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Research Article

TPM Implementation in Piston Manufacturing Industry for OEE

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Abstract

Frequent machine breakdowns, low plant availability and increased overtime are a great threat to a manufacturing plant as they increase operating costs of an industry. The main aim of this study was to improve overall equipment effectiveness (OEE) at a manufacturing company through the implementation of innovative maintenance strategies. A case study approach was used. The paper focuses on improving the maintenance in a piston manufacturing set up using an innovative maintenance regime mix to improve overall equipment effectiveness. Interviews, reviewing documentation and historical records, direct and participatory observation were used as data collection methods during the research. Reduced demand and lack of raw materials particularly imported items are adversely affecting the manufacturing operations. The company had to reset its targets from a higher limit to a very lower one due to lower availability of machines as result of breakdowns as well as lack of raw materials. The price reductions and uncertainties as well as general machine breakdowns further lowered production. Some recommendations were given. For instance, employee empowerment in the company will enhance responsibility and authority to improve and totally eliminate the big losses. If the maintenance department is to realize its proper function in a progressive, innovative industrial society, then its personnel must be continuously trained to meet current needs as well as future requirements. To make the maintenance planning system effective, it is essential to keep track of all the corrective maintenance jobs and preventive maintenance inspections. For large processing plants these cannot be handled manually. It was therefore recommended that the company implement CMMS.

Keywords: *Maintenance, Manufacturing, Overall Equipment Effectiveness*

1. Introduction

Maintenance has been largely considered as a support function which is none productive since it does not generate cash directly. However for industry to produce goods of the right quality and quantity for the customers and be able to deliver them at the right time its plant or equipment must operate efficiently and accurately. For every manufacturing company the objective is to produce goods at a profit and this is only achieved by using an effective maintenance system (M. Ahmad et al, 2007) that helps maximize availability by minimizing machine downtime due to unwarranted stoppages. Without an effective and economically viable maintenance system, equipment reliability suffers, and the plant pays the price with poor availability and increased downtime. All these mentioned poor key performance indicators could be a result of poor machine condition and sometimes low employee morale. Low plant availability and overtime costs will negatively affect an industry's operational efficiency. Company engineers must therefore design an effective maintenance system for the plant and its equipment.

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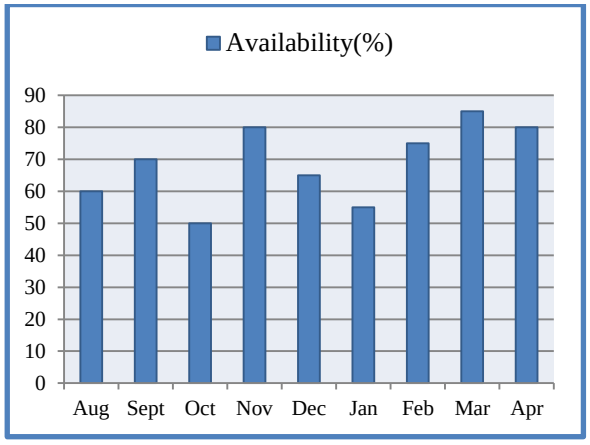
1.2 Introduction to the company

The company under study is based in India and is currently manufacturing piston. The key production equipments in the company are the foundry, CNC Lathe, drilling, grinding, reaming and pin fitting. These machines are supposed to function without interruptions. The situation on the ground is however different as there are numerous breakdowns which affect process continuity, hence compromising on the product quality due to drops and fluctuations in operating times. These breakdowns tend to be frequent and longer thus affecting production targets. Start-up failures are also experienced after carrying out maintenance. The maintenance department has been affected by unpredictability of the equipment operational patterns such that there is always a shortage of key spare parts some of which are only sourced outside the country. The current equipment availability varies between 65-70% against a world class target of 95%. The monthly availabilities for the period August 2010 to April 2011 are shown in figure below. As shown in the figure, there is no consistence pattern in the availability patterns. Besides the downtimes resulting from ineffective maintenance planning and strategies, the

sporadic power load shedding power cuts also affect process continuity. Overall Equipment Effectiveness optimization is therefore crucial so as to fully utilize all the available time. The company is however currently experiencing frequent machine breakdowns that are causing excessive downtime resulting in low machine availability which in turn results in low productivity of the plant. A contributing factor to this problem is the absence of an effective maintenance management system. The problems affecting the company can be traced to its origin and inherent flaws in the repair and maintenance cycle. The organization lacks comprehensive maintenance strategies and policies.



Maintenance department is affected by unpredictability of the equipment operational patterns and equipment failures which cause disruption in production. Supervisors are totally responsible for the quality, maintenance, productivity and decision-making, with little or no responsibility devolved to the operator. The production department tends to overlook the maintenance functions in an effort to meet the production targets. This results in critical and at times prolonged equipment failures (Moubray et al, 1997). Tasks that require cross-functional teams are performed separately leading to down times and increased reworks. The company is always late in dispatching the product.

1.3 Research Objectives and scope

• To maximize overall equipment effectiveness
• To reduce equipment downtime while improving quality and capacity.
• To increase competitive advantage.

The research targeted critical elements of production in trying to establish a framework for application of total productive maintenance as a management system. The winding wire enameller department, the press shop, die casting and the machine shop were analysed in an effort to identify major areas of improvement.

2. Maintenance and its goal

Moubray defines maintenance as the execution of activities, which ensure physical assets continue to do what their users want them to do. However Tsang et al look at maintenance as the routine and recurring process of keeping a particular asset or machine, in its normal operating condition so that it can deliver its expected performance (Kelly et al, 1997) or services. The Japanese craftsmen define maintenance as maintaining and improving the integrity of the production and quality systems through the machines, processes, equipment and people who add value to the products or services, that is, the operators and maintainers of equipment. The goal of any well run maintenance organization as alluded to by Moubray and Kelly is to have the lowest cost of the sum of two quantities, i.e.

• Maintenance labor and material
• Production loss

The above loss includes lack of ability to produce, and value added material that is lost as a result of a break down resulting from an inadequate maintenance program. Maintenance itself can result in excessive downtime and associated costs. This results from the requirement to take the machinery off-line to carry out maintenance. According to Kutucuoglu with the change in manufacturing processes emphasizing lean manufacturing, the reliability and availability of plant are vitally crucial.

Fig.1 Maintenance process

Poor machine performance, downtime and ineffective plant maintenance lead to the decrease in the profit, loss of market opportunities, and loss of production. The danger of infant mortality after it has been put back on line again and also the cost of the maintenance action itself contributes to costs. Companies should be able to put a cost to their loss of production resulting from equipment down time. When maintenance costs are at a minimum the cost of lost production is at its highest. As maintenance effort and costs are intelligently increased the production loss gradually decreases until the lowest combined cost is achieved. This is the maintenance goal. Maintenance effort applied beyond this point, increases costs. Maintenance (A.H.C. Tsang et al, 1999) can increase costs because of the need to take equipment off line to carry out maintenance, infant mortality after being put back in service, etc. There are also the costs of the maintenance itself with labor and material costs.

In general terms, the Maintenance management process can be considered as having six phases, as illustrated below.

2.1 Need of maintenance system

Presence of a well-organized maintenance system helps an organization to increase machine availability, reduce production downtime, production losses and overtime costs. It also lowers labor requirements for maintenance personnel leaving them with more time on ordinary adjustments and repairs than on breakdown repairs. Good maintenance practice also leads to fewer large-scale repairs and repetitive repairs, fewer product rejects and better quality control of the products. Another good result is greater safety for workers and improved protection of the plant leading to lower compensation and insurance costs. Maintenance actions can be divided into four general categories or strategies as shown in figure 2. The maintenance plan for a company's assets will be a combination of these four strategies. Market forces demanding more emphasis on customization, quick delivery and superb quality, in response to these requirements manufacturers are opting for using high-tech equipment as well as adopting non-traditional maintenance management techniques such as TPM.

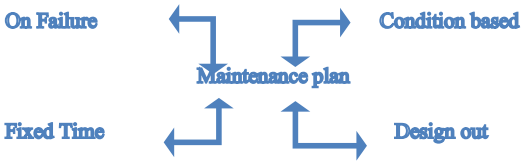


Fig.2 Maintenance strategies

The ideal model to drive maintenance activities has become a key research topic and a fundamental question to be dealt with in order for organizations to attain effectiveness and efficiency in maintenance management and in fulfilling enterprise objectives.

Results

3. Qualitative Results

Qualitative analysis involves collecting, analyzing, and interpreting data by observing what people do and say. In analyzing qualitative data, patterns such as changes over time or possible causal links between variables can be identified.

3.1 Interviews and Questionnaire findings

Interviews with various stakeholders were successfully held without any hindrances and the general responses to the questions are detailed below. The interview questions were designed to find out views from employees about maintenance problems encountered during the manufacturing processes and how the problems can be overcome so as to eliminate reworks and improve both maintenance management and productivity. Responses to unstructured interview questions for further understanding are also noted in the following sections. The questionnaire consisted (A. Raouf et al, 2005) of six sections each comprising four questions that sought to solicit the respondents' opinions on various aspects of the company's maintenance systems and practices. The response rates for every section are analysed and discussed below.

3.2 Views of the employees towards maintenance Responsibility

All employees acknowledged that the company had problems with maintenance. When asked about who was responsible for maintenance different answers were given and the researcher tabulated the responses into figure 3. A possible reason for different opinions was because employees are not involved in any maintenance activities and are not aware that maintenance is the responsibility for everyone.

3.3 Maintenance Management

Table 1 shows the responses for maintenance management. From the responses, it shows that most employees are well aware the maintenance process is reactive rather than proactive as it is conducted when there is a breakdown in the departments. From the responses, it shows that employees are well aware of the company's mission, as evidenced by the 50% of respondents who agreed.

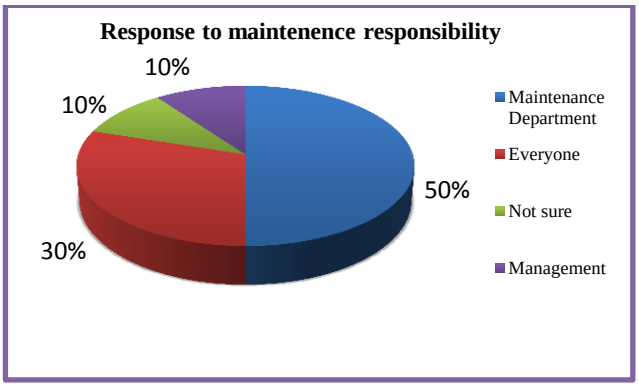


Fig.3 Response of maintenance responsibilities

Table1 Maintenance management

	Disagree	Not sure	Agree
All employees know the mission of the company	0	30	70
Employees know the company's maintenance goals	0	40	65
Management is visibly involved in developing a maintenance culture.	30	40	55
Mutually supportive partnership between management and employees exists	0	60	45

The employees also know the company's maintenance goals as proved by 65% of the respondents who agreed.

3.4 Autonomous Maintenance

Table 2 shows the responses on Autonomous Maintenance. The results show that operators are very responsible for equipment and machinery as shown by the respondents who concurred. The respondents disagreed on the aspect. On the issue of carrying out basic maintenance, the results revealed that operators carry out routine checks and inspections on the machine (C.A. Schuman et al, 2005), confirming that they carry out basic maintenance as evidenced by the response rate. Most respondents also agreed that operators practice autonomous maintenance.

Table 2 Autonomous maintenance response

	Disagree	Not sure	Agree
Management is committed to continual improvement of maintenance	0	30	35
There is measuring of maintenance performance	55	0	65
Employees are empowered to contribute their ideas towards continual improvement	65	30	25
Maintenance benchmarking is done	75	0	0

3.5 Continuous Improvement

From table 3, it seems there is a general lack of commitment on continuous improvement of maintenance by Management. This is evidenced by 35% of the respondents who believed that management lacked commitment.

Table 3 Continuous improvement

	Disagree	Not sure	Agree
Management is committed to continual improvement of maintenance	55	0	35
There is measuring of maintenance performance	25	15	70
Employees empowered to contribute their ideas towards continual improvement	55	15	25
Maintenance benchmarking is done	75	25	0

3.6 Maintenance Execution

Table 4 reveals that 35% of the questionnaire respondents disagreed that maintenance work is carried out on time despite the availability of enough manpower whilst 40% were in agreement with the notion. 20% agreed that maintenance spares are readily available in the event of a breakdown. This shows that the company is facing a shortage of spare parts mainly due to the unavailability of foreign exchange. 75% of the respondents agreed that the plant experienced recurrent failures and breakdowns.

Table 4 Maintenance execution response

	Disagree	Not sure	Agree
Is maintenance work carried out	55	0	35
Are maintenance spares readily	60	15	20
Are there recurrent failures and	25	0	75

4. Quantitate results

4.1 Production

Production at the study company is based on the total number of pistons produced per day. The target number is 1000 at 100% availability. Reduced demand and lack of raw materials particularly imported items are adversely affecting the manufacturing operations. The company had to reset its targets from the usual figure of 90% production per day to a mere 50% per day due to lower availability of machines as a result of breakdowns as well as lack of raw materials. The price reductions and uncertainties as well as general machine breakdowns (Davis et al, 1996) further lowered production figures. The production statistics for the period August 2010 to April 2011 are shown in figure 4 below.

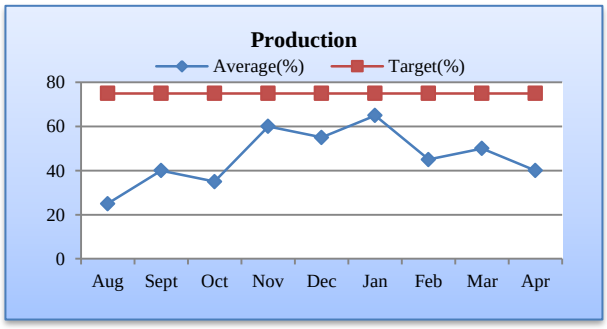


Fig 4 Average production

4.2 Downtime Due to Breakdowns

Figure 5 shows the prevalence of different forms of machine failures. Breakdown due to mechanical failure constitutes (D. Koshal et al, 2010) 60% of the total downtime. Electrical failures contribute 30% whilst 10% of breakdowns are due to other types of failure.

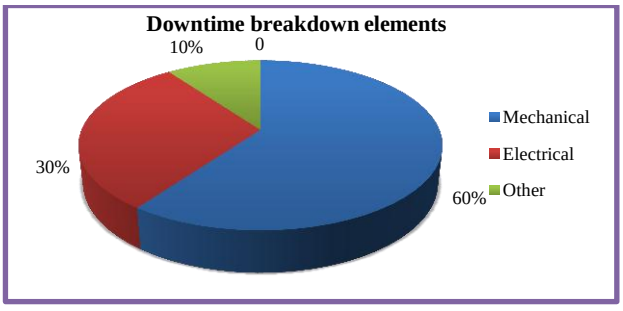


Fig. 5 Downtime breakdown elements

4.3Downtime by Machine

Figure 6 shows downtime values for major machine components. The figure shows that the machines contributing major downtime are the CNC turning and reaming with a daily average of 0.8 hours.

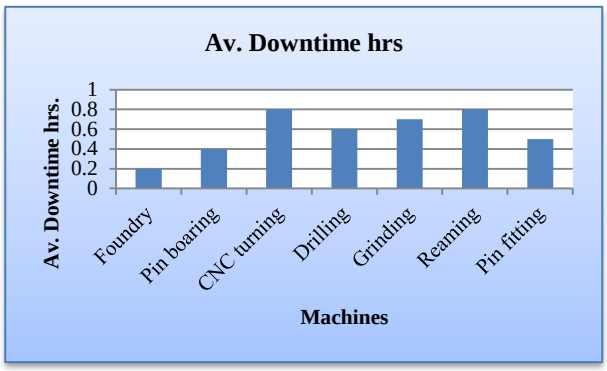


Fig. 6 Downtime by machines

4.4 Downtime versus Production Time

Figure 7 shows the proportion of cumulative downtime and actual production time. The figure shows that the monthly average availability rate was 75 %, which is below the company's monthly target of 90%. The forced downtime (Hartman et al, 1992) has adversely affected daily throughput.

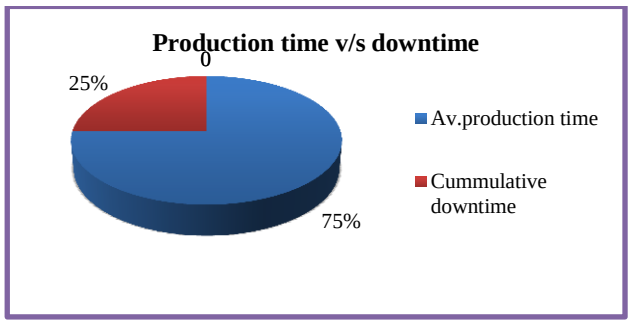


Fig. 7 Production time v/s downtime

4.5 Availability

Availability was used to measure the total lost time when each of the sections was not operating because of breakdown, set-up adjustment and other stoppages. It indicated the ratio of actual operating time to the planned time available. The planned time was calculated as 480 minutes per shift. In determining this value, a shift of 8 hours (460 minutes) was used as the basis Availability is the most important part of operations in the company. The Availability (A) is calculated using the following formula (Maggard et al, 1992):

$$A = \frac{Possible\ operating\ time - Downtime}{Possible\ operating\ time}$$

The availability patterns for the period December 2006 to July 2007 are summarized in figure 8 below. Figure 8 below graphically illustrates the relationship between target availability and the monthly availability figures for the period of August 2010 to April 2011.

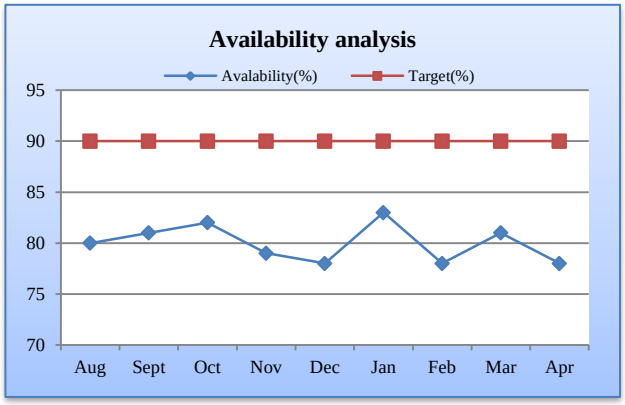


Fig. 8 Availability analysis

4.6 Performance efficiency issues

Performance efficiency was calculated as a function of both operating speed rate and net operating rate. The operating speed rate of equipment referred to the discrepancy between the ideal speed and its actual operating speed.

Table 5 Operating time and downtime

Period	TW Hrs	PW Hrs	OpT Hrs	OvT Hrs	UDT Hrs	PDT Hrs	Availability %
Aug	278	200	80	50	71	15	56
Sept	300	200	90	60	65	15	87
Oct	322	200	98	65	67	15	76
Nov	302	200	95	54	70	15	49
Dec	298	200	96	53	68	15	70
Jan	295	200	97	56	69	15	76
Feb	314	200	98	67	63	15	68
Mar	365	200	88	87	64	15	73
Apr	321	200	89	98	61	15	72
Total	2795	1800	831	590	598	135	627
Average	310.6	200	92.3	65.6	66.4	15	69.7

P.W = Planned operating hours, Op.T = Operating time,

Ov.T = Overtime, U.Dt = Unplanned downtime,

P.DT = Planned Downtime

The net operating rate measured the maintenance of a given operating speed over a period of time. This calculated the losses resulting from minor recorded stoppages, as well those that went unrecorded on daily shift logs. Minor stoppages were regarded as those that did not exceed three to four minutes.

4.7 Availability vs. Downtime

Over the 9 month period under study the average percentage availabilities of all the individual departments were computed and used to come up with factory weekly and average monthly availability [17-18] as outlined as in Table 6. Data in the table reveal, the planned operating

time is being extended by an average of about 65.6 hours per month that is overtime is approximately:

$$\%\ Overtime = \frac{Overtime}{Planned\ working\ hrs} = 32.8\%$$

This amount of overtime has been necessitated by the need to meet targets and satisfy customers. Increasing frequency in machine breakdowns have been singled out as the root or main cause for a 32.8% of planned working hours. This increased percentage of time means that the costs spent on overtime are also high. All these are symptoms of a poor maintenance system that needs rectification.

4.8 Downtime Distributions

Referring to the data given in figure 9 below, unplanned downtime constitutes the greatest percentage of the downtime. This means that most of the maintenance jobs are breakdown maintenance services. The existing maintenance systems and resources are being under-utilized as most time is being spent on breakdown repairs and less to no time on preventive maintenance as all the time is spend to repair one machine or the next. Even though much time is dedicated towards these repairs the problems are of a recurrent nature even after repairing.

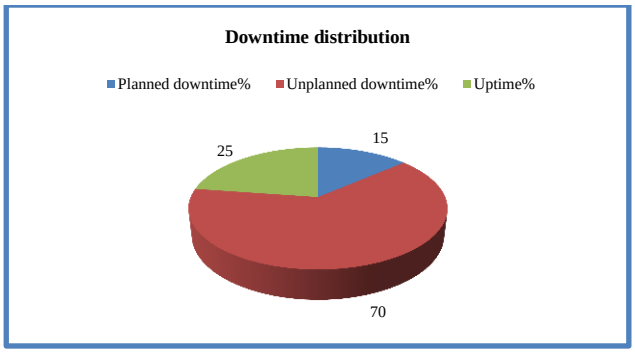


Fig. 9 Downtime distribution

The 15% in planned downtime is not planned downtime as in time allocated for some preventive maintenance actions this culminates from the three hours a week of load shading by the power supply company. This time is used for general housekeeping by the machine operators though some PM tasks are done such as lubrication of mating parts though to a lesser extent.

4.9 Nature of breakdowns

An analysis of the nature of breakdowns was done and it was found that mechanical breakdowns were the most frequently experienced breakdowns. Data on the machines' number of breakdowns, failure modes, nature of their breakdowns and their meantime before failure was collected and an in-depth analysis of these values was carried out. The failures are usually random and very frequent. Hydraulic and pneumatic breakdowns are minimal and when they occur the maintenance work is outsourced at a cost by the organization as such expertise is not found within the maintenance department.

4.10 Potential revenue lost due to the current maintenance system

The department and the company have lost lacs of rupees in potential revenue due to poor machine availability. This is considered as an opportunity cost of goods that could have been produced but were not produced due to poor equipment performance. If there was high equipment availability and a complementing high utilization factor, production targets could have been met and such soaring figures for opportunity cost could have been minimized.

4.11. Overtime Costs

Overtime costs could have been avoided. Besides cost of labor due to overtime; there are many other associated costs that add on top of opportunity costs that have been incurred already. The monthly average overtime for the eight month period under study is 65.6 hours which represents 40.5 % of actual planned working hours

4.12. Current Maintenance Practices

The company currently uses three Maintenance Management approaches namely:

a. Failure Driven Maintenance
b. Time Based Maintenance
c. Condition Based Maintenance

4.13. Maintenance Planning and Scheduling

Production and Maintenance personnel gather information on the physical characteristics of the equipment to be maintained and how it is to be maintained. The maintenance planner then compiles a maintenance schedule i.e. a comprehensive list of maintenance and its incidence. The schedule sets out all the tasks – inspections, lubrication, adjustments, component replacement, and overhaul together with the frequencies that are considered necessary to maintain (Sekine et al, 1998)a facility efficiently. The schedule consists of an individual sheet for each facility. The sheet indicates: The name and identification number of the item of the equipment.

a) The location of the item.
b) Safety procedures to be followed.
c) Detailed list of tasks to be carried out.
d) The frequency at which each of the listed tasks be carried out.

4.14. Work Order Requisition, Execution and Data Capture.

The Production personnel generate work orders in the form of Job Cards after identifying a possible future equipment failure or a failure has occurred. The work

request is authorized by the Production Foreman and forwarded to the Maintenance Department for raising a job card and the subsequent execution. The details contained within the job card include; the date, the job card number, a description of what transpired, the section, the name of the writer, etc. Response by the maintenance crew to a job card depends on manpower availability, spare parts availability and in most cases on the criticality of the breakdown. After the execution of the task the equipment is handed back to the production personnel and the artisan completes the job card. The document has a column for the comments by the artisan, the planner and the production foreman. After this the planner and the artisan file the document for record keeping.

4.15. Production /Maintenance Interface

The production and engineering departments report to the technical director. The departments present their monthly reports to the director and other managers. Maintenance provides a service to the production department. The functions of maintenance and production are interrelated. The two departments communicate mostly when a breakdown occurs and when the maintenance department plans (Suzuki et al, 1992) for the plant shutdown. However there are some differences in the calculations of plant performance such as the downtime, availability and OEE. It is important that both the maintenance and operation of the plant are considered and planned on a unified basis with the objective of achieving the minimum overall production costs.

Conclusion and recommendation

This paper addresses the use of effective maintenance strategies to improve overall equipment effectiveness of production machines. Total Productive Maintenance was chosen as the appropriate tool for the company to implement to enhance its OEE. The following conclusions were made:

1. It can be concluded that TPM is a maintenance strategy that when ensured with the application of the appropriate tools or following thoroughly all the pillars performance. Data shows that no such tools are in use in the company and as a result the maintenance management system is weak.
2. The company can only benefit from TPM if it ensures management commitment through activities such as permitting, supporting, managing, and leading by example.
3. Adoption of TPM can reduce such losses and also reduce rework to or below the acceptable levels. TPM can also help the company to increase profitability and image, both of which will ensure its competitiveness in the current economic turmoil.
4. The process of recording information must remain simple, but effective for future data analysis. If provisions were made to highlight such problems and possible causes, then it may lead to the correction of common problems such as breakdowns and rework. Ultimately if possible, the aim is to eliminate such causes. Information provided by the trend analysis can provide a basis for forming- long-term plans. The maintenance department can plan spending requirements by using historical information to state and return on investments by contributing to the annual business plan of the company.
5. It is a maintenance program that works with TQM and lean management. However the employees must be appropriately trained, empowered and convinced that TPM is a sustainable and management should be totally committed to the program. It is envisaged that the adoption of the recommendations of the study will result in optimum levels of machine availability and sustained higher production rates. Empowerment will give every employee in the company the responsibility and authority to improve and totally eliminate the six big losses. It makes effective decision makers of people closest to the problem, resulting in quick action. Empowerment enables two way communications. Obstacles to empowerment are based on a traditional mistrust between management and the workforce. Empowerment requires process management to be successful as empowerment in the company will go through denial, resistance, exploration and commitment phase and each will require action from management.

1. Computerized Maintenance Management System*:* To make the maintenance planning system effective, it is essential to keep track of all the corrective maintenance jobs and preventive maintenance inspections. For large processing plants these cannot be handled manually. The objective of CMMS is to facilitate the management of the maintenance resource, to monitor maintenance efficiency, and to provide appropriately analysed management information for further consideration. It is therefore important for the company to implement CMMS.
2. Maintenance Benchmarking: The company should actively benchmark its maintenance services against other organizations. Benchmarking is essential to search for optimum methods for Maintenance Management practices in order to improve the overall effectiveness of operations and maintenance of the plant.
3. Manpower Training and Development: If the Maintenance Department is to realize its proper function in a progressive industrial society, then its personnel must be trained to meet current needs and future requirements. Training should be a continuous and progressive process designed to improve the individual potential of maintenance staff members. This enables a person to understand the reason for and purpose of his efforts.

References

A.H.C. Tsang, A.K.S. Jardine, H. Kolodny (1999), Measuring maintenance performance: a holistic approach, *International Journal of Operations & Production Management*, Vol. 19 No.7, pp.691-715

A.H.C. Tsang, A.K.S. Jardine, H. Kolodny (1999), Measuring maintenance performance: a holistic approach, *International Journal of Operations & Production Management*, Vol. 19 No.7, pp.691-715

A. Raouf, M. Ben-Daya (2005), Total maintenance management: a systematic approach, *Journal Of Quality in Maintenance Engineering*. 1995. Vol.1, p 6-14

C.A. Schuman, and A.C. Brent (2005), Asset life Management: towards improving physical asset performance in the process industry, *International journal of Operations and Production Management*. Vol.25, No.6 pp. 566-579.

D. Koshal (2010), Manufacturing Engineer's Handbook, *Butterworth Heinemann*, 1993. World Academy of Science, Engineering and Technology 61.

Davis, R. (1996), Making TPM a part of factory life', *Works Management*, Vol. 49, Part 7, pp16-7.

D.J. Smith (2005), Reliability, Maintainability and risk: Practical Methods for Engineers including RCM and Safety-Related Systems, *Butterworth Heinemann*

Hartman, E.H (1992), Successfully Installing TPM in a Non-Japanese Plant, TPM Press, Allison Park, PA. Koelsch, J.R., A dose of TPM: downtime needn't be a bitter pill, *Manufacturing Engineering*, April, pp. 63-6

Kelly, A(1997), Maintenance Organisation& Systems, Business *Centred Maintenance, Butterworth-Heinemann*, Oxford.

K.Y. Kutucuoglu, J. Hamali, I. Iran, and J.M. Sharp (2001), A framework for managing maintenance using performance measurements systems, *International Journal of Operations & Production Management*, Vol. 21 No.1, pp.173-95.