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International
Journal
Of Modern Engineering Research (IJMER)

Methodology used for improving overall equipment effectiveness by Implementing Total Productive Maintenance in plastic pipe manufacturing industries

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Abstract: *The global marketplace is highly competitive and organizations who want to survive long-term, have to continuously improve, change and adapt in response to market demands. Improvements in a company's performance should focus on cost cutting, increasing productivity levels, quality and guaranteeing deliveries in order to satisfy customers. Total Productive Maintenance (TPM) is one method, which can be used to achieve these goals. TPM is an approach to equipment management that involves employees from both production and maintenance departments. Its purpose is to eliminate major production losses by introducing a program of continuous and systematic improvements to production equipment.*

I. Total Productive Maintenance

In today's industrial scenario huge losses/wastage occur in the manufacturing shop floor. This waste is due to operators, maintenance personal, process, tooling problems and non-availability of components in time etc. Other forms of waste includes idle machines, idle manpower, break down machine, rejected parts etc are all examples of waste. The quality related waste are of significant importance as they matter the company in terms of time, material and the hard earned reputation of the company. There are also other invisible wastes like operating the machines below the rated speed, start up loss, break down of the machines and bottle necks in process. Zero oriented concepts such as zero tolerance for waste, defects, break down and zero accidents are becoming a pre-requisite in the manufacturing and assembly industry. In this situation, a revolutionary concept of TPM has been adopted in many industries across the world to address the above said problems.

TPM is a unique Japanese philosophy, which has been developed based on the Productive Maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971. Total Productive Maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce.

A strategic approach to improve the performance of maintenance activities is to effectively adapt and implement strategic TPM initiatives in the manufacturing organizations. TPM brings maintenance into focus as a necessary and vitally important part of the business. The TPM initiative is targeted to enhance competitiveness of organizations and it encompasses a powerful structured approach to change the mind-set of employees thereby making a visible change in the work culture of an organization. TPM seeks to engage all levels and functions in an organization to maximize the overall effectiveness of production equipment. This method further tunes up existing processes and equipment by reducing mistakes and accidents.

TPM is a world class manufacturing (WCM) initiative that seeks to optimize the effectiveness of manufacturing equipment (Shirose, 1995). Whereas maintenance departments are the traditional center of preventive maintenance programs, TPM seeks to involve workers from all departments and levels, including the plant-floor to senior executives, to ensure effective equipment operation.

TPM as the name suggests consists of three words:

(1) **Total**. This signifies to consider every aspect and involving everybody from top to bottom.

(2) **Productive**. Emphasis on trying to do it while production goes on a minimize troubles for production.

(3) **Maintenance**. Means keeping equipment autonomously by production operators in good position.

Goals of Total Productive Maintenance

The goal of TPM focuses on improving corporate culture through improvement of human resources and plant equipment. The Japan Institutes of Plant Maintenance (JIPM) has put forward the five goals of TPM which are the minimum requirements for the TPM development.

1. Improving equipment effectiveness.
2. Improving maintenance efficiency and effectiveness.
3. Early equipment management and maintenance prevention.
4. Training to improve the skills of all people involved.
5. Involving operators in routine maintenance.

Improving Equipment Effectiveness

Equipment effectiveness is a measure of the value added to production through equipment. This goal is to increase equipment effectiveness so each piece of equipment can be operated to its full potential and maintained at that level. Nakajima describes in his book that TPM maximizes equipment effectiveness though two types of activity to insure that the equipment performs to design specifications which is the true focus of TPM

- ***Quantitative***: It increases the equipment's total availability & improving its productivity within a given period of operating time.
- ***Qualitative*****:** It reduces the number of defective products, stabilizing & improving quality.

Although the equipment must operate at its design speed, produce at the design rate, and produce a quality product at these speeds and rates, there are factors which might obscure efficient utilization of the equipment. Examining, identifying and eliminating all losses which obscure the efficiency of the equipment will increase the efficiency of the equipment

The concept of zero breakdowns and zero defects are inevitable to maximize equipment effectiveness. These equipment losses include: equipment downtime loss, performance loss, and defect loss. Various equipment losses can be quantitatively calculated through measuring equipment effectiveness that ties the '6 major losses' to three measurable.

II. Literature Review

TPM is a unique Japanese philosophy, which has been developed based on the Productive Maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971. ***Nakajima (1989)*** A major contributor of TPM has defined TPM as an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving the total workforce. TPM is not a maintenance specific policy; it is a culture, a philosophy and a new attitude toward maintenance. He suggests that equipments should be operated at 100 percent capacity 100 percent of the time. ***Pirsig et al. (1996)*** emphasizes upon seven unique broad elements and four main themes in any TPM implementation program. The key themes in the TPM implementation program include training, decentralization, maintenance prevention and multi-skilling, while the broad elements include asset strategy, empowerment, resource planning and scheduling, systems and procedures, measurement, continuous improvement and processes. Have proposed developed the eight-step approach to the implementation of TPM involving system, measurement, autonomous maintenance, housekeeping, continuous improvement, culture, training, and plant design. ***Maier et al. (1998)*** consider preventive maintenance, teamwork shop floor employee competencies, measurement and information availability work environment, work documentation, and extent of operator involvement in maintenance activities as factors reflecting TPM implementation. The basic practices of TPM are often called the pillars or elements of TPM. The entire edifice of TPM is built and stands, on eight pillars ***Noon et al. (2000)*** explained TPM seeks to maximize equipment effectiveness throughout the lifetime of the equipment. It strives to maintain the equipment in optimum condition in order to prevent unexpected breakdown, speed losses, and quality defects occurring from process activities. There are three ultimate goals of TPM: zero defects, zero accident, and zero breakdowns ***Marco Castro (2013)*** Total Productive Maintenance (TPM) is one of the World Class Manufacturing tools that seeks to manage assets by involving everyone in the manufacturing organization. The financial and productivity bane fits of implementing TPM are significant. Many approaches have been proposed regarding TPM implementation procedures, of which logically sequenced implementation procedure is an identified success factor, yet the majority of TPM implementation attempts fail to achieve their intended goals.

III. Methodology

Overall Equipment Effectiveness

Overall Equipment Effectiveness has been developed by the JIPM. OEE is regarded as an important measurement for assessing the performance of equipment. The method distinguishes the six big loss types, and three key performance measurements: availability, performance rate and quality rate that combines into one consolidated metric. The OEE can be used to help focus on improving the performance of machinery and associated processes by identifying those performance opportunities that will have the greatest impact to the bottom line. Improvements in changeovers, quality, machine reliability, working through breaks and more, can be measured and improved utilizing the OEE metric. It is the ratio of actual equipment output to its theoretical maximum output. OEE can be viewed as the percent of time that equipment would need to run at its maximum speed in order to attain the actual output of that tool or machine. It is calculated using the following formula.

$$OEE = Availability \times Performance\ Rate \times Quality\ Rate$$

To find the overall equipment efficiency of the plastic Industry, identifying the six major losses of the machines was the first stride by organizing under three key factors. And then data pertinent to those losses was collected for randomly selected machineries. The major losses that are identified and the OEE of the selected machineries presented as follows.

Calculating Overall Equipment Effectiveness

Some of the data pertinent to the above loss are difficult to obtain, since the company doesn't apply the overall equipment efficiency concepts in evaluating the performance of the machines at the individual level. It has been attempted to gather some relevant data to estimate the OEE of the typical machinery.

Availability

The availability is the ratio of time needed for operating the equipment to the time actually consumed for operation and it is expressed as:

$$Availability = \frac{Actual\ Running\ Time}{Scheduled\ Running\ Time} \times 100$$

Whereas Actual Running Time = Scheduled running time – Unplanned stoppages.

Unplanned stoppage means the period during which the line is stopped due to equipment failure, setup, adjustment, and change over and so forth.

So that:-

$$\text{Availability} = \frac{\text{Scheduled running time} - \text{Unplanned stoppages}}{\text{Scheduled running time}} \times 100$$

Performance Rate

The performance rate is the ratio between actual average production and standard production. This factor indicates the ratio of the actual output and the targeted output. Actual output is the actual performance of the operation and is less than the targeted output due to rough running of the equipment, jams and equipment wear. Hence, it is expressed as:

$$Performance\ Rate = \frac{Actual\ average\ production}{Standard\ production}\ X\ 100$$

$$\textit{Average production rate} = \frac{Total\ production\ in\ cycle\ period}{No.of\ working\ days\ in\ a\ cycle\ period}$$

Quality Rate

This is percentage of good parts out of total produced sometimes called "yield". Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects. We can express a formula for quality like this:

$$Quality\ Rate = \frac{No.of\ Products\ Processed - No.of\ Products\ rejected}{No.of\ Products\ Processed} \times 100$$

IV. Case Study

About the Company

Shiv Plastic Pvt. Limited Company Are a Certified Company Situated In Fatehabad Industrial Area. Company Are Manufacturing Plastic Polythene Pipes Of Different Sizes According To The Demand Of Customers And Uses In Different Area. The Material Are Supplied To Company From Delhi. The Product Are Supplied In Different Area.

The Different Diameter From 5 Inches To 12 Inches Pipes Are Manufacturing.

Sr. no.	Dia. in Inches	Dia. In cm	Dia. In mm
1.	5	13	130
2.	6	15	150
3.	7	18	180
4.	8	20	200
5.	9	23	230
6.	10	25	250
7.	11	28	280
8.	12	30	300

Dia. of pipes to manufacturing in industry

Sample of Monthly Production of Pipes Before TPM (May 2013 To Sept. 2013)

S. No	Month	Production(Quintal)
1	May	2200
2	June	2190
3	July	2150
4	August	2170
5	September	2100

Production and Wastage Before

TPM (May 2013 to September 2013)

Months	Production (Quintal)	Waste (Quintal)	%
May	2200	250	11.36
June	2190	239	10.91
July	2150	235	10.93
August	2170	235	10.82
September	2100	230	10.95

V. Calculating Overall Equipment Effectiveness before TPM

$$\text{Availability} = \frac{\text{Scheduled running time} - \text{Unplanned stoppages}}{\text{Scheduled running time}} \times 100$$

Scheduled Running Time of Extruder & Electrical control machine

(8am to 6 pm) = 10 hours (600 min's)

Unplanned Stoppages 3 to 4 Times = 45 min

Scheduled Running Time for 1 Month = 30 days = 30 $\times$ 10 = 300 hours (18000 min's)

Unplanned Stoppages for 1 month = $45 \times 30 = 1350\ min's$

$$\text{Availability} = \frac{\text{Scheduled running time} - \text{Unplanned stoppages}}{\text{Scheduled running time}} \times 100$$

$$\text{Availability} = \frac{18000 - 1350}{18000} \times 100 = 92.50\%$$

Performance Rate Without Implement TPM (From May 2013 To September 2013)

The performance rate is the ratio between actual average production and standard production. This factor indicates the ratio of the actual output and the targeted output. Actual output is the actual performance of the operation and is less than the targeted output due to rough running of the equipment, jams and equipment wear. Hence, it is expressed as:

$$Performance\ Rate = \frac{Actual\ average\ production}{Standard\ production}\ X\ 100$$

$$Actual\ average\ production = \frac{Total\ production\ in\ a\ cycle\ period}{No.of\ working\ days\ in\ a\ cycle\ period}$$

Total pipe manufactured in five months (cycle period) = 10810 Quintal
No. of working days in five months (cycle period) = 150
Standard production = 75 Quintal per day

$$Actual\ average\ production = \frac{10810}{150} = 72.066\ Quintal\ per\ day$$

$$Performance\ Rate = \frac{72.066}{75}\ X\ 100 = 96.088$$

Quality Rate (From May 2013 To September 2013)

This is percentage of good parts out of total produced sometimes called "yield". Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects. We can express a formula for quality like this:

$$Quality\ Rate = \frac{No.of\ Products\ Processed - No.of\ Products\ rejected}{No.of\ Products\ Processed} \times 100$$

Output for 1 day = 75 Quintal (10hours)
Waste for 1 day = 7.9 Quintal
Output for 1 month = 2250 Quintal
Waste for 1 month = 237 Quintal

$$Quality\ Rate = \frac{2250 - 237}{2250} \times 100 = 89.466\%$$

From the above the quality rate of the Extruder And Electrical Control machine is 89.466%

Therefore, the Overall Equipment Efficiency of the machine is obtained by multiplying the above three factors and the result is

.925 X .96 X .894 X 100 = 79.38 %

The calculated Overall Equipment Efficiency of the machines is 79.38 % before TPM.

The major losses that are identified

1. **Equipment failure loss**
2. **Setup and adjustment loss**
3. **Startup loss**
4. **Minor stoppage and idling loss:**
5. **Speed Loss**
6. **Quality Defect and rework loss**

VI. Calculating Overall Equipment Effectiveness After TPM

Sample of Monthly Production of Pipes After TPM (Dec. 2013 To April 2014)

S. No	Month	Production(Tones)
1	December	2240
2	January	2250
3	February	2160
4	March	2240
5	April	2220

Production and Wastage After TPM(Dec 2013 to April 2014)

Months	Production (Tones)	Waste (Tones)	%
December	2240	195	8.7
January	2250	190	8.4
February	2160	170	7.8
March	2240	170	7.5
April	2220	165	7.4

Scheduled Running Time of Extruder & Electrical control machine
(8am to 6 pm) = 10 hours (600 min's)
Unplanned Stoppages 2 to 3 Times = 35 min
Scheduled Running Time for 1 Month = 30 days = 30 $\times$ 10 = 300 hours (18000 min's)
Unplanned Stoppages for 1 month = $35 \times 30 = 1050\ min's$

$$\text{Availability} = \frac{\text{Scheduled running time} - \text{Unplanned stoppages}}{\text{Scheduled running time}} \times 100$$

$$\text{Availability} = \frac{18000 \mathrm{I} 1050}{18000} \times 100 = 94.166\%$$

Performance Rate With Implementation TPM (From Dec. 2013 To April 2014)

The performance rate is the ratio between actual average production and standard production. This factor indicates the ratio of the actual output and the targeted output. Actual output is the actual performance of the operation and is less than the targeted output due to rough running of the equipment, jams and equipment wear. Hence, it is expressed as:

$$Performance\ Rate = \frac{Actual\ average\ production}{Standard\ production}\ X\ 100$$

$$Actual\ average\ production = \frac{Total\ production\ in\ a\ cycle\ period}{No.of\ working\ days\ in\ a\ cycle\ period}$$

Total pipe manufactured in five months (cycle period) = 11110 Quintal
No. of working days in five months (cycle period) = 150
Standard production = 75 Quintal per day

$$Actual\ average\ production = \frac{11110}{150} = 74.066\ Quintal\ per\ day$$

$$Performance\ Rate = \frac{74.066}{75}\ X\ 100 = 98.755$$

Quality Rate (From Dec. 2013 To April 2014)

This is percentage of good parts out of total produced sometimes called "yield". Quality losses refer to the situation when the line is producing, but there are quality losses due to in-progress production and warm up rejects. We can express a formula for quality like this:

$$Quality\ Rate = \frac{No.of\ Products\ Processed - No.of\ Products\ rejected}{No.of\ Products\ Processed} \times 100$$

Output for 1 day = 75 Quintal (10hours)
Waste for 1 day = 5.9 Quintal
Output for 1 month = 2250 Quintal
Waste for 1 month = 178 Quintal

$$\text{Quality Rate} = \frac{2250 - 178}{2250} \times 100 = 92.088\%$$

From the above the quality rate of the Extruder And Electrical Control machine is 92.088%
Therefore, the Overall Equipment Efficiency of the machine is obtained by multiplying the above three factors and the result is $.941 \times .987 \times .920 \times 100 = 85.44$ %

The calculated Overall Equipment Efficiency of the machines is 85.44%.

VII. Conclusion

The main objective of this paper understand TPM concept and to generate awareness among the budding technologies about TPM. During research in Shiv plastic Pvt. limited we have compare before implementing TPM and after implementing TPM data and distort major problems by TPM based corrective action plan we have reduce 60% problems improve OEE. TPM methodology not only increases the effectiveness of the manufacturing system but also increase the effectiveness of the entire organization through mandatory participation and continuously improve Productivity, quality, cost, Delivery, safety health and Morale.

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