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An Approach for Total Productive Maintenance and Factors Affecting its Implementation in Manufacturing Environment

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ABSTRACT : Modern manufacturing requires that to be a successful organization, it must be supported by both effective and efficient maintenance. One approach to improving the performance of maintenance activities is to implement and develop a Total Productive Maintenance (TPM) strategy. However it is well documented that a number of organizations are failing to successfully implement such strategies. The purpose of this paper is to investigate the contribution of total productive maintenance initiatives to manufacturing industries in India. The study is carried out at case company Leader Valves Ltd. in India that has initiated the TPM strategies. This paper is aimed at discovering the factors affecting the successful implementation of TPM in manufacturing industries in India. The study also led to the recommendations to improve the TPM development & implementation program of case study organization. The calculation methodology used in this paper is to improve the overall equipment effectiveness (OEE) of case company. This model can be adapted to all processing types and/or plant type manufacturing equipment for calculating OEE.

Keywords: Total productive maintenance, Overall equipment effectiveness, Implementation, Maintenance, Barriers.

I. INTRODUCTION

Recent trends indicate that systems are increasing in complexity with the introduction of new technologies, are not meeting customer expectations in terms of performance and effectiveness, and are becoming more costly relative to their operation and support. In the production of goods, manufacturing systems are often operating at less than full capacity, productivity is low, and the costs of factory operations are high. This is happening at a time when international competition is increasing worldwide. In many companies, productivity is low and the costs of operating and maintaining equipment in the factory have become a significant factor in the production of goods. According to a study, 15 to 40 per cent (with an average of 28 per cent) of the total cost of finished goods can be attributed to maintenance activities in the factory [1]. The maintenance cost is often regarded as a necessary expense that belongs to the operating budget. With regard to the issue of cost due to maintenance activities, a large portion of this cost can be categorized under production losses. It is a common item on the hit list of cost reduction programs. With asset availability and reliability becoming critical issues, the strategic importance of maintenance in such businesses should be recognized [2]. Poor organizational competencies in managing the maintenance function effectively can severely affect competitiveness by reducing productivity, increasing inventory, and leading to poor due-date performance [3]. The traditional misconception about maintenance being viewed as an operational expense to be minimized and not as an investment in increased process reliability has to be done away with in realizing manufacturing performance excellence. Equipment technology and development capabilities have become major factors that demonstrate the strength of an organization and set it apart from others. Maintenance has now become a strategic tool to increase competitiveness rather than simply an overhead expense that must be controlled [4]. Investment in maintenance, one of the basic functions of a firm, returns improved quality, safety, dependability, flexibility and lead times [5]. Over the past decade there has been increased recognition that in world-class manufacturing (WCM), maintenance is not a separate, isolated function that makes repairs and performs assorted activities as needed. Rather, maintenance is a full partner, striving together with the other functions to achieve the firm's strategic goals. Thus, maintenance has become a strategic issue for manufacturers across the world.

II. TPM A PROPOSED SOLUTION

In response to maintenance and support problems in the commercial factory, the Japanese developed and introduced the concept of TPM in 1971. Manufacturing organizations striving for world class performance have shown that the contribution of an effective maintenance strategy can be significant in providing competitive advantage through its total productive maintenance (TPM) program [6]. The emergence of TPM is intended to bring both functions (production and maintenance) together by a combination of good working practices, teamworking and continuous improvement. First developed in Japan in 1971 by the Japanese Institute of Plant Maintenance (JIPM) and widely adopted in Japanese firms today, TPM is a notion taken from the TQM concept of zero production defects and applying it to equipment where the aim is to have zero breakdowns and minimal production losses [7]. TPM, a relatively new approach to the development of maintenance systems, is a scientific company-wide approach in which every employee is concerned about the maintenance and the quality and efficiency of his or her equipment [8]. Operators and maintenance workers need to have a greater understanding of each other's function and often have to acquire some new skills. For example, operators need to learn to anticipate problems and should be able to carry out minor adjustments and basic preventive maintenance, such as routine checking, cleaning and lubrication, an enhanced role in which multi-skilling is seen as providing essential support. In practicing TPM, the maintainers are released from the tasks of lower skill levels and are able to move onto jobs which require higher level of skills such as “equipment improvement, more complex preventive maintenance and overhauls". In short, the objective of TPM is to create a sense of joint responsibility between supervision, operators and maintenance workers, not only to keep machines running smoothly, but also to optimize their overall performance [9]. The target of TPM activities is to make the improvement of OEE and labor productivity, eventually to secure the equipment failure zero, defects and rework zero and industrial accident zero. To achieve this, the eight major elements of TPM activities such as individual improvement, autonomous maintenance, planned maintenance, skill-up education and training, quality maintenance, maintenance prevention (MP), safety and environment, TPM in office are implemented, and the setting and control of TPM effect measuring indices are required [10].

According to Nakajima [11] (Japan Institute of Plant Maintenance), the concept of TPM includes the following five elements:

1. TPM aims to maximize equipment effectiveness (overall efficiency).
2. TPM establishes a thorough system of preventive maintenance (PM) for the equipment's entire life span.
3. TPM is implemented by various departments in a company (engineering, operations, and maintenance).
4. TPM involves every single employee, from top management to the workers on the factory floor.
5. TPM is based on the promotion of preventive maintenance (PM) through "motivation management" involving small-group activities.

In the evaluation of a manufacturing system relative to the above, it is necessary to establish the appropriate methodology for measurement purposes. TPM can be defined in terms of overall equipment effectiveness (OEE) which, in turn, is a function of equipment availability, performance efficiency, and quality rate and is often used as a metric for TPM.

III. CALCULATION METHODOLOGY

OEE is the overall index to measure the operating efficiency by the time loss structure for the processing type equipment, and it is obtained by multiplying time availability, performance efficiency and goods quality rate. This index indicates whether the present equipment contributes to the added value or not under the total consideration of the condition of present equipment in view of the time and speed, and what the condition of goods quality rate is [12]. OEE highlights the actual "Hidden capacity" in an organization. OEE is not an exclusive measure of how well the maintenance department works. The design and installation of equipment as well as how it is operated and maintained affect the OEE. It measures both efficiency (doing things right) and effectiveness (doing the right things) with the equipment. It incorporates three basic indicators of equipment performance and reliability [13]:-

1. Availability (A) or uptime
2. Performance Efficiency (PE)
3. Rate of quality output (Q)

Thus, OEE = (A) × (PE) × (Q)

where,

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

Availability = (Operating Time) / (Loading Time)

Operating Time = (Loading Time) – (Unplanned Down Time)

Loading Time = (Gross Available Time for Production) – (Planned Down Time)

Planned down time losses includes

1. Start-ups time
2. Shift changes

3. Coffee and lunch breaks
4. Planned maintenance shutdowns

Unplanned down time losses includes

1. Equipment breakdown
2. Changeovers
3. Lack of material

(*b*) Performance efficiency (PE) is directed towards reducing the losses due to slowdowns or reduced speed.

Performance efficiency (PE) = (Operating speed rate) × (Net operating rate)

where

Operating speed rate = (Ideal cycle time) / (Actual cycle time)

where the cycle time represent the theoretical time that it takes to process an item as compared with actual time. This factor represents the difference between ideal speed (based upon equipment capacity as per design specifications) and actual operating speed of the equipment. Speed losses, small stops, idling, and empty positions in the line indicate that the line is running, but it is not providing the quantity that it should provide.

Also,

Net operating rate = [(Processed amount) × (Actyal cycle time)] / (Operating time)

where, processed amount indicates the output of machine depending upon actual cycle time. The net operating rate indicates the persistence of equipment, and the degree of loss caused by the minor stoppage.

Therefore,

PE = [(Ideal cycle time) × (Processed amount)]/ (Operating time)

(*c*) The third factor in OEE calculation is

Quality rate = [(Processed goods) – (Defected goods)] / (Processed goods)

where processed goods refer to the number of items processed per day (or month) and defected goods represent the number of items rejected due to quality defect or require rework or scrapped per day (or month).

Putting the values of (A), (PE) and (Q) in equation of OEE calculation, OEE can be calculated. In case that the processing type equipment is composed of several dependent equipments, the calculation of OEE must be done for bottleneck equipment.

Referring to Nakajima's text, an OEE of 85 percent is considered as being world class and a benchmark to be established for a typical manufacturing capability [11].

IV. CASE STUDY

The organization under investigation in this study is Leader Valves Limited. Leader valves limited is a leading valve manufacturing company of India. It is a totally integrated valves manufacturing unit with own Ferrous & Non Ferrous Foundries, Forging units, state of art Machining and Testing facilities. It is an ISO-9001: 2000 company since January, 1996. It is a world leader in wide range of gas safety devices, manually, electrically and pneumatically operated valves in brass, cast steel, forged steel, cast iron, gun metal for plumbing and industrial applications.

The data has been collected for over eight months for the calculation of OEE of bottleneck equipment in the various sections in the plant. Calculations have been made making the assumption like each year has 12 months, each month has 4 weeks and each week has 7 days.

V. OEE CALCULATION FOR HMC MILLING (HOURN MAKE) AND CNC TURNING (SWED TURN)

Both machines are working for 24 hr a day (three shifts, each shift of 8 hrs) and 6 days a week.

Data type	***Time***	
	HMC	***CNC***
No. of setups per day	1	2
Setup time per day	90 min	60 min
Break time per day	180 min	180 min
Preventive maintenance per year	4 days	4 days
No. of failures per month	4	6
Time to cover each failure	2 hr	2 hr
Shift hr loss due to failure	1 hr	1 hr
Short stoppage per year	30	45
Time for one short stoppage	30 min	30 min
Machine designed cutting capacity	2000 mm/min	600 mm/min
Machine actual speed of cutting	800 mm/min	200 mm/min
No. of goods per day	100	1000
Rejected goods per month	4	120

Calculation steps:

(A) Availability (A)

Sr. No.	Parameter	Formula used	HMC	CNC
1.	Set up time per day	(No. of setups per day) × (Setup time per day)	1 × 90 = 90 min/day	2 × 60 = 120 min/day
2.	Break time per day	(Break time per shift) × (No. of shifts per day)	60 × 3 = 180 min/day	60 × 3 = 180 min/day
3.	Preventive maintenance per day (min.)	$\frac{\text{Preventive maintenance per year}}{\text{Number of days per year}}$	$\frac{4\times24\times60}{12\times4\times6}$ = 20 min/day	$\frac{4\times24\times60}{12\times4\times6}$ = 20 min/day
4.	Planned down time	(Setup time) + (Break time) + (Preventive maintenance time)	(90 + 180 + 20) = 290 min/day	(120 + 180 + 20) = 320 min/day
5.	Unplanned down time due to failures per day	Time in minimum of failures Per month / Working days per month	$\frac{4\times(2+1)\times60}{4\times6}$ = 30 min/day	$\frac{6\times(2+1)\times60}{4\times6}$ = 45 min/day
6.	Unplanned downtime due to short stoppages	Stoppages per year × Stoppage time / Working days per year	$\frac{30\times30}{12\times4\times6}$ = 3.13 min/day	$\frac{30\times30}{12\times4\times6}$ = 4.69 min/day
7.	Loading time	(Gross available time for production) – (Planned down time)	(24 × 60) – 290 = 1150 min/day (24 x 60) - 290	(24 × 60) – 320 = 1120 min/day
8.	Operating time	(Loading time) – (Unplanned down time)	1150 – (30 + 3.13) = 1116.88 min/day	1120 – (45 + 4.69) = 1071.31 min/day
9.	Availability	$\frac{\text{Operating time}}{\text{Loading time}}\times100$	$\frac{1116.88}{1150}\times100$ = 97.12%	$\frac{1070.31}{1120}\times100=95.56\%$

(B) Performance Efficiency (PE)

Sr. No.	Parameter	Formula used	HMC	CNC
1.	Actual cycle time at actual cutting speed	Operating time per day / Number of goods per day	$\frac{1116.88}{100}=11.17$ min	$\frac{1070.31}{1000}=1.07$ min
2.	Number of actual products at unit cutting speed (1 mm/min)	Number of goods per day / Machine actual cutting speed	$\frac{100}{800}=0.125$ nos.	$\frac{1000}{200}=5$ nos.
3.	Number of products at designed cutting speed	Number of actual products at unit cutting speed × Machine designed cutting speed	(0.125 × 2000) = 250 nos.	(5 × 600) = 3000 nos.
4.	Ideal cycle time at designed cutting speed	Operating time / Number of products at designed cutting speed	$\frac{1116.88}{250}$ = 4.47 min	$\frac{1070.31}{3000}=0.36$ min
5.	Performance efficiency	Ideal cycle time × Processed amount / Operating time × 100	$\frac{4.47\times100}{1116.88}\times100$ = 40%	$\frac{0.36\times1000}{1070.31}\times100=33.63\%$

(C) Quality Rate (Q)

Sr. No.	Parameter	Formula used	HMC	CNC
1.	Quality Rate	[(Processed goods per month) – (Defected goods per month)] / Number of goods per month	$\frac{(100\times4\times6)-4}{(100\times4\times6)}$ = 99.83%	$\frac{(1000\times4\times6)-120}{(100\times4\times6)}$ = 99.50%

Therefore, OEE for HMC (HOURN MAKE)

OEE = 97.12% × 40% × 99.83% = 38.78 %

The OEE for HMC (HOURN MAKE) is 38.78% against the desired level of 85%.

OEE for CNC Turning

OEE = 95.56% × 33.63% × 99.50% = 31.97 %

The OEE for CNC Turning is 31.97% against the desired level of 85%.

From the above data, it can be seen that the major factor that is affecting the OEE of the case company's equipment is performance efficiency. The OEE of all the equipment under study is well behind the desired level of 85%. So the work has to be done to increase OEE. When reviewing the areas of opportunity for improvement, there are two factors that need to be addressed if the objective of TPM concept is to be realized.

1. Improve the performance efficiency of the equipment in the factory.
2. Improving the organizational approach in the accomplishment of system maintenance activities.

The solution to above discussed problem is to implement TPM effectively. The experts consider operational elements of TPM program should aim to provide the five pillars of TPM development that are summarized by Nikajima 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.

In an attempt to achieve increase output, reduced manpower cost while maximizing plant availability and reliability, management has launched TPM initiative.

VI. PHASES OF TPM

At the time of this study, the TPM initiative had been on the agenda for 10 months and some of its elements had been implemented. Every employee has been taking turns to go on a team building course, (where the team members are form different departments like production, maintenance, quality, management), for the initiative of team-working and TPM. According to initiative, TPM, also called plant care, is about all the members of a multi-disciplinary team pulling together to assure no breakdown, no waste and no accident in the plant [14]. This involves improving the plant through the activity of improvement groups and the development of skills of workforce. The operators have to be more careful with equipment they use. They have to be trained by their maintenance team members to carry out basic maintenance tasks, called task sharing, which would be done by maintenance technicians otherwise.

After the team building phase, all the members are going through the introduction of 5'S program. It is a systematic process of housekeeping to achieve a serene environment in workplace involving the employees with a commitment to sincerely implement and practice housekeeping. 5'S is a foundation program for the implementation of TPM. It consists of five Japanese terms:

1. SEIRI, this means sorting and organizing the items as critical, important, frequently used, useless, or items that are not need as of now.
2. SEITON, this concept is that each item has a place & only one place.
3. SEISO, this involves cleaning of workplace free of grease, oil, waste, scrap, burrs etc., no loosely hanging wires or leakage form the machines.
4. SEITKETSU, it means standardization of commonly used parts in whole organization, like spares parts of machines, tools used on various machines etc.
5. SHITSUKE, it means self-discipline among the employees and bring it in their habits, like wearing gloves, badges, following work instructions, punctuality, dedication towards work and the organization etc.

The second step after 5'S is JISHU HOZEN, means Autonomous maintenance. It is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activities and major repairs.

Third step in TPM implementation is KAIZEN. Kai means change, and Zen means better. It is for small improvements carried out continuously and involve all the people in the organization. Kaizen requires no or little investments. The various tool used are Why-Why analysis, POKA YOKE (means mistake proof).

The forth step is PLANNED MAINTENANCE, aiming at trouble free machines and equipment producing defect free products for total customer satisfaction. This breaks maintenance in four groups:

1. Preventive Maintenance (PM), means daily maintenance like cleaning, inspection, lubricating and re-tightening.
2. Breakdown Maintenance (BM), means maintenance when equipment fails.
3. Corrective Maintenance (CM), means improving the equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be re-designed.

4. Maintenance Prevention (MP) means design of new equipment. Weakness of current machines is evaluated through the past data. The observations are shared with the equipment manufacturer to make necessary change in new equipment design. The target is to achieve zero breakdown, improve reliability and maintainability, reduced maintenance cost, and ensure availability of spare parts all the time.

The fifth step is QUALITY MAINTENANCE, aimed towards customer satisfaction through highest quality & defect free manufacturing. Focus is on eliminating non-conformances in systematic manner. Equipment evaluation programs focus at what part of the equipment affect product quality, and begin to remove current quality concern. Transition is from reactive to proactive (Quality control to Quality assurance). The target is to achieve and sustain zero customer complaint, reduced process defects, and reduced cost of quality.

The sixth step is the most important step in TPM implementation. The TRAINING, which is aimed to have multi-skilled employees whose morale is high and eager towards work and to perform all functions effectively

The seventh step in TPM implementation is OFFICE TPM. Office TPM must be followed to improve productivity, efficiency in administrative functions and to identify and eliminate losses.

The eighth step in TPM implementation is SAFETY. The target is zero accident, zero health damage and zero fires. The focus is on to create a safe workplace and surrounding area that is not damaged by our processes

VII. DIFFICULTIES FACED IN TPM IMPLEMENTATION

The number of companies successfully implementing a TPM program is considered relatively small and failure has been attributed to the following three major obstacles [15]:

1. Lack of management support and understanding.
2. Lack of sufficient training.
3. Failure to allow sufficient time for the evolution.

One of the difficulties in implementing TPM as methodology is that it takes a considerable number of years. The time taken depends upon the size of the organization. The lack of management support is attributed to management not completely understanding the true goal of the TPM program. For example if management consider that TPM is a means to reduce maintenance staff, they have failed to understand the true goal and purpose of the program. The real goal is to increase the equipment's effectiveness, not reduce the labor head-count. The time required to change from a reactive program to a proactive approach will be considerable by some estimates it may be a three to five year venture before achieving a competitive venture for the TPM program. TPM must be seen as a long-term commitment to strive for zero losses and not a way of obtaining short-term fixes [16]. An active management consultant implementing improvement programs considers that limited applications of TPM have led to regressive steps, including [17]:

1. Converting skilled maintenance personnel into routine operators.
2. Shifting line authority for maintenance crews to production managers.
3. Pushing TPM as a means to reduce the apparent overhead of the maintenance department.
4. Applying TPM principally to reduce maintenance costs.

Following are the difficulties faced in the case company during start of TPM program:

1. Major difficulty is strong resistance to change by the employee.
2. Majority of people treat it as just another "Program of the month" without paying any focus and raising doubts about its effectiveness.
3. Not sufficient resources are provided, like trained people, funds, time, etc.
4. Many employees consider it as additional work/burden.
5. Insufficient understanding of the methodology and philosophy by middle & top management.
6. Department barrier existing within business unit. It is considered to be the job of maintenance department only.
7. The program does not implement change on shop floor due to production pressure on workers.
8. Lack of education and training.
9. Poor structure to support the TPM teams and their activities.

In the business environment of the early 2000s, much of management focus is spent on headcount reductions or downsizing of the workforce. This practice is detrimental to the employee involvement required by TPM. In some companies, TPM starts as a middle management activity. The line employees begin to contribute ideas that increase productivity as they know their machine best. But, because senior management has never been properly educated about the actual process at machine, they use the increase in productivity (output) to focus on reducing expenses to further increase profits. When this occurs, the employee involvement required by TPM diminishes and the TPM strategy fails.

TPM activity starts with cleaning of the equipment, forming teams to discuss theoretical improvements, and creating visual systems to make the plant look better. Although these activities are a part of the overall TPM strategy, they are implemented without any tangible results. Therefore, the companies spend their physical and financial resources with little, if any, financial return on investment. Unless all of the initiatives in TPM are tied to financial benefits or improvements, senior management support diminishes over time. Senior management eliminates support for strategies that are not providing an immediate return on investment.

VIII. CONCLUSION

A manufacturing facility has been studied and analyzed to study TPM implementation methodology, calculations of OEE, difficulties in implementation, the roadmap followed and key benefits as a result of TPM implementation. In the case study firm, there have been attempts by management and the maintenance workers to involve the production people in basic maintenance work. But success has been limited for reasons discussed earlier, with negative effects. The study reveals that successful implementation of TPM requires top management support and commitment, a greater sense of ownership and responsibility from operators, co-operation and involvement of both operators and maintenance workers and an attitude change from "not my job" to "this is what I can do to help" [11]. The study shows how TPM significantly contribute to improve the productivity, quality, safety and morale of workforce. In case company, if there was any practice of TPM and teamworking between the maintenance and production people, this practice only existed informally, based upon personal relationship rather than taking it as TPM initiative. The study reveals the need for a more proactive approach to maintenance management and greater integration between maintenance and production departments. In the case company, the driving force came mainly from the maintenance department, which was keen to transfer some of basic maintenance tasks to their production fellows. But production operators resisted towards these changes as they have productivity pressure from middle management and they treat it as an additional workload. The study shows that implementing TPM is by no means an easy task without strong backup from the top management.

IX. FURTHER RESEARCH FOR CASE COMPANY

The top management is more concerned about the profits and cutting down the costs in all departments. Maintenance cost is on hit list of these cuttings. But TPM requires investment in the same initially. So we have to convince them for the same by relating it to profits in future. We can show them the direct relation between an increases OEE of the whole plant through implementation of TPM and the profits earned in term of increased productivity due to lesser breakdowns, lesser defected goods leading to increased customer satisfaction and hence reliability, safe and motivated work place, better operations and hence saved manufacturing cost. Contributive effect acquired by 1% upraised OEE should be calculated in terms of additive contribution profits and saved manufacturing cost.

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