Implementation of TPM to Enhance OEE in A Medium Scale Industry

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Abstract - *Today, machine maintenance and in particular, implementing an appropriate maintenance strategy has become increasingly important for manufacturing industries. Total Productive Maintenance (TPM) is an excellent approach for maintaining plants and equipment's which optimizes the equipment effectiveness, eliminates breakdown and promotes autonomous operator maintenance through day-to-day activities, which involves the total work force. This paper presents the study and overview of implementation of TPM in an automobile spare parts manufacturing industry to enhance OEE. For this purpose the current OEE of machines are analyze and critical machine is selected for implementation of TPM. The methodology includes step wise implementation of 5S, Autonomous maintenance, Kaizen and Planned maintenance. After implementation of TPM on the critical machine increase in availability, performance and quality is achieved thereby enhancing overall equipment effectiveness. Comparison of OEE before and after TPM implementation validates the success of TPM implementation in the industry.*

Key Words: **TPM (Total Productive Maintenance), OEE (Overall Equipment Effectiveness), AM (Autonomous Maintenance),KK(KobetsuKaizen),PM(Planned Maintenance).**

1.INTRODUCTION

The main goal of an effective TPM program effort is to bring critical maintenance skilled trades and production workers together. Total employee involvement, autonomous maintenance by operators, small group activities to improve equipment reliability, maintainability and productivity, and continuous improvement are the principles embraced by TPM. A TPM program typically enlarges the responsibility of production employees from merely operating machines to such areas as detecting machine failures, performing basic maintenance, and keeping work areas clean and organized. The practices of TPM help eliminate waste arising from an unorganized work area, unplanned downtime, and machine performance variability thereby achieving marked improvements in overall equipment performance.

1.1 Implementation of TPM

Implementation of TPM is based on systematic implementation of its pillars.Many companies struggle to implement TPM due to two main reasons. First is having insufficient knowledge and skills especially in understanding the linkages between the pillar activities in TPM. The second reason is that TPM requires time, resources and efforts than most of these companies believe they can afford. The pillars of TPM are explained below.

1.1.1 5S-Base of TPM

5S forms the base and is the start point for TPM implementation. It helps to uncover problems. Making problems visible is the first step towards improvement.

Table -1: 5S

Japanese Term	Equivalent 'S' term	Meaning
Seiri	Sort	Sort between items needed and not needed
Seiton	Set in order	Keep needed items in correct place for easy and immediate retrieval
Seiso	Shine	Work areas, work surfaces and equipment clean and free from dirt,debris.
Seiketsu	Standardize	Standardize activities, procedures and schedules
Shitsuke	Sustain	To maintain new standards and procedures

1.1.2 Pillar 1-Autonomous maintenance

Autonomous maintenance is handing over responsibilities of basic maintenance activities to operators. It can be implemented through establishing and maintaining basic conditions, enhancing knowledge of operators and providing operator ownership of equipment. Due to this workers become more responsible and reduction in downtime is achieved.

1.1.3 Pillar 2- Kobetsu Kaizen

Kobetsu Kaizen is structured team based approach to drive elimination of identified losses. It can be implemented by developing cross functional teams working on problematic equipment and kaizen project for maintenance. This helps in promoting lean methodology to workers thereby producing large base of employees with right tools for solving problems.

1.1.4 Pillar 3- Planned maintenance

Planned maintenance is structured approach to establish maintenance plan. It can be implemented by scheduling of maintenance activities and carrying out maintenance when machine is idle or producing little. Due to this breakdowns are reduced gradually and no expensive parts are added to inventory.

1.1.5 Pillar 4- Quality maintenance

Quality maintenance is about controlling interactions between men material and machine & methods that enables defects to occur. This can be achieved by investigating current state, implementing improvements and sustain quality by standardizing parameters and methods to achieve zero defects. Due to this defects are minimized or eliminated. Getting quality right the first time and quality issues with permanent solutions are the other benefits.

1.1.6 Pillar 5- Training

Training is a companywide initiative including all levels from operators to managers. Operators are taught basic skills for maintaining equipments. Higher level training is provided to the technical staff and TPM skills to the managers. This in turn leads to successful implementation of TPM in the industry.

1.2 Overall equipment effectiveness

Overall equipment effectiveness (OEE) is a term coined by Seiichi Nakajima. It provides a way to measure the effectiveness of manufacturing operations from a single piece of equipment to an entire manufacturing. OEE is an effective tool used in TPM and Lean Manufacturing as a Key Performance Indicator. It is percentage of planned production time which is truly productive. OEE measurement is essential for every organization committed to eliminate waste & losses through implementation of TPM.
Thus OEE is a function of the three factors namely availability, performance and quality.

1.2.1 Availability

Availability (A) of the machine is proportion of time machine is actually available out of time it should be available.

$$\text{Availability} = \frac{\text{(Planned Production time - Downtime)}}{\text{Planned Production time}}$$

Availability losses include equipment failures and changeovers indicating situations when the line is not running although it is expected to run.

1.2.2 Performance

Performance (P) of the machine is the speed at which work center runs.

$$\text{Performance} = \frac{\text{Ideal cycle time x Parts produced}}{\text{Available time}}$$

Performance losses include Speed losses, small stops, idling, and empty positions in the line, indicating that the line is running, but it is not providing the quantity it should.

1.2.3 Quality

Quality (Q) is percentage of good parts out of total produced parts.

$$\text{Quality} = \frac{\text{(Total units started-Defective units)}}{\text{Total units started}}$$

Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects.

Therefore OEE= Availability × Performance × Quality.

2. LITEARTURE REVIEW

Dr. Ramachandra, C G Prashanth Pai, M Dr. T. R. Srinivas, Raghavendra M J, have studied measurement of effectiveness of TPM implementation in manufacturing & service industries. They did a review on range of journals related to TPM published in span of 10 years and have stated that improvement of OEE is observed through availability, performance & quality thereby proving an effective tool for measuring effectiveness if TPM[1].

Ashwin B. Virupakshar and Anil Badiger, have stated that to achieve overall equipment efficiency TPM is ideal tool. TPM helps the management to improve the overall performance of the firm and by proper implementation of TPM concepts the manufacturing industries can gain great benefits with the very less investment. They achieved reduction of cycle time for each operation by combining two or more operations and by providing special attachment wherever possible for a traub machine thereby increasing its productivity [2].

Rishi J, Dr. Ramachandra C and Dr. T R Srinivas, stated that TPM can be best suited for achieving lean manufacturing. They successfully implemented TPM in Automotive Axles and achieved higher efficiency by reducing setup time and increasing OEE. They carried out SWOT analysis is order to analyse the problem associated with the original equipment manufacturers [3].

Vijay Lahri and Dr. Pramod Pathak, have stated that OEE tool is route map to boost the effectiveness of manufacturing process and equipment. OEE extracts all the reason for delay of the job and not just only measures inefficiency but also categorizes those into 3 categories for better understanding of manufacturing procedure. They carried out carried out OEE on CNC Table type boring & milling machine to find out the bottleneck and hidden losses and achieved increased in OEE after implementing various suggestions [4].

Parth N Chandegra and Vivek A. Deshpande, have studied that with the help of Total Productive Maintenance (TPM) approach cycle time reduction can be achieved. They did the same for PCF gear assembly using 5S methodology and other pillars and refined the assembly in appropriate manner. They also found that by applying the approach of TPM, improvement in production effectiveness by identifying and eliminating production losses in the production system through active participation of all employees can be achieved [5].

Prof. Ravi Ngaich, Pavan Kumar Malviya, evaluated the contributions of total productive maintenance (TPM) towards improving manufacturing performance in Small and Medium scale Enterprises. They investigated the relationship between Total Productive Maintenance (TPM) and manufacturing performance (MP) and improving it by using the fundamental TPM Pillars and reducing the six big losses in a Manufacturing Industry [6].

Nithin Raj and Sanukrishna S, have stated that improvement in OEE can be achieved by improving maintenance strategies of critical equipment's. They analyse imperfections in existing maintenance policy and suggested corrective actions for the same. The machines under study were Vertical Turret Lathe & Drilling Machine. They achieved impact growth in OEE in a short period of time [7].

Chowdury M. L. Rahman and M. A. HoqueRaj, have studied and evaluated implementation of autonomous maintenance & planned maintenance in an semi-automated manufacturing industry. They carried out pareto and statistical analysis of downtimes and based on the results suggested maintenance management & productivity planning in order to improve maintenance [8].

Pradeep Kumar, Raviraj Shetty and Lewlyn L.R. Rodrigues, carried out empirical study based on real time data analysis to achieve results. They distributed questionnaires to asses information on successful implementation of TPM. They carried out autonomous maintenance (AM) & productive maintenance (PM) to detect faults and thereby improve output, total productivity and OEE of printing machine [9].

E.Sivaselvam and S.Gajendran, have stated that using overall equipment effectiveness calculations one can determine the present situation in the production system, effectiveness of the maintenance system, conditions of the machines, worker's skill and utilization of the machines. Calculating the OEE also gives the company where they are and where the weakness point is and how to improve. From the calculated OEE high cycle time, more waiting time and Low productivity can be identified [10].

3. CASE STUDY

3.1 About company

Naminath Engg. Pvt. Ltd. is a leading manufacturer of precision turned & cold forging components, automobile spare parts and various other components like studs, taper plugs, banjo bolts, dowel pins, pins, nuts, shafts, screws, adapters, connectors, bushes, spacer, filler & magnetic plugs. It has been more than two decades that the company is manufacturing components for various sectors namely automotive, farm equipment, switchgear etc. Some of the companies esteemed clients are Mahindra & Mahindra Ltd. (Automotive Division), Piaggio Vehicles Pvt. Ltd. and Larsen & Turbo Limited.

3.2 Problem definition

After carrying out several visits and direct observations of machines on the production shop floor and analyzing previous machine utilization records at Naminath Engg. Pvt. Ltd it was found that machines were not operating up to its full production capacity due to following problems associated with the machines

a) Housekeeping of the machines is carried out during machining hours which accounts for production delay.
b) Time loss occurs during loading and setting of job on machines which accounts for setup loss.
c) Time loss during changeover from one job to other on machine accounts for setup loss.
d) Break downs of machines due to improper cleaning and lubrication of machine parts which accounts for availability loss.
e) Lack of planned maintenance schedule for machines which accounts for performance loss.
f) Frequent tool breakage due to operator inefficiency which accounts for performance loss.

All the above mentioned problems are affecting the overall equipment effectiveness of machines on the production shop floor and thereby effecting overall plant efficiency. Hence there is need to implement total productive maintenance strategy in order to overcome the above mention problems and achieve improvement in overall equipment effectiveness.

3.3 Methodology

In order to overcome problems mentioned in previous section a brief study was carried out and implementation of TPM methodology to improve OEE was finalized. To start with TPM few machines were selected.

These machines were selected on the basis of most important activities performed on the production shop floor which included bolt forming, drilling, thread rolling and surface grinding. Hence the following machines were selected for TPM study.

Table -2: Machines selected for TPM study

Sr .No	Name of Machine	Make	Product
1	3/8 Bolt Former	National	Stud, banjo bolt, pins
2	Two Spindle Drilling Machine	Glider	Banjo bolt
3	Thread Rolling	Raco Smith	M6 to M26 Studs
4	Centreless Grinding	Satnam	Plunger, Banjo bolt, Stud

3.3.1 Steps for implementation of TPM

In order to achieve success TPM should be implemented in proper stepwise manner. In each step one TPM pillar is to be implemented as per requirement of the company. The stepwise implementation is shown in following diagram.

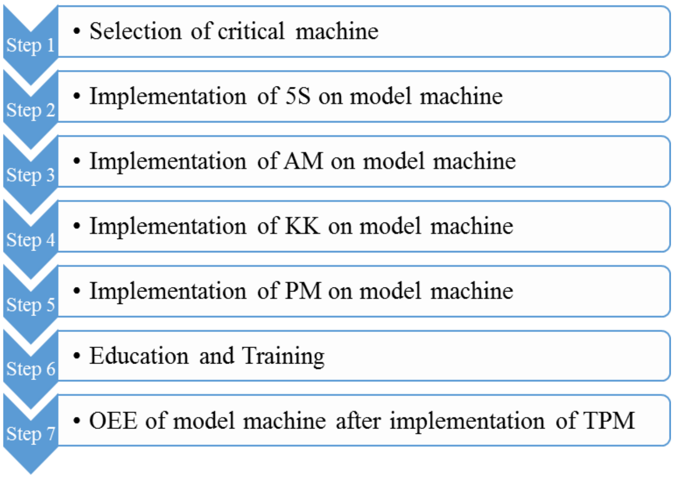

Fig -1: Steps to implement TPM

Step 1: Selection of critical machine

From the machines selected in table no 2 critical machine is determine by calculating OEE of all the four machines. The data to be collected for all the four machines and stored in excel format. Excel sheet for data collection includes machine name, product name, duration, observer name, date, shift length, break time, down time, ideal run rate, total pieces and reject pieces.
After collection of data OEE is be calculated in excel sheet which includes planned production time, operating time, good pieces, availability, performance, quality and overall OEE.The OEE calculated for the four machines is shown in the following table.

Table -3: OEE before TPM implementation

Sr .No	Name of Machine	Availability %	Performance %	Quality %	OEE %
1	3/8 Bolt Former	79.68	96.42	99.99	76.42
2	Two Spindle Drilling Machine-BDR-01	48.46	74.82	99.81	36.19
3	Thread Rolling TR-13	96.63	90.57	99.99	87.50
4	Centreless Grinding CG-01	95.91	93.56	99.97	89.71

After analyzing the above table it is found that critical machine is BDR-01 whose OEE is 36.19%. This machine is named as TPM model machine who's OEE is to be improved by implementation of TPM.

Step 2: Implementation of 5S on model machine

a) **Seiri/Sort/Clear:** The first pillar of 5S is implemented to sort out between items needed in the work area from those not needed on priority basis. Items not needed are red tag and moved to red tag area.

Fig -2: Implementation of 1S

b) **Seiton/Set in Order/Configure**: The second pillar of 5S is to be implemented to keep needed items in correct place for easy and immediate retrieval. The correct position for every tool, item and material is chosen in relation to how work is to be performed.

Fig -3: Implementation of 2S

c) **Seiso/Shine/Clean:** The third pillar of 5S is implemented to keep work areas, work surfaces and equipment clean and free from dirt, debris, oil etc.

Fig -4: Implementation of 3S

d) **Seiketsu/Standardize/Conformity:** The fourth pillar of 5S is implemented to standardize activities, procedures, schedules. Machine diagram is prepared and new SOP is set for operating machine. Labelling of all components is done for easy identification.

Fig -5: Implementation of 4S

e) **Shitsuke/Sustain**: This fifth and final pillar of 5S is implemented in order to be focus to maintain new standards & procedures and continuously improve 5S state of workplace in disciplined manner. For thispurpose person responsible for 5S is define and posters of 5S are displayed in regional language.

Fig -6: Implementation of 5S

Step 3: Implementation of AM on model machine

After implementing 5S on the model machine the next step is implementation of autonomous maintenance (AM). This pillar is based on the concept that if operators take care of small maintenance tasks it will free up the skilled maintenance people to concentrate on more value added activity and technical repairs.

For this CLIT tool is used under which cleaning, lubrication, inspection and tightening standards are set to be followed by operators on daily basis.

Table -4: Standards for cleaning

Sr No.	Location	Method of Cleaning	Standard	Frequency
1	Rollers of Limit Switch	Air blow gun	No dirt, chips	Daily
2	Work piece Area	Air blow gun	No dirt, chips	Daily
3	LM guide ways of part loading cylinders	Dry cloth	No dirt	Daily
4	Machine Table	Chip remover	No chips , coolant mist	Daily
5	Electric Motor	Dry cloth	No dust, mist	Daily
6	FR Unit	Knob release	No moisture	Daily

Table-5: Standards for lubrication

Sr No.	Location	Method of lubrication	Type of Lubricant	Frequency
1	Right and Left spindle	Manual	Oil	Daily
2	LM guideways of part loading cylinders	Manual	Oil	Daily

Table -6: Standards for Inspection

Sr No.	Location	Method of inspection	Standard	Frequency	Corrective Action
1	Belt drive	Visual	No Tension, wear	Daily	Corrected
2	Pressure Guage (Power Pack Unit)	Visual	Right-20 to 25 kgf/cm2 Left-35 to 40 kgf/cm2	Daily	Adjust to standard
3	Pressure Guage (FR Unit)	Visual	6 to7 kgf/cm2	Daily	Adjust to standard
4	Spindle Bearing	Noise	No noise	Daily	Inform Maintenance person

Table -7: Standards for Tightening

Sr No.	Location	Tool to use	Frequency
1	Limit switches	Spanner	Daily
2	Part grippers	Allen Keys	Daily
3	Collet	Collet Spanner	Daily

Step 4: Implementation of KK on model machine

After successful implementation of AM the next step is implementing Kobetsu Kaizen pillar also known as focused improvement. Kaizen i.e. continuous improvement involves small improvements to be carried out on continual basis by people of all levels in the company. The results of KK implementation is shown below.

Table -8: Kaizen's perform on model machine

Sr No	Type of abnormality	Reason	Effect	Countermeasure	Benefits
1	Piston wear of de clamping cylinder	Continuous and prolonged use	Improper declamping of finished parts	Piston of declamping cylinder replaced and spare pistons made in-house	Availability & Performance
2	Pressure gauge of FR unit not visible	Improper location of FR unit	Unable to adjust air pressure	Position of FR unit change so that air pressure can be easily visible and controlled	Performance
3	Wear and tear of limit switches	Continuous and prolonged use	Improper functioning of limit switches	New limit switches setup	Performance
4	Trial and error method for setting up limit switches	No standard set for setting up limit switches	Time consuming to get right depth of cut	Scale mounted perpendicular to limit switches and provided with standard markings	Performance & Quality
5	Air leakage through pneumatic cylinder used for part gripping	Wear and tear between piston rod and seal	Insufficient pressure leading to lose gripping of parts	Piston rod seals made in house and kept in spare parts list for instant replacement	Performance

Step 5: Implementation of PM on model machine

The next step after implementation of KK is to implement Planned Maintenance pillar. Based on the previous experience of maintenance staff breakdown details related to machine failures are recorded. Root cause Analysis(RCA) tool is used to determine all possible root causes of the problem.

Table -9: Machine breakdown details

Sr No	Problem	Frequency of breakdowns	Corrective Action
1	Limit switches failure	5	Replaced
2	Part gripping failure	10	New bolting done
3	Spindle run out	4	Readjust play between bearing & spindle
4	Coolant pump motor failure	1	Replace

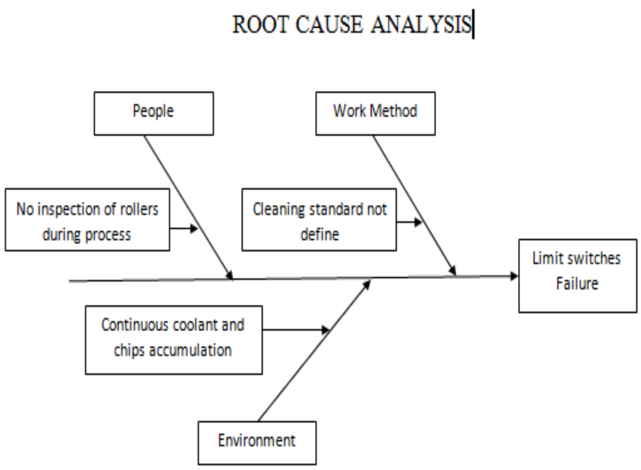

Fig -7: Root cause analysis of problem

Based on root cause analysis of the problems preventive maintenance schedule is prepared for the machine.

Table -10: Preventive Maintenance

Sr No	Problem	Corrective Action	Preventive Action
1	Limit switches failure	Replaced	Daily clean and extra switches kept in spare
2	Part gripping failure	New bolting done	Daily tightening and extra plates kept in spare
3	Spindle run out	Readjust play between bearing & spindle	Monthly inspection of check nut
4	Coolant pump motor failure	Replace	Daily cleaning of pump surface

Step 6: Education and Training

Education & Training is important pillar of TPM. TPM can be misunderstood by employees due to lack of proper training and education. Hence there is need for companywide initiative to involve everyone right from operators to manager. Training and Education is carried out during implementation of different pillars of TPM.

4. RESULTS AND DUSCUSSION

After implementation of TPM on the model machine i.e BDR-01 OEE is recalculated. The results thus obtained are as follows.

Table -11: Comparison of OEE before and after TPM

Sr .No	Parameters	Before TPM Implementation	After TPM Implementation
1	Availability %	48.46	93.69
2	Performance %	79.22	88.29
3	Quality %	99.52	99.90
4	OEE %	38.21	82.64

The table shows that there is increase in availability and performance of the model machine. The graphical analysis is shown in the following diagram.

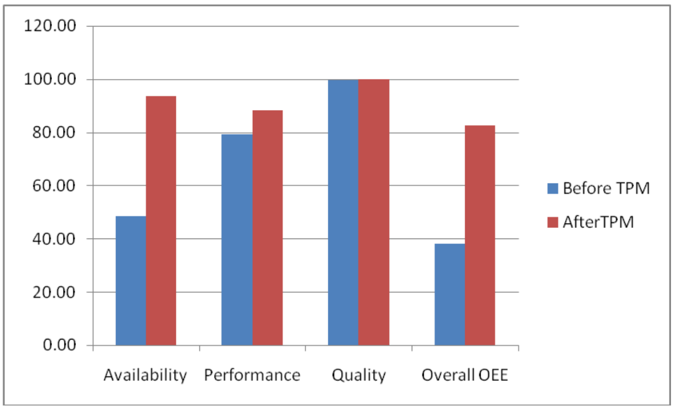

Fig -8: Comparison of OEE

4. CONCLUSION

Today in the era of globalization, to compete with other industries it is necessary to move towards modern ways of maintaining plants and equipments. TPM forms the best strategy for industries to remain competitive and effective when it comes to overall effectiveness of the company. Through this study a medium scale manufacturing industry is studied and analyzed to assess maintenance and overall equipment effectiveness of machines. Thus after carrying out stepwise implementation of TPM in the company marked improvements in availability, performance efficiency and quality rate can be achieved thereby leading to increase in OEE of model machine and which will further lay down foundation for companywide implementation of TPM.

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