Implementation Of TPM In A Forging Unit – A Case Study

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Abstract

The increased dependence on the production equipment to reliably and repeatedly manufacture high quality products has created the need for a new approach to equipment management. Total Productive Maintenance (TPM) is an effective method for addressing this equipment management challenge.

Forging units are currently undertaking a metamorphosis in order to become more competitive in the commercial market. A large component of this change is an effort to improve manufacturing capabilities and reduce wastage, which reduce overall production costs. To accomplish these goals, any forging unit must improve both the quality of their products and the reliability of their production equipments. The implementation of Total Productive Maintenance (TPM), in the proper environment, can provide effective set of processes to drastically improve their manufacturing effectiveness through more reliable production equipments. A case study was carried out in a typical SME forging unit in Gujarat which currently does not have a reliable and repeatable methodology for implementing TPM. The intent of case study was to establish an effective approach for implementing TPM.

This paper explains the methodology of the measurement of Overall Equipment Effectiveness (OEE) in the forging unit shops. A computer software was developed to help the organization to find out the systematic stoppage analysis & OEE of hammer and other forging equipments. By considering shift data, consisting of number of acceptable products, rejection, rework and reason for break down, OEE could be calculated and report can be automatically generated and updated. Also this paper contains methodology of TPM implementation in the forging unit.

By implementing TPM in these situations, the down time (manufacturing costs) associated with six big losses (variability in both product quality and production schedules) can be reduced and OEE can be improved. The paper shows the improvement in OEE and reduction in down time by implementation of basic principles of TPM.

By analyzing the results, conclusions have been drawn and suggestions for further scope have been provided.

Keywords: TPM, OEE, Productivity

1.0 INTRODUCTION

Industrial manufacturing of products is facing accelerating changes of pace in technology and market demands.

The competition not only directly concerns competitor's products, but also indirectly corporate and management strategies as well as production philosophies and processes.

The production system determines not only the final qualities of the products, but also has a large impact on time-to-market, time-to-customer, delivery punctuality and product cost. The ability of manufacturing companies to adapt to their changing environment is a key to long-term success.

To cope with the dynamic manufacturing situation and to achieve high use of the production system, several concepts, strategies, and trends have been developed. Like world class manufacturing (WCM), Lean Manufacturing, Total Quality Management, Six Sigma organizations are a common aim of many manufacturers

Increasing competition to produce reliable products at lower costs and customer driven specification has led to implementation of techniques like Just In Time (JIT), Kanban and Total Productive Maintenance (TPM) in to the manufacturing systems. Companies face dilemma due to the manufacturing constraints and high equipment cost. Should they go for increasing the plant capacity or study the current equipments for their performance efficiency, quality and utilization in optimal working conditions? The motivation is to reduce the Cost of Ownership (COO).

TPM typically addresses these concerns by optimizing the use of manufacturing resources including the tools. TPM involves all functions of the organization, from top management to the shop floor worker. Overall Equipment Effectiveness is the key metric of TPM. OEE monitors the actual performance of a tool relative to its performance capabilities under optimal manufacturing conditions. It not only measures the utilization but also production efficiency due to various metrics and quality of the final product of the process. Various functional departments have different metric to measure their performance but the overall performance of the system depends on balancing the various metrics to arrive at optimal solution and to avoid trade off's. Implementing OEE hence, requires cross-functional teams to achieve its goal. OEE uses various tools to analyze the bottleneck operations that define the plant capacity

Since, OEE requires lots of data related to shop floor control parameters and their dependence on various performance metrics, dynamic statistical data collection is suggested. This data if used in simulation of the processes and the plant layout should give us the overall system view which helps is visualizing the key processes and their impact on overall plant effectiveness.

2.0 TOTAL PRODUCTIVE MAINTENANCE

There are two main approaches to defining TPM, described as the Japanese approach and the Western approach.

2.1 The Japanese Approach To Defining TPM

It defines TPM as "Productive maintenance involving total participation in addition to maximizing equipment effectiveness and establishing a thorough system of PM", where PM is a comprehensive planned maintenance system.

2.2 The Western Approach To Defining TPM

A partnership between the maintenance and production organisations to improve product quality, reduce waste, reduce manufacturing cost, increase equipment availability, and improve the company's overall state of maintenance.

2.3 Objectives Of TPM

Notwithstanding the different definitions stated above The ideal goals of TPM are to achieve Zero Failures, Zero Defects, and Zero Accidents. Although these goals are extremely difficult to achieve, and in many cases may not be economically feasible due to the high cost of eliminating all failures, defects, and accidents; they provide a directional target that the organization can shoot for.

2.4 Eight Pillars Of TPM

the eight pillars of TPM development which are shown by Yeomans and Millington in Figure 1 and summarised by Nakajima as:

(1) Implement improvement activities designed to increase equipment efficiency. This is accomplished mainly by eliminating the ``six big losses" .
(2) Establish a system of autonomous maintenance to be performed by equipment operators. This is set up after they are trained to be ``equipment conscious" and "equipment skilled."
(3) Establish a planned maintenance system. This increases the efficiency of the maintenance department.
(4) Establish training courses. These help equipment operators raise their skill levels.
(5) Establish a system of maintenance prevention (MP) design and early equipment management. MP design generates equipment that requires less maintenance, while early equipment management gets new equipment operating normally in less time. The eight pillers are shown in the fig. 1

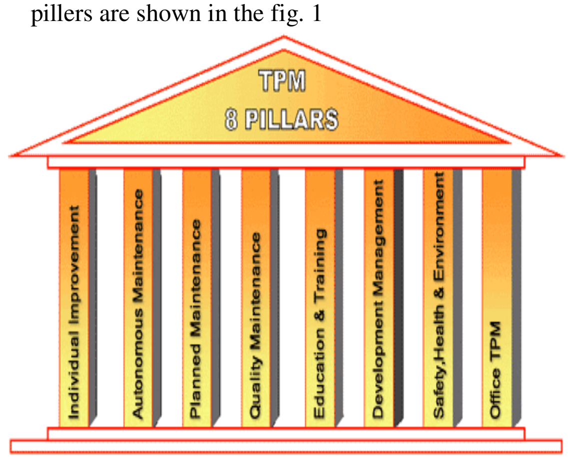


Fig. 1: The Eight Pillars Of TPM [44]

2.5 Major activities of TPM

Total Productive Maintenance involves improvements to production equipment, as well as making the practice of maintenance more efficient. This requires accurate planning and scheduling, access to reliable equipment information, and a good spare parts inventory system. It can also involve "designing or redesigning equipment to make maintenance easier and quicker to perform, or purchasing equipment that requires less maintenance". TPM activities can effectively be collected in the following six separate components. Following fig. 2 shows six major TPM activities.

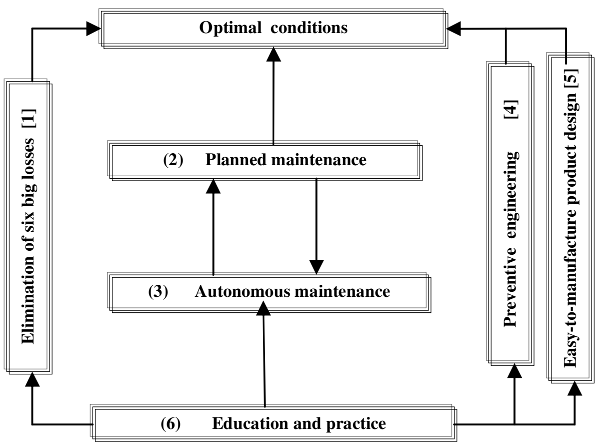


Fig. 2: Six major TPM activities [4]

The various TPM activities are

2.5.1 Elimination of six big losses

These six big losses are (1) Equipment failure/breakdown losses, (2) Set-up/adjustment time losses, (3) Idling and minor stop losses, (4) Reduced speed losses, (5) Reduced yield and (6) Quality defects and rework are losses in quality.

2.5.2 Planned maintenance

A planned maintenance system is established mainly by maintenance department. It consists of planned breakdown maintenance and planned corrective maintenance.

2.5.3 Autonomous Maintenance

Autonomous maintenance requires the proactive involvement of equipment operators to eliminate accelerated equipment deterioration through: cleaning, monitoring, fastener tightening, data collection, and reporting equipment conditions and problems to the maintenance staff. Further, the operators must work to develop a deeper understanding of their equipment which should improve their operating skills.

2.5.4 Preventive engineering

It deals with early equipment management" entails a sequence of well-managed corrective actions to transform operations into commercial production as soon as possible. For this purpose, the causes of troubles must be eliminated not only in this commissioning period, but also in the earlier period, when a series of plant engineering tasks takes place. Instances include conceptual design, basic design, detailed design, procurement and fabrication, installation, test runs, commissioning, and turnover.

2.5.5 Easy-to-manufacture product design.

It deals with ease in manufacturing and quality assurances are built in at the product design stage.

2.5.6 Education and Training

This element supports all the other TPM components by ensuring that employees have the necessary knowledge and skill to do a quality job while performing TPM related tasks.

2.0 OVERALL EQUIPMENT EFFECTIVENESS (OEE)

OEE is the best practice to monitor and improve the efficiency of manufacturing processes (e.g. machines, manufacturing cells, assembly lines). OEE is frequently used as a key factor in Total Productive Maintenance (TPM) programs.

TPM programs improve the overall effectiveness and efficiency of manufacturing plants by creating a joint responsibility between operators and maintenance personnel to achieve **zero product defects, zero mechanical breakdowns,** and **greatly reduced changeover times.**

OEE gives a consistent way to measure the effectiveness of TPM programs and other initiatives by providing an overall framework for measuring production efficiency.

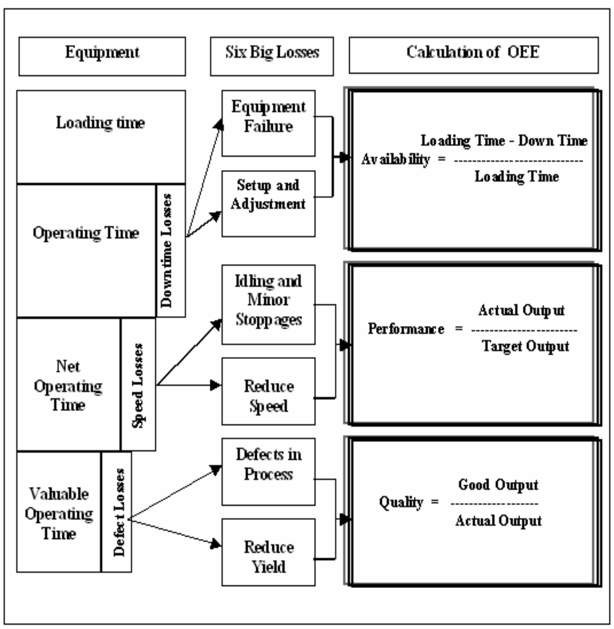
OEE can be defined as:
"A bottom-up approach where an integrated workforce strives to achieve overall equipment effectiveness by eliminating the six big losses"

One of the major goals of TPM and OEE programs is to reduce and/or eliminate **Six Big Losses** – the most common causes of efficiency loss in manufacturing. The table 1 and table 2 show lists of the Six Big Losses, and shows how they relate to the OEE loss categories. Categorizing data this way makes analysis very simple. It also makes it easy to collect and display this data so that it can be put to use throughout the day. Also the table 2 shows how OEE can be calculated.

Table 1: Six Big Losses, OEE loss categories.

Six Big Losses	OEE Category	Comment
Breakdowns	Down Time Loss	There is flexibility on where to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
Setup and Adjustments	Down Time Loss	Includes tool change over.
Small Stops/Idling	Speed Loss	Typically only includes stops that are under five minutes and that do not require maintenance personnel.
Reduced Speed	Speed Loss	Anything that keeps the process from running at its theoretical maximum speed (minimum cycle time).
Startup Rejects	Quality Loss	Rejects during warm-up, startup or other early production.
Production Rejects	Quality Loss	Rejects encountered during steady-state production.

Table 2: Overall Equipment Effectiveness and Goals



3.1 Calculation of OEE Components

$$\textbf{Availability} = \frac{\textbf{Actual operating time (mins)}}{\textbf{Planned operating time (mins.)}} * 100$$

where

Planned operating time= Total shift time
- Planned maintenance

and

Actual operating time = Planned operating time
- Unplanned maintenance
- Minor stoppages
- Setup & changeover

Performance efficiency = (Net operating rate * Operating speed rate) * 100

Where

Net operating rate = (No: produced * Actual cycle time) / Operation time

and

Operating speed rate = (Theoretical cycle time * Actual cycle time)

Or performance rate may be defined as,

$$\textbf{Performance rate} = \frac{\textbf{Actual Output}}{\textbf{Target Output}} * 100$$

$$\textbf{Quality rate} = \frac{\textbf{Total No. Good Output}}{\textbf{Total No. Actual Output}} * 100$$

OEE = Availability * Performance * Quality

4.0 TYPICAL TPM IMPLEMENTATION PLAN

It may use a staggered scheduling approach, which starts with the highest priority equipment, as determined by a cross functional team. The prioritization is based on equipment safety, reliability, quality, etc. Once the first implementation team is up and running, the next highest priority equipment will be targeted. The plan also uses the concept of ‘natural work groups’ for forming planning and implementation teams.

This implementation plan was prepared for the Forge shop of a typical forging plant, however the scope of this plan can be expanded to include all other departments of the plant.

4.1 Goals

The following is a summary of the goals of this implementation plan: (1) Increase the amount of time that the production equipment is available for use, (2) Reduce the amount of hardware variability in the parts produced, (3) Reduce the number of accidents in the workplace, (4) Encourage production mechanic ownership of, and responsibility for, their equipment, (5) Provide factory production mechanic/equipment operator ownership of this plan, (6) Raise the level of maintenance support for the equipment, (7) Integrate manufacturing initiatives (TPM, 5-S/Housekeeping, HVC, Safety), (8) Improve the orderliness of the factory, (9) Avoid the elimination of jobs and 10. Minimize the negative impact of change on the affected individuals.

Each task of the implementation effort should provide the following information: (1) Goals of each task, (2) Training required, (3) Data collection requirements, (4) Problem solving tools utilized, (5) Team membership requirements, (6) Team leader responsibilities (including what organization they should be from), (7) Activities to be performed, (8) Time required to perform activities and (9) Role of management

4.1.1 Following are the tasks

Task 1: Determine TPM Program Scope: Form TPM Management Team
Task 2: Develop TPM Implementation Priorities: Form TPM Planning Team
Task 3: Implement TPM Program: Form TPM Implementation Team
Task 4: Introduction to TPM Training
Task 5: Implement Lockout/Tag/Tryout Safety Procedures
Task 6: Establish 'Cleaning is Inspection' Techniques
Task 7: Implement Visual Controls
Task 8: Standardize Lubrication Processes
Task 9: Perform Process Improvement Exercise
Task 10: Finalize & Standardize Autonomous Maintenance
Task 11: Develop Preventive Maintenance Plans
Task 12: Integrate Production and Maintenance Schedules
Task 13: Establish Reliability Engineering & Predictive Maintenance Practices
Task 14: Develop Equipment Design & Start Up Management Methods
Task 15: Hold the Gains

Nevertheless to say that each team member plays a great role and have responsibilities for successful implication of TPM.

5.0 CASE STUDY

The following section discusses the case study carried out in a typical forging plant employing around 100 workers and 10 technical staff in the state of Gujarat. Within this section the manufacturing processes are considered. The application of TPM and OEE within this environment is presented

5.1 Manufacturing process at the forging plant.

The manufacture of typical forge components is a multi-stage process. The forge parts must be produced from a raw material of high quality steel with relatively high strength, so that it can withstand the forces during and immediately after impact deployment. Firstly, according to requirement of the customer die design is prepared then die is made from die steel. Raw material of required size is cut from billet by shearing machine or hacksaw machine. Cut material than fed to furnace for heating to forging temperature. After reaching set temperature forging operation done on drop hammer. Next immediate operation is trimming which cut the flash near the parting line. Due to heavy impact loading internal stress is developed which disturb microstructure, so all forged parts must be heat treated (normalizing) for relive internal stress. After heat treatment parts are sent to the shot blasting for cleaning operation.

5.2 Focusing the Implementation

There are a number of options available to determine which equipment needs the extra care that comes from a TPM program. A judicial combination of various methods is better option. The team creates a matrix that includes data on breakdowns, accidents, part quality, set-up times, throughput; etc. the team applies a weighting factor to each of these attributes which identifies the factors that are more important. For example, safety concerns are obviously more important to the equipment operators than just reducing the set-up times.

It can be concluded that forging operation is an expectable candidate for implementation of TPM, because in forge shop Hammer, press, Furnace, cutting machine all depends on each other and if any one machine breakdown then entire forging unit stop. So it was decided to start implementation of TPM by considering first the forge shop as pilot study.

5.3 Initial development of OEE

In order to start the OEE measurement process, operational performance data collection of the three OEE variables, availability, performance and quality, were carried out during a period of four weeks. The construction of this initial OEE measure was undertaken by utilizing existing Forging department performance data for downtime, speed losses and quality losses, while most of the existing measurement data already collected was of a suitable basis to develop the OEE measure. The main reason for measuring production losses was to highlight reasons for major losses, and use this information as a means of prioritizing the application of improvement and TPM activities. [1]

5.4 Collection of Data and Software Development and its use

The data required for the OEE measure was collected on a daily basis by shop floor supervisor, and these shift wise data entered in the computer. A OEE software was developed. The Software is developed using Visual basic, MSSQL and Crystal Report. Data entry form has been designed in such a way that minimum data entry is required. Following section gives description about Input and pre defined data required to calculate OEE and stoppage analysis report. The software is designed so as to free the supervisor for the manual calculation of OEE as the tool developed is flexible to the need of the user, without interference of software programming, easy to use, expandable to future needs, minimal input, maximal information

On screen gives all the information of one OEE-calculation to the operator or line-manager. Many reports are instant-ready, and direct available for shortest feedback. The operator/line manager immediately gets feedback on the data; Availability-, Performance- and Quality rates and OEE, Graphical presentation of the stoppage reasons, Provides up to date shift report.

The flowchart based on which the software is developed is shown in fig. 3.

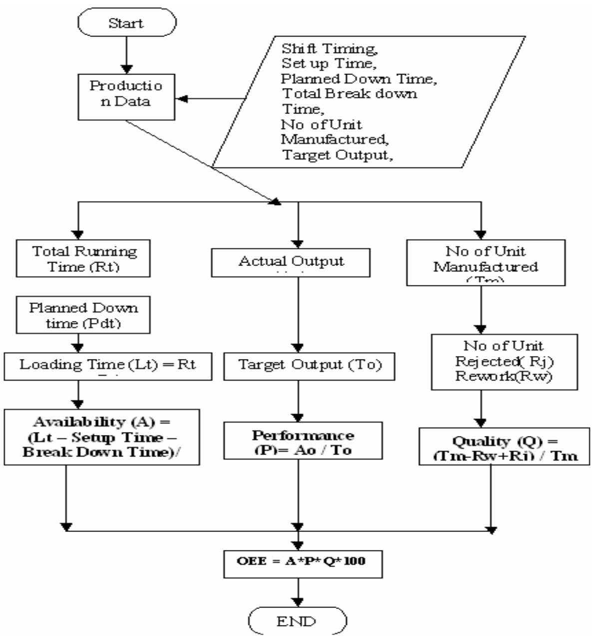


Fig. 3: Flowchart to calculate OEE

From the data entered in the computer the actual OEE figures calculated by the computer software with the computer installed in the plant office. Each day, the new figures representing the last 24 hours' OEE performance are displayed in the report generated by computer. Every set of OEE data consisted of 4 different histograms representing Availability, Performance and quality rate, and OEE figures respectively. Percentages for all the factors were expressed separately, the conclusion of this process resulted in an average OEE measure being calculated which was used to indicate the current performance of the forging department (Hammer) as a whole. OEE data base update daily as the shift data entered and every time updated report is generated. Overall OEE and stoppage analysis report can obtained shift wise, daily, weekly or monthly, so that management can view any date report any time.

Computer software also provide down time (Stoppage) analysis represented by histogram, which indicate down time reason in the graphical form separately with time. Report of OEE and down time analysis helps to monitor progress, make decisions, and make necessary course of corrections before repeating. Also it highlights reasons for major losses, so team will take decision about what are the key reasons for major part of down time. It is necessary to eliminate such downtime for improvement. After investigation it became obvious, the reasons for the relatively low average OEE performance which was about 48 percent. The main reasons of such situation were considered to be due to lack of preventative action, corrective maintenance, excessive breakdown, high levels of defects and speed losses.

The cost of six big losses for the forging hammer is arrived at Rs. 103000 per annum on the basis that if OEE is targeted to 85% from the present 52% . However more realistic figure for such plant can be around 70%.

5.5 Outcomes of TPM implementation

It is interesting to note that during first one month of data collection, the stoppage analysis report shows that the breakdown time due to lifting belt broken is more frequent. By careful observation and discussion with operator and maintenance personnel, it was found to change the clamping device of the belt. The frequency of the lifting belt getting broken reduced drastically. So by this way increase in availability, reduction in down time and increase in OEE of the hammer could be obtained. Simmillarly it was carried out for other equipments in forge shop and OEE could be obtained from computer.

Due to initialization of the TPM concepts, the equipment operators now perform more cleaning, inspection, and minor maintenance tasks. Additionally, the maintenance staff focuses on planned maintenance and equipment analysis studies, rather than constantly battling an out of control work order backlog. It is difficult to calculate the value of improved morale, better relationships between maintenance and operations, and management, as well as the feeling of pride and sense of accomplishment from making the equipment and work areas look better and run better. Following changes are observed during implementation stage of TPM.

- Breakdowns and unscheduled downtime are less frequent and are resolved more quickly. Breakdown time reduced to 22.5 Hrs. per month.
- Planned maintenance activities are carried out time to time and are incorporated into the production schedule.
- OEE improved by 9%
- Accident rates in the manufacturing cells are lowered.
- Equipment set-up and change-over times are reduced.
- Hardware variability is reduced and part quality is improved (less rework and rejections).
- Schedule variability and production delays are reduced.

Fig. 4 to 7 show the outcome of TPM implementation in forge shop. Fig. 8 shows a typical shift report. The implementation could be carried out by the management in other areas of manufacturing to reap rich results.

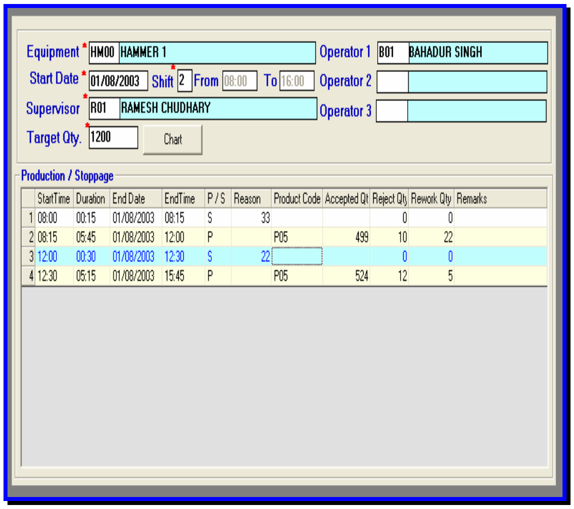


Fig. 4: Data entry screen of OEE software

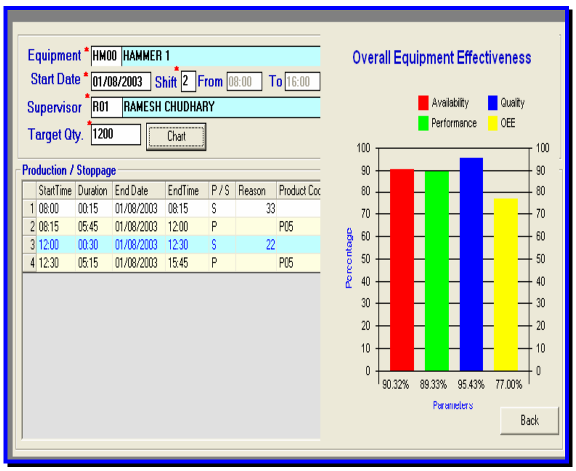


Fig. 5: Data entry screen of OEE software with chart

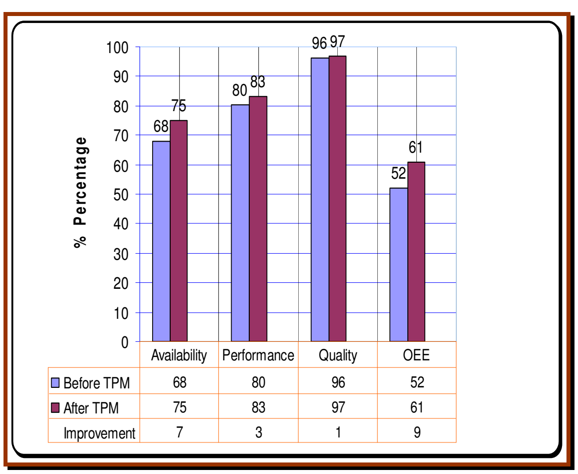


Fig. 6: Comparison of OEE

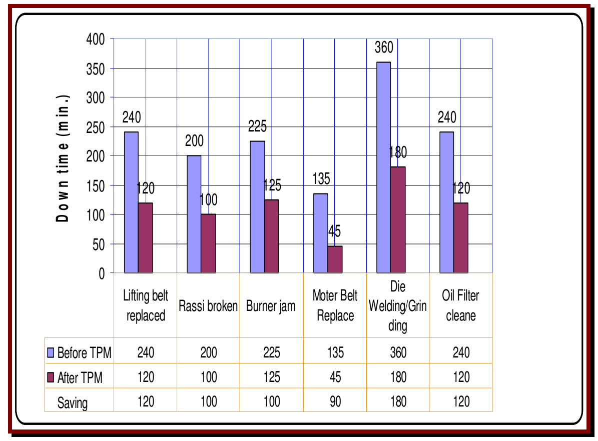


Fig. 7: Comparison of Down Time

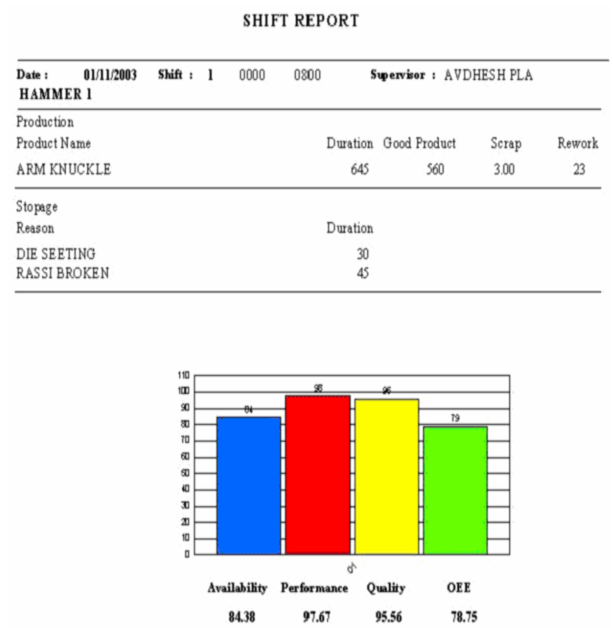


Fig. 8: Shift report

6.0 CONCLUSION

In the present world of competitive environment industries have to come out with quality products at lower cost. For this various concepts are available out of which Total productive maintenance is one of the most efficient, reliable and widely accepted philosophy to fight against the lower productivity.

TPM can be implemented in any industy irrespective of its size. OEE is a tool to measure effectiveness of the equipments used and thus show the areas that need to be improved first. Training has to be provided to the workers for motivating them, to adopt new methods and concepts for successful implementation of TPM. The following conclusions have been compiled from pilot implementation of TPM in forging industry. Total Productive Maintenance (TPM) is an effective method for addressing equipment management challenge.

- Software was developed for determination of overall equipment effectiveness and for analyzing down time which facilitates improvements in OEE and reduction in down time in shorter duration.
- A TPM implementation plan was developed for the forge shop.

Teams that have started implementing TPM have quickly realized that equipment performance is critical to reduce manufacturing costs. The equipment variation leads directly to hardware variability, which has repeatedly been proven to increase manufacturing costs. In the present study OEE is well below 'world class' level. After implementing TPM in the forge shop, improvement in Overall Equipment Effectiveness is found to be increased from 52% to 61%, ie 9% improvement in OEE. Also down time reduced approximately 22.5 Hours. per month

Further implementation of TPM in a continuous manner will facilitate the organisation in achieving better results An integrated approach within the organization is necessary for reaping the benefits of TPM fully.

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