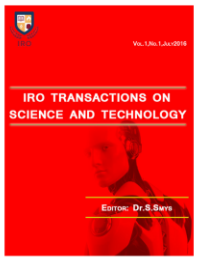
IRO TRANSACTIONS ON SCIENCE AND TECHNOLOGY
IROJOURNALS.COM
VOL.1, NO.1, JULY 2016



Waste Reduction in Surface Treatment Process by Lean Six Sigma Approach

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Abstract. The objective of this research is to reduce waste in surface treatment process which was applied in electronics manufacturing by Lean Six Sigma approach. This research was studied with automotive product and found defective rate 2.83% of all production before improvement. This research consists of 5 steps of DMAIC method (I) Defining problem from customer's complaint (II) Measuring phase for problem identifying by using 7 wastes, flow process chart and Pareto diagram which found 2 waste in current condition of process are waiting waste and defects waste (dent) in the solder cream printing process which is part of surface treatment process (III) Analyze phase for root cause's problem identifying by using why-why analysis and cause and effect diagram that found unsuitable working operator and approximate working step in waiting waste which is the main factor of defects waste (IV) Improve phase is to solve problem by using ECRS principles and design of experiment which has 3 concerned factor in dent defect experiment : weight, time and solder height (V) Control phase is to control and monitor the defined input's parameter from experiment and control working operator with standard working step by using work instruction. The result of improvement has shown the process capacity increase to 50% and overall defective rate in process decrease to 69.26%

Keywords
Lean Six Sigma, Flexible Printed Circuit, Electronics Industry, Waste Reduction

1. Introduction

Lean Six Sigma (LSS) concept is the well-known methodology in global for waste and quality management which consists of 2 principle; Lean principle and Six Sigma methodology. The purpose of Lean principle aims to reduce waste from resources, non-value added with product, to be zero defect and focus on human resource. The purpose of Six Sigma methodology aims to solve problem in process and service for the better quality. Although the both methods

are aimed at different, but if the both methods used together that make the improvements more efficiently. The main purpose of Lean Six Sigma concept makes satisfaction (Quality, Delivery) to the customer by the fastest response

Lean Six Sigma concept was applied in various industries, including Electronics industry. In this research, the company's case study manufactures the Flexible Printed Circuit (FPC) which is used with many industry such as hard disk drive industry, automotive industry and communication industry. In the current working condition, the company's case study has received complaints from customer about the quality issues. Many defectives fell to the customer that affect to assemble with customer's product which is high precision product's component of automotive part. From the problems mentioned in the introduction, the company was fined a lot of money from customer and also affect to disfavour of customer very seriously. Hence, Lean Six Sigma concept was considered to solve the problem about waste reduction in current working.

2. Concept

Lean Six Sigma (LSS) concept is the methodology for improvement that could be divided into 2 concepts which are Lean principle and Six Sigma Methodology. LSS concept was initiated by General Electric (GE) Company where there is successful implementation of Six Sigma methodology which was applied in the company. GE Company has been considering the ways to improve and develop the company continued by applying Lean principle with Six Sigma methodology which has a quite good for business directly.

2.1 Lean Production Principle

Lean Production is the concept of processes management to maximize the production efficiency. This principle began using in automotive industry which require the skill of the employees as the main that made high production costs. Later, Henry Ford, who is a Ford motor company founder, has a concept to build a production line similar to the flow of water by using conveyor belt used in the automotive industry for production time reduction. Subsequently, Toyota executives have taken Ford's concept to implement in their company and found that there is no availability. Thus, Toyota seeks to develop production systems by using pull system basis which was later called Toyota Production System (TPS). TPS principle is to produce a product based on the amount and timing of customer needs and focusing on the reduction or elimination of the following 7 types of waste in production line.

Types of Wastes

1. Transportation: Unnecessary movement of operators or parts between processes.
2. Inventory: Unnecessary storage of product, including raw material.
3. Motion: Unnecessary movement of operators or parts in a process.
4. Waiting: Operators or parts wait something which necessary to complete.
5. Over-production: Excessive production, more than customer demand.
6. Over-processing: Process step does not add value to product or beyond the standard which customer's requirement.
7. Defects: Errors during production, including rework process.

Tools of Lean Production

A total of 27 types were collected and divided into 4 categories based on the results of the tool. This can give an example of each type as below.

1. Flow: 5S is to improve work condition, including environment.

2. Flexibility: Set up reduction is to reduce the time of machine preparation.

3. Throughput Rate: Flow cells is to manage material flow and prioritize the production line with cycle time.

4. Continuous Improvement: KAIZEN is to provide all employees participate in continuous improvement.

KAIZEN

Guidelines for using KAIZEN to improve is following the basic principle is:

1. 5W1H is the question to analyze the current working condition and search new working condition which is the better way. These question consist of six question:

- What: What is the purpose of improvement?
- When: Period or sequence of working.
- Where: The proper workplace of working.
- Who: The right person for the job.
- How: The proper method of working.
- Why: Discuss about above 5 questions again for finding out the best solution.

2. ECRS Technique can be used for productivity improvement such as operator work load analysis, bottle-neck in process problem-solving. This technique consists of four method which are described as follows:

- Eliminate: Elimination is to reduce unnecessary working step.
- Combine: Combination is to integrate the similar working step together.
- Rearrange: Rearrangement is to make the work flow better.
- Simplify: Simplification is making the work easier.

2.2 Six Sigma Methodology

Six Sigma Methodology combines various improvement principle about quality improvement for all employee level that it can be easy to understand and execute. This methodology is recognized in general and the popular in various industry. The implementation of Six Sigma Methodology always using DMAIC approach which are described as follows:

- D (Define): Define phase is the first of Six Sigma methodology and the important step for defining the problem and purpose to be solved which should meet the need of customers.

- M (Measure): Measure phase is a step of measuring the capacity of the production process by studying the stage of the process in detail, including prioritization of issues for determining the cause of the problem is expected to affect most severely the process.

- A (Analyze): Analyze phase is a step in the analysis of key input of production process which may be the possible root cause of problem.

- I (Improve): Improve phase is to study about capability of process though variable that is the key input which affect to the product's quality of customer requirement. This phase makes the production processes to produce quality products which are meet the customer needs, including the slightest deviation in a production processes.

- C (Control): Control phase is a comparative analysis of before and after the improvement and to determine the next step of the process to maintain the improvement continuously.

3. Discussion

3.1 Define Phase

This research was studied in Electronics Company which produces the electronics components. The company has three main customer groups: automotive customer, hard disk drive customer and communication customer. The customer group, who has chosen to study, is automotive customer, who has been producing the safety equipment in cars, since the company had a major issue from customer complaints about the product's quality. The safety equipment in cars is very important what if there are mistakes from the operation that means the safety or life of driver. Thus, it should not have any defect or defective occur on product, especially defects associated with solder height criteria which was printed on the product and dent criteria which is making the product's pattern on copper plate tear or crack that affect to the electric current cannot flow through it.

From customer quality department information found that during the month of August 2015, company was fined a lot of money from the waste has dropped to customer, especially dent criteria. Therefore, all concerned had to check the historical data back to six months as shown in Figure 1.

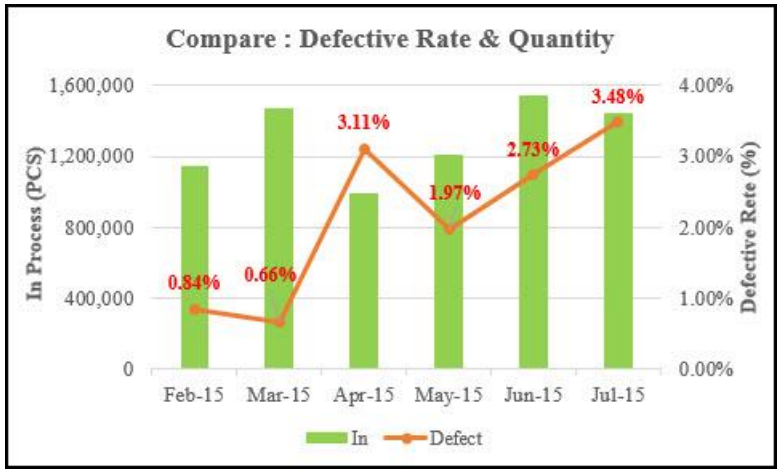

Figure 1 Historical data six months in the past

From Figure 1 is shown about comparison of overall defective rate of this product and quantity which were loaded in process that the defective rate was increasing to 3.48% in the latest month and average of defective rate was 2.83% of 4 months in past which was starting the

period of this problem. Then, overall defective rate were separated by type of defective as shown in Figure 2.

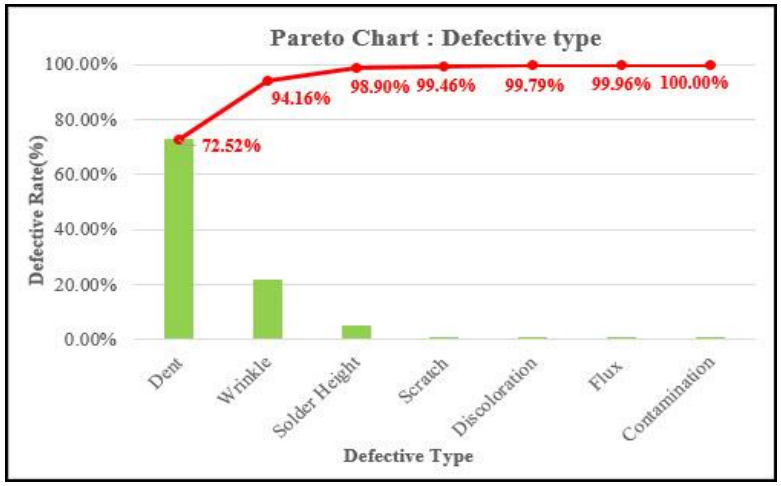

Figure 2 Pareto chart of defective type

From Figure 2 is shown about defective type which were separated by Pareto chart that dent criteria is 72.52% or the highest defective rate of all criteria which is consistent with a customer complaint. Thus, the main topic that needs to be improved urgently is dent criteria reduction.

3.2 Measure Phase

This phase is to measure about capability of process which was produced problem's product. The process, which produced problem's product, is called overall process that the surface treatment process department. This department is divided into five process which are polyimide pre-tack, oven dry, surface coating, solder paste and final inspection process. Each of process was measured and analyzed by mapping process method. Testing method was loading raw material 40 sheets or 1,000 pieces in each of process for checking about dent criteria as shown in Figure 3.

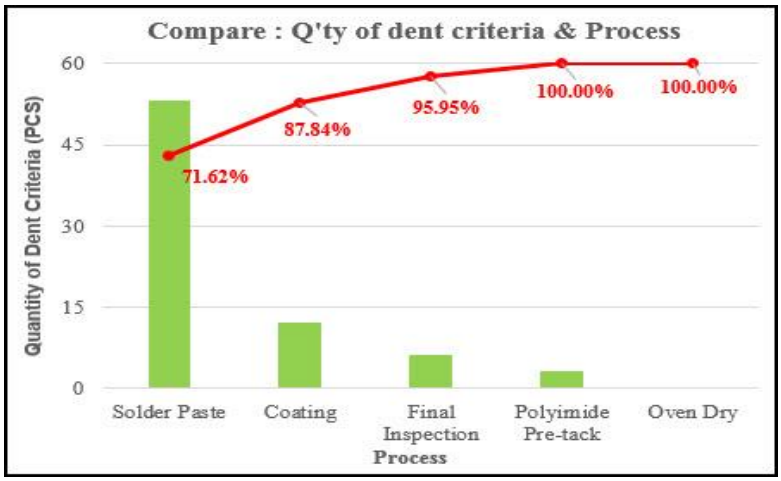

Figure 3 Quantity of dent criteria in each of process

From Figure 3 is shown about quantity of dent criteria which occurred in each of process and found that the highest quantity of dent criteria occurred at solder paste process or 71.62% of all process.

3.3 Analyze Phase

After knowing that the dent criteria was the highest defective rate and occurred at the solder paste process. Then, dent criteria divided into two categories which are crack criteria and slit criteria. Thus, this problem had to analyze for finding about root cause of crack and slit criteria by using cause and effect diagram as shown in Figure 4 and Figure 5.

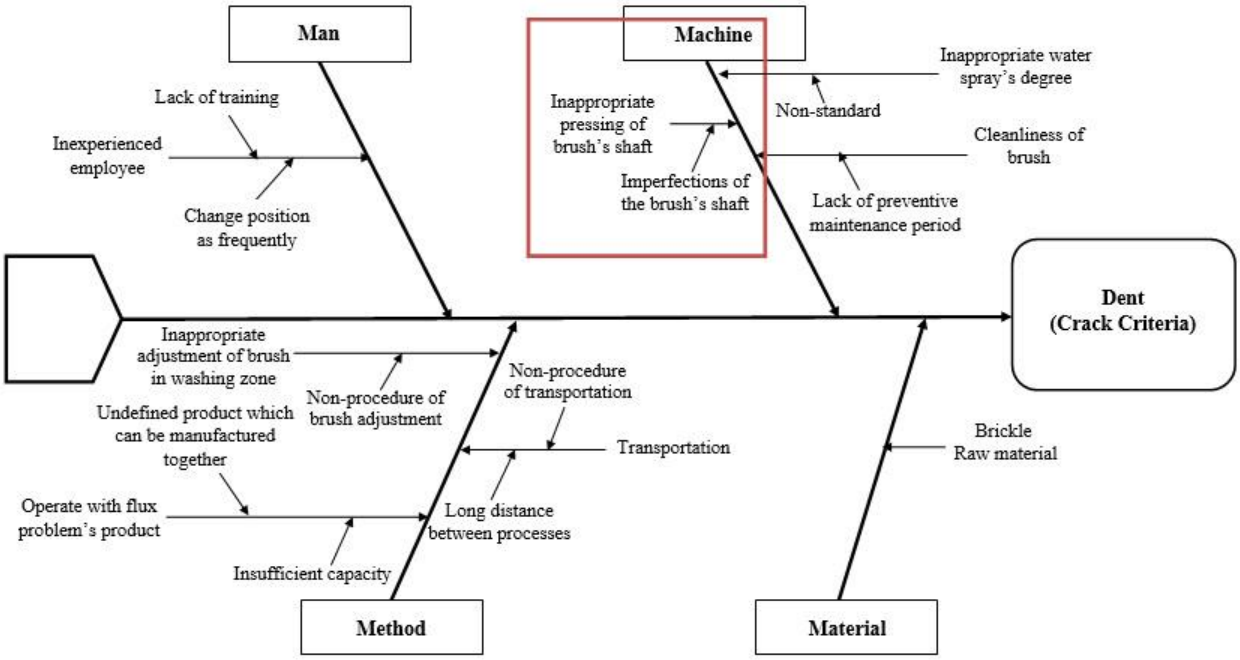

Figure 4 Cause and effect diagram with crack criteria

From Figure 4 is shown about root cause of crack criteria by using cause and effect diagram and why-why analysis method. Crack criteria caused from machine's problem which was inappropriate pressing of brush's shaft. This shaft, which has two important functions, is to be the core of brush and the axis of rotation that the both shaft are assembled and operated together. The available brush which consists of one core of brush and two axis of rotation that cause two connection point between shafts. This connection point is very important that is causing the swing what if the three shafts were poorly assembled. The swing's shaft causes the defect on product such as the wrinkle criteria that is from brush, which was pressed too much, and the contamination criteria that is from brush which was pressed too small. Thus, the connection point on the shaft should be a minimum or none.

From Figure 5 is shown about root cause of slit criteria by using cause and effect diagram and why-why analysis method. Slit criteria caused from method of working step as the main root cause which was insufficient process capacity and caused from material of packaging for use with packing process. In the current working condition, material of packaging in packing process uses the plastic bags to separate the lot of products. The plastic bags are very thin that cannot get a lot of weight, pressing down from above layers, when the products were superimposed from waiting to operate in next working step and this product has the height of solder which was printed on product so that the material of packaging should be change to be the new material which is more stronger for support a lot of weight from pressing down from above layers in the abnormal case

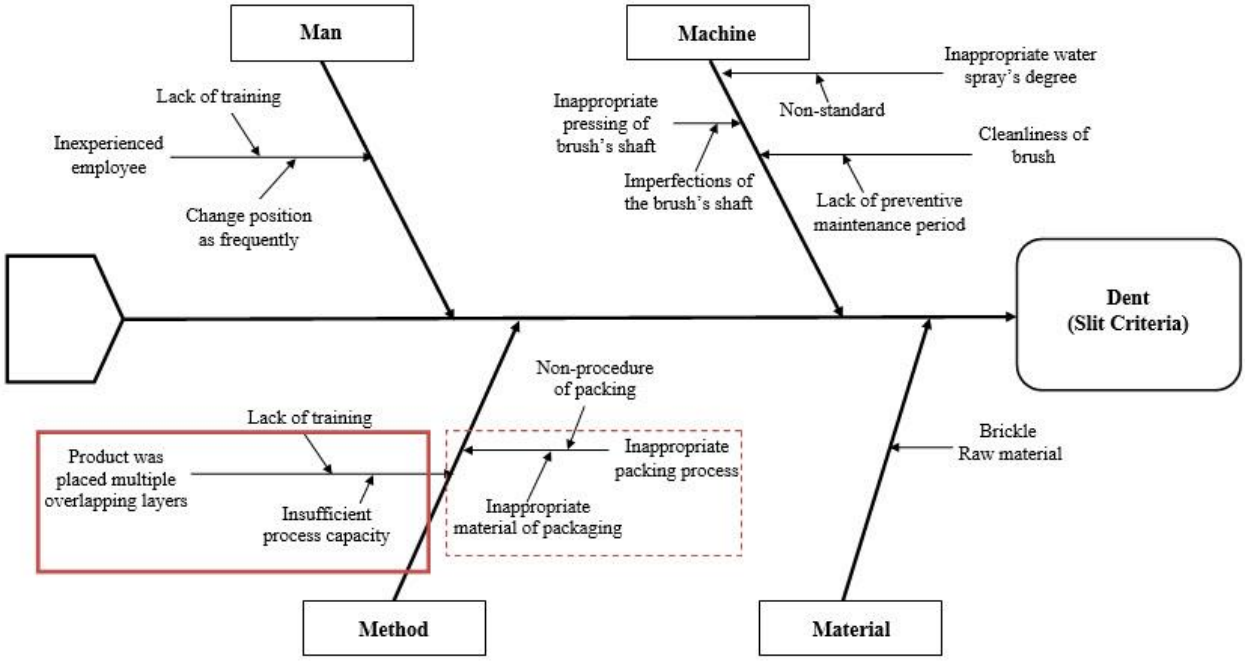

Figure 5 Cause and effect diagram with slit criteria

The main root cause of slit criteria, which from product was placed multiple overlapping layers, caused from insufficient process capacity that affects to be the waiting waste in process. Then, the process capacity, which produces this product, was reviewed as shown in table 1.

Table 1 Process capacity of problem's product

Process	Resource (Man-power per one shift)	Capacity (Pieces per one shift)
Polyimide pre-tack	2	103,808
Oven dry	1	120,000
Copper surface coating	1	30,946
Solder paste	5	20,790
Final inspection	14	55,493

From Table 1 is shown about capacity of each process where the problem's product is operating. The solder paste process is the lowest capacity (20,790 pieces per one shift) that there is to be the bottleneck of process or work in process (WIP). Then, solder paste process was considered about value added or non-value added activity as shown in Figure 6.

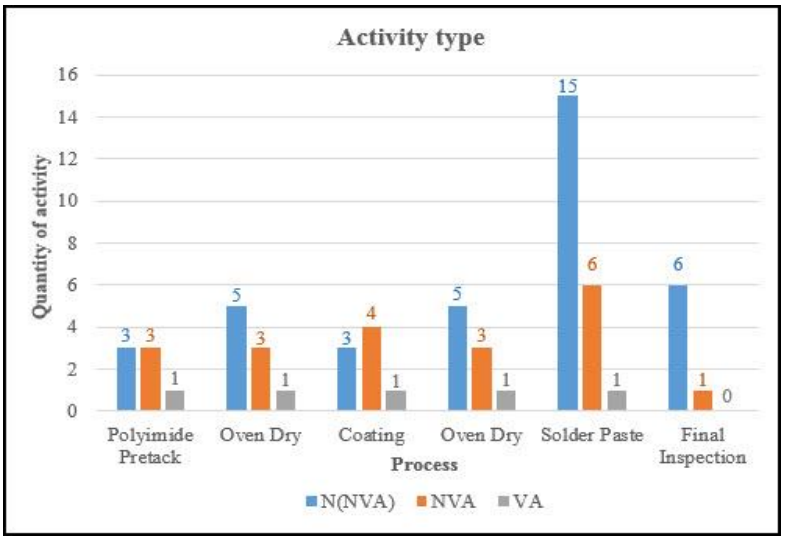

Figure 6 Activity type of each process

From Figure 6 is shown about activity type in each process of overall process which is called that surface treatment process department. The solder paste process was focused on since this process was the bottleneck of overall process and found that this process had the most activities or 22 activities which divided into three type of activities: non-value added but necessary (N(NVA)) is 15 activities, non-value added (NVA) is 6 activities and value added (VA) is 1 activity. Thus, the activities in solder paste process were reviewed again that each activity was necessary or not, especially, non-value added but necessary and non-value added.

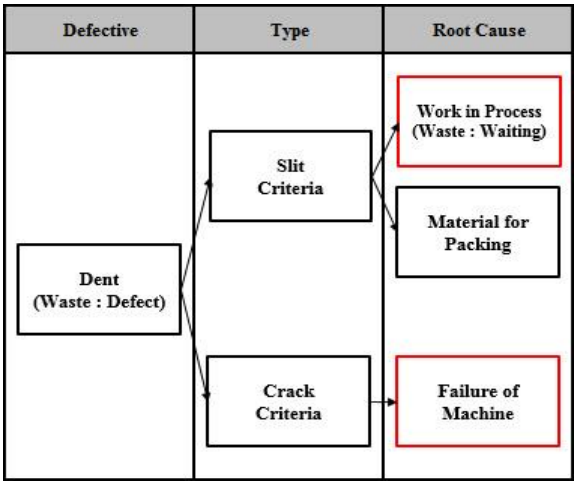

Figure 7 Conclusion of analyze phase

Thus, the analyze phase could be concluded about problem and root cause of each problem that this product had the problem about dent criteria which was separated 2 type; one is crack criteria which from machine's problem and another is slit criteria which has the main root cause from waiting waste. This conclusion is simplify to understand as shown in Figure 7.

From Figure 7 is shown about the conclusion of analyze phase which concluded that this product had 2 wastes; one is defect or defective waste and another is the waiting waste which is the root cause of defect or defective waste. Then, these root cause of each problem would be improved and took measures to prevent the recurrence of problem.

3.4 Improve Phase

This phase is to improve about processes, produce the problem's product, for waste reduction. The waste has two types that occurred with this product; one is the defect waste and another is the waiting waste. The defect or defective waste can be divided into two types and has the ways to improve as follows.

3.4.1 Slit criteria

After knowing about root cause of slit criteria in analyze phase that from product was placed by multiple overlapping layers. Then, the factor, which be concerned with the waste, would be tested by design of experiment (DOE) method for finding the optimal value in each concerned factor. The factors, which were tested with DOE method, are time of overlapping, weight of overlapping and height of solder which was printed on product. The result of DOE method as shown in Figure 8.

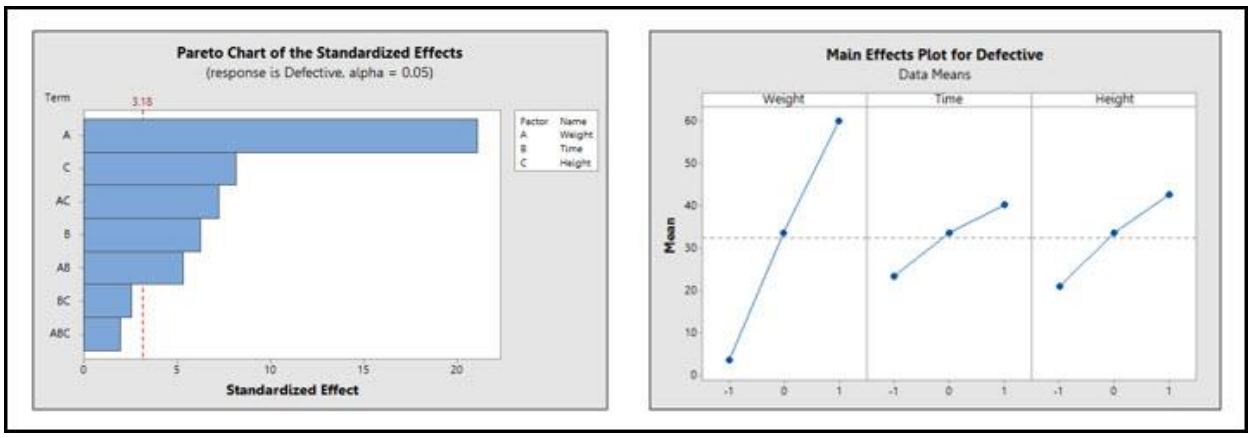

Figure 8 Result of DOE method

From Figure 8 is shown about the result of DOE method that the three factor affect to defect waste as significant. The most impact factor is weight of overlapping. However, the slit criteria could be classified into 2 types of root cause as follows.

(1) Bottleneck or work in process (waiting waste)

After the activity in process was reviewed and found that the solder paste process was a bottleneck and had the most activities or 22 activities. The result of process review as shown in Figure 9.

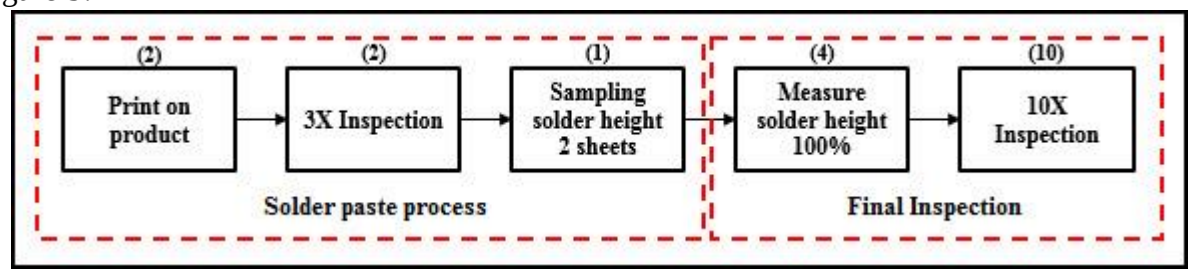

Figure 9 Result of solder paste process review

From Figure 9 is shown about the result of solder paste process review that the process has the three major activities which are printing, 3x inspection by magnifier and sampling solder height two sheets for every lot of product. After reviewing that the activity of sampling solder height two sheets in solder paste process and the activity of measure solder height 100% in final inspection process are the same purpose but there are some of working step which is different. The sampling solder height two sheets is to measure as sampling about solder height two sheets per lot of product and the solder height data and variation of solder height, printed on product in each lot, would be recorded on document which was attached to customer. The solder height 100% measurement is to measure all pads and all sheets but this activity would not be recorded. However, the bottleneck activity of solder paste process is 3x inspection which caused from inappropriate man-power management. In the current working condition, the 3x inspection process has two man-power that is not enough to operate and there are some activities that can be

eliminated or rearranged. Therefore, ECRS method is selected for studying and improving about this root cause which is the waiting waste as shown in Figure 10.

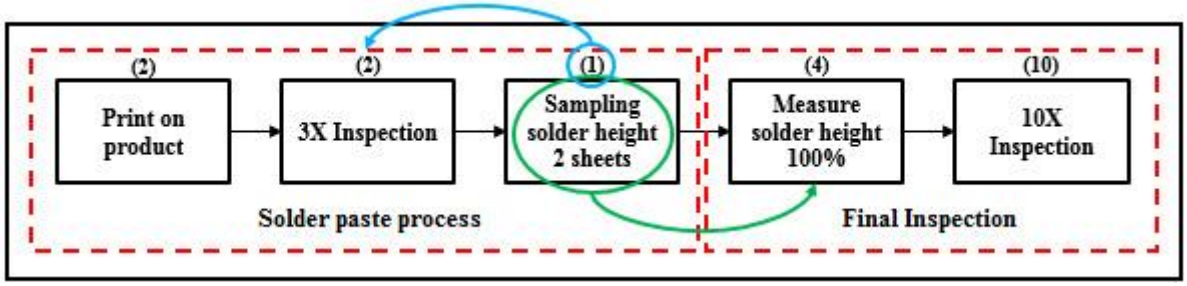

Figure 10 ECRS Method for waiting waste reduction

From Figure 10 is shown about how's to reduce the waiting waste by using ECRS method that could describe the detail as below.

- E (Eliminate): A sampling solder height two sheets step was eliminated out of solder paste process since this step was the same as the measure solder height 100% in final inspection process that could reduce 2 activities or 372.29 second per lot of product and 1 manpower from this step elimination.

- C (Combine): The main function of sampling solder height step was measuring solder height of two sheets and recording about data and variation of solder height, which was measured, on document that would be operated with measure solder height 100% step in final inspection process. Normally, 100% solder height measurement would measure solder height of all sheets in lot of product and the data did not record on document but the new workflow that this working step still doing the current working condition and would be assigned more function which is to record the data and variation of solder height by sampling 2 sheets from 40 sheets (1 lot size).

- R (Rearrange): A manpower who was reduced from elimination step would be added in 3x inspection process to increase capacity of process since the average capacity of a manpower was only 10,395 pieces per one shift. Consequently, rearrangement by adding one manpower in 3x inspection process would increase the capacity of process from 20,790 pieces per two manpower per one shift to 31,185 pieces per three manpower per one shift.

- S (Simplify): This simplification would be improved in 3x inspection process. In current working condition uses 3x magnifier to inspect product. The method of inspection with this tool that the products, which were inspected, would be tilted to an angle with the magnifier light for checking about dent criteria and this method did not standardized and based on the skill, experience and ability of employee. Therefore, the new tool, which is available but it's not utilized, would be used instead of the 3x magnifier. The new tool was modified by using monitor to connect with adjustable 4x microscope that the picture would show on monitor. The method of

new tool is placing the products parallel on the plate which for support product that is easier than original tool and did not based on skill of employees, including this model would be the new standard of 3x inspection process.

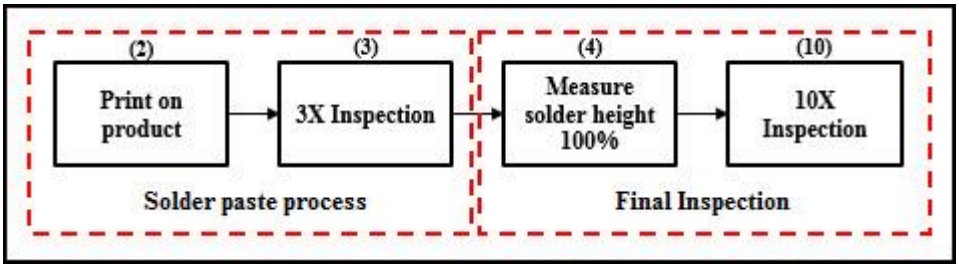

Figure 11 Conclusion by using ECRS method for improvement

From Figure 11 is shown about conclusion by using ECRS method for improvement that could be reduced the activities of process and increasing the capacity of process by using a manpower who is changed working function from solder height measurement process to be 3x inspection process.

(2) Inappropriate material of packaging

After the weight of overlapping factor which was proved by using DOE method that is the main effect to affect dent criteria directly. Not only the waiting waste which have improved already but also the material of packaging in packing process affected to dent criteria.

In current working condition, plastic bags were used in packing process which are very thin and cannot get a lot of weight from pressing down of overlapping multi-layers. Therefore, tray supports, which is new material that can separate the lot of products and better to get more pressing down from overlapping, was designed as fit to the product. This new designed material of packaging can be superimposed on each other without touching of product that can reduce slit criteria from transportation, when the products were transported within process or other locations that the products would be direct exposed since there is no space to catch products up, and direct overlapping of product as shown in Figure 12

Figure 12 Re-designed the material of packaging

From Figure 12 is shown about re-designed the material of packaging for dent criteria reduction from transportation and overlapping. Tray supports were designed for direct overlapping protection the products that do not exceed the lot size of product which were determined and adding a catch up space of moving that without direct touching on products.

3.4.2 Crack criteria

After knowing about root cause of crack criteria in analyze phase that from machine's problem which was inappropriate pressing of brush's shaft. The inappropriate pressing was from shaft's swing which caused from assembled brush that had many connection point. Thus, the connection point of assembled brush would be reduced to a minimum or none. Brush would be re-designed to be the long axis of a single core which has not the connection point on axis to prevent mistake from assembly that caused to be the brush misalignment as shown in Figure 13.

From Figure 13 is shown about re-designed the brush cleaner in washing zone by using a single core. In current working condition, the distance of misalignment from center point around 280 micron. However, after improvement that can reduce distance of misalignment from center point around 200 micron or 71.43% (from 280 micron to 80 micron).

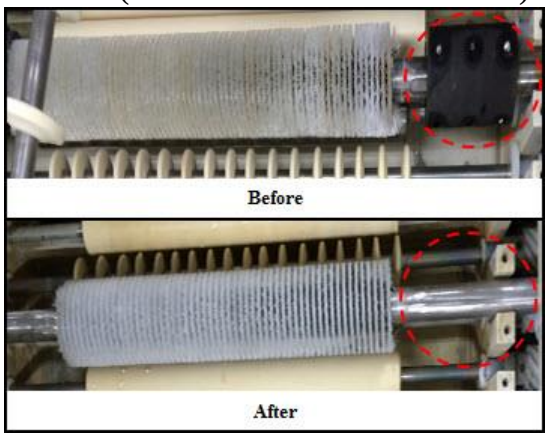

Figure 13 Re-designed the brush cleaner in washing zone

3.5 Control Phase

This phase is so important to control about parameters, which affect to be the defect or defective on product, for maintaining the quality after improvement including, controlling and checking back of continuous improvement. Control method would be determined by work instruction document which concerned with working step, detail of working. Work instruction document for this problem-solving consists of the important parameters as main topic below.

(1) All product lot would be still 100% inspection and add two sheets sampling method at 100% solder height measurement process and the solder height data from sampling method that would record on document which attaches to customer.

(2) All product lot NEED use tray supports and the lot size is not exceed 40 sheets per one lot size.

(3) Brush cleaner in washing zone NEED use a single core/shaft.

These three item as above that are the main parameters which need control since these parameter directly affect to the both of dent defective; slit and crack criteria.

4. Result

After problems were analysed and improved with the root cause of problem, then the result of improvement, which is monitoring and controlling, could show the result as shown in Figure 14.

From Figure 14 is shown about the result of improvement by monitoring the defective rate. Defective rate, which was monitoring and controlling, has two types are overall defective rate and dent criteria defective rate which is a direct affect to overall defective rate. The overall defective rate of before improvement during past six months (monitoring from Feb'15 to Jul'15) which has the average is 2.13% but this problem was starting during 4 months (from Apr'15 to Jul'15) before this problem would show up (this problem was starting around Apr'15) that defective rate would be calculated only 4 months which the average is 2.83%. Hence, this problem was improved during 3 months (from Aug'15 to Oct'15) and the result of improvement is decreasing from 2.83% to 0.87% or can reduce defective rate 69.26% from current working condition. Then, this improvement is still continuous monitoring and controlling from Nov'15 to Jan'16 and found that the defective rate average is still 0.91%. Furthermore, the average capacity of solder paste process is increasing up to 50% from this improvement.

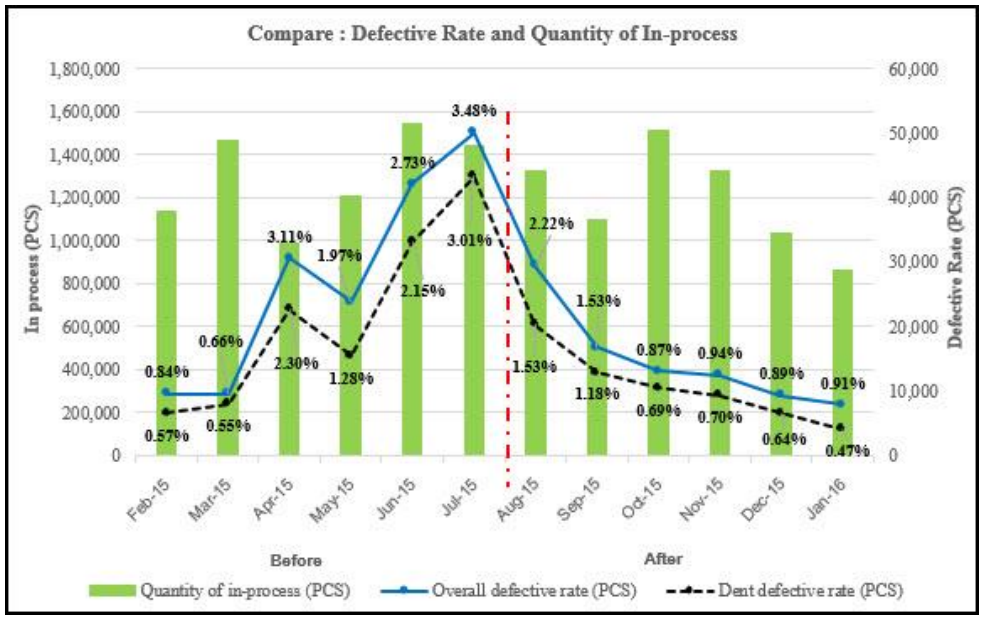

Figure 14 Result of improvement

5. Conclusion

Lean Six Sigma (LSS) concept was implemented in the electronics industry and focused on surface treatment process. Six Sigma methodology was used to help solving the problem as systematics by following the DMAIC process. The core of Six Sigma methodology is the quality improvement or effectiveness. Lean production principle is focusing on productivity of process and the main tools of Lean principle is ECRS method which was used with waste management. This research uses DMAIC process, as the problem-solving structure, and ECRS method together to be useful in troubleshooting. The result of improvement by using these tools could reduce the defective rate from 2.83% to 0.87% within 3 months or accounted for 69.26%. Hence, Lean Six Sigma concept was proved that is the valuable tools for systematic problem-solving of waste management and this concept could apply with other appropriate tools that would affect to be more effectiveness.

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