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Research paper

A Framework for Improving Manufacturing Overall Equipment Effectiveness

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Abstract

Nowadays, manufacturing is getting more and more challenging and complex due to shorter product life cycle, high mixed low volume production situation, low equipment performance and volatile customer demand. To overcome all these detractors and rising demands from all angles, manufacturer needs to be fast and agile, as efficient and as transparent as possible. Productivity is the key factor for company in order to become competitive advantage and securing the organization work place. Due to this strong pressure, it forces company introduce many production programs in order to fight the battle. Production productivity programs such as Total Quality Management (TQM), Zero Defect (ZD) initiative, Next Level of Productivity (NLoP), Lean Manufacturing (LM), total productive maintenance (TPM) and Toyota Production System (TPS) are well-known to many manufacturing industries. OEE topic has become progressively popular and widely used to improve productivity and as a research discussion in operation management. However, OEE framework for previous studies was developed on a piecemeal basis. This paper presents a new and complete conceptual framework that illustrates the most important factors that influence and contribute to OEE improvement. The comprehensive framework is able to provide effective guidance and direction to industry practitioner on how to improve OEE.

Keywords: *Productivity; Key Performance Indicators (KPIs); Total Productive Maintenance (TPM); Overall Equipment Effectiveness (OEE); Overall Equipment Effectiveness Improvement (OEEI) Framework.*

1. Introduction

In today's competitive market place and complicated manufacturing industry, the performance of overall equipment effectiveness and efficiency plays an important role to determine operation competitiveness of the organization as well as the degree of success accomplished in the organization[1]. Semiconductor manufacturers required flexible manufacturing methods to achieve high manufacturing productivity. Over the past twenty years, the Malaysian manufacturing sector has achieved outstanding performance in contributing to the nation's gross domestic product growth and successfully attracted an enormous amount of foreign direct investment to this country [2].

The equipment utilization and installed capacity in today's manufacturing industry is still low and the main reasons for these are low equipment effectiveness, very limited shop floor involvement in autonomous maintenance and little evidence on small group activities participation in continuous improvement [3]. The equipment throughput can be calculated as the output divided by the machines hour or capacity utilized [4].

TPM strategy production program designed for continuous improvement of the plant availability by reducing production waste. TPM concept is adopted by many industry manufacturers as a management tool to improve productivity in the cutting edge manufacturing environment. The most critical key performance indicator (KPI) to measure successful of TPM implementation is OEE index. OEE provides a powerful management tool to improve production deficiencies. OEE index able to help company to speed up the return of investment (ROI) on production assets particularly plant equipment. OEE index is not a production metric that related only to maintenance activities, but it also able to improve entire manufacturing operations as a whole. Many manufacturing companies able to improve their productivity through measured of OEE. In manufacturing, everything can measure, can improve it.

This papers reveals a study for the developing an overall equipment effectiveness improvement (OEEI) framework for organization to improve overall equipment effectiveness in a more systematic and holistic also can educate and guides the engineers and managers in improving equipment OEE.

2. Literature Review

Total Productive Maintenance (TPM) is an equipment performance improvement methodology founded by Nakajima [5]. He developed OEE as a metric that measures the effectiveness of TPM. OEE is a powerful measurable for identification and reducing production six big loses and hence improving production efficiency to achieve world class manufacturing [6]. The three important factors in OEE are availability, performance and quality.

A number of pasts studies regarding the direct or indirect on OEE framework with various aspect have been empirically conducted as presented in table 1. Based on the table, there are proven that the OEE are widely used as the production improvement program in manufacturing in order to improve overall production performance. There is a clear theoretical and also research foundation for the belief that OEE is contribute in obtaining high organizational performance. In addition, most of the studies from the table utilised case study as the research methodology. According to [7], OEE lacks a comprehensive framework for practitioners in order to systematically improve equipment performance.

The framework developed by Garcia *et al.* and Santos *et al.* [8, 9] based on OEE and the wireless technology solution for improving overall manufacturing operations is mainly driven by the two key components: the OEE indicator and continuous improvement methodology. The main contributions and values of these framework are integrated the wireless advance technology in the field of operations management to drive for continues improvement in maintenance. Nevertheless, the both framework were presented in macro view and still difficult for practitioners to adopt the concept. The next level of OEE framework is paramount in order to enable the production engineer and manger to implement OEE in their manufacturing process. The missing item for both frameworks is the financial benefit enjoyed by the organization after the implementation.

Based on the framework developed by Nguyen et al. [10], they integrated both value stream mapping (VSM) and overall equipment effectiveness (OEE) based on the market demand trend. Anyway, VSM is only one of the lean tools to improve OEE in the bottleneck process. Referring to the framework developed, it did not clearly demonstrated how the OEE being improve by applying the framework. The developed framework is still in high level picture.

Based on the framework developed by Puvanasvaran *et al.* [11], they integrating quality tools such as cause and effect diagram, FMEA, Pareto chart, fish bone diagram, FMEA and continues improvement activities to improve OEE at the bottleneck process in one of the well-known semiconductor manufacturing in Malaysia. The framework mainly only focus on quality aspect of OEE and did not focus on the other two elements which are the performance rate and availability. The framework also did not demonstrate the detail how the OEE been improved.

Sahu *et al.* [12] had developed a conceptual model of 5S, OEE and manufacturing productivity in order to examine the relationship among these three elements. Nevertheless, the model did not demonstrated how the three elements affecting each other. The model is also very general and did not showing how to improve OEE through 5S and ultimately improve overall productivity in any organization.

Nazim et al. [13] also developed a maintenance management performance model by measuring OEE in Malaysia palm oil mills based on the theoretical maintenance framework. The model focuses on identification of the current production performance gaps between the current and planned performance and provide where to take action in order to close the gap as much as possible. The developed framework is considered high level and not able to know the detail how to improve the OEE.

Fakhruddin and Yusri [14] developed a conceptual framework based on the work done by Gupta and Garg [15], the conceptual framework link the six main Total Productive Maintenance (TPM) to the OEE improvement and industrial sustainability. The main motivation of the study done by Fakhruddin and Yusri was determine the relationship these six TPM elements to the industrial sustainability. The framework did not demonstrate how to improve OEE in industry manufacturing.

Haitham and Mohammad [16] developed a framework evaluation for operational performance of the work over rigs in oilfields. The main motivation of this framework is used as a basis to analyse and enhance the performance of the work over rig including the improvement in rig efficiencies and reduction in operational costs. Nevertheless, the framework did not show the detail how to improve the OEE in the wells. The framework should include the cost benefits after implement OEE in the organization.

Most of the researchers provided piecemeal information and activities in OEE improvement. As a result, there is a need to develop a comprehensive framework in order to provide complete guidance to manufacturing practitioners.

Based on the six large losses measured by [17], which is a function of availability (A), performance (P) and quality rate (Q) expressed as

$$OEE = A \times P \times Q \tag{1}$$

Where

$$\text{Availability}(A) = \frac{\text{Operating time}}{\text{Loading time}} \times 100 \tag{2}$$

$$\text{Performance}(P) = \frac{\text{Actual throughput for sale}}{\text{Planned Throughput for sale}} \times 100 \tag{3}$$

$$\text{Quality}(Q) = \frac{\text{Total prodution parts} - \text{Defects parts}}{\text{Total production parts}} \times 100 \tag{4}$$

3. Research Methodology

The research methodology of the framework as presented in Figure 3.1. The development of the Overall Equipment Effectiveness Improvement (OEEI) framework based on the previous research gap and the six-big production losses defined by Nakajima [5] for the research. It also was referring to to SEMITECH, SEMI E10 and SEMI E79 standard. The Semi Standard defined the time categories. The detail of OEEI framework is explained as below.

i. Level 1 : OEE Objective Definition

The level 1 of the framework is defining clearly the objective of the OEE the organization intends to achieve. The objective defined according to the company OEE target set during forecasting activities. It is vital to indicate the OEE target with exact quantifiable value.

ii. Level 2: Three OEE Components Categorization

After the objective been defined by the organization, level two in the OOEI framework is the OEE component categories. The OEE will be categorised into Availability (A), Process Performance (PP) and Quality Yield (QY).

iii. Level 3: Identify the Losses for the Three Components

In level 3, it identified the OEE loss categories lost code which are equipment downtime loss, speed loss follow by quality yield loss. In order to maximizing the values of the three components OEE, operation will bring down the losses as minimum as possible

iv. Level 4: Identified Type of Losses for each Downtime

The next level of this framework is the equipment major loss down time identification based on target set. The equipment major losses are unscheduled/unplanned downtime loss, scheduled/planned downtime loss, standby downtime loss, non-scheduled downtime loss, engineering downtime loss, speed loss downtime loss, minor stoppages downtime loss, production reject loss and start-up reject loss.

v. Level 5: Potential Root Causes for all Downtime Identification

The level 5 is to identify most probable root causes that causing the equipment downtime. The downtime percentages are defined based on the entitlement target set during planning stage. The events defined in this level are based on the experiences collected and it might be different if the process or equipment type is different.

vi. Level 6: Solutions Proposition

Level 6 in the framework development is proposed a list of immediate, mid-term and long term solution actions to reduce the root-causes of the equipment downtime which causing high downtime and hence cannot achieved desire equipment throughput. The implementation of the proposed solutions and management's attention and follow up is paramount to ensure effective and efficient.

vii. Framework Testing

Once all parameters and detail are defined in the OEEI framework, the next activity is to test the OEEI framework in the production. If the OEE result is not promising, the user must always revisit the root causes of the equipment downtime, implement with appropriate action and monitor again the OEE result until satisfy.

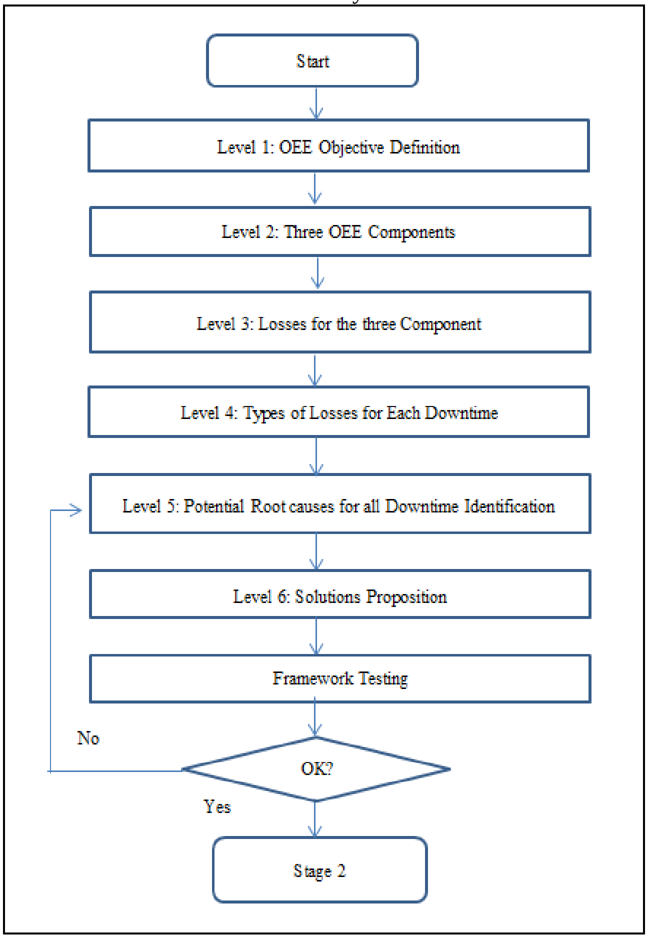

Fig. 3.1 OEEI framework development flow

4. The Framework Development

The Overall Equipment Effectiveness Improvement (OEEI) framework was developed as a functional framework based on the minimization on the equipment breakdown and the operation is supported by the OEE dashboard system. Figure 4.1 shows the framework's design or the structure of OEEI framework. The Level one is the OEE target in the process; level two is identify the three main components in OEE. The level three will reduce the losses form the three main OEE components. Level four is identifying the type of losses that contribute to each downtime. Level five is identifying the root-causes of each type of losses and level six is proposing the actions to minimize the negative effect of the identified root-causes.
The naming of the six levels of the OEEI framework is as follows:

1. Level 1: The OEE target
2. Level 2: OEE components
3. Level 3: Reduce losses of each components
4. Level 4: Type of losses
5. Level 5: Root-causes
6. Level 6: Proposed solutions

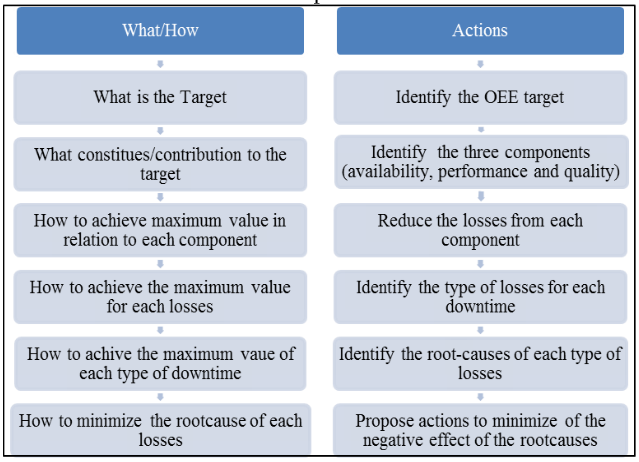

Fig. 4.1: The OEEI framework structuring design

Figure 4.2 present Overall Equipment Effectiveness Improvement (OEEI) framework. The framework can be illustrated as a flow diagram which divided into six levels. The detail for each level will be discussed in the following.

4.1. Explanation on Each Level in the OEE Framework

Level one lists the ultimate objective and the motivation of the framework. The aim of the objective is the improvement of Overall Equipment Effectiveness (OEE) in the bottleneck process and must achieve the target set by IE department. OEE can be calculated weekly, every shift or monthly. It also can calculate OEE by equipment or a group of equipment depends on the users. The calculation can refer to equation one. Figure 4.3 demonstrates the objective is to achieve OEE 75.7% in the bottleneck process.

Fig. 4.3: The target is to achieve 75.7% OEE in test

Level two presents the three important components in OEE. The three main components are Availability (AV), Process Performance (PP) and Quality Yield (QY). The equipment availability is the percentage of the time that the equipment is in a good condition to perform its intended function by using the period of total time. The Total Time (TT) is the total tine in hours during which a production equipment is been observed. It can be a day (24 hours), a shift (8/12 hours) or a week (168 hours).
Process Performance is the proportion total number of actual units produced during the measured productive time to the theoretical possible number of parts produced during the productive time at

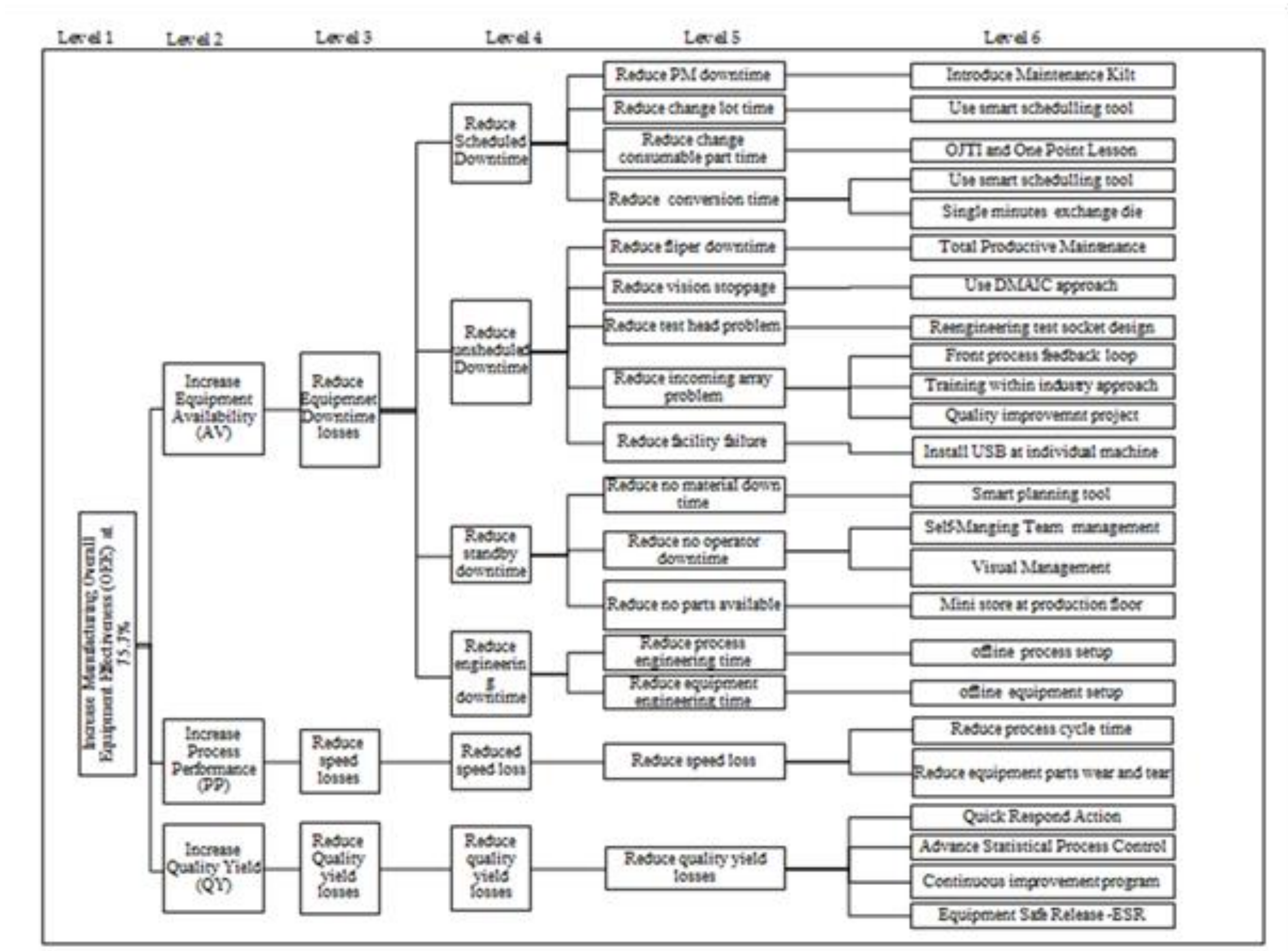

Fig.4.2: Overall equipment effectiveness improvement (OEEI) framework

planning stage. If the actual throughput is greater than the planned target, the process can conclude that having performance gain. On the other hand, if the actual throughput is lesser than the planned target, the process is defined as having performance speed loss. Quality yield is the proportion of the number of good part that able to sale to the total number all the parts processed. The level 2 can be illustrated as below Figure 4.4.

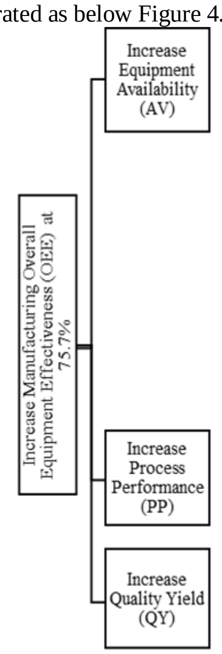

Fig 4.4: Three main OEE components

Level three in the OEEI framework just direct mapping the OEE three main components to the "OEE loss" in the three components. The downtime is a period of the time (normally in (hour) when the equipment not in a condition to perform its intended function. The loss for equipment availability is equipment downtime loss; the loss of process performance is speed loss whereas the loss of the quality yield remains as quality yield loss. The main idea of this level three is to identify the type of "OEE category loss" for each component in OEE. Figure 4.5 demonstrate the type of loss for OEE three main components in level three in the framework.

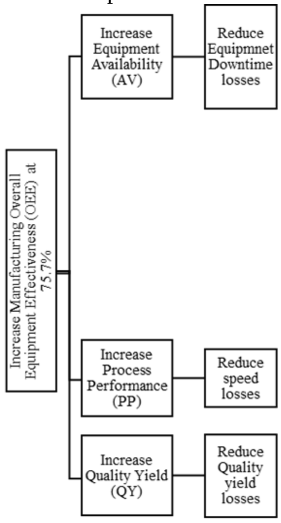

Fig.4.5: The losses in the three main components in OEE

Level four further breakdown the loss to downtime state or the OEE major loss that causing the equipment breakdown. It is the deeper classify the losses into type of downtime in order for engineer to determine the root cause for the following step. The OEE major losses are described as below.

For equipment downtime loss, the major OEE losses are scheduled downtime, unscheduled downtime, engineering downtime and standby downtime. Whereas for speed loss, the equipment speed loss and equipment minor stoppages are the two main OEE losses. Finally for quality yield loss, the production reject and start up reject.

Scheduled Downtime (SD) is a period of time in (hour) when the equipment is not available to perform its intended function due to the planned downtime events In idea case we expect the equipment produces output all the times but this is not realistic. Scheduled maintenance downtime is essential to constitute and maintain the equipment and process in the optimum conditions. Based on the Japanese Institute of Plant Maintenance (JIPM), they viewed planned maintenance as an activity where when practicing and exercising will raised the equipment output which contribute to zero defects, zero equipment downtime and from production abnormalities in shop floor. The ultimate goal also improves the quality of maintenance technician and production operators. Finally it improves and increases equipment availability. Implementing these activities efficiently can reduce input to maintenance tasks.

Unscheduled Downtime (UD) is a period of time in hour (hour) when the equipment is not in a condition to perform its intended function due to unplanned equipment breakdown down events. Unscheduled downtime can lead to many disruptions in the production and end up with high production cost lost. Unscheduled downtime events interrupt equipment operation and quality level of product. As a result, it is important to determine the ways to prevent and stop the unscheduled downtime from occurring.

Engineering downtime is a period of time in (hour) when the equipment is in a condition to perform its function but is operated to conduct engineering and process experiments. During this period of time, the parts produced are not saleable. This is also considering as a time loss to Advance Semiconductor. The engineering time can be improved by considering few aspects which will discuss in detail in next section.

The final loss in the downtime category is the standby time. Standby time is the time in hour when the equipment is in a condition to perform its function but it not operated. During standby time state, the equipment did not producing any part due to equipment idle.

For process performance loss is the proportion of the total units produced during the measured time period to the theoretical possible number of units been targeted during planning stage by IE department. The downtime state for process performance is the process speed lost and minor stoppage loss.

The final portion of level 4 is the quality yield loss. The further breakdown for quality losses are assembly reject, end of line reject and test reject.

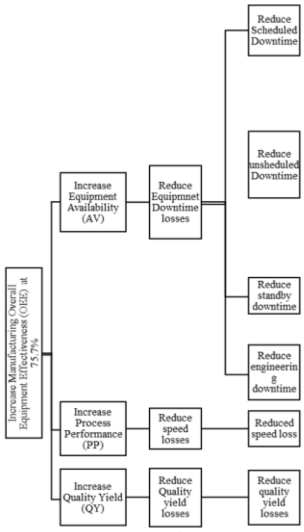

Fig. 4.6: The root causes of the losses

Level five is the potential root causes of the OEE major loss. The construction of level 5 will show in detail for each OEE major losses. The event breakdowns are based on the previous experiences accumulated and the inputs from engineers from Advance Semiconductor. The event breakdowns are not identical and may different due to the process and equipment type. For the Advance Semiconductor case company, the below event breakdowns were identified in the OEEI framework.

1. The scheduled downtime state includes:

a. Preventive maintenance downtime:

i. The preventive maintenance divided into time based and usage based maintenance.

ii. For time based maintenance, it is scheduled based on fixed interval of time in order to perform the maintenance activities. The fixed interval can be shift based, daily, weekly, monthly, quarterly, half yearly and yearly. When time interval reach the equipment will be scheduled for maintenance. All the downtime will be input into a system and auto email will be triggered to the maintenance owner to carry out the activities. The system triggering is a good manufacturing practice to prevent maintenance service overdue and lead to quality issue to the final product.

iii. For usage based maintenance, maintenance activity which is scheduled based on some measure of equipment usage i.e. volume of material remove, number of units processed, number of production cycles and operating hours. This maintenance approach is more cost effective because it based on the actual usage of the equipment parts or component part rather than based on the time.

iv. The activities preventive maintenance are inspection, cleaning of machine parts, change worn out machine parts before the functionality of the equipment is affected and replacement of certain critical equipment part which direct contact to the product.

v. The preventive maintenance event is carry out by the maintenance technician rather than machine operator

b. Change lot

i. Lot size in semiconductor manufacturing defines as the quantity of a product to be manufactured in several process steps in a single production run.

ii. For traceability purposes, semiconductor manufacturer defined the lot size quantities during production planning and started from the first process in assembly i.e. die-bonding process.

iii. Each assembly lot will identified with one assembly lot number for traceability usage.

iv. After completed the lot number one, some activities need to be carried out in order to continue for subsequent production lot. The changing lot an activity is defines as “change lot”.

c. Change consumable material/part

i. Is defines as changing the axillary parts that are needed in order to complete a process. In testing, changing the rubber tip at pickup-head due to wear and tear is one of the change consumable parts.
ii. The main purpose of changing the consumable parts is to ensure Advance Semiconductor deliver best in class product quality to customer.
iii. The equipment need to be stopped in order to execute the planned task. This will incur equipment loss.
iv. The changing consumable part's frequency is defined by maintenance and process engineer.
v. The types of consumable parts needed to be replaced were defined by engineers and machine manufacturer based on self-life study

d. Equipment conversion downtime
i. Equipment conversion from one product to another product is unavoidable due to the high mixed low volume situation
ii. Due to the investment limitation, the product cannot be dedicated to produce only at a fixed equipment type and this will lead to inflexible.
iii. Outcome from above issue, the equipment are sharing to test the same family type of product by perform equipment conversion activities.

2. Unscheduled Equipment Downtime
a. Reduce flipper module problem
i. In testing the flipper module had identified as the most problematic part at the machine
ii. This module is one of the most critical parts in the machine where it considers as heart of the equipment. The main function is transporting the component for testing, hold the components so that will not drop-off it, flip the components before test.
iii. Based on experience and history, this module given the most downtime during production running because it involves a lot of mechanical steps throughout the complete process.

b. Reduce vision problem test head problem
i. Vision system equipped with camera and lighting system in test equipment
ii. The function of the vision system is to sort and filter out the rejected unit due to the dimension failure, the package contrast failure and the positioning of the package.
iii. Vision problem is also sticky topic in test because it involves parties such as incoming material topic, the camera, the lighting and the software

c. Reduce test-head problem
i. Test-head downtime is also critical because the test probe direct contact to the part
ii. Test-head also the heart of the module in tester since it is the medium gadget between the physical part and the electrical test
iii. It involve mechanical and electronic issues

d. Reduce incoming array problem
i. Testing is the last process in Advance Semiconductor and all the incoming problem will be filter out at this process
ii. The array referring to the incoming material in the square form from the up-stream process
iii. If the machine encountered reject such as warpage, missing cross-mark and the machine will stop and waiting for machine operators to rectify the problem

e. Reduce plant facility problem
i. Plant facility problem referring to the IT and plant facilities such as electrical and water treatment interruption topics

3. Standby Downtime
a. No material
i. The no material downtime referring to no product or lots is available from the up-stream processes
ii. The machine and operator is available and only no material present during the period of time. Machine fore to stop and it is a loss to the equipment

b. No manpower
i. The other scenario is the material and machine is available but no operator to operate or attend the equipment
ii. If any machine breakdown during this period of time, it consider a loss to the operation and affecting availability
iii. There might be due to break-time, meeting or not turn up to work

c. No machine parts
i. When machine breakdown the parts is not available due to zero inventory on hand or machines replacement pat ordered but not in time to arrive. Maintenance technicians need to wait for parts arrival
ii. The equipment force to down

4. Engineering Time
a. Process engineering downtime
i. The process engineering needed for process characterization and incur equipment downtime
ii. The process engineering activity normally conducted by process engineer to determine process parameters and optimization.

b. Equipment engineering downtime
i. The equipment engineering downtime referring to evaluation of equipment and component of equipment
ii. The equipment engineering will carry out by maintenance or equipment engineer to optimize equipment parameters or new equipment part evaluation.

5. Speed loss
a. Speed loss contribute from equipment speed loss and minor stoppage
b. The equipment speed loss referring to the equipment running with slower speed than recommend by machine maker. It may contribute by the longer process cycle time due to additional test parameter been added. As a result, IE play an important role to ensure all the parameters always the latest.
c. Minor stoppage referring to the short period of equipment stoppage due to jamming for example and causing the through is lower than planned target. In Advance Semiconductor, minor stoppages is defines as machine stop and recovered within six second.
d. This speed loss is in percentage and not time loss

6. Quality yield loss
a. Quality yield loss is referring to part scrap due to out of specification which defined by customers
b. Rework and sorting of the material also defined as quality yield loss
c. The quality yield loss in OEE calculation for Advance Semiconductor is using the weekly yield
d. The improvement action list are contributed by yield improvement activities

Level six proposed and provides solutions in order to resolve the potential root cause that causes the equipment breakdown. The proposed solution divided into short term and long term actions. Some of the actions need to improve the organization culture and some of the actions need approval from management in order to allocation budget to purchase items and spare part in order to reduce the equipment down time during normal production.

Below section show the detail of the propose solutions to improve the equipment downtime for test machine in Advance Semiconductor.

1. Reduce preventive maintenance downtime
- Implementing maintenance Kits: all parts need to perform maintenance locate at a mobile cabinet in order to reduce the time to search for parts. This practices also ensure all parts need to replace during preventive maintenance activities been completely carried out.
- Maintenance technician's skill sets assessment and enhancement to equip all technicians with same level of competency. The as-

sessments conducted also intend to identify the gaps among technician and install corrective action to improve the technician skill knowhow.

- Modular concept. Using plug and play concept to reduce the part assembly process during preventive maintenance activity. Concept such as single minute die exchange where some of the parts can be prepare and assembled 'off-line' while the equipment still running and this approach able to reduce the preventive maintenance downtime.

2. Optimizing change lot activities downtime

- Batch up lot by combined more than one lot in order to increase the lot size and hence reduce change lot frequency. The lot batch is important for traceability purpose. During changeover lot, a number of activities need to be carried out by the machine operators before they can proceed to test the material. Activities such as initial material by-off by quality department, product quality inspection to ensure the good quality of the final product after test and some other statistical process control required by the control plan need to be done before proceed to test process. By increase the lot size, all above activities can be reduce within a shift (8 hours/a2 hours) and hence reduce the changeover lot downtime.
- Using smart scheduling tool to prepare material in advance to reduce the nonvalue added time to hunt for material. The smart scheduling was developed to ensure what is the material or product to be test for the subsequent test process. This is crucial to avoid the machine operators incur additional downtime to hunt for material for next test sequent.
- Perform quarterly change lot know-how activities assessment for all operators. The new operator must be certified to execute the task and the current experienced machine operator need to re-certify and re-asses to ensure they are fit and qualify to execute the change lot task.

3. Optimizing change consumable material time

- Improve spare part management by having monthly inventory count to ensure part available all the time. This approach is important to ensure the consumable parts is available when need to be replace to avoid additional downtime for operator or maintenance to searching for the replacement parts.
- Intensive training by using on-job-training-instruction (OJTI) and one-point-lesson (OPL) approach to train and retrain shop floor operators. The OJTI and OPL is preparing by the experienced engineers. The training materials were prepare step-by-step and even record using recorder to ensure the right procedures are follow exactly. This is also to ensure the time spend to replace the consumable parts are same for all machine operators in order to avoid additional downtime incur and hence reduce the availability
- Mini-store implementation to ease the operator to obtain consumable part for replacement. Advance Semiconductor production is running 24 hours daily, seven day a week and without shutdown except during the yearly plant facility maintenance. During night time especially, the consumable parts must available for shift maintenance technicians to avoid additional time spend to locate the parts and hence incur more equipment downtime.

4. Reduce equipment conversion downtime

- Use smart scheduling tool to reduce number of changeover conversion time
- Adopt single minutes exchange die (SMED) concept to improve the conversion time needed
- Maintenance technician's skill sets assessment and enhancement to equipped all technician with same level of competency

5. Reduce flipper downtime problem

- Revitalize TPM program to enhance improvement action. TPM is a culture change where the theme of TPM was total employee participation for improvement in manufacturing performance. TPM program is focus on continuous improvement, autonomous maintenance, preventive maintenance, education and training and safety, health and environment. The machine operator will train to perform certain basic activities such as cleaning, lubrication and simple checking of the equipment. By doing so, it free up the maintenance technician to perform the task on equipment improvement to settle all problems brought up by machine operations. With this concept, it able to improve the flipper problem to minimum level to reduce unscheduled downtime in test equipment.
- Contact machine maker for technical support. This is the fastest action list to improve the flipper topic. Machine maker is the party where fully aware about the problem encountered by the buyer. Certain agreement must be agreed between purchasing department and machine maker during purchase the equipment.
- Baby seat the equipment and monitor closely performance. Special task force must form to gather data and improve the flipper problem. Everything can measured can be improved.

6. Reduce vision stoppage downtime

- Engage external vision vendor and seek for technical support. The vendor having the highest technical knowhow because they are the specialist to rectify the problem encountered by buyer.
- Revitalize TPM approach to resolve technical problem
- Light source optimization by improve software programing

7. Reduce test head problem downtime

- Focus at pogo pin and application board topic. Pogo pin is the probe that mouth onto the application electronic board and direct contact to the component during testing process.
- Reengineering on test socket design
- Wiring technical improvement.

8. Reduce incoming array problem

- Previous process optimization by working closing with the respective engineer
- Setup quality improvement project to improve incoming material issue
- Training operator using training-within-industry (TWI) concept to enhance operator competency level to handle problem in the line

9. Reduce facility failure

- Install uninterruptable power supply (USB) in the machine to restore all data during power serge

10. Reduce no material downtime

- Using smart planning tool and ensure minimum impact due to no material. The smart planning tool enables the material planner to have big picture to oversee the material from the up-stream process and ensure material available all the times.
- Visual control to have better visual aid for material availability
- The material are store into a cabinet and easy to access for all machine operators

11. Reduce no manpower downtime

- Break time management to ensure operator self-arrangement. The self-managing team in the shop floor adopted stagger break time management where machine operators are break by batches and ensure there are always resources they during break time period.
- Apply Endone board to monitor staff attendance and staff availability. The board creates better visibility to all members in the shop floor and request coverage from other shift's members in order to ensure resources always sufficient.
- Using multiskilling approach to ensure staff can handle more than one process. Supervisor able to arrange enough resource by 'loan' the operator from the nearest process to occupy the production line that insufficient of manpower.

12. Reduce no machine part available

- Set-up a 'mini-store' in production floor and inventory part must regularly conduct to ensure the minimum stock level is always achieved.

13. Reduce process engineering time

- Using smart planning tool to ensure when the engineering slot is given and prepare all the necessary items to minimize the engineering process setup time.
- It is also ensure the engineer is available during the engineering slot time to avoid the machine idle waiting for expert to carry out the evaluation.
- The smart planning tool also ensures the production hand-over the equipment on time to engineering group to avoid any delay.

14. Reduce equipment engineering time
- Using smart planning tool to ensure all parties are release and return back the equipment on time. No further delay and cause additional downtime due to engineering
- Equipment setup externally before equipment engineering activities execute to ensure no further delay during equipment engineering.

15. Reduce speed loss
- Focus on process cycle time improvement and optimization. IE and process engineers are require gauging any potential to optimize the machine parameters. IE department must ensure all the units per hour (UPH) data base are updated all the time to avoid miss-match between actual performance and planning figure.
- Focus on minor stoppage by implementing TPM concept to further improve the reliability and availability of the equipment.

16. Improve Quality Yield
- Quick respond action approach (QRA). Engineer, supervisor and maintenance technician are requiring gather together and investigate immediately if encounter any quality topic in shop floor. This is important to demonstrate the team is serious about the quality yield and stop the bleed immediately to prevent further serious damage to production
- Implement TPM and green line concept. The intention is to ensure stability of the equipment and process to ensure zero defect achieve in Advance Manufacturing Company.
- Continuous Improvement Program roll-out to improve quality at the source and stimulate the spirit of the team in order to achieve zero defects in the company.
- Layer Process Audit (LPA) lead by shop floor supervisor and team leader in order to create sense of ownership and ensure shop floor compliance to procedures and quality policy. Audit is the fastest way to gauge the operator follow whatever engineer asked to do and check the effectiveness
- Equipment safe release (ESR). The production material must buy-off after machine stoppage due to breakdown. The main motivation is to minimize the scrap at the end of the process and incur huge quality loss to the company

The level six is the proposed solutions can be adopted by manufacturing industry to improve the negative effect of the root causes that causing the low equipment OEE. The proposed actions able to reduce the equipment down time by eliminate and sustain the root causes of the each downtime identified.

5. Conclusion

Improve equipment OEE can be a daunting and challenging task due to many of the factors that can be changed and the interaction between each other. This paper provides comprehensive and detail explanation on the basic factors that affect equipment OEE. The detail explanation can be used to educate the staff on the basic concept of OEE. The paper also presents a comprehensive conceptual framework that illustrates the actions that able to apply to maximize the three main important OEE components. This framework also provided as easy-to-apply tool that managers, engineers, supervisors and shop floor technicians can be used to determine a course of action to improve OEE in the manufacturing plant. The comprehensive OEEI framework can be adopted by manufacturing to implement OEE in a more systematic and holistic way. The OEEI framework also can be used as the material to teach university students to understand in detail how to improve equipment OEE in manufacturing. The developed OEE framework hopefully can extend for use in other department or industries. It also provides guidance and assistance to industry practitioner to speed up the learning curve during OEE implementation.

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