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Implementation of TPM in a CNC Machine shop to Improve Overall Equipment Effectiveness

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Abstract

Industrial manufacturing of products is facing accelerated changes of pace in market demands and technology. Manufacturing industries have also experiencing unprecedented degrees of change in the major areas like management, process technology, customer expectations, supplier attitudes and competitive behavior. To overcome the accelerated changes, the manufacturing companies worldwide have implemented world – class manufacturing strategies such as Total Productive Maintenance (TPM). Total Productive Maintenance is considered by many authors to be an indispensible contribution to Lean production supporting Just-in-time (JIT) manufacture and Total quality management (TQM), and has been shown as an essential pillar for manufacturers seeking world class manufacturing status. Therefore, the measurement of Overall Equipment Effectiveness (OEE) by the implementation of Total Productive Management on manufacturing of cars Steering knuckle line at a CNC machine shop is presented in this paper.

Keywords— Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE)

I. INTRODUCTION

Any living entity in the world must change and change is the permanent feature. So the manufacturing Organizations must also change to meet the global competitions and to get competitive advantages. Total Productive Maintenance is one of a strategic change management approach that has considerable impact on the internal efficiency of manufacturing organizations. It is an organization-wide strategy to increase the effectiveness of production environments, especially through methods for increasing the effectiveness of equipment.

The Auto Component industry is one of the technically most competitive and sophisticated industry. Auto component industries are on the leading edge when it comes to developing new techniques to find better and improved ways to build a car, in an effort to make them affordable to all sections of society and with perceived quality than their competitors.

To achieve a competitive advantage among different players in the auto component industry, organizations have implemented various world class manufacturing techniques or strategies. One such strategy is TPM.

TPM goals are:

- Zero breakdowns
- Zero abnormalities
- Zero defects
- Zero accidents (Nakajima, 1988)

The path to this ideal situation is continuous improvement that requires total and dedicated commitment from everyone in the organization from top management to machine operators. With this in mind, the paper discusses the implementation TPM and measurement of OEE at the car steering knuckle line of Auto Components Manufacturing unit .

II. REVIEW OF LITERATURE

A. TOTAL PRODUCTIVE MAINTENANCE

According to Nakajima (1989), the word "total" in "total productive maintenance" has three meaning that described the principal features of TPM.

- Total effectiveness indicates TPM"s pursuit of economic efficiency or profitability which includes productivity, cost, quality, delivery, safety, environment, health and morale.
- Total maintenance system includes maintenance prevention and maintainability improvement as well as preventive maintenance: It refers to "maintenance-free" design through the incorporation of reliability, maintainability and supportability characteristics into the equipment design.

- Total participation of all employees includes autonomous maintenance by operators through small group activities: The small group activities promote planned maintenance through "motivation management".

Various authors defined Total Productive Maintenance, (TPM) but the definition given by Nakajima (1989) is more correct and apt one under the given situation.

The definition is as follows: "TPM is a plant improvement methodology which enables continuous and rapid improvement of the manufacturing process through use of employee involvement, employee empowerment, and closed-loop measurement of results."

TPM is an innovative concept which originated in JAPAN (1971) in response to the maintenance and support problems encountered in manufacturing environments and was an equipment management strategy designed to support the Total Quality Management Strategy. According to the Japanese Institute of Plant Maintenance (JIPM), TPM is defined as a team-based maintenance strategy, designed to maximize equipment effectiveness by establishing a comprehensive maintenance production system covering the entire life of equipment related fields and involving everyone, from top management to the production floor operators.

Seichi Nakajima is credited with defining the fundamental concepts of TPM and seeing the procedure implemented in hundreds of plants in Japan with the key concepts being autonomous maintenance performed by the machine operators together with small-group problem-solving activities (Nakajima, 1989).

The modern TPM approach reflects a concern to integrate all the necessary business departments, which affect the process of maintenance management in such a manner that the roles, responsibilities, and care of the assets are optimized throughout its service to the manufacturing company.

TPM"s strict definition has five steps, (Nakajima, 1998):

- Maximizing equipment effectiveness through optimization of equipment availability, performance efficiency and product quality;
- Establishing a maintenance strategy (level and type of classical preventive maintenance) for the life of the equipment;
- Includes all departments such as the planning, the user and the maintenance department;
- Involving all staff members from top management to shop floor workers; and
- Promoting improved maintenance through small- group autonomous activities.

TPM also encourages radical changes such as:

- Flatter organizational structures, i.e. fewer managers and empowered teams;
- Multi-skilled workforce; and Rigorous re-appraisals of the way things are done, often with the goal of simplification.

TPM has two main aspects:

1. A structured approach which uses a number of tools and techniques such as Kaizen, 5S, Reactive, Preventive, Reliability-centered and Predictive maintenance to achieve very effective plants and machinery and to measure its effectiveness; and
2. A philosophy, which is based upon the empowerment and encouragement of factory floor-based personnel from all areas (Davis & Willmott, 1999).

B. OVERALL EQUIPMENT EFFECTIVENESS (OEE)

Overall Equipment Effectiveness (OEE) is defined as a gauge system on equipment that measures quantities such as uptime, units produced, and sometimes even the production speed. This technique works to eliminate the six big losses indicated by Nakajima, as down time losses, speed losses and defects (Nakajima. 1989).

C. MEASUREMENT OF TPM EFFECTIVENESS

From a generic point of view, TPM can be defined in terms of overall equipment effectiveness (OEE). The goal of TPM is to maximize equipment effectiveness. OEE provides an effective way of measuring and analyzing the efficiency of a single machine/cell or an integrated manufacturing system. OEE is also used as a driver for improving performance of the business by concentrating on quality, productivity and machine utilization issues. It is aimed at reducing non-value adding activities, often inherent in manufacturing processes.

D. MAINTENANCE PERFORMANCE INDICATORS

According to Campbell and Jardine (2001), the commonly used maintenance performance indicators are measures of:

- Equipment performance such as availability, reliability and OEE;
- Process performance such as the ratio of planned and unplanned work, as well as of schedule; and
- Cost performance such as labour and material costs of maintenance.

E. PURPOSE OF OEE

- According to Nakajima (1989), the purposes of OEE are:
- Firstly, the OEE measure can be used as a benchmark for measuring the initial performance of a manufacturing plant in its entirety. In this measure, the initial OEE measure can be compared with the future OEE values, thus quantifying the level of improvement made.
- Secondly, an OEE value, calculated for one manufacturing line, may be used to compare line performance across the factory, thereby highlighting any poor line performance.
- Thirdly, if machines process work individually, an OEE measure can identify which

machine performance is worst and therefore indicate where to focus TPM resources.

F. THE SIX BIG LOSSES

Nakajima (1989), reports that the chronic and sporadic disturbances in the manufacturing process result in different kinds of waste or losses. These can be defined as activities which absorb resources and create no value. The objective of OEE is to identify these losses. It is a bottom-up approach where an integrated workforce strives to achieve overall equipment effectiveness by eliminating the six big losses.

These six big losses are grouped into three major categories:

- Downtime
- Speed losses and
- Defect losses.
-

Nakajima (1989) defines these six big losses as shown in the table below.

TABLE I

THE SIX BIG LOSSES **Loss categories**	**Six big losses**
Downtime (Lost availability)	Equipment failures Set-up and adjustments
Speed losses (Lost performance)	Idling and minor stoppages Reduced speed of operation
Defect losses (Lost quality)	Scrap and rework Start-up losses

G. TPM IMPLEMENTATION

Mora (2002), states that implementing Total productive Maintenance (TPM) is not a difficult task. However, it requires some customized training in order to succeed. The results of implementing an effective program in terms of increased plant efficiency and productivity are outstanding.

According to Kennedy (2005), it should be acknowledged that TPM implementation is not a short-term fix program. It is a continuous journey based on changing the work-area, then the equipment so as to achieve a clean, neat, safe workplace through a "PULL" as opposed to a "PUSH" culture. Significant improvement can be evident within six months, however full implementation can take many years to allow for the full benefits of the new culture created by TPM.

Sorabh Gupta et al (2010), reports that at this global competition, the implementation of TPM not a matter of liking it or following the fashion. While TPM was in the 1960"s, just an innovative thing, today it has turned into a survival strategy. TPM is capable of bringing a machine back to original condition and even better. The cost of postponing a decision of implementing TPM, that have to make sooner or later, can be excessive. It is convincing that the losses for each day of delay are out of imagination.

Apparently, successful TPM implementation can achieve better and lasting result as compared to other isolated program because there is an ultimate change in people (knowledge, skills, and behavior) during the progress.

Almeanazel (2010), reports that , by implementing TPM strategy elimination of most of the waste happened like the time waste while changeover or the downtime losses, with this maintenance strategy the responsibility of maintenance is all operator and engineering responsibility, there will be no more "his or my" fault the break down will be solved as fast as possible. The operator in the shop floor should involve in each maintenance operation because he is the one close to the machine and he know what are the abnormality of the machine.

The most important thing to ensure successful TPM implementation relies on strong support and commitment from top management. Additionally, Hansson, Backland, and Lycke (2003), put forward the importance of top management leadership to focus on strategic planning, training and education, monitoring and evaluation, empowerment, and information and communication in increasing the successful implementation of not only TPM but TQM and Reliability centered maintenance also.

More importantly, Tsnag and Chan (2000) revealed the importance of management leadership, employee involvement, education and training, strategic planning and communication for TPM in a high-precision machining company. Cooke (2000) also identified top management support, alignment of management initiatives and change, employee training, autonomy to employees and communication as important factors for the success of TPM.

III. METHODOLOGY

A more common method practiced worldwide to implement TPM is the twelve step procedure method. The same twelve step method was followed in this case also. There is a primary difference between the JIPM process and methods followed in Western countries. In this case the JIPM method is followed. The twelve steps include the following:

1. Announcement of top management decision of implementing TPM
2. TPM education Program and collection of information
3. Establish an organizational structure
4. Formulate basic TPM policies and goals
5. Master plan for TPM deployment and its presentation
6. Feasibility study & its presentation
7. Pilot installation
8. Plant-wide installation
9. Introduction audit
10. Progress audit
11. Certification
12. TPM Award

The organization under this study is a leading Auto Component Manufacturer. It is an integrated auto

component manufacturing unit with its own foundry. It is an ISO 9002 certified company. It produces various auto components like Steering knuckle, Brake drums, Brake discs, Hubs, Brake calipers, Carriers, Differential Cage and Manifolds.
The data has been collected for the calculation of OEE of the knuckle line1, because it is the chosen line for typical TPM implementation on a model basis. Calculations have been made making assumption like each year has 12 months, each month has 4 weeks and each week has 7 days.

A. DATA COLLECTION

Data pertaining to the daily production, rejection and various types of losses were recorded accurately. The various types of losses include the following:

1. Machine breakdown
2. Setting change
3. Tool change
4. Want of load
5. Want of man power
6. Want of power
7. Want of cutting tool
8. Want of Jig & Fixture
9. Want of Coolant
10. Want of Hydraulic Lubricating oil
11. Preventive maintenance
12. Want of schedule
13. Want of packing material
14. Process Correction
15. Casting Defect

B. OEE CALCULATION

The Steering Knuckle line is working for 24 hr a day i.e. three shifts of 8 hrs each and 6 days a week. On Sundays the machine shop works only for two shifts. No set up is required since we run a dedicated product in this line.
The first shift or morning shift starts at 7 AM and ends at 3.30 PM with a half hour break for lunch between 12 noon and 12.30 PM. Second shift starts at 3.30 PM and ends at 12 PM again a half hour break for dinner. The night shift starts at 12 PM and ends at 7 AM next morning with a duration of 7 hours only.
There is a 15 minutes break between each shift to clean the machine by the operators. Conventional cleaning methods are used by the operators. They use compressed air, cloth, broomstick, wire brushes to clean the machine. During that break they also exchange information regarding the machine functioning and other production related information.
Based on the data collected the three factors namely Availability factor, Performance factor and Quality factor were calculated using the equations given below

$$\text{Availability factor} = \frac{\text{Operating time} - \text{Down time}}{\text{Total operating time}} \quad (1)$$

$$\text{Performance rate} = \frac{\text{Total output}}{\text{Potential output at rated speed}} \quad (2)$$

$$\text{Quality rate} = \frac{\text{Good output}}{\text{Total output}} \quad (3)$$

OEE = Availability factor x Performance rate x Quality rate (4)

Using equation (1), (2), (3) and (4) We have

$$\text{Availability factor} = \frac{968}{1315} = 0.736 = 73.6\%$$

$$\text{Performance rate} = \frac{2.57 \times 330}{968} \times 100 = 87.6\ \%$$

$$\text{Quality rate} = \frac{330 - 1}{330} \times 100 = 99.6\%$$

Therefore, OEE for machining line under study using equation (4)

OEE = 73.6 x 87.6 x 99.6 = 64.2%

The OEE for selected line is 64.2% against the desired level of 85%. From the above data, it can be seen that the major factor affecting the OEE of the machining line is availability factor. So work has been done to increase availability factor.
The various TPM activities done in the selected line is briefly presented here:
To improve OEE, implementing TPM is the best way. Present status and working conditions of the various machines were recorded and documented. Based on the observations, the following decisions were made by the TPM implementation committee and implemented in the machine shop.
Small team comprising the machine operator from various shifts, maintenance technicians, people form production department, engineering department persons were constituted. Their goals were defined. They are given needed training and education on team working, achieving goals, machine maintenance and data recording and motivational aspects. Each team is assigned with specific machine.
Cleaning and Inspection activities are carried out using the small teams as well as the operators of the machine. Cleaning and inspection standards were created for each machine. People involved in cleaning may have doubts, they are asked to encourage to voice or clear doubts through questioning. Initially, the workers have lot of reservation to ask question to their superiors namely production supervisors and engineers. The author passionately answered and cleared the

doubts of the cleaning workers. Moreover he took this opportunity to explain the importance of cleaning and inspection and about TPM and its effect on the workers skill development. Each team is given with a note book to record their observation during cleaning and inspection activity. Cleaning and Inspection produced the following team activities:

a) Safety concerns
b) Source of contamination
c) Areas those are difficult to access for cleaning and inspection
d) Ideas for improving cleaning activities

Detect machine minor defects and set right them immediately if possible or otherwise group is trained to record them in their notebook.

Using maintenance personnel and manufacturers recommendations, and based on past experience certain machine standards were also developed. It states that what should be the condition of the machine after implementing and continually following TPM activities.

A tool kit consist of the following was developed for each team, who are all involved in eliminating minor abnormalities in their equipment.

a. TPM program safety
b. Cleaning and inspection materials
c. M – tags
d. 1 – point lessons
e. Team notebooks
f. Cleaning and inspection standards

In addition to the above the following measures were also carried out towards the successful implementation of TPM activity in the selected line. They include the following:

1. Preparation of M-tag
2. Preparation of 1 – point lesson
3. TPM activity check list
4. Maintenance improvement methodologies.
5. Cleaning and inspection audits
6. Raising the technical competency level of the machine operator through continuous training
7. Creation of specific maintenance tool box for each kind of machine
8. Failure analysis
9. Training in spare part and tool management system
10. Implementation Computerized maintenance management system (CMMS)

IV. RESULT AND DISSCUSSION

After implementing all the above discussed TPM measures once again the various data‟s pertaining to machine losses, details of productions, reworks and rejects were carefully recorded. The OEE was calculated again using the equations (1), (2), (3) and (4)

Availability factor = 76.6%

Performance rate = 88.5%

Quality rate = 99.6%

OEE = 76.6 X 88.5 X 99.6 = 67.5%

It has been observed that the implementation of TPM at the selected line of the machine shop has yielded an increase in OEE level of 3.3% over the initially measured value. The availability factor has increased by 3%. The performance rate has also increased by 0.9% within a period of four months time.

Implementing TPM is not an easy task as it seems to be. A great infrastructure and commitment of all personnel from top level management to bottom level is required. A lot of problems have to be faced, while implementing it. Some of them are as follows:

- TPM is not a “quick fix” approach, it involve cultural change to the ways to do the things.
- Incomplete understanding of the methodology and philosophy by middle management.
- Many people treat it just another “program of the month” without paying any focus and also doubt about its effectiveness.
- Workers show strong resistance to any change.
- Many people considered TPM activities as additional work or threat.

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