

## DEVELOPMENT OF TPM IMPLEMENTATION PLAN IN SWITCHGEAR & ENGINEERING COMPANY

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### ABSTRACT

Modern manufacturing requires effective and efficient equipment management. This project studies the equipment management in a manufacturing company using Total Productive Maintenance (TPM) approach. The case study was conducted in a switchgear & engineering company in Johor, Malaysia. Equipment efficiency in the company was low and there was lack of co-operation between departments. A questionnaire was developed to facilitate the data collection in the company. The questionnaire was used to gather information of employees' perception on maintenance in the company. The survey focused on mechanical section in production, maintenance and engineering departments. Evaluation of equipment effectiveness was conducted based on daily production record. The project evaluated the equipment effectiveness of bending machines. TPM was the equipment management philosophy suggested to the company. Finally, a TPM implementation plan was suggested. The plan can be modified and implement into other company, especially for small and medium industry.

**Keywords:** TPM, Equipment effectiveness, Implementation.

### 1. INTRODUCTION

Equipment is a major component of any manufacturing company. Every product has three main properties to be considered: quality, price (cost), and delivery time [1], and equipment affect all these three criteria. Equipment breakdown, repair, quality defects are daily problems arise in manufacturing industry and can affect quality, cost and delivery time.

Equipment is always designed to operate in an optimal condition. Oakland [2], states, "The best equipment will not work satisfactorily unless it is cared for". Therefore, maintenance activity is important to optimize equipment usage. In explaining the concept of TQM, according to Antero [1], Lillrank highlighted that "Maintenance activities should be executed according to total productive maintenance (TPM) philosophy". Equipment maintenance is even more critical with the advancement of automation in industry.

TPM emphasizes on total employee involvement (TEI) and improving the efficiency of the total organization, not just the manufacturing capability. TPM involves every employee in an organization and aims to maximize equipment effectiveness. Based on TPM, maintenance and production operators must work in a team in conducting maintenance activities. Employees will have new roles, better job function and responsibilities in TPM environment.

### 2. OVERVIEW OF TOTAL PRODUCTIVE MAINTENANCE (TPM)

Maintenance activity was first introduced in the 1950's and was known as 'preventive maintenance'. During the 1960's, preventive maintenance activities moved to a new era called 'productive maintenance'. Theories developed in that era include maintenance prevention (1960), reliability engineering (1962), maintainability engineering (1962) and engineering economy. The development of Total Productive Maintenance (TPM) actually began in the 70s.

In the early 70's, TPM only consisted of three major components; education and training, autonomous maintenance, and improvement of overall equipment effectiveness (OEE). Today, TPM covers all the components added into TPM since 1970s such as early equipment management, schedule maintenance, office TPM, safety, cost reduction and clean factory. Nakajima the father of TPM, summarized these component and identified them as the five major pillars of TPM, which consists of increase equipment effectiveness, training, autonomous maintenance, early equipment management, and planned preventive maintenance [3]. After years of development, "easy-to-manufacture product design" is identified as another major components of TPM [4]. Different TPM pillars had been adopted by Ireland [5]; focus improvement, autonomous maintenance, planned maintenance, quality maintenance, education and training, early equipment maintenance, and safety and the environment.

TPM is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous operator maintenance through day-to-day activities involving the total workforce. Based on small-group activities, TPM takes productive maintenance company wide, with the support and co-operation of managers and employees at all levels. The implementation of TPM not only involves employee on the shop floor but also the management team. It promotes group activities throughout the organization for greater equipment effectiveness and trains operators to share responsibility for routine inspection, cleaning, maintenance and minor repairs with maintenance personnel.

TPM aims to allow the machinery to operate at maximum effectiveness, thereby reducing processing speed, minor machine stoppage and process defects. In addition, it also aims to reduce the occurrence of equipment failure and the associated costs of repeated machine and process set up. Losses occur in an equipment are identified and grouped under 6 major categories; *breakdown, setup and adjustment, idling and minor stoppage, speed loss, quality defects and rework, and start-up/yield loss.*

Most of the losses have been overlooked while some were 'solved' by traditional problem solving technique. Overall equipment effectiveness (OEE) is a simple but powerful technique, which enables industry to identify its equipment effectiveness and where the main losses are. Once identified, corrective action can be taken to reduce the total losses. In order to measure equipment effectiveness, OEE approach is emphasized in TPM. The 6 major losses are grouped under three main groups; *availability, performance rate and quality.* Each group of the OEE has sub-components data that must be collected by equipment operators in order to calculate OEE. This method clearly identifies causes of losses in manufacturing effectiveness, and allows the continuous monitoring of the most important factors. Additional benefit of OEE is this technique maximizes effectiveness of every single equipment without affecting the overall production system.

Nakajima suggests that 85% is the ideal OEE of a manufacturing plant, with availability greater than 90%, performance efficiency greater than 95%, and rate of quality products greater than 99%.

$$\text{OEE} = \text{Availability} \times \text{Performance Efficiency} \times \text{Quality}$$

### 2.1 Autonomous Maintenance

Autonomous maintenance brings production and maintenance department together to perform maintenance tasks. Operators not only conduct daily operation, but also learn and carry out some simple but important tasks. These tasks include cleaning and inspection, lubrication, precision checks, and some simple replacement and repairs. Autonomous maintenance provides opportunities for operators to learn and understand more about how their equipment functions, what are the common problems and why those problems occur. At the same time, operators understand the importance of detection and treatment of abnormal

conditions in preventing the occurrence of problems or breakdown. Autonomous maintenance encourages operators to be active with maintenance and engineering personnel in improving equipment performance and reliability. Operators need the ability to look at the quality of the products and the performance of the equipment. They have to understand the machine well and recognize the causes of problems. Operators should be able to respond quickly if there is any abnormality on their equipment.

### 2.2 Benefits of TPM

TPM is a philosophy of managing equipment in the manufacturing industry. The benefits are not limited in the maintenance activities, but also increases productivity, reduce quality defects, reduce inventory, improve safety and improve morale. TPM helps change the role of maintenance from reactive to proactive. By shifting less technical maintenance tasks to operators, maintenance personnel have more time to focus on proactive equipment improvements, equipment performance analysis and simplification of existing maintenance practices. Companies that have successfully implemented TPM have achieved reduction in breakdown of up to 80%-90% [6], reduce maintenance labor by 60% [7].

By eliminating unscheduled downtime, organizations can spend more time on value-added activities, such as producing products. By implementing TPM, equipment productivity can increase by 50%-80% [6], labor productivity increase up to 150% [7] and setup time dropping by 50%-70%. By reducing the losses in quality, the costs of quality defects drop by 55% after implementing TPM.

### 3. METHODOLOGY

TPM implementation not only focuses on maintenance department but it involves every employee in the organization, from top management to shop floor operator. Management team should understand employees' ideas and predict their response before designing a proper implementation plan.

Survey is the most powerful tools for this purpose [8], and questionnaire is used. A survey/case study of TPM was carried out in a switchgear & engineering company in Johor, Malaysia. In this study, production data was also collected to analyze the Overall Equipment Effectiveness (OEE) for only the bending machines, as these machines is the most critical in the production of this product

### 4. SURVEY RESULT

The questionnaire is designed to understand current condition and employees' perceptions towards maintenance. The results showed that only 60.53% of operators claimed that they are doing preventive maintenance, whereas 7.89% employee are not doing maintenance and there are 31.58% of operators who do not understand about maintenance.

Currently, the company does have an organized scheduled maintenance. They have a list of maintenance activities to be conducted on a daily, weekly, or monthly

basis. Although more than 50% of the operator does daily maintenance such as lubrication, only a small number of them know the correct method. Moreover, they are only concern about daily maintenance tasks and they always ignore weekly and monthly maintenance tasks such as greasing ball screws and checking hydraulic level. Training is needed in order for them to conduct proper planned maintenance.

Referring to the table 1 only 35.6% of employees agree that the machines are in good condition. From discussion with operators, it was found that the machines can be operated smoothly but occasionally have some minor problems causing it not functioning optimally. This is a sign of medium and minor defects in the equipment. Detailed investigation should be done to prevent those defects from becoming a major defect, which can cause machine breakdown. None of the supervisors are satisfied with the machine performance, and all maintenance staffs agree that improvement should be done on the machines. The result indicates that the equipments need better maintenance. In future, the company should organize a meeting and invite all parties to discuss and schedule more preventive maintenance tasks.

Table 1: Summary of Machine Condition

Position	Is machine working in good condition? (%)		
	Yes	Not Sure	No
Engineer	40.0	20.0	40.0
Supervisor		57.1	42.9
Operator	45.2	29.0	25.8
Maintenance Staff			100.0
TOTAL	35.6	31.1	33.3

#### 4.1 General Maintenance

The survey has also looked at the perceptions of employees towards maintenance. Figure 1 is the summary of responsibility on machine breakdown. Both operators and supervisors have the perception that maintenance staffs should hold full responsibilities on machine breakdown. Moreover, they believe that machine breakdown is not an operator problem (scale 3: neutral). Supervisor and operators have such opinion as they are avoiding from holding the responsibility. Employees on the shop floor still work with the traditional methods, where the production department is involved in producing, while the maintenance are responsible for machine breakdown and repairs.

However, maintenance staffs have different perception and they totally disagree with these two statements. In their point of view, machine breakdown also affect production. Some of the breakdowns occur due to mis-operation or the operators not following scheduled maintenance.

The engineers also disagreed with these two statements. The average for engineers in this two statement is 2.6 (2-disagree, 3-neutral). Engineers understand the role of maintenance and production department on machine breakdowns. Maintenance department has to repair the breakdown machine as quickly as possible while production has to be stopped

and operator idling. For the responsibility, maintenance staffs are responsible to plan out proper maintenance schedule while operator should conduct the maintenance tasks.

It is clear that most of the employees in production are not clear about their roles in maintenance activity. There is lack of co-operation between maintenance and production department. This is critical situation and must be considered in designing TPM implementation plan. In order to ease maintenance job, shop floor employees must understand that maintenance task helps to maintain machine and equipment work in optimum condition. Maintenance not only prevents machine from breakdown, but it also helps to maintain machine performance and safety.

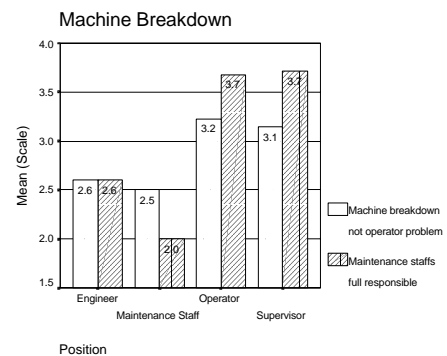


Fig 1. Responsibility on Machine Breakdown

A summary of benefits from maintenance is shown in Table 2. All the employees agree that proper maintenance tasks will bring benefits to production. Maintenance staffs give the highest rate, as they know the role of maintenance very well; followed by engineer, operator and supervisor. Overall, respondents have the opinion that maintenance tasks can help operator to complete their daily operation easier. Besides, maintenance plays an important role to increase safety level and product quality. The lowest rate of the benefits is helps to increase machine capability. This criterion is seldom discussed in traditional maintenance tasks and this might be the reason why respondents do not expect maintenance to play the role in machine improvement. In TPM, equipment improvement is one of the major components. TPM approach will improve equipment capability by maximizing equipment effectiveness.

Table 2:Benefits of Maintenance

	Engineer	Operator	Supervisor	Maintenance Staff	AVERAGE
Prevent machine breakdown	4.60	3.84	4.43	5.00	4.07
Easier in daily operation	4.40	4.29	4.29	4.50	4.31
Increase safety level	3.80	4.45	4.14	3.50	4.29
Increase product quality	4.60	4.35	3.86	4.00	4.29
Minimize tool ware	3.80	4.16	3.57	4.50	4.04
Increase machine capability	4.00	4.03	3.86	4.50	4.02
Decrease production cost	4.20	4.13	3.86	4.50	4.11
<b>AVERAGE</b>	<b>4.20</b>	<b>4.18</b>	<b>4.00</b>	<b>4.36</b>	<b>4.16</b>

**4.2 Autonomous Maintenance**

Figure 2 shows the levels of agreement in implementing autonomous maintenance. Overall, all the staffs support autonomous maintenance, where maintenance staffs support the most. Maintenance staffs understand that autonomous maintenance will not reduce off their authority but will only ease their burden in maintenance. Operator is the second highest, they contact directly with the equipment, and they always know what the equipment need most. They agree with implementation of autonomous maintenance that they need to carry out some maintenance tasks. In the future, it is expected that the operator will discuss with maintenance personnel to suggest and design some suitable maintenance tasks.

In autonomous maintenance, operators are not only required to perform planned maintenance, they need to conduct daily inspection and some simple repair. In daily inspection, operators must understand the critical part of the equipment. Through survey and discussion, it is believed that maintenance staffs support operators to conduct daily inspections and report any abnormalities to them. For operators, they know their equipment and are confident of detecting any abnormality.

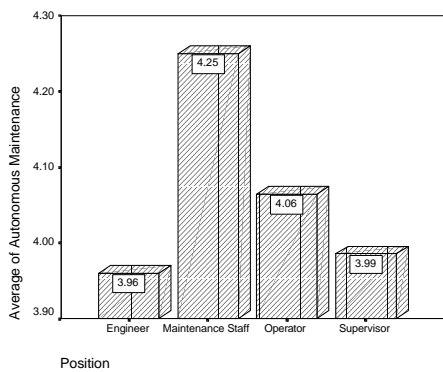


Fig 2. Summary of Autonomous Maintenance

**4.3 Overall Equipment Effectiveness Analysis**

The study has also analyzed the OEE of bending machines. There are altogether 7 bending machines (A,B,C,D,E,F,G). During data collection, only 6 bending machines was operating while machine D is idling. The OEE of bending D is zero and is considered as major losses. The current OEE level is 27.91%. The main

reason for the low OEE level is because of the idle machine D during the data collection. The machine is available in good condition but it is left unused.

Table 3:OEE Analysis

Machine	Availability	Performance Efficiency	Quality	OEE (%)
A	0.7826	0.6918	0.9830	53.22
B	0.7956	0.6583	0.9353	48.99
C	0.7991	0.7030	0.9480	53.26
D	-	-	-	0
E	0.7939	0.6857	0.9196	50.06
F	0.2992	0.5801	0.9325	16.19
G	0.7866	0.6701	0.9199	48.49

By ignoring machine D, the OEE is 44.32%, which is still lower than 50%. In other words, production department cannot fully utilize their equipment. Machine F has the lowest OEE. Its availability level is as low as 0.2992 as it breakdown and remain unrepaired for more than a week due to spare parts shortage.

The OEE without breakdown was calculated (without machine D and F), which is 50.80%. This is the utilization of equipment in daily production. Although the OEE level is as low as between 40 ~ 50%, the result is as expected. In Irjan (1998) research, the average value of OEE level before TPM implementation is as low as 55%. Among the entire three major categories, performance efficiency (0.6818) is the lowest, and followed by availability (0.7917) and quality (0.9412). The low performance efficiency is due to occurring of minor problems, while too many set up and adjustments are the main reasons of low availability.

**5. TPM IMPLEMENTATION PLAN**

TPM implementation requires a long-term commitment to achieve the benefits of improved equipment effectiveness. Successful implementation requires a significant amount of training, management supports and teamwork. The following section will suggest a unique implementation plan after analyzing the questionnaire and OEE results. This plan provides a step-by-step approach to implement TPM Company wide.

The implementation plan was suggested base on Nakajima [3] and Hamacher [7]. Some modifications are made and new ideas added into the TPM implementation plan such as quick response system and standardization of components in product design.

### *Step 1: Develop TPM Implementation Team*

In the first step, the top management must announce about the decision of implementing TPM. The objectives and goals of TPM must be developed with the initial scope of the TPM program. Management should also provide the necessary support to the TPM Implementation Team.

Management can assign a full-time TPM co-coordinator, who knows TPM in detail to lead the TPM implementation teams. Training course must be provided in order for him to lead the team towards correct goals.

Engineers, maintenance staffs, production supervisors are important members in this team. The team members must have a basic idea on what TPM is, including the knowledge on how to support the goals of manufacturing and facilities maintenance. The team can have representative from human resource department for training issues. The team will plan, develop and implement TPM program in detail.

### *Step 2: Set TPM Implementation Priorities*

It is believed that no organization can implement TPM on a company wide basis the first time. TPM implementation team must select the priorities in implementing TPM. Data such as OEE, waste and safety must be collected and analyzed which will reflect the current situation. Pareto analysis is suggested to identify the sequence of implementing TPM. TPM implementation team can develop goals and objectives after identifying the priorities. The information gathered here will be useful for evaluating improvements after implementation. Those employees operating the equipment should also be selected to be part of the TPM implementation team.

### *Step 3: Training for Introduction to TPM*

Related operators and supervisors must be informed about any improvement activities. They must be provided with introductory training and motivation to encourage their participation. The training provides basic knowledge on TPM and informs the employees regarding their roles in TPM. They must be convinced that TPM would not increase their burden but will provide a better working environment.

### *Step 4: Implement Autonomous Maintenance*

Autonomous maintenance is the process of transferring knowledge from maintenance personnel to equipment operators. This will provide opportunities for operator to know their equipment in details. Maintenance staffs must prepare a checklist for operator to conduct cleaning. This checklist must be updated when new critical situation is encountered. Situation that makes daily maintenance difficult will be identified. This step also recognize causes of contamination, downtime, quality defects can be identified.

#### *Implement Safety Procedure*

Based on the checklist developed, several critical parts, which might create accident, are identified. Visual control should be added to these critical parts.

Employees' safety must always be the first consideration.

#### *Develop Cleaning and Lubrication Standard*

This step will summarize the entire checklist updated. This step is aimed at finding out the best cleaning and lubrication method and to standardize them.

#### *Conduct Training for Inspection & Repair*

Operator should also be given the responsibility to carry out daily inspection and some simple repair and replacement. Maintenance staffs must identify operators' capability through discussions and must also provide training to operators with assistance from Human Resource Department.

#### *Conduct Process Improvement Exercise*

This activity is to eliminate the major losses at equipment. The TPM team will identify the area of losses and develop improvement plans. Checklists developed earlier will be useful in this stage. Some problem solving tools such as brainstorming, Pareto analysis, and fishbone diagram are suggested in this activity, as it is useful and simple. The improvement plan will then be proposed and implemented.

#### *Finalize and Document Autonomous Maintenance*

This step is the final stage of autonomous maintenance. Results obtained here will be finalized and standardized. Every element will be documented and integrated with existing manufacturing activities.

### *Step 5: Establish Preventive Maintenance Plan*

In this step, maintenance staff will develop an equipment maintenance schedule for preventive maintenance activities. The plan should include the managing of equipment spare parts inventory. Historical data helps in determining the frequency of periodic inspection and estimates the time required to perform inspection & repair.

### *Step 6: Develop Quick Response System*

Each member in TPM implementation team must receive fast and accurate information. Quick response system is necessary for communication purposes as the team members reside in different departments. The MIS (Management of Information System) department should develop a system to ease the TPM implementation. This system must be user friendly as operators are included in the TPM implementation.

### *Step 7: Develop Early Equipment Management*

The goal of this step is to utilize the knowledge gained through the TPM program to develop new manufacturing equipment that is easier to maintain. A standard process is necessary for introducing new manufacturing equipment into the workplace to maximize the performance. Engineering department should develop initial service requirements based on reliability data from similar existing equipment.

#### *Step 8: Standardize Components in Product Design*

The high rate of set up constitutes the major losses in machine availability. Design department should standardize the product they design. This will reduce the number of setup and changes of punch and die for bending machine.

#### *Step 9: Implement TPM Company Wide*

The goal of this step is to continue implementing TPM Program company wide using Continuous Improvement (CI) approach. At this stage, TPM implementation team has to provide feedback to management on implementation results and lessons learned. The relevant record must be documented for future reference.

Once the above tasks have been implemented and stabilized, the team should continue follow up the implemented equipment and focus on another equipment. This will return to step 2: TPM Implementation Priorities and search for another improvement opportunities. Therefore, these steps will repeat to obtain zero breakdowns, zero defects and zero losses.

### **6. CONCLUSION**

By conducting survey and collecting data from the production department, the current situation of the company was understood. The results show that there is a need for TPM in the company.

A TPM implementation plan was developed to suit the company needs. This plan can be modified and implemented into other similar companies, especially for small and medium industry (SMI). In Malaysia, TPM is still a new concept and it is expected that more and more company will implement TPM in the future

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