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Application of Integrated FMEA and Fish Bone Analysis – A Case Study in Semiconductor Industry

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Abstract

With the rapid growth of semiconductor industry, manufacturers are always seeking for improvement at their manufacturing sites in order to survive under competitive marketing environment. High product quality and productivity with lower price become necessity for surviving. However, these matters are easily affected by the failures occurred on the machines. Thus, a systematic failure analysis framework is required to reduce the failures effectively. This paper presents the implementation of integrated FMEA and Fishbone analysis to analyze the problem faced. Furthermore, general approach for improvement plan based on failure causes are presented as conducted in a semiconductor company. The finding from this study was that the proposed framework is useful and applicable in performing systematic and effective failure analysis and solution finding. It also proves that failure analysis is an important task to be done in order to improve the machine capability and reliability.

Keywords
FMEA, Fishbone analysis, semiconductor industry, Integration Definition for Function Modeling (IDEF0)

1. Introduction

Currently, customer value based marketing plan has lead to the change of the nature of the production environment. Quality product, speedy response with lower price becomes an essential element for a manufacturing organization to survive in the competitive marketing environment. Almost every company in industries is struggling to survive in this competitive world especially semiconductor industry. Nevertheless, products' quality and productivity are always subjected to the machine's reliability.

Therefore, improving the reliability of machine using systematic scientific analysis approach becomes favorable choice for company. Low machine reliability is usually due to the malfunctions. Failure analysis is a common but significant approach to analyze the root cause of the malfunction systematically and improve the machine's reliability by reducing the failures for long-term plant usage. Throughout the existence of failure analysis approaches, FMEA is a popular yet powerful approach in conducting failure analysis.

The applications of FMEA can be found in different areas included process improvement, design and reliability study in different industry. For instance, [1] had applied FMEA during design phase of an electric motor controller for vehicle heating/ventilation/air conditioning system to understand and improve the failure mechanisms. Besides, FMEA also had been implemented in improving the reliability of wind turbine system [2]. Application of FMEA also could be found in aircraft industry, where [3] attempted to improve the reliability of a rotor support system of a modern aircraft engine.

Different analysis tools have been integrated into FMEA to conduct a more systematic and effective analysis. For example, [4] had conducted an analysis on failure of hard disk drive by integration of FMEA and fishbone analysis. Integration of FMEA and fishbone analysis also had been found in identifying and analyzing of problems occurring in complex machine-building company production systems to improve the effectiveness of the system [5]. While, [6] had presented an application of FMEA and fishbone in analyzing the fissure appearance causes in the grinding process of the bearing rings. Moreover, the application of FMEA and fishbone analysis also can be found in food industry and agriculture industry [7-9]

The applicability and effectiveness of FMEA has been proven from the popularity of the FMEA and fishbone analysis. However, proper established FMEA with fishbone analysis is required to provide better quality planning, continuous improvement and lower manufacturing costs, in addition to fulfilling the customer requirements. Thus, this paper intends to present an implementation of integrated FMEA and fishbone analysis framework in drilling process of flexible circuit board fabrication company.

Drilling process is one of the most important processes in flexible circuit board fabrication and is mainly used for drilling vias, an electrical connection to connect between each layer of conductors in a circuit. Vias allows the electrical and thermal connection of conductors on opposite sides of the circuit board. These drilled holes require precision placement and are most commonly done with the use of an automated drilling machine. Failure to produce accurate vias will affect the product's quality or even rejected. Therefore, any malfunction should be prevented in order to produce a high quality product. The remained of the paper is organized into three sections: section two clarifies the systematic methodology with regards to FMEA implementation and section three demonstrates the application in semiconductor company and section four draws the conclusion.

2. Methodology

As mentioned, proper established FMEA with fishbone analysis is a must for a successful implementation and improvement. Thus, this section presents a detail process of carrying out as shown in Figure 1.

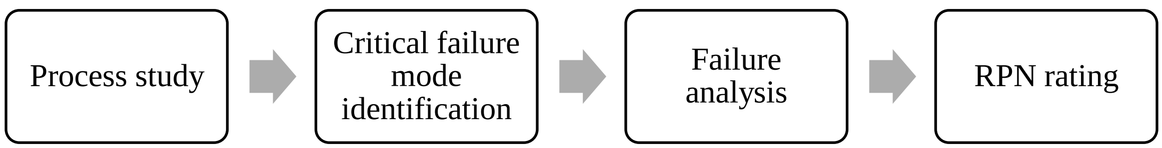

Figure 1: FMEA process

From Figure 1, the methodology can be separated into five major steps included process study, critical failure mode identification, failure analysis, RPN rating and suggestion of solutions.

Step 1: Process study
It is a necessity to study and understand the existing process involved in the initial stage of analysis. A good understanding of the process and operation involved in the machine is helpful in providing effective analysis in the next step. The process could be studied through observations in actual environment, conversation with experience's personnel and study of the handbook or any related available documents.

Step 2: Critical failure mode identification
Failure modes occurred was identified in this step after gaining sufficient knowledge and understanding regarding the process. In order to provide an effective analysis, the process started with focusing on failure modes that caused major problem to the production based on the historical machine breakdown data. High level of breakdown had affected the overall performance of the machine and decreased the productivity. Therefore, the critical failure mode was defined based on its occurrence rate. Then, failure analysis was performed to find the root cause of the critical failure mode.

Step 3: Failure causes analysis
In this step, fishbone analysis was integrated to FMEA in analyzing the failure causes. Fishbone analysis is able to provide a graphical vision on the failure causes in detail and systematic way. Fishbone diagram can be used to illustrate in a graphical way the relationship between a given outcome and all the factors that influence the outcome. Besides, fishbone diagram is able to determine the root causes of a problem, focusing on a specific issue without resorting to complaints and irrelevant discussion and identifying areas where there is lack of data. In this study, the failure causes was analyzed based on three aspects; man, machine and maintenance. These 3 aspects basically referred to the highest contributing causes for the failure to occur. Man was referred to operator's behavior during

the process, machine was referred to the condition of the component inside the machine and maintenance was referred to the improper maintenance activities towards the machine, which all of these aspects contributed to the failure. Each aspect has smaller division representing the subordinate of the major factor.

Step 4: RPN rating
The RPN rating was calculated according to the multiplication of Severity, Detection and Occurrence value. Severity was used to rate the seriousness of the effect of the failure on the machine while detection referred to the ability to detect the failure before it could adversely affect the machine and occurrence provided information about the expected frequency of each failure as a result of each given cause. Rating scale of severity, detection and occurrence are based on [10, 11]. The highest value indicates that it is in serious situation and needs immediate action towards it. Recommended action should be planned and executed to avoid repetitive failures on the machine.

3. Case Study

A company equipped with highly automated state-of-the art facilities and leading age technologies producing flexible printed circuits was chosen to validate the proposed methodology. Even though the company realized the important of drilling process, but they were still facing problem with the performance in drilling process due to its frequent breakdown. Therefore, drilling process had received high attention to be studied due to its important in producing quality product on time.

Step 1: Process study
As mentioned in section 2, step 1, the initial stage of analysis is to understand the production process involved in the drilling process. The whole flow of drilling process is described in Figure 2 using integration definition of function modeling (IDEF0).

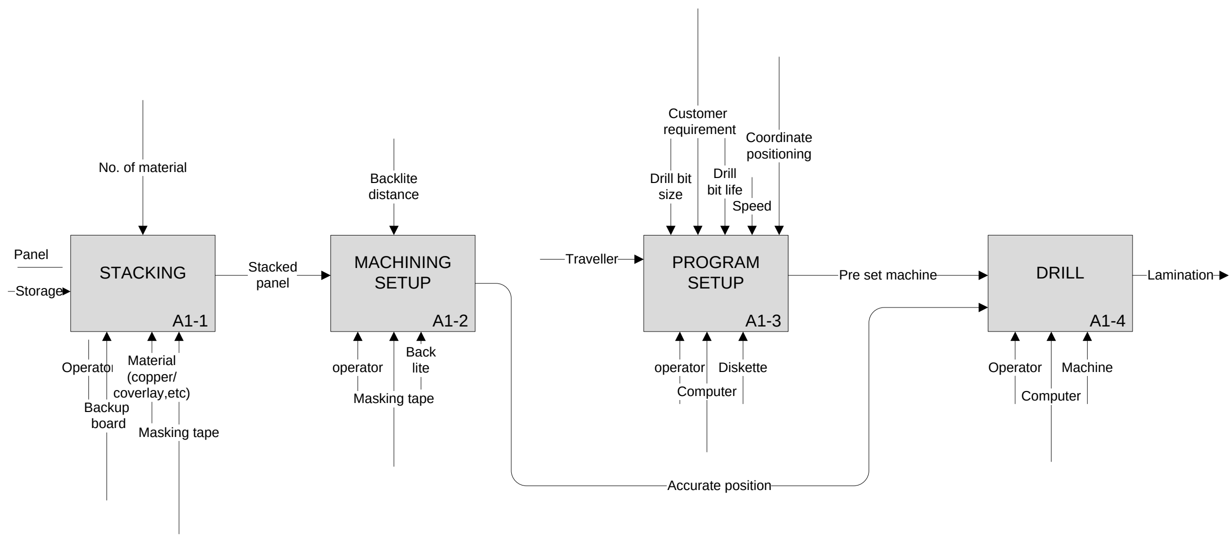

Figure 2: Drilling Process flow

The drilling process starts with stacking process where the panels are stacked together before transporting it to the drilling department. Basically, the number of panel involved for stacking process will depends on the need of that particular time. It is an important step in order to avoid panels from moving during the drilling process. The mechanism of backup board, material (copper, coverlay and etc) and masking tape is used by operator to perform the stacking process. This also allows the operator to identify the quantity of the panels that has been done because each set of stacking contain a fixed numbers of panels. Thus, stacking process could reduce the total time of process setup.

Machining set-up is a process to setup the machine to desired function for producing a high quality product. Firstly, panel becomes an input from the stacking process. At this stage, the operator needs to control the back lite positioning because it is vital for the process to get a precise and accurate hole. Operator, masking tape and back lite function as a mechanism at this point because their task is to make sure the panels are positioned at the specific place without moving as the hole will be drilled on the panel. This is an essential process before the drilling process begins since lack of method in stacking will interrupt the drilling process

Once the previous step is completed, it will proceed to program set up. The traveller will be the input of this particular sub-process because the traveller consists of all the process involved in order to process the product as desired. For drilling process, the machining setup only involves the stacking process and drill bit position since all the parameters that need to be control are done by the machines itself. At this stage, customer requirement, drill bit size, drill bit life, speed and coordinate positioning need to be control because all of these will make sure that the drilling process will be run successfully. For example, if the operator do not control the drill bit size and choose the wrong size, then, the panel will not satisfy the customer requirement which is a part of a vital process. So, the operator needs to be aware in controlling these. The operator needs to use the diskette to upload the program into the computer as to run the drilling process at a specific rate. The position of drill bit must be correctly placed to prevent any interruption occur during machining. After that, the machine will be ready to run.

At this point, only the operator, machine and computer are functioning. It means that during the drill process running, the machine will function according to the computer program that had been uploaded from the diskette before and the operator will change the panel after one another.

Step 2:
There were various type of failures occurred in drilling machine. In order to determine the most critical failure, occurrence of machine failure frequency had been documented and tabulated in Table 1.

Table 1: Failure occurrences for drilling

Failure Type	Occurrence
Spindle collect damage	25
Low air pressure	13
Spindle down	7
Servo out of control	3
Spindle overload	2
Laser communication	2
Vacuum defect	1

Referring to Table 1, there were seven types of failure mode occurred in drilling process. Spindle collect problem had the most frequent occurrences in the drilling process, it could achieve as high as 25 times per month. They were damages happened on the collector, which connected to the spindle to hold the drill bit during the process. Due to some causes, it would get stuck and affected the result on the panel. It had to be changed as soon as possible since it was an important component in drilling machine to perform the process. This failure gave a serious effect to the machine since the collector was connected to the spindle on the machine. When the collector was damaged, the performance of spindle was affected and subsequently reduced the productivity of the machine and resulted in longer lead time.

Step 3: Failure causes analysis
All the potential causes were categorized on the diagram based on the classification of causes related to 3M. Apart from that, the potential causes of failure had been excavated deeply by using Fishbone Analysis as in Figure 3.

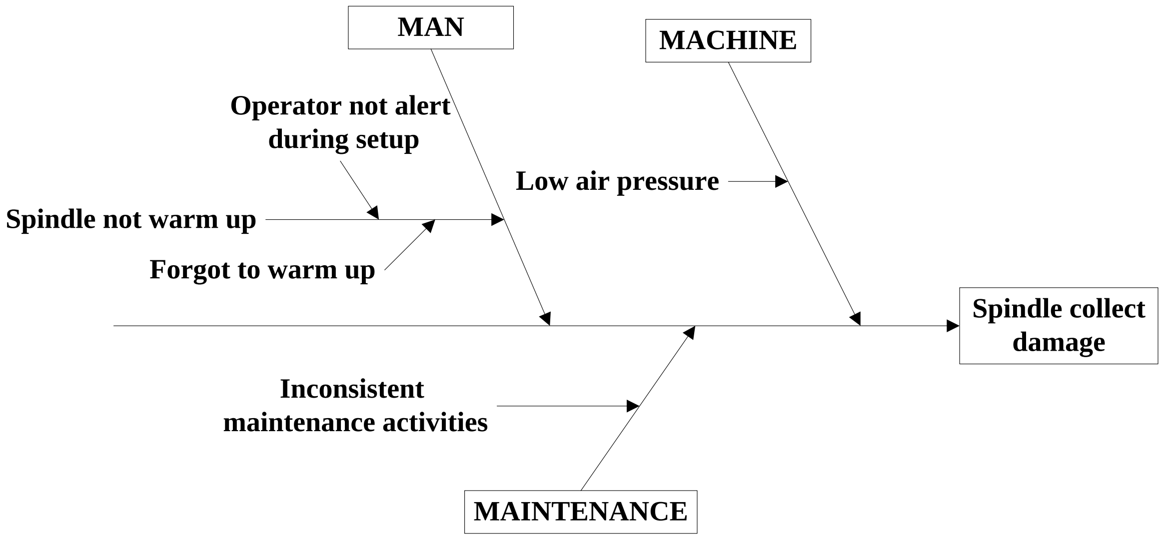

Figure 3: Fishbone analysis for spindle collect damage

The main cause of the collect problem was due to operator's error in handling when they forgot to warm up the spindle before starting the process. They were unaware to the important of the warming up procedure to the spindle as well as the effect when it was not properly warm up. The second cause was due to the irregular maintenance activity. Maintenance activity would only be carried out when failure occurred and there was no scheduled maintenance. The third cause was due to the low air pressure. Lack of air pressure would reduce the spindle performance and would not work properly

Step 4: RPN rating
From the analysis, there were five common failure causes that occurred in drilling machine. Failure risk of each identified failure causes were calculated and tabulated in Table 2.

Table 2: RPN of failure causes

Failure effects	Sev	Failure cause (s)	Occ	Dect	RPN	Suggested solution
Spindle could not be used and machine jammed	6	Forgot to warm up	5	5	150	Auto warm up program
		Operator not alert during setup	4	5	120	
		Low air pressure	3	4	72	Alarm system
		Inconsistent maintenance activity	6	2	72	Schedule maintenance every 8 hours

As in Table 2, it can be observed that the severity of failure effect to the whole process was reaching a serious level. Aside from that, number of occurrences and detectability of failure are also vital in column four and five in Table 2. Based on the RPN results, it showed that failure that caused by operator had achieved the highest RPN of more than 100 and should be given extra focus. This was due to operator's unaware to the importance of warming up the spindle before running the machine. It means that every time before running the process, the spindle should be warmed up first to avoid the damage. From the brainstorming with experienced personnel with drilling machine, an automatic warm up program had been added into the machine's programming. With the automatic system, the machine will warm up automatically once the machine has stopped functioning for more than 3 hours.

Other than that, low air pressure and inconsistent maintenance activities were another two failure causes that affected the drilling process. Suitable air pressure should be supplied to the machine in order to run the process smoothly without any disturbances or delays. This failure will stop the machine or reduce the performance of the machine by just looking at the low quality drills on the panel surface. Once the air pressure is low, it will affect the quality of the panel and all these panels will be considered as reject products. From the brainstorming with the same personnel, a solution of installing an alarm system was proposed in order to alert the operator when the pressure is low. By using this alarm system operator will receive early warning of low pressure and stop the drilling process until the pressure return to the required level.

Drilling process also produces a lot of dust that can affect the spindle operation which becomes one of the major causes of spindle failure. Dusts produced from drilling process could enter into the spindle component which will produce unnecessary friction in the spindle rotation process. Through the brainstorming process, all personnel agreed that consistent cleaning of dust accumulated around the spindle should able to reduce the possibility of failure and prolong the spindle lifetime. The minimum cleaning duration on every 8 hours has also been determined in the brainstorming season.

4. Conclusion

Through the case study, it shows that the proposed methodology shows the capability in assisting company management to conduct analysis in a systematic, effective and engineering way. Integration of fishbone analysis not only has provided a better focus on every aspect that causes the occurrence of failure but also produced a graphically visualized relationship between failure mode and cause. The FMEA provided a complete documentation of related information for company to plan and prevent repetitive failures while at the same time improves the related machines in agility way.

Failure analysis is an important task to be conducted in order to understand machine capability and improve the reliability. Thus, the proposed methodology should play an important role in continuous improvement of machine to ensure a bigger period of time for implementing the action plans.

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