1000	592375	99.81%
14	Grinder Machine Maintenance Cost	650	593025	99.92%
12	Safety related Cost	500	593525	100.00%

TABLE XI: Pareto Analysis of Cost Factors of Milling M/c 2 over ten weeks

Sr. No	Cost Factors	Frequency (Rs.)	Cumulative Frequency	Percentage
8	Total Roller Cost (one time purchase)	401000	401000	69.60%
7	Manpower Expenses	107500	508500	88.26%
11	Production Loss Cost due to Downtime	14500	523000	90.78%
6	Electricity Bill	12500	535500	92.95%
1	Total Cost of Milling Cutters	12000	547500	95.03%
5	Roller Transportation Cost	10125	557625	96.79%
15	Defect and Rework Cost	9900	567525	98.51%
4	Miscellaneous cost for sudden equipment failure	2000	569525	98.85%
10	Motor Maintenance Cost	1800	571325	99.17%
13	Tool Regrinding Cost including Cutter Cost	1200	572525	99.38%
2	Total Cost of Bearing	1000	573525	99.55%
3	Total cost of Pinion	850	574375	99.70%
14	Grinder Machine Maintenance Cost	650	575025	99.81%
9	Coolant Expenses	600	575625	99.91%
12	Safety related Cost	500	576125	100.00%

TABLE XII: Pareto Analysis of Cost Factors of Chasing M/c over ten weeks

Sr. No	Cost Factors	Frequency (Rs.)	Cumulative Frequency	Percentage
8	Total Roller Cost (one time purchase)	401000	401000	62.03%
7	Manpower Expenses	107500	508500	78.65%
11	Production Loss Cost due to Downtime	42500	551000	85.23%
1	Total cost of Chasing Cutters	39900	590900	91.40%
15	Defect and Rework Cost	20825	611725	94.62%
6	Electricity Bill	12500	624225	96.55%
5	Roller transportation cost	10125	634350	98.12%
2	Total cost of Bearing	2500	636850	98.51%
4	Miscellaneous cost for sudden equipment failure	2000	638850	98.82%
10	Motor Maintenance Cost	2000	640850	99.13%
3	Total cost of Pinion	1800	642650	99.40%
9	Coolant Expenses	1500	644150	99.64%
13	Tool Regrinding Cost including Cutter Cost	1200	645350	99.82%
14	Grinder Machine Maintenance Cost	650	646000	99.92%
12	Safety related Cost	500	646500	100.00%

III. RESULTS AND DISCUSSION

From the data analysis, we have seen that the OEE of all the three machines are varying from each other. Availability depends on the downtime loss as shown in the above analysis. Performance depends on the theoretical cycle time of each machine, which varies from one machine to other. So improvement in OEE of each machine can be achieved by reducing the theoretical cycle time of each machine.

The defective number of rollers produced by all the machines varied from a minimum value of one to a maximum value of four. The maximum quality rate is obtained from the Milling Machine 1 over the weeks Oct 15 to Oct 21, Oct 29 to Nov 4, Nov 20 to Nov 27 and its value is 0.889.The minimum quality rate is obtained from the Milling Machine 1 for the week Nov 26 to Dec 2 and the value is 0.555.

So calculating the OEE of the respective machines weekly over a period of 10 weeks, it is found that the highest value is 0.622 given by the Chasing Machine on the week Nov 5 to Nov 11.The Milling Machine 2 is found to be the least effective as it continuously produces below par values of OEE.A value of 0.166 is found for the week Oct 22 to Oct 28,another value of 0.222 was found for week Oct 1 to Oct 7 and 0.266 for Oct 29 to Nov 4.The Milling Machine 2 is deprived of even a single OEE score of 50% over the calculated period compared to the other machines. So it is the worst machine in terms of effectiveness amongst all.

As the rollers are one time purchase, so we are practically considering the Material Cost of all machines as constant.

TABLE XIII: Table showing main causes of Downtime Loss, Defect & Root cause of Defect, High Cost Incurred

Machine	Main Cause of Down Time Loss	Main Defect & Root Cause of Defect	Main Cause of High Cost Incurred
Milling Machine 1	Load Time	Rough Surface, High Cutting Speed	Production Loss Due To Downtime
Milling Machine 2	Load Time	Rough Surface, High Cutting Speed	Production Loss Due To Downtime
Chasing Machine	Load Time	Rough Surface, High Cutting Speed	Production Loss Due To Downtime

A. Literature Analysis to measure improved OEE

From the above discussions, we have seen that the OEE of the machines are relatively very poor compared to the benchmark. Also the various factors contributing heavily to such values have been discussed and analyzed in detail.

The numero uno cause of downtime loss for all the machines operating for six days a week is found to be the “Load time”. We can neither make any influence on the “Cut Time” as operational motion loss and speed loss are beyond manual interference. These factors totally depend on the motor speed, cutting speed, spindle speed, voltage supply and fluctuate with unnoticeable uncertainty. Hence trying to reduce these time units is of no avail as it won’t guarantee a significant reduction always.

1) Review of Research Articles

From literature,

Amit Kumar Gupta & Dr. R. K Garg, (2012) [1] implemented TPM in an automobile manufacturing organization for OEE improvement. They used various pillars of TPM like 5S, Jishu Hozen, Kobetsu Kaizen, Planned maintenance and education and training of employees. They selected four machines for the implementation viz. Broaching machines, Cylindrical Grinder and Surface Grinder.

The data before and after the implementation of TPM for improvement in OEE in the Broaching Machine is shown in Table XIV and Table XV respectively.

Similarly they implemented TPM on the rest of the machines as well and found them to be quite satisfactory. The OEE of the Broaching Machine 2 increased from 60% to 69%, Cylindrical Grinder from 53% to 67%, Surface Grinder from 50% to 65%.

Ranteshwar Singh, Ashish M Gohil, Dhaval B Shah, Sanjay Desai, (2012) [2] implemented TPM in a machine shop. They used pillars like 5S, Jishu Hozen, Planned Maintenance, Kaizen, Quality maintenance, Training, Office TPM, Safety health and environment. They addressed a number of problems in their case study starting from coolant leakage problem from hose, filter and tank, loose nut and bolts in the machine assembly, parts kept in an unorderly manner in the workplace etc and rectified them primarily through 5S and Kaizen.In a nut shell the conclusions were:

Success of TPM depends on various pillars like 5-S, Jishu Hozen, Planned Maintenance, Quality maintenance, Kaizen, Office TPM and Safety, Health & Environment and world class TPM implementation is possible with continuous support from various quarters.

The data before and after TPM implementation is shown in Table XVI.

TABLE XIV: Data before TPM implementation

Before TPM implementation		
A	Shift Time(General)	450
B	Planned Downtime	60
C	Running Time(A-B)	390
D	Running Time Losses	78
E	Operating Time(C-D)	312
F	Availability(E/C)*100	80%
G	Output	180
H	Machine Speed(No of components/min)	0.75
I	Expected Output(O*E)	234
J	Efficiency(G*100)/I	76.9%
K	Rejection	8
L	Quality(G-K*100)/G	95.5%
M	OEE(F*J*L)	58.7%

TABLE XV: Data after TPM implementation

After TPM implementation		
A	Shift Time(General)	450
B	Planned Downtime	60
C	Running Time(A-B)	390
D	Running Time Losses	58
E	Operating Time(C-D)	332
F	Availability(E/C)*100	85.1%
G	Output	207
H	Machine Speed(No of components/min)	0.75
I	Expected Output(O*E)	249
J	Efficiency(G*100)/I	83.1%
K	Rejection	2
L	Quality(G-K*100)/G	99%
M	OEE(F*J*L)	70%

TABLE XVI: Data before and after TPM implementation

Sl. No	Category	Before TPM implementation	After TPM implementation
1	Shift Time	720 min	720 min

2	Total production in a shift	160 nos.	72 nos.
3	Scheduled Break	50 min	50 min
4	Non Scheduled Break	5 min	0 min
5	Breakdown	4 min	0 min
6	Cleaning, Inspection and Tightening of Insert	15 min	15min
7	Operator Absent	55 min	6.5 min
8	Non-conforming Product	5 nos.	3 nos.
9	Theoretical Cycle Time	3 min	7.5 min
10	Availability(A)	0.90	0.98
11	Performance Efficiency(PE)	0.73	0.85
12	Quality Rate(QR)	0.96	0.95
13	OEE(A*PE*QR)	0.63	0.79

2) Targeted improvement in OEE of the three machines:

On the basis of these three papers, the average reduction in downtime loss is calculated and accordingly applied in the project undertaken.

In the first paper, planned production time is 390 mins and the reduction in downtime is 20 mins. In the second paper, planned production time is 720 mins and the reduction in downtime is 57.6 mins. Calculating the average value of planned production time and reduction in downtime, we get them as 555 mins and 38.8 mins respectively.

Applying the same logical criteria of the above researchers to our undertaken project, we can accordingly reduce the downtime with respect to the planned production time.

The performance rate increase in the above two cases before and after TPM implementation is noted and their average increase is used to determine the improvement in performance in our project. In the first paper, the performance rate after the implementation of TPM increased from 76.9% to 83.1%.In the second paper, the performance rate after TPM implementation increased from 73% to 85%.So on an average, the increase in performance rate was 74.95% to 84.05%.

However in the case of quality improvement, the process is not so simple. Quality rates depend on a number of factors starting from improving machine conditions, cutter specifications, regrinding machine conditions, coolant used, handling of rollers and cutters and good work collaboration. In the ten weeks taken for the survey, the defective number of rollers ranged from 1 to 4 in all the four machines.

To improve the quality rate, a general get together of all the workers and employees of the industry was conducted as an initiative for TPM implementation. The above mentioned factors were explained to them in detail and the benefits of quality improvement were discussed. The target value of maximum number of defective rollers was set as 1 after a discussion with the team. Moreover further discussions were held regarding the practical reduction of downtime and improvement of performance steps.

Target values for TPM implementation on Milling M/c 1

TABLE XVII: Initial values and final target values for Milling M/c 1

Category	Initial Values	Final Target Values
Downtime Loss (min)	735	483.33
Availability	0.800	0.870
Performance	0.753	0.844
Quality(average)	0.778	0.889
OEE(average)	0.468	0.653

Target values for TPM implementation on Milling M/c 2

TABLE XVIII: Initial values and final target values for Milling M/c 2

Category	Initial Values	Final Target Values
Downtime Loss (min)	540	288.33
Availability	0.850	0.919
Performance	0.470	0.527
Quality(average)	0.809	0.833
OEE(average)	0.323	0.403

Target values for TPM implementation on Chasing M/c

TABLE XIX: Initial values and final target values for Chasing M/c

Category	Initial Values	Final Target Values
Downtime Loss (min)	1125	873.33
Availability	0.688	0.757

Performance	0.969	0.969
Quality(average)	0.828	0.933
OEE(average)	0.552	0.684

3) Targeted improvement in the average values of OEE over ten collective weeks:

The average OEE before and after improvement for Milling M/c 1 as found from literature is 46.8% and 65.3% respectively. So applying the same logic for all the collective ten weeks, we get improvement from 43.06% to 60.08%.

The average OEE before and after improvement for Milling M/c 2 as found from literature is 32.3% and 40.3% respectively. So applying the same logic for all the collective ten weeks, we get improvement from 28.68% to 35.78%.

The average OEE before and after improvement for Chasing M/c as found from literature is 55.2% and 68.4% respectively. So applying the same logic for all the collective ten weeks, we get improvement from 49.00% to 60.71%.

The initial OEE values and the targeted improved OEE values over ten collective weeks are shown in Table XX.

TABLE XX: Initial and final obtained targeted OEE values over ten collective weeks

OEE	Initial values	Final values obtained (targeted)
Milling m/c 1	43.06%	60.08%
Milling m/c 2	28.68%	35.78%
Chasing m/c	49.00%	60.71%

The graph of comparison of initial OEE values and the improved final targeted OEE values obtained over ten collective weeks for Milling M/c 1, Milling M/c 2 and Chasing M/c is shown in Figure 1.

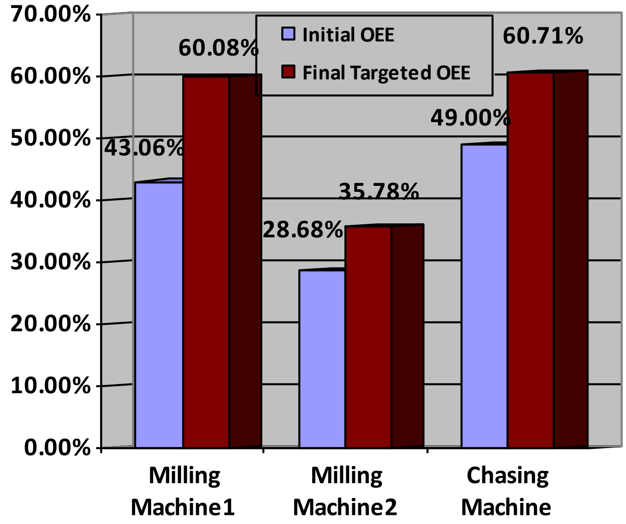

Fig 1: Graph showing OEE comparison of initial values and final targeted values of the three machines

IV. CONCLUSION

Total Productive Maintenance is definitely a necessary criterion but may not be the sufficient one for improving Overall Equipment Effectiveness. The scope of Overall Equipment Effectiveness improvement is very vast and it requires many complex operations to reduce the time factors which are purely machine controlled. Also reducing production cycle time is another vital cog in this process.

The general get together of all the employees in the enterprise was a great success as it formed the base for a successful future TPM implementation. The discussion on various measures for the reduction of defective rollers and imparting the knowledge of TPM and its benefits to the workers by suggesting the maintenance of a proper and enthusiastic work environment, total worker involvement, proper inspection and lubrication of parts, good training programmes, reduction of accidents in workplace and boosting employee morale was definitely a positive step towards futuristic TPM implementation plans. The improved OEE values can be used as the target values by the enterprise for future TPM implementation.

To achieve this target efficient maintenance is necessary, in order to establish autonomous maintenance teams, better communication and team-work must be promoted. It is essential that the enterprise devices an efficient data recording system, so that up-to date and accurate information will be available to the management and information provided by the trend analysis can provide a basis for forming- long-term plans.

Acknowledgment

I offer my sincere and deep sense of gratitude to my respected teacher, Dr.Parimal Bakul Barua, Professor and Head, Deptt. of Mechanical Engineering, Jorhat Engineering College for his priceless motivation and providing the opportunity to undergo the research work. I would like to extend my sincere regards for my respected teacher and guide, Mr.Ajoy Krishna Dutta, Assistant Professor, Deptt. of Mechanical Engineering, Jorhat Engineering College for his constant inspiration, erudite guidance and indelible suggestions throughout the course of the research work. Finally I would like to extend my heartfelt gratitude to Mr. Anindra Sundar, machine incharge of Hydron Engineering Works and all those who are directly or indirectly involved in myself conducting the project.

References

[1] Gupta K. Amit & Garg R.K., "OEE improvement by TPM implementation: A case study", International Journal of IT, Engineering and Applied Sciences Research (IJIEASR), Volume 1, No. 1, October 2012.

[2] Singh Ranteshwar, Gohil M. Ashish, Shah B. Dhaval, "Total Productive Maintenance implementation in a machine shop: A Case Study", ELSEVEIR, Procedia Engineering 51 (2013) 592-599.

[3] Ljungberg O., "Measurement of overall equipment effectiveness as a basic for TPM activities", International Journal of Operations & Production Management, 18(5), 495-507 (1998). http://dx.doi.org/10.1108/01443579810206334.

[4] Jonsson P. & Lesshammar M., "Evaluation and improvement of manufacturing performance measurement systems – the role of OEE", International Journal of Operations & Production Management, 19(1), 55-78 (1999) http://dx.doi.org/10.1108/01443579910244223.

[5] Ireland F. & Dale B.G, "A study of total productive maintenance implementation", Journal of Quality in Maintenance Engineering, Vol.7 No.3, (2001), pp. 183-191.

[6] McKone E. Kathleen & Schroeder G. Roger, "Total Productive Maintenance: a contextual view", ELSEVEIR, Journal of Operations Management 17(1999).

[7] Varambally K.V.M, Rodrigues L.R. Lewlyn, "A Methodology for Implementing Total Productive Maintenance in Manufacturing Industries-A Case Study", International Journal of Engineering Research and Development, Vol 5, Issue 2(Dec 2012), pp.32-39.

[8] Poduval S. Prasanth, Pramod V.R., "Barriers in TPM Implementation in Industries", International Journal of Scientific and Technology Research, Vol 2, Issue 5, May 2013.

[9] Bangar A., Sahu Hemlata, Batham Jagmohan, "Improving Overall equipment Effectiveness by Implementing Total Productive Maintenance in Auto Industry", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Vol 3,Issue 6, June 2013.

[10] Khan FirdosJahan, T.Z. Quazi, "Implementation of Kobetsu Kaizen pillar in Improving Overall Equipment Effectiveness of Machine", International Journal of Engineering Sciences and Research Technology , ISSN 2277-9655, July 2014.

[11] Jayaswal Pratesh, Rajput S. Hemant, "Implementation of Kaizen and Jishu Hozen to enhance Overall Equipment Performance in a manufacturing industry", IJRIM, ISSN 2231-4334, Vol 2, Issue 8, August 2012.

[12] H. Kamath Nagaraj, Rodrigues L.R. Lewlyn, "A Pilot study for Total Production Management in Printing Industry", International Journal of Applied Research, Vol 4, Issue 12, Dec 2014, ISSN-2249-555X.

[13] Phoewhawm Ravee, "A Case Study on Kaizen as a Learning Tool for a Management Team", Asian Journal of Management and Innovation, January-May 2014.

[14] Hedge G. Harsha, Mahesh N.S., Doss Kishan, "Overall Equipment Effectiveness Improvement by TPM and 5S Techniques in a CNC Machine Shop", SASTECH, Vol 8, Issue 2, September 2009.

[15] Mulla Mohammedasif, C.G.Ramesh, "Enhancing Overall Equipment Effectiveness of HMC machines through TPM and 5S techniques in a manufacturing company.", International Journal on Mechanical Engineering and Robotics, Vol 2, Issue 2, 2014.

[16] Tamizharasi G., Kathiresan S., "Optimizing Overall Equipment Effectiveness of high precision SPM using TPM tools.", International Journal of Computer Trends and Technology, Vol 3, Issue 4, Number 1, July 2012.

[17] Gudadhe Mangesh, "A Review Study on Improvement of Overall Equipment Effectiveness in Construction Equipments.", International Journal of Engineering Development and Research, Vol 3, Issue 2, 2015.

[18] Gautam Rajesh, Kumar Sushil, Singh Sultan, "Kaizen Implementation in an Industry in India: A Case Study.", International Journal of Research in Mechanical Engineering and Technology, Vol 2, Issue 1, April 2012.