AUTONOMOUS MAINTENANCE – AN EFFECTIVE SHOP – FLOOR TOOL TO IMPROVE PRODUCTIVITY

PROF. DR. SALLEH YAHYA

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AUTONOMOUS MAINTENANCE – AN EFFECTIVE SHOP-FLOOR TOOL TO IMPROVE PRODUCTIVITY

[1]Eliatamby Nadarajah
[1]Murali Sambasivan
[2]Salleh Yahya
[1]Graduate School of Management
Universiti Putra Malaysia
[2]Institute of Technology Management and Entrepreneurship
Kolej Universiti Teknikal Kebangsaan Malaysia

ABSTRACT

This paper highlights one of the powerful approaches to improve productivity in a shop floor viz, Autonomous Maintenance (AM), a pillar of Total Productive Maintenance (TPM). Japanese and American manufacturers have successfully tried this approach and the results are very encouraging. This paper explains the underlying concepts, issues, and benefits of AM implementation through a case study. The company discussed in this study is an MNC manufacturing electronic components in Malaysia. After the implementation of AM, the yield loss was reduced by about 65% which resulted in savings of about RM 39,000 per week.

Keywords: Productivity, Fuguai mapping, Autonomous Maintenance

INTRODUCTION

The companies throughout the world are constantly struggling to improve the productivity of their operations and this improvement results in higher profitability. The companies that fail to improve their operations (lower cost and higher quality) will be wiped out of the market in due course of time. This is especially true with small and medium enterprises. Malaysia has just come out of the crisis after two years. These two years must have given ample opportunities to the companies to go back to the drawing board for finding out ways to improve their operations. The companies that managed to improve their operations, reduce cost, and improve profitability can face the uncertain future with greater resilience.

Companies adopt different approaches to improve their productivity. Each approach has a particular cost and time frame associated with it. The approach that costs the least but maximizes the benefits in the shortest possible time is the one that is likely to be favored. The companies have been struggling to find one such approach. This constant struggle has led to the advent of several techniques like TQM, BPR, Benchmarking, TPM and so on. However, there is no one technique that is panacea to all the problems. In this paper we highlight one such approach that can be effectively employed by medium and small-scale enterprises to improve productivity.

The approaches that are applicable at the shop-floor level are the ones that have direct impact on the productivity. The second industrial revolution that was triggered in 1970s saw the advent of automation in the shop floor. Automation became popular among Japanese manufacturers. Automation eliminates the drudgery of manual labor, improves the quality, and reduces costs. However, automation fails if the equipments are not maintained properly. Japanese manufacturers started to move towards an approach that would guarantee Zero Accidents, Zero Defects, and Zero Breakdowns. Thus, came TPM (Total Productive Maintenance) into existence. One of the main pillars of TPM is Autonomous Maintenance (Tajiri and Gotoh, 1992). The uniqueness of Autonomous Maintenance is that the maintenance is carried by the Production Department (shop-floor personnel) and not by the conventional Maintenance Department. The success of TPM depends upon the success of the Autonomous Maintenance program. This paper attempts to highlight the success of an organization that improved its productivity by meticulously implementing the Autonomous Maintenance program in its shop floor.

Section 2 of this paper briefly describes the essentials of a TPM program with emphasis on Autonomous Maintenance. Section 3 describes the steps taken by an MNC in Malaysia to implement Autonomous Maintenance and the benefits that have been derived and the lessons that can be learnt by other organizations.

TPM and Autonomous Maintenance

TPM refers to small group activities calling for total employee involvement and implemented primarily by the production, maintenance, and plant engineering departments to maximize productivity. In short, it is a strategy to realize Zero Accidents, Zero Defects, and Zero Breakdowns (Gotoh, 1991; Tajiri and Gotoh, 1992). TPM implementation must take into account the conditions that exist in each company or factory, such as plant configuration, organization, local history, and culture at the plant site. TPM consists of the following major activities as shown in Table 1 (Nakajima, 1988):

TABLE 1
TPM Major Activities

Activities	Department Responsible	Remarks
mination of six big losses	Production, Maintenance, Plant Engineering	Breakdown losses Setup and Adjustment losses Minor stoppage losses Speed losses Quality defect and rework Yield losses
Planned Maintenance	Maintenance	Reduce variability of parts life, extend parts life, restore deteriorated parts, predict parts' life
utonomous Maintenance	Production – shop floor personnel	Seven-step program Initial cleaning Countermeasures to sources of contamination Cleaning and Lubricating Standards Overall Inspection Autonomous Maintenance Standards Process Quality Assurance Autonomous Supervision
cused Improvement and reventive Maintenance/ Engineering	Plant Engineering	Early equipment management – prevention better than cure
Easy-to-manufacture product design	Product Design	Design for Manufacturability
aining and Development support above activities	All employees in all departments	
TPM in Office and Administration	Office and Administration	TPM can be applied in all operations
nvironment safety and hygiene	Production, Plant Engineering, Maintenance, Product design	This becomes especially critical in chemical, process, and electronic component industries

I is not an end in itself and it is not a one-time process. The discipline of TPM has e instilled in each and every employee and the improvements through TPM is a inuous process. What does TPM achieve?

Improves reliability and maintainability of equipment thereby increasing productivity and improving quality

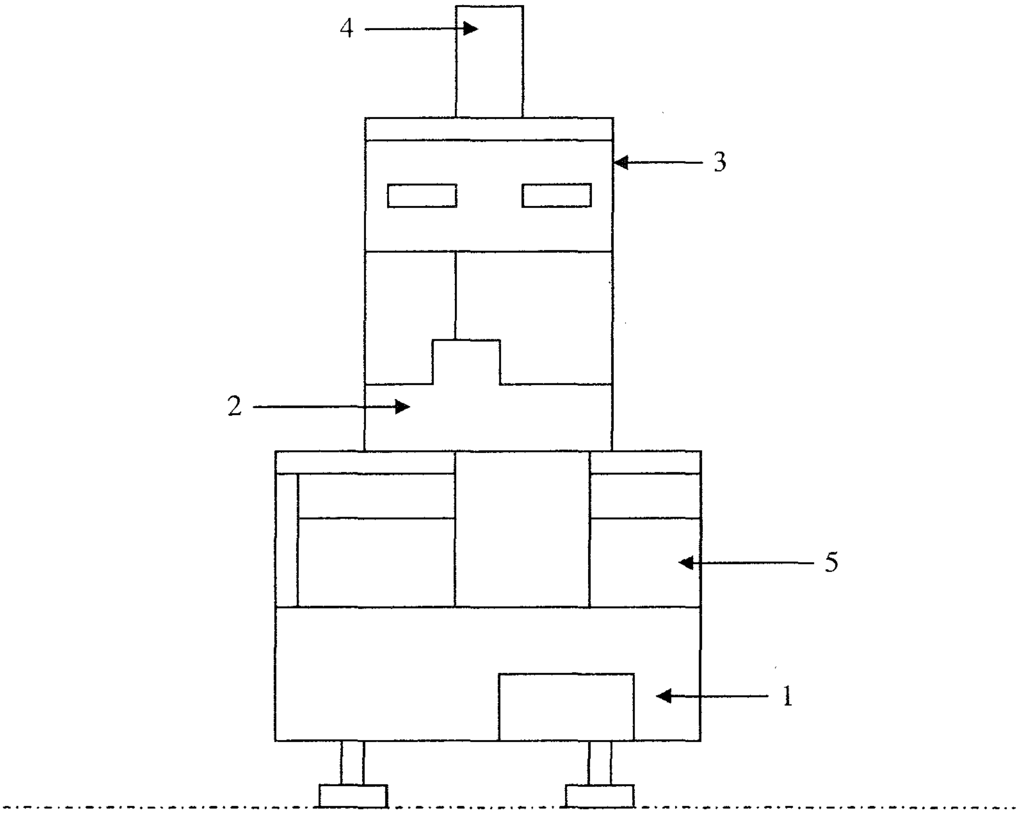
- Develops knowledgeable operators – most of the activities of TPM are carried out by the operators themselves
- Helps in building ease in manufacturing and quality assurance at the product design stage itself
- Increases value added per employee and promotes automation
- Helps to establish safe, environment friendly workplace and product, and favorable workplace by way of education and total employee involvement

TPM was born on the shop floor of Japanese manufacturers and has been making progress since then. Many American MNCs like Motorola have subscribed to the philosophies of TPM and have implemented in their factories.

One of the main arms of TPM is Autonomous Maintenance (AM), called as Jitshu Hosen in Japanese. The success of TPM, to a large extent, depends upon the success of AM. The three main objectives of AM are: (1) it establishes an orderly shop floor where any departure from normal conditions can be identified immediately, (2) it fosters the development of operators as **knowledgeable workers** since most of the routine maintenance tasks are carried out by the operators themselves with assistance from maintenance department, and (3) it brings/maintains the equipment in the "near new" condition. The steps to be followed in the AM program are (Motorola Internal Document, 1999):

- Equipment selection and team formation: Selection of the right equipment during the initial stages of implementation of AM is very important. A quick success in the initial stages will always provide sufficient momentum to the whole TPM program. In the MNC that is discussed in this paper, the equipment was selected based on the yield loss from that equipment. The equipment that was selected for implementing AM contributed to about 63% of the total yield loss from a particular manufacturing line. As will be shown later, the benefits obtained by implementing AM on this equipment have been quite substantial. TPM emphasizes on cross-functional teams. The team members must be from departments like Engineering, Equipment, and Manufacturing. By having a cross-functional team all aspects can be looked into and each team member is given a specific task to accomplish.
- Initial cleaning: This step emphasizes on hands-on activity. First, the surrounding area is cleaned and all unnecessary items around the equipment are

removed. Once the surrounding area is clean, the team can start focusing on the equipment itself. Initial cleaning of the machine consists of cleaning of dust, dirt, grime, oil, grease, and other contaminants in order to expose the hidden defects inside the equipment. All covers, guards, and compartments should be opened up to expose the actual condition of the machine. Based on the TPM philosophy "cleaning is inspection", inspection is a step to detect any abnormalities or "Fuguai". The process of combing through the machine and identifying all the abnormalities is called "Fuguai mapping". Figure 1 shows an example of Fuguai mapping. A sketch of the machine is drawn by hand and fuguais are tagged and classified as long and short-term fuguais. The fuguais are removed and the progress is monitored closely. The mapping and the removal processes enable the team to identify the critical cleaning points. Then proper cleaning procedures and the time taken for cleaning can be established and monitored. The cleaning standards are instituted in the form "One point Lesson" and "Cleaning check sheets". One point lesson is a document that holds all procedures related to a certain task in a single sheet. The task is explained with a diagram to facilitate easy understanding to the operator. An example of One Point Lesson is shown in Figure 2. The "Cleaning check sheets" lists all the tasks that need to be carried out by the technicians and operators in a very systematic way. An example of Cleaning check sheet is shown in Figure 3. The operators and technicians must be trained and educated on the significance of cleaning and its impact on the safety. At this stage of AM minor flaws like excessive play, deformation and wear can be detected and corrected.



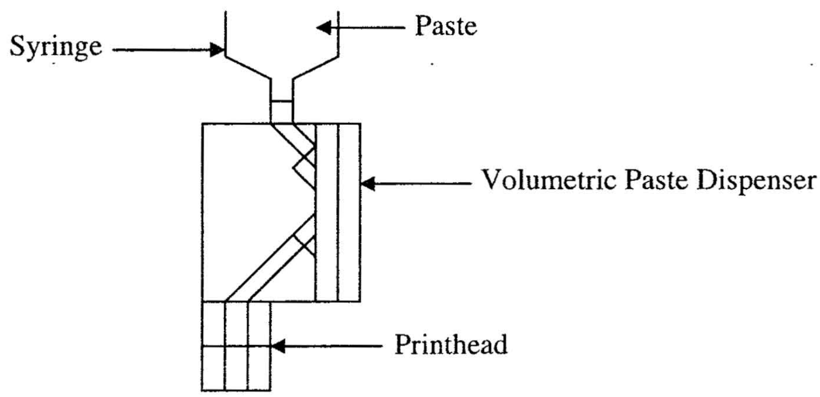
Fuguai #	Fuguai Description	Date Found / Restored	Remarks
1	Dirty panel – left bottom		Short term
2	Screw missing on cover		Short term
3	Paint worn out		Short term
4	Exhaust tubing – loose		Long term
5	Flexiglass – dirty/broken		Long term

FIGURE 1
An example of Fuguai Map (Front of the Equipment)

One Point Lesson

Theme	**Printhead through hole**		
Classification	√Basic Knowledge	Troubleshooting	Improvement

Prepared by		Date:	Serial #
Operations Manager	Engineer Manager	Maintenance Manager	Manufacturing Manager



When setting up the printhead, ensure that the printhead through hole is clean and not clogged

In the case of excessive paste drying and paste clogging during machine operation, check the printhead through hole to see if there is any clogging

In both the above cases, if there is clogging then use the Branson cleaner to clean the print head

Trained and certified by:

Date:

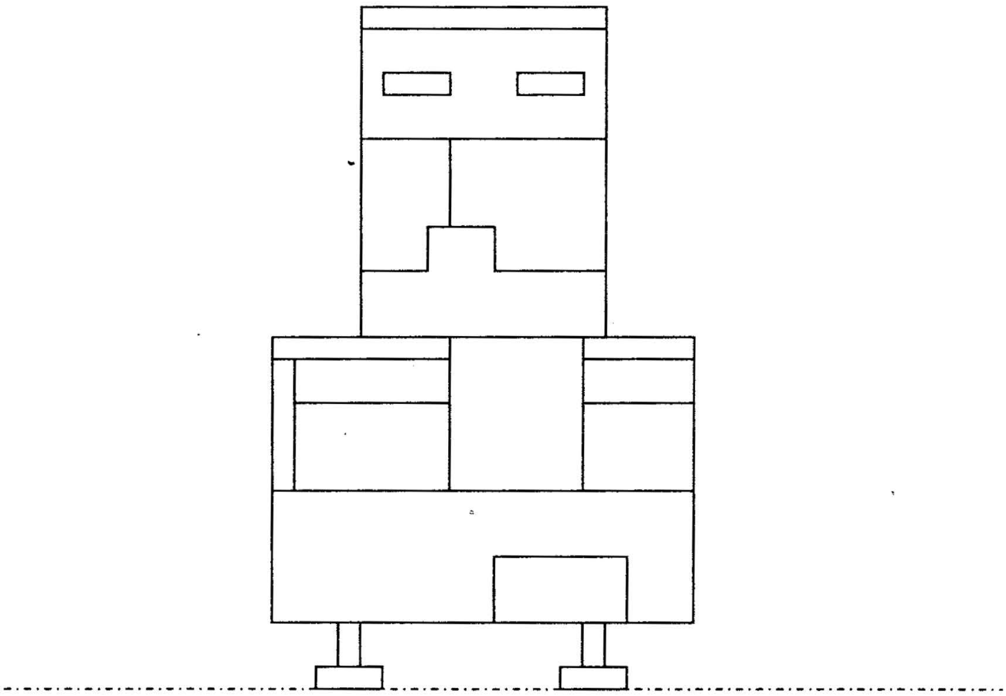
Trainee:

FIGURE 2
An example of One Point Lesson

Cleaning Check Sheet

Name of the Equipment:

Approved by:



No	Sites	Method	Standard	Resp	Per shift	Daily	Week	Bi-week	Mth	Time mins
1	Machine top	Clean with lint free cloth and S6	No dust	Opr		Y				1.0
2	Front panel	Clean with lint free cloth and Autosol	No paste mark	Opr			Y			0.2

FIGURE 3
An example Cleaning check sheet

Eliminate sources of contamination and inaccessible areas: The basic objective of this step is to identify the sources of contamination and to provide solutions to permanently correct these sources. This could be done by either eliminating the source or by containing the contamination in such a way that it does result in losses. This is done by "Why Why" analysis method. This type of analysis starts with a current problem being faced and goes through each level of analysis with a "Why?" question. Subsequently all answers are treated with "Why?" question again. The series of "Why?" helps in identifying the root cause of the problem. The other objective of this step is to identify the hard-to-access areas for the operator to do the cleaning. The solutions are worked out to make these areas accessible for cleaning.

Establish Cleaning and Inspection Standards: In this step, the focus is on the mechanics of equipment. This step emphasizes on prevention of any malfunction by studying the lubrication system of the equipment and the equipment as a whole. Proper lubrication guarantees smooth running of the equipment and reduces the wear and tear on the equipment. The AM standards are set describing the tasks to be performed, the tools to be used in performing the task, standard time to be taken to perform the task, and the frequency of performing the task (daily, weekly etc.). The critical inspection points on the equipment like gauges, levels are identified and these critical points are added to the AM standards on cleaning and inspection. However, please note that these standards are developed after working on preventive solutions to minimize/eliminates cleaning and inspection time by preventing abnormalities. AM standards are institutionalized and displayed on the equipment. The technicians and operators can follow this checklist in maintaining the equipment. It is also important to record the observations made during cleaning and inspection. The operators must be trained in recording the observations. This data can be further analyzed to predict any impending problem.

Proper training and Education/Training to Operators and Technicians: Unless the operators are trained and educated about the impact the autonomous maintenance on the quality of the product, scrap rate, and ultimately the cost of production, they will never be able to appreciate its importance. This step helps in developing "knowledgeable" operators who can solve/avoid most of the equipment and quality related problems on the shop floor.

AM attempts to achieve Zero Breakdowns, Zero Accidents, and Zero Defects situation on the shop floor. If AM is implemented in a systematic and phased manner in the shop floor, it can bring in substantial benefits. This section described TPM and AM in brief. In the next section, a case study on the implementation of AM as a step towards TPM will be discussed in detail.

An implementation – a case study

The MNC that is going to be discussed in this paper is a reputed electronic component manufacturing company in Malaysia. During the year 1999 the company had a big problem with one of the critical equipments manufacturing a high-precision electronic component. The yield loss from that equipment had been continually increasing and it accounted for nearly 63% of the yield loss for that component. The Top Management of the company assembled a cross-sectional team with members from Production, Maintenance, Quality Assurance, Purchase to study the reasons for the high yield loss. The reasons were classified under 4 categories: (1) Man, (2) Machine, (3) Material, and (4) Method.

The Management Team (MT) identified the possible root causes through an Ishikawa diagram or Fishbone chart. Figure 4 shows the Ishikawa diagram that was developed by the team. After analyzing the causes, the team (MT) came up with number of alternate solutions to tackle the problem. Figure 5 shows the alternate solutions for the individual causes in the Ishikawa diagram. The team (MT) came up with five alternatives: (1) buy a new machine, (2) retrain operators and technicians since the setup on the equipment is considered to be complicated, (3) automate the machine completely since the machine is semi-automatic, (4) control the variability of input variables, and (5) implement TPM by starting with Autonomous Maintenance.

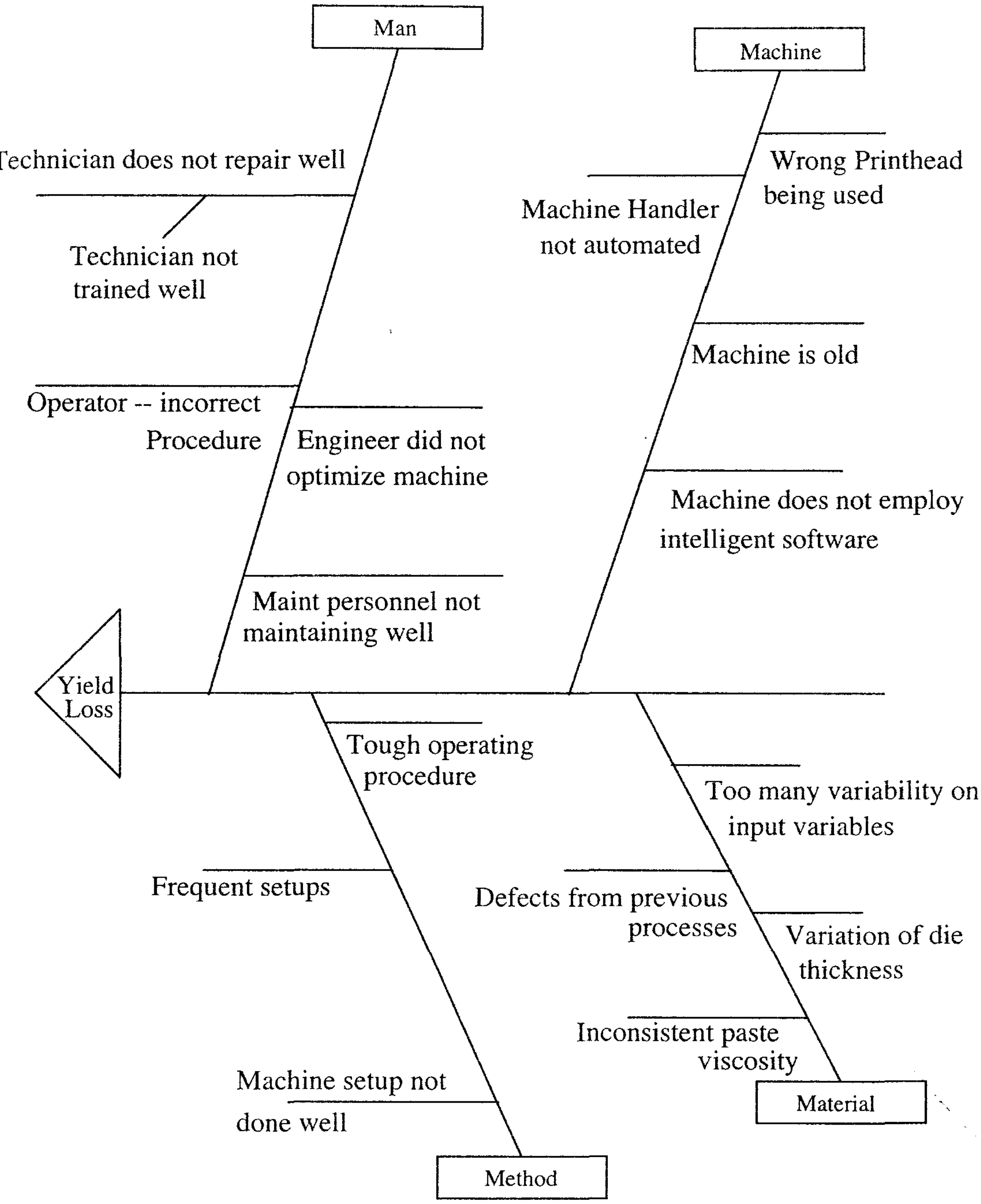


FIGURE 4
Ishikawa diagram

4M	**Possible Solution**
Man	
Technician not trained well	Retrain operators and technicians
Technician does not repair well	TPM and retrain operators and technicians
Operator's operation incorrect	TPM and retrain operators and technicians
Engineer did not optimize machine	DOE (Design of Experiment)
Maintenance personnel do not maintain properly	TPM and retrain operators and technicians
Machine	
Machine handler not automated	Automate current handler
Wrong printhead being used	TPM/Pokayoke – mistake proofing
Machine is old	Purchase new machine
Machine does not employ intelligent software	Purchase new machine
Method	
Variation in input variables	TPM/Control variability of inputs
Build up of paste due to splattering	TPM
Operation procedure is tough	TPM
Machine setup not done well	TPM and retrain operators and technicians
Material	
Defects from previous processes	Control variability of inputs
Paste viscosity not consistent	Control variability of inputs
Variation in die thickness	Control variability of inputs

Five main alternatives that can be derived from the above table are: (1) Retrain operators and technicians, (2) control variability of input variables, (3) TPM, (4) Purchase new machine, and (5) Automate machine, viz., machine handler.

FIGURE 5
Summary of alternate solutions for the individual causes in Ishikawa diagram

he team (MT) worked out the costs and benefits for each of the alternate solution and lculated the payback period. Table 2 gives the summary of cost-benefit analysis.

TABLE 2
Summary of cost-benefit analysis

Alternative	Costs (RM) in 000's	Benefits (RM) in 000's Per year	Payback period
Purchase new machine	614	600	1 year
Retrain Operators and Technicians	3.5	50	1 month
Automate Machine	94	150	8 months
Control Input variables	5 + recurring increased material cost	260	-
AM	28	520	1 month

fter analyzing all the alternatives and the expected capacity improvement from each ternative, the team (MT) considered implementing AM as a first step towards TPM. PM helps in eliminating the problems that are internal to the company before looking solutions that are external. The team (MT) started to work towards the implementa- on of TPM.

PM team formation: TPM emphasizes a cross-functional team from Engineering, uipment, and Manufacturing departments. A team was assembled from these three partments. There were 8 members in the team and each member was assigned a ecific task. The specific tasks were: Up keeping and Updating various TPM activities, llow up Action (Before and After implementation), Fuguai Mapping and its status, ne point lesson, Analysis of cleaning/inspection sheets, Calculation of Equipment sses and performance, Establishing cleaning/inspection time, and Monitoring and intaining TPM expenditure. The team would meet regularly and monitor the status implementation.

Initial cleaning: The team started with cleaning the surrounding area of the machine and removed all the unnecessary items scattered around the machine. The team cleaned up the dust, dirt, grime, oil, grease and other contaminants that can affect the quality of the product. The covers, guards, and compartments were opened up to expose the actual condition of the machine. The team combed through the machine under static and dynamic conditions. The abnormalities were detected (Fuguai Mapping) and tagged as "Short-Term Fuguais" and "Long Term Fuguais". Short-term Fuguais are the abnormalities that can be rectified immediately (presence of dirt, loose screws etc.) and Long-term Fuguais are the abnormalities that may not be possible to rectify immediately (worn-out part that needs replacement, vibration etc.). The abnormalities were later on removed and process of restoration monitored. During Fuguai Mapping the team also identified critical cleaning/inspection points and established cleaning/inspection procedures for these critical points. The procedures were institutionalized through "One Point Lessons" and "Cleaning Check Sheets".

- Sources of contamination and inaccessible areas: The team identified three source of contamination: (1) Raw material, (2) Paste Dispenser, and (3) Pick-up arm that picks up the component. The team performed the "Why" analysis on each source and came up with solution to rectify the problem of contamination. The team came up with cleaning procedures to keep the paste dispenser and the pick-up arm clean and procedures to store the raw material. These solutions were then implemented after a thorough analysis.
- The team also identified hard-to-access areas for cleaning. The team came up with solution to overcome this problem by designing a special brush.
- Cleaning and Inspection Standards: The team studied the complete lubrication system of the equipment and the mechanics of the equipment as a whole. This was done to reduce the wear and tear on the moving parts of the machine. After minimizing the cleaning and inspection time by creating more preventive solutions, the team established proper lubrication procedure, cleaning, and inspection procedures for the equipment. This checklist was then pasted on the machine so that the operators and technicians can follow the procedure in a systematic manner. An example Maintenance Standard chart is given in Figure 6.
- Training and Education: All the operators and technicians were trained by the team on the concepts of TPM/AM, one-point lessons, cleaning and inspection standards, and the importance of following these meticulously. When AM is carried on to other equipments, these operators can train the new team. The ultimate aim of the company is to implement AM on all the equipments in the shop floor.

Maintenance Standard Chart

Equipment Name: Responsibility: Process:

Cleaning/Inspection

No	Section/Part	Standard	Tool	Method	Shiftly	Daily	Week	Mth	Time Mins	Action if abnormal
1	UDC Assly	No dust	Hand	S6&LFC		Y			0.5	

Lubrication

No	Lub Point	Lub. Type	Tool	Method	Shiftly	Daily	Week	Mth	Time	Action if abnormal
1	UDC Slider	Light Oil	Dispenser	One drop			Y		0.5	

Tightening

No	Tightening Point	Standard	Tool	Method	Shiftly	Daily	Week	Mth	Time	Action if abnormal
1	Leaf spring force	30-40 gms	Hand	Gram guage			Y		0.5	Technical specialist

Approved by:

Date:

FIGURE 6
An Example Maintenance Standard Chart

The company, by systematically following TPM/AM, had improved the productivity of the low-yield equipment quite substantially. TPM/AM implementation had restored the equipment to "near new" condition. The benefits derived by implementing TPM/AM are manifold. However, a word of caution about TPM/AM is deemed appropriate at this juncture. TPM/AM cannot start yielding benefits overnight. It takes few months for implementation and the benefits start accruing once substantial portion of the implementation is complete. In the MNC that is described in this paper, implementation (including training all employees) took about six (6) months and the benefits started accruing later. The company is already in the process of taking TPM to the entire shop floor.

Benefits From Implementation

In the last eight (8) months, after the implementation of TPM/AM, the yield loss has been reduced by 65%. This is equivalent to a savings of about RM 39K per week. The down time of the equipment and the rejection due to contamination have reduced by about 40%. The operators and technicians have been provided with better guidelines to follow and this has improved their morale. Since TPM/AM is implemented through team-based approach, team spirit among the employees has increased and this has enabled them to work as a single unit for the betterment of the company. Through a structured approach the team has been able to eliminate the problems under the control of the shop floor. The phenomenal success with equipment in a production process, has motivated the management and the workers to implement TPM/AM on all the equipments in the shop floor.

Lessons learnt

(1) Management support in terms of time, money, and manpower and commitment of all employees are important for the success of TPM, (2) "First" success is very important as this motivates everyone to propagate the principles of TPM/AM, (3) Team composition and commitment of the team are crucial to success, (4) Constant monitoring and motivation to the team is important during the early stages of implementation, (5) Implementation must be done in a very systematic manner, (6) All the procedures especially, cleaning and inspection, must be institutionalized and the workers should perform them as a part of their routine tasks, (7) Cleaning and inspection records must be maintained properly and analyzed regularly and this guarantees continuous improvement, and (8) Constant follow up after implementation is required to ensure the success of TPM/AM.

CONCLUSION

emand for high quality products at a reasonable cost is driving most of the manucturers worldwide to embrace equipment management programs like TPM. As can : seen from the case study, TPM/AM has significantly: (1) reduced the yield loss, (2) duced the downtime of equipment, (3) reduced the rejection rate due to contaminaon, and (4) reduced the cost of operations and improved profitability. There is no oubt that TPM/AM provides tremendous competitive edge to the manufacturers. This ill be very significant to SMEs because quality, cost, and price decide the fate of these mpanies. The companies that do not listen to the "voice of the customer" are sure be wiped out from the market. TPM is a simple but effective tool to improve the ofitability of operations.

ne authors believe that management support and total commitment of all employees e critical to the success of TPM. It should be remembered that TPM/AM is not short-term solution to the problem of decreasing productivity and it is also not a ne-time process.

REFERENCES

otoh, F. 1991. *Equipment Planning for TPM*, Productivity Press, Portland, OR, USA.

otorola Internal Document. 1999. *Total Productive Maintenance – Manufacturing Excellence.*

akajima, S. 1988. *Introduction to TPM*, Productivity Press, Portland, OR, USA.

ijiri, M. and Gotoh, F. 1992. *TPM Implementation – A Japanese Approach*, McGraw Hill, Inc.