Improvement of Overall Equipment Effectiveness (OEE) using TPM in industries

P. V. Mulik*, G. S. Kamble, M. R. Jadhav, P. J. Patil

Tatyasaheb Kore Institute of Engineering and Technology, Warananagar, Kolhapur, Maharashtra, India

ABSTRACT

KEYWORDS

Total Productive Maintenance (TPM), 5S, Autonomous Maintenance, Preventive Maintenance, Focus Improvement.

Total Productive Maintenance has been proven to be a very effective tool for the improvement of productivity and efficiency of employees and equipments. From the TPM perspective reliability and availability are the ultimate goals. The way to accomplish the goals is through elimination of major losses. These losses are only due to mechanical nature and visualized by key figure OEE. In this paper, the study of OEE improvement in Printing Industries Ltd is discussed. During this study, The 11 CNC machines were considered for the first phase of TPM implementation. The study of the old setup of machine shop of the company was done to find out different drawbacks and barriers. It was observed that machine shop has less OEE, lack of self improvement of operator, strong resistance to change by operators, improper use of resources, and poor arrangement system of tools. It was decided to use TPM tools to eliminate the above problems and to improve the OEE. The TPM plan was executed by using different methodologies. Machine performance data were collected for 11 machines under consideration after TPM implementation. These data were used for comparison of utilization time, idle time, efficiency and OEE of the 11 machines before and after TPM activity.

During implementation of TPM various tools were used such as 5S, Autonomous maintenance, Preventive maintenance and Focus improvement (SMED). All methodologies contributed to increase utilization time and OEE of machines in different manners. The result of this work is increase in utilization time and decrease in idle time by 5% and 3% respectively as compare to old machine setup. Thus average OEE of 11 machines reaches to 72.56% which shows 3.26% increase than the previous year.

1. Introduction

Mechanical industries have gone through the significant changes in last decade. Competition has increased dramatically. Customers focus on product quality, product delivery time and cost of product. Because of these, a company has to develop or introduce quality and maintenance system. The maintenance organization now has a role in making the business more profitable and the manufacturing system more competitive by continuously improving the capability of equipment as well as making the practice of maintenance more efficient. Total productive maintenance (TPM) is a methodology that aims to increase the availability of existing equipment, hence reducing the need for further capital investment [4].

TPM is a maintenance system defined by Nakajima (1998) in Japan. To solve the maintenance and the support problems encountered in manufacturing environments, the Japanese developed and introduced the concept of TPM initially in 1971. It covers the entire life of equipment in every division including planning manufacturing and maintenance. According to Nakajima, the word 'total' in TPM has three meanings total effectiveness, total maintenance system and total participation of all employees [1]. TPM is an aggressive strategy, focuses on improving the function and design of the production equipment. Production equipment is like the goose that lays the eggs. If you want to keep the getting golden eggs, you need to take care of the goose.

*Corresponding author,
E-mail: pvmmech@tkietwarana.ac.in

TPM perform same thing in company's business. TPM aims to increase the availability/ effectiveness of existing equipment in a given situation through the effect of minimizing input and the investment in human resources, which results in better hardware utilization to make business more profitable. This work is related to take advantage of this concept by implementing it in Industry.

2. Literature Review

A considerable research work in the area of total productive maintenance has been carried out. Here a few references presented on maintenance are reviewed. A lot of research has been done on TPM. The purpose of this literature review is to go through the main topics of interest. F.T.S. Chan et. al [1] have discussed execution plan for implementation of TPM along with case study of an electronics manufacturing company of Hong Kong. The practical aspects within and beyond basic TPM theory, difficulties in TPM and the problems came across during the implementation are discussed and analyzed. One Yoon Seng et. al [2] focused on the two TPM operational strategies, which are posited, will improve the extent of TPM implementation in manufacturing organizations. This study was an attempt to look at the TPM implementation from the perspective of a developing country such as Malaysia. In this paper, Hongyi Sun et. al [3] have studied case of the pilot implementation and evaluation of Total Productivity Maintenance (TPM) in the advanced manufacturing environment of a Hong Kong Manufacturing company. The pilot project turned out to be very successful. The experiences from this were useful for the company to apply to all manufacturing. It provides a reference for other companies that would like to implement TPM. Jack Roberts [4] have discussed through this paper about definition of TPM in some detail, its strengths and weaknesses evaluation as a maintenance philosophy, and implementation procedures. He highlights the some examples of successfully implemented programs. Telsung M. T. [5] has explained different aspects of TPM along with its objectives and scope. His book provides useful information about pillars and stages involve in implementation of TPM. J. Santosa et. al [6] have discussed how technology can go hand-in-hand with the philosophy of Lean Manufacturing through the implementation of the OEE rate (Overall Equipment Efficiency) framed within the philosophy of TPM (Total Productive Maintenance). It provides 5 indicators, was updated before weekly meetings, allowing workers to verify the impact of the improvements they proposed. Halim Mad Lazim et. al [7] focused on the failure of equipments or machines to produce products on time as required can reflect efficiency in operations thus, failure to deliver the products to the customers. Also discusses part of a preliminary study finding focusing on two main TPM practices namely autonomous maintenance and planned maintenance in a Malaysian SME. M.C. Eti et. al [8] have discussed TPM as a strategy and culture for improving its performance and suggests self-auditing and bench-marking as desirable prerequisites before TPM implementation. Remarkable improvements have occurred recently in the maintenance management of physical assets and productive systems, so that less wastages of energy and resources occur. In this paper, K.D.P. Singh et. al [9] have studied an endeavour to eliminate losses in the oxygen plant by the application of Total Productive Maintenance (TPM) technique thereby improving the overall performance of the plant. Out of the 8 Pillars of T.P.M, two most important pillars i.e. Jishu-Hozen (Autonomous Maintenance) and Kobetsu-Kaizen (Continuous Improvement) have been used for the investigations. Sorabh Gupta et. al [10] have focused on the concept of introduction and implementation approach of Total Productive Maintenance (TPM) in detail. TPM is a maintenance program which involves a newly defined concept for maintaining plants and equipment. S. Fore et. al [11] have studied 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. Thomas R. Pomorski [12] has explained "Total Productive Maintenance is based on teamwork and provides a method for the achievement of world class levels of overall equipment effectiveness through people and not through technology or systems alone." He highlights the basic concepts of TPM and reviews the significant literature related to design, implementation, and maintenance of TPM programs in manufacturing operations. Investigation includes the organizational structures, human interactions, analytical tools, and success criteria associated with the implementation of Total Productive Manufacturing programs.

Table 1
Average data of machine utility parameters.

	Utili.	Idle hrs	Setting	Rework	Setup Time	Effi.	OEE
CNC-4	78.94	12.22	8.55	1.16	44.35	85.54	67.5
CNC-9	79.48	11.83	7.43	1.52	59.89	83.12	66.06
CNC-10	79.38	12.88	7.41	0.98	69.1	86.25	68.33
CNC-11	84.92	7.85	4.41	2.8	55.72	88.95	75.81
CNC-12	85.45	7.78	3.65	3.44	65.72	86.75	74.03
L-11	79.45	12.36	6.44	1.75	58.32	83.25	66.26
L-8	81.1	12.02	5.78	1.31	55.96	84.69	68.86
G-10	83.14	13.17	2.94	1.5	29.41	88.09	73.27
CNMC-5	78.04	9.79	3.98	8.19	73.62	87	67.92
CNC-5	81.10	12.02	5.78	1.31	55.96	84.69	68.86
CNMC-6	79.45	12.36	6.44	1.75	58.32	83.25	66.26

The literature review has been carried out as focused on the basic concept of TPM such as autonomous maintenance, planned maintenance, equipment effectiveness, availability of equipments, six major losses, and calculation of OEE, implementation steps and methodologies. Also, review of different current research activities is taken. This literature review points out that how to improve the Overall Equipment Effectiveness (OEE) through the implementation of innovative maintenance strategies. It highlights design, implementation, and maintenance of TPM programs in production industries. Different case studies explained in the papers provide path for preparing the TPM implementation plan and its successful execution for Printing Industries Pvt. Ltd.

3. Analysis of Existing Activities

Over a period of last 30 years, Printing Industries has invested substantially to create the modern and sophisticated infrastructure for manufacturing highly precision components. Today, almost 40 CNC machine tools are installed to derive the advantages in terms of flexibility in production, productivity and high precision dimensional controls. Highly skilled and dedicated as well as a trained personnel are engaged by using modern techniques of manufacturing to ensure the efficient management of the production environment. Latest and advanced technologies in cutting tools along with modern accessories are implemented to get the optimum utilization of machine tools' capacity, by keeping very close interaction with the world class manufacturers like M/s Widia, Sandvik, Iscar, Nexos and the likes. The manufacturing facilities are also supported by automation in material handling, storing and in-house transportation facilities. The advanced Quality Assurance facilities, like CMM, other ultra-modern testing equipment and highly sophisticated assembly practices render extra muscle to entire manufacturing process. Printing Industries decided TPM implement on 11 Machines.

3.1 Average data of machine utility parameter

The following table gives information of machines such as utilization, Efficiency, OEE, etc.

Total Productive Maintenance is nothing new to the Printing Industries Pvt. LTD. Machine shop have been working on their TPM plans for nearly three years. This section analyzes a handful of the on-going TPM implementation efforts to gain additional insight into what creates a successful TPM program. The common issues that each organization has faced, the barriers that they have encountered and the factors that have enabled their successes are provided. Also, a brief list of recommendations that could eliminate some of these barriers, and enhance their programs is provided.

3.2 Drawbacks in existing approaches

- At present overall equipment effectiveness is comparatively less, due to improper utilization of machine resources.
- The self-involvement of operators is very less, due to the lack of maintenance knowledge.

Hence operator has to depend on service department's persons

- In current environment, there is deficiency of moral support induction program. The present strategy of company is not sufficient to motivate the employees.
- Not sufficient resources (people, money, time, etc.) and assistance provided.
- Insufficient understanding of the methodology and philosophy by middle management.
- The maintenance performed on the tools and equipment was primarily breakdown repair, and had virtually no operator involvement in inspections and maintenance. Also, there was very little proactive maintenance, and most planned maintenance was determined by calendar days rather than by equipment usage or need.

4. Implementing TPM in Printing Industries

Drawbacks in existing approaches, barriers encountered in the system and recommendations for the improvement are discussed in the previous chapter. This chapter is dedicated to design proper plan of TPM to overcome the investigated problems. The preparation of master plan and selection of the different methodologies for TPM are crucial and fundamental steps for the success of TPM. After the announcement of TPM implementation in Printing Industries, the 12-step process is designed to implement TPM.

4.1 Developing TPM plan

This plan includes the following steps,

- **Announcement of top management decision of implementing TPM**

  Top management of Printing Industries decided to go for phase wise implementation of TPM. Coordinating committee started the work with Machine and at beginning concentrated on the above motioned 11 CNC machine setup. In this connection, it is essential to create awareness amongst the employees and healthy environment in department that will support the introduction of TPM. TPM objectives and benefits should be spread in proper way to the employees. For this purpose the meetings should be arranged with all staff and informed them through company circulars.

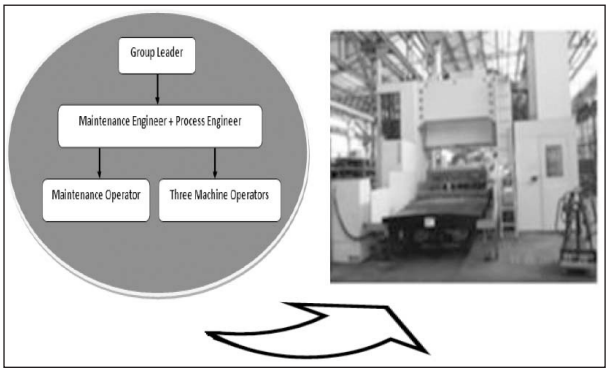

Fig. 1. Structure of organizational group allocated to a machine.

- **TPM education program and collection of information**

  This program will inform and educate everyone in the machine shop department about TPM activities, benefits and its objectives. For managers: offer seminars according to level, for general workers: provide slide presentation. This step of implementing TPM also consists of collection of information about TPM and to understand how it works. TPM coordinator must understand what TPM is, how it works, its proper implementation sequence, the amount of effort that will be required, how it can be benefited for the plant, how long it will take to implement etc. Information resources include TPM seminars, magazines, the Internet, and conversations with consultants.

- **Establish an organizational structure**

  This group needs to include members from every level of the organization from management to the shop floor. This organizational group will promote and sustain TPM activities once they begin. Team-based activities are essential to a TPM effort. This structure will promote communication and will guarantee that everyone is working toward the same goals. For this phase, 11 groups are required to be created and allocated to the proper selected machines. Each group contains one group leader, one maintenance engineer, one process engineer, one maintenance operator, and three machine operators.

- **Formulate basic TPM policies and goals**

  Analyze the existing conditions and set the goals that are result oriented, specific, measurable, attainable and realistic. Then predict the

results. The established TPM policies and goals should be very much clear to everyone involved in TPM implementation. The survey of existing systems is already discussed in the earlier chapter. The investigation will be enhanced and concentrated on the considered 11 machines setup.

- **Master plan for TPM deployment and its presentation**

  After establishing TPM policies and goals, a detailed proposed master plan for implementation of TPM is prepared and proposal is presented to top management. This activity can be carried out by a TPM coordinator. It is began with a CNC machines setup visit to observe production operations, learn about the equipment (type, function, condition, problems and losses etc.), study maintenance operations (structure, size and tasks etc.), orderliness and cleanliness in the shop floor, and talk to employees to determine their motivation and attitude. The presentation will be result of data obtained and analyzed during the machine shop visit of TPM coordinator. The presentation should end with a recommendation to install TPM. Normally, management will make positive decisions at this point. These decisions will be included in the master plan. This plan will identify what resources will be needed and when for training, equipment restoration and improvements, maintenance management systems and new approaches.

- **Kick off the TPM and feasibility study and its presentation**

  Every successful TPM installation has been preceded by a good feasibility study. The results of the feasibility study, will establish a base line, against which TPM results and progress can be measured and also helps in setting the realistic goals, based on the data obtained. It will include overall equipment effectiveness (OEE) observations and calculations for 11 machines. The study will evaluate the condition of these equipment and the required current & future maintenance activities. This Feasibility study of machine will be carried out by the corresponding allocated group and results will be presented. It should conclude with a recommendation that TPM is to be installed. At this point, management will make a second and final commitment to install TPM.

- **Establish a 5S system for improving production efficiency**

  After feasibility study and kick of the TPM, teams should be focused on 5'S' pillar. The team will take effort to implement the 5S for machine shop.

- **Develop an autonomous maintenance program for operators**

  An Autonomous maintenance program will be prepared which includes seven steps. These steps are as, Initial cleaning, Counter measures at the source of problems, Cleaning and lubrication standards, General inspection, Autonomous maintenance, Orderliness and tidiness and Fully Autonomous maintenance.

- **Establish a system for improving production efficiency. (Focused Improvement)**

  Focused Improvement program will be prepared which includes following steps, Determine equipment condition, Determine current maintenance performed on equipment, Analyze equipment losses, Develop and rank equipment improvement needs and opportunities, Develop setup and changeover improvement needs and opportunities, Execute improvement opportunities as planned and scheduled activity and Check results and continue with improvement as required.

- **Establish and deploy the maintenance prevention activities**

  Company has already their preventive maintenance policies. Step includes the review of the existing policies and suggests some modified activities. In this, trained maintenance staff will be used to train the operators to better maintain their machine.

- **Progress audit**

  To insure good progress and successful installation, audits have proven to be very valuable. There are two types of audits: the first audit is fairly simple and checks if the

Table 2
Targeted OEE.

Machine	CNC4	CNC9	CNC10	CNC12	CNC11	CNC5	CNC6	CNMC5	G10	L8	L11
OEE	65	65	70	75	65	65	72	70	70	65	70

TPM fundamentals are done correctly and whether the program is on schedule. They will be typically carried out 3 month after launch by internal specialists. This audit will point out existing deficiencies to bring TPM to a successful conclusion. The progress audit will take review of Preventive maintenance is carried out by the TPM teams, Equipment improvement activities have been executed according to schedules, Increase in OEE has been reached and The improved equipment condition has been accomplished and documented.

- **Implement TPM fully and aim for higher goals**

The final and most rewarding step of a TPM installation is achieving the TPM fully in the machine shop. It is certain that implementing TPM using the above 12 steps will lead to "zero breakdowns" and "zero defects." To make TPM successful, not only support is required from top management, but also from the every member of the team. The implemented TPM will motivate the employee which in turn will lead to better progress and aim for higher goal.

4.2 Execution of TPM Plan

TPM plan is developed. It is thoroughly explained in above section. Now, it is the time of execute the plan. Different systematic efforts are required for the success of plan. This point deals with efforts were taken for stepwise implementation of plan.

- **Announcement of implementing TPM**

TPM implementation was started with formation of coordinating committee. It was formed and announced by the management. This committee and management officially declared about phase wise implementation of TPM on 11 CNC machines. The notice was issued for employees. The meetings were arranged with all staff.

- **Arrangement of TPM education programs**

In this step, efforts were taken on education and training of staff members involved in this activity. The seminar and presentation were organized for operators and engineers in front of management. In addition to this, magazines, books, reports on TPM were made available which was useful to create the awareness amongst the employees.

- **Formation of organizational structure**

The execution was continued with formation of an organizational structure. It is explained in step 3. The 11 machines were selected for this phase. 11 groups were created and allocated to the proper selected machines. Each group contains one group leader, one maintenance engineer, one process engineer, one maintenance operator, three machine operators. The circular corresponding to organizational structure was displayed.

- **Decision of TPM policies and goals**

The study of existing system was done. The results are used for the further investigation. It was more concentrated on the considered 11 machines setup. The collected information will be used to decide targeted OEE for individual CNC machine. It is given below in Table No.2

- **Master plan and kick off the TPM**

Before preparing the master plan, committee visited to machine shop. The situation of every machine was studied in master plan point of view. The following steps involve before the preparation master plan. Study of production operations of machines, maintenance operations, orderliness and cleanliness in the machine shop, talk with employees to determine their motivation and attitude, study of considered methodologies used for TPM implementation, decision about the time duration for every methodology

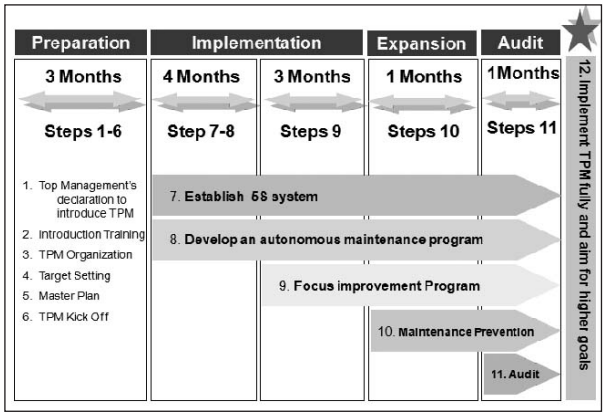

Fig. 2. Master plan.

and finalize the total span for complete implementation of TPM on 11 CNC machines. The output of this step was the master plan which is shown below. 12 steps of TPM plan are divided into five groups i.e. preparation, implementation, expansion and audit. This plan guided team to execute 12 steps within decided time period. The plan was under gone the feasibility testing which was carried by TPM coordinator and management. Final master plan as shown in fig. 2 was presented in front of management again. Management gave permission to kick off the TPM on 11 CNC Machines.

- **Implementation of 5 'S'**

TPM starts with 5S. It is a systematic process of housekeeping to achieve a peaceful environment in the work place involving the employees with a commitment to truthfully implement and practice housekeeping. Making problems visible is the first step of improvement. 5S is a foundation program before the implementation of TPM; hence it has been positioned in the base. If this 5S is not taken up seriously, then it leads to 5D. They are Delays, Defects, Dissatisfied customers, declining profits and Demoralized employees. This 5S implementation in Printing Industries was carried out in phased manner as mentioned in TPM Plan. First the current situation of the every CNC machine was studied by allocated organizational group. This audit uses check sheets to evaluate the current situation.

Form the data obtained from the check sheet, the necessary steps were taken for complete and effective implementation of 5S such as all equipment, tools, files and cupboards etc. are arranged and provided with index list etc. These implementation was done on every machine and overall in machine shop step by step. It is found great changes in the working environment of the machine shop. The each of the above-mentioned 5S is implemented and audit is conducted at regular intervals to evaluate the success of implementation. Audit sheet used for this process. This activity ensures and monitors that every team member in true spirits in the work place. In first audit, it is found that all teams are working enthusiastically for great success of 5S.

- **Autonomous Maintenance**

This pillar 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 activity and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating. By use of this pillar, the aim is to maintain the machine in new condition. The activities involved are very simple nature such as cleaning, lubricating, visual inspection, tightening of loosened bolts etc. During this activity, coordinating team tried to involve operators, maintenance and engineering personnel in maintaining and improving the performance of equipment. The policy was designed for autonomous maintenance to eliminate the defects at source through active employees' participation. Finally it was implemented gradually in six well-defined steps described as follows

1. Initial cleanup of machines 2. Counter Measures 3. Cleaning and Lubrication Standards 4. General Inspection 5. Autonomous Inspection 6. Standardization.

Up to the previous step only the 11 CNC machines were the concentration. However in this step the surroundings of machinery were organized. It includes organization of items, such that there is no searching and searching time is reduced. This part was already considered during implementation of 5S. In this step, the activity was enhanced through environment modifications. In addition to these, instructions were given to everybody to follow strictly. The implementation of autonomous maintenance was completed as it run with full swiftness.

- **Focused Improvement**

  This pillar is geared towards developing operators to be able to take care of small tasks, thus people to spend time on more value added activity, develop and rank equipment improvement needs and opportunities. The operators are responsible for upkeep of their equipment to prevent it from equipment losses. By use of this pillar, the aim was to maintain the machine setup and changeover improvement needs and opportunities. For this activity, operators were write abnormalities which were observing during working conditions in TPM resistor. On these abnormalities, TPM team was takes action daily.

  The activities involved are very simple nature to improve equipment to its highest required level of performance and availability. The execution of this pillar on set up of 11 machines was done by following the flow chart which is given below fig. 3.

  The previous data of machines and maintenance results were used to carry out the analysis of equipment losses. Team found the need of taking efforts on loss due to failures, setup adjustment, rework and start-ups. Efforts taken in this connection are summarized below

- Eliminating Loss Due to Failure :- Establish the basic condition (clear, lubricate, tighten), Maintain the basic operating condition, Restore all deterioration functions at the original level and Improve the design weakness of the machinery were considered. Most of these points were covered in autonomous and preventive maintenance. Very fewer deficiencies were observed at this stage of implementation and necessary actions were taken to completely eliminate them. It decreases the losses due to failures.

- Eliminating Loss Due to Setup Adjustment (Single Minute Exchange of Die):- In the previous system, losses due to setup adjustment were considerable due to improper setup method. This is point where great improvement has done by TPM team. Single Minute Exchange of Die (SMED) Methodology was used. The first step of SMED is to analyze what is done during "online" setups, and determine the manner in which these operators can be moved to the offline format.

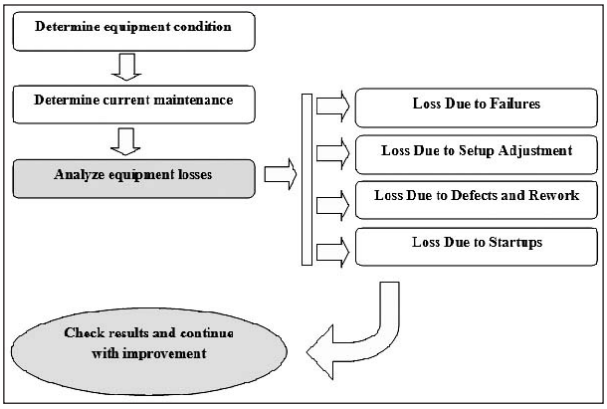

Fig. 3. Flowchart for activities in focus improvement.

SMED reduces the non-productive time by streamlining and standardizing the operations for exchange tools, using simple techniques and easy applications. The applicability of the proposed SMED approach was tested for CNC 12 machines changeovers in the industry. The implementation has enabled reduction in setup time, through company's internal resources reorganizations without the need for significant investment. The four major steps which used to change "online" setup to "offline" setup are given below

- Stage I (Internal and External setup)
- Step II (Separating internal and external setup)
- Step III (Converting the internal setup to external setup)
- Step IV (Streamlining all aspects of the setup operation)

SMED was implemented step by step on all considered machines. The case of CNC 12 is explained below

The case study was based on the need to obtained time reduction of changeovers in CNC 12 machines, through the implementation of the SMED approach. The SMED based approach used during the study was implemented as next presented. Initially was observed of a significant number of changeovers occurred in CNC 12 machines in order to make the collection of time spent on tasks performed during this activity, allowing to obtain a deeper knowledge about the procedure used in changeovers. Due to the absence of the possibility of recording the changeovers observed, it was only possible to know the current process of changeovers made in CNC 12 machines by observing and recording each of the operations carried out during the exchange of templates, making the measurement of time spent in each of the operations. The

Table 3
SMED summary of result.

SMED Summary of Results				
Area	Machine	Machine	CNC12	
	Before	After	Difference	% Change
Internal Time	80	65	15	18.75
External Time	20	20	0	
Total Time	100	85	15	

initial observation found that the achievement of a changeover is an extremely complex; the first step is the process of stopping the machine. Each time it is necessary to make a changeover the machine must be stopped. After the machine is stopped, proceed with the dismantling of the previous wall which is on the machine. After the removal of the previous wall has to be set up so next wall clamped on the table by using clamping material and job truing, offset calculation are carried out. For removing the chips from machine table T slot use of new equipment which is removes the chips from T slot easily. So it can be reduce chip removal time. In table cleaning process use of compressed air and water gives less time to clean the table.

During setting layout of wall equipment's are arranged near to CNC 12 machine by using cupboards and racks. Due to which setting layout time reduced. Then for clamping of wall on the machine table sizable clamping studs are used so alignment time of studs with wall is minimized.

- **Preventive maintenance**

During survey of existing system, TPM team found that company has good preventive maintenance schedule. It was also observed that activity is executed properly and consistently. The considered machines of machine shop were already the part of this procedure. During this step, team did not require more efforts to implement it. Only slight modifications were done in the schedule to enhance it effectiveness.

- **Progress audit**

About eleven months activities pushed the TPM team at end of plan. As mentioned above, audit is integral part of any planning and implementation process. First audit was done in eleventh month. It was carried out by the TPM coordinator, management persons. The TPM audit took review of

1. Preventive maintenance success.
2. Executed equipment improvement activities.
3. Increase in OEE.
4. The improved equipment condition
5. Documentation

- **Implement TPM fully and aim for higher goals**

The TPM implementation leads to "zero breakdowns" and "zero defects" in considered CNC machines setup. It gives number of positive outcomes not only for management but also for employees. These are summarized at the end of this report.

During implementation activities, better results are obtained but same time there is chance of more improvement. It is not 100 % achievement of goals. The execution was journey of learning through mistake and success. At the end, prepare for the next higher goals.

5. Results and Discussion

It is not possible to stop just by implementation of TPM as per the plan. The activity is continued with investigation of modified system. It is important as it provides a systematic and complete way to acquire operating information. Data were collected for the 11 CNC machines to find out the OEE. The observations were made for the utilization of machine, idle time, rework, setting, time per setup and efficiency. OEE is a major key performance indicator for machine. OEE introduces availability, performance and quality. Therefore, it has been used as a key metric in this study. The aim is to get a consistent way to measure the effectiveness and other initiatives

by providing an overall framework for measuring production efficiency. The sample calculations of OEE are given below. The OEE was calculated for one month. Referenced month duration distribution is given in Table 4.

The machine shop was working 3 shifts with 8 hours,

OEE calculation for CNC 12 Machine as follows,

OEE= Availability x Performance x Quality

Availability = Operating Time / Planned Production Time

Operating Time = [Planned Production Time – (Idle +Setting +Rework)]

= [582 – (22.00+39.67+30.50)] = 489.83 hrs

Planned Production Time = 582 hrs

Availability = 489.83 Hrs /582 Hrs = 0.8416 (84.16%)

Table 4
Month duration distribution.

Item	Data CNC 4	Data CNC 12
Planned Production Time	322 Hrs	582 Hrs
Idle Time	32.75 Hrs	22.00 Hrs
Setting Time	33.00 Hrs	39.67 Hrs
Rework Time	2.17 Hrs	30.50 Hrs
Standard Time	217.34 Hrs	427.03 Hrs

Performance = Standard Cycle Time / Operating Time

Performance = [427.03 / 489.83] = 0.8718 (87.18%)

Quality = Good Pieces / Total Pieces = 1 (100%)

OEE = Availability x Performance x Quality, OEE= 0.8416 x 0. 8718 x 1= 0. 7338 (73.38%)

The comparison of new and previous system is essential to decide the success of TPM. Different machine performance data were collected for considered 11 machines. This information is used for comparison. Average utilization, idle time, efficiency and OEE of the 11 machines before and after TPM are considered. These parameters are shown in table no. 1. OEE is product of machine utilization and efficiency. As explained above the utilization parameter is greatly increased due to 5S, reduction in losses, material planning and modification in old system. Consequently it was observed that efficiency decreased for the individual machine. The combined effect of these two parameters decides the change in the OEE. The rate of increase of utilization is more over the rate of decrease in the efficiency. Hence the OEE of individual machine shows considerable increase in value even though there is decrease in efficiency. is plotted for the comparison of old OEE and OEE after TPM.

The higher increase in OEE is recorded for CNC 4, CNC 10, L11 and CMMC 5. CNC 11 shows smaller

Table 5
Average data of machine utility parameter after implementation.

	Utili.	Idle	Setting	Rework	Setup Time	Effi.	OEE
CNC-4	86.57	9.91	10.3	1.92	46.02	84.57	72.24
CNC-9	80.14	6.62	8.36	1.87	57.78	84.29	67.52
CNC-10	84.94	7.45	7.19	0.41	68.77	84.87	72.11
CNC-11	84	5.49	3.14	7.23	76.55	84.4	70.86
CNC-12	86.5	3.98	4.56	4.91	70.19	86.24	74.15
L-11	87.53	7.76	4.71	0.19	54.54	82.1	71.88
L-8	83.64	8.1	8.28	0.63	56.66	83.14	69.28
G-10	85.21	12.38	2.4	0	32.62	86.25	73.5
CNMC-5	84.22	6.43	4.62	4.18	67.36	85.85	72.27
CNC-5	77.6	13.47	5.55	3.36	71	85.84	66.56
CNMC-6	87.78	5.36	6.03	0.81	63.52	87.45	76.78

OEE because it has less utilization and efficiency. Table No.5 shows machine utilization parameter after TPM implementation.

6. Conclusion

The detail literature survey of TPM technique and its implementation was taken during this research work. The comparison of new and previous system was done to decide the success of TPM. Machine performance data were collected for 11 machines under consideration. This information was used for comparison. Effect on average utilization, idle time, efficiency and OEE of the 11 machines before and after TPM were studied. Effect of different methodologies on various parameters are summarized below

- Implementation of 5S improves housekeeping and achieves a peaceful environment in the work place. It is also observed that employees sincerely commitment to implement and practice housekeeping. Employees experience the benefit of the 5S. The results of 5S are overall increase in the utilization time and reduction in the idle time which boosts the OEE.
- Autonomous maintenance is continuous process and schedule was made regarding cleaning, inspection and lubrication and it includes details like when, what and how. It increases self involvement of operator for cleaning and lubrication of machines and provides good working environment. It reduces the idle time due to almost zero breakdown and increases utilization of machine.
- Focused improvements are responsible for eliminating loss due to setup adjustment by using single minute exchange of die. The SMED technique reduced cycle time of CNC 12 machine by 18.75%. The loss due to startups is eliminated by designing the new chip collector system for L11 which leads to decrease the idle time by 25 to 30 % and increase in efficiency by 5%.
- Preventive maintenance schedule activities were executed properly and consistently. Slight modifications done in the schedule reduces load on maintenance department and consequently time.

The work is concluded with the following remarks,

- It is clear that availability of all machines increases excepting the CNC12 due to reduction in the losses. The great increase in utilization was found for CNC4, CNC 10, L11 and CNMC 5 machines. The overall utilization time of the considered machines is 84.9. It shows 5% increases as compare to previous year.
- CNC 10, L 11, G10 and CNMC 6 had large idle time before TPM implementation. It was observed that the idle time of 11 machines decreased after TPM implementation. The overall idle time of the 11 machines is 7.9 %.
- The calculated overall efficiency is 85.2 % after TPM. But it slightly surprising that efficiency of individual machine shows drops off in the value. Same time it was found there is decrease in overall efficiency by 1.07 % as compared to previous year. It is parameter where the further improvement is required.
- It was observed that minor stoppage losses and adjustment losses were responsible for lower efficiency. In addition to this, speed losses also contributed in the problem of efficiency. Sometime operators run the machine at slower speed than the planned speed to avoid defects. It increases speed loss. The efficiency can be increased by minimizing these losses.
- The higher increase in OEE is recorded for CNC 4, CNC 10, L11 and CMMC 5. CNC 11 shows less OEE because it has less utilization and efficiency. The OEE of individual machine shows considerable increase in value even though there is decrease in efficiency. The average OEE for all machines is 72.56 %. The OEE can be improved by increasing the efficiency of the individual machines.

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Dr. Pramod V. Mulik is presently working as Head & Asst. Professor, Department of Mechanical Engineering, Tatyasaheb Kore Institute of Engineering & Technology, Warananagar, Kolhapur, Maharashtra, India. He is a graduate in Mechanical Engineering in 1999 and M.E. in Production Engineering in 2011 from RIT Sakharale, Rajaramnagar. He is obtained Ph.D. from Visvesvaraya Technological University, Belgavi in 2020. He has 15 years of teaching experience and 4.5 years of industrial experience. He has published 10 international Journals and 6 national papers. His area of interest is manufacturing and energy engineering.

Prof. Gautam S. Kamble is working currently as Assistant Professor, Department of Mechanical Engineering, Tatyasaheb Kore Institute of Engineering and Technogogy, Warananagar, India. He graduated from DY Patil College of Engineering, Kolhapur, in 2001 and obtained his post graduation from PVPIT College of Engineering Sangli, in 2007. He is pursuing his Ph.D from Shivaji University, Kolhapur. He has 13 years of teaching experience and 02 years of industrial experience. He has published 10 papers in international Journals. His area of interest is Heat Power Engineering.

Dr. Mahesh Rama Jadhav is working currently as Asst. Professor, Department of Mechanical Engineering, Tatyasaheb Kore Institute of Engineering & Technology, Warananagar, Kolhapur, Maharashtra, India. He graduated from KITs College of Engineering, Kolhapur, Shivaji University, Kolhapur in 2005 and obtained his post graduation (M.Tech) From Walchand College of Engineering, Sangli in 2009. He obtained his Ph. D. from Shivaji University, Kolhapur in 2019. He has 11 years of teaching experience and 02 years of industrial experience. He has published papers in International and National in SCOPUS indexed Journals. His areas of interest are Conventional Machining, Non-Conventional Machining and Composite Materials

Dr. Prashant J. Patil is working currently as P.G. Coordinator & Asst. Professor, Department of Mechanical Engineering, Tatyasaheb Kore Institute of Engineering & Technology, Warananagar, Kolhapur, Maharashtra, India. He graduated in 1996 and obtained his post graduation in 2010. He is obtained Ph.D. from Visvesvaraya Technological University, Belgavi in 2019. He has Academic 13 years, Industrial 10 year experience. He has published 10 international and 3 national papers. His area of interest is Design Engineering.