

# Semiconductor's Automotive Burn-in Testing Improvement by Using Six Sigma

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## Abstract

Burn-in is generally known as a compelling methods for screening out early failures to prevent defective parts shipped to consumers. This project was conducted in a burn-in service provider industry that has been a leading provider of semiconductor testing and burn-in services for more than 45 years. With significant milestones in achieving internationally recognized quality awards such as QS 9000, the company strive towards service excellence, seeking to expand capacity in all laboratories and expand the markets for extensive range of test and measurement products. This project focuses mainly on 144lds ICs since this product is always having customer complaint due to the sliver defect escaping to their end customers causing premature failures due to short circuits. Additional process like 40x inspection is required to screen out the defect which affected the overall cycle time and output for this 144lds product. This process is time consuming and delays other lots for shipment and production facing hard time to meet the output. More over the company is spending additional man power cost which is none value added to the company to screen out the defects. Therefore the root cause of misload which creates the sliver defect was identified to be mainly on machine related issues and the most cost effective solution by installing misload sensors and single press plate was successfully implemented to eliminate the defect using six sigma approach. Besides that, the overall cycle time was improved by 19% by solving sliver issue and man power cost of around 400,000 Ringgit Malaysia was reduced by the elimination of 40X inspection process. The successful implementation of the misload sensors and single press plate at autoloader has lead to zero returns from customers and substantial cost saving for this company's Burn-in test operations through the elimination of manual 40X inspection process.

**Keywords:** Six sigma, TQM, Burn-in, Wiskers, Quality, kaizen

## 1. Introduction

Burn-in is one such technique that is broadly used inside the semiconductor industry process to encounter the need to provide the guarantee of reliability that conforms to an industry standard. This burn-in service industry offers semiconductor companies with testing services. The company are well known for conducting burn-in services for integrated circuit which has different type of lead count such as 64lds, 80lds, 100lds, 144lds and 176lds. The types of products that have been classified are loaded in different type of burn-in boards and undergoes different burn-in durations.

It will be mainly focusing on 144lds ICs since this product is always having customer quality complaint due to the defect it caused from the foot and riser of the lead at loading process. The defect on the lead as mentioned is caused by the sharp area of the socket pin which scratch the lead surface when the device is misplace in the socket. Additional process like 40x inspection is required to screen out the defect which affecting the overall cycle time for this product. The improvement will be focusing on the elimination of the defect and cycle time

improvement to improve the overall output of this 144lds product via six sigma approach and Design of Experiment (DOE).

## 2. Literature Review

### 2.1 Introduction on burn-in

Burn-in is one such technique that is broadly used inside the semiconductor industry. Circuits with infant mortality problems can be weed out using burn-in technique by stressing the circuit needed but it is a very expensive procedure that requires special ovens to maintain a high temperature during device stressing. According to Burn-in et al., (2009), in addition to the need for powerful test techniques for disorder screening and velocity binning for these ICs, there may be an ever growing call for excessive tool reliability and the faulty elements according to million degrees. Guin et al., (2014) explains that the ICs are tested sufficiently long enough under any stress conditions in order to prevent early system failures and to estimate the overall operating life of a particular device. The device lifetime can be estimated when the reliability issues of an IC are properly addressed and it can be shipped confidently to the customers. Figure. 2 often known as the bathtub curve which illustrates typical device failure characteristics.

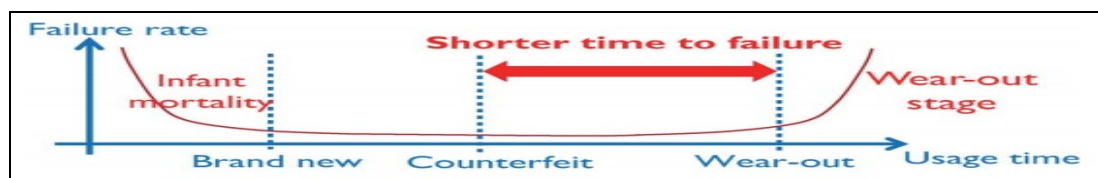


Figure 2.1. The typical device failure characteristics illustrated using the classical bathtub curve.

### 2.2 Background of IC component socket

An IC component socket is generally known as an electromechanical system which provides a separable electrical and mechanical connection between an electronic component and a Printed Circuit Board. According to Liu et al., (2001), plastic housing and metal contacts is the basic structure of an IC component socket.

### 2.3 Background of sliver

Slivers as shown in Figure 2.3 are semiconductor package defects seen mostly in leaded QFP IC package types. Sliver is a form of metal burr caused by slicing effect between the device lead surfaces with another hard surface. The sliver defect is normally protruding out horizontally from the IC leads and has high potentials to cause metallic bridging between two individual device leads during end customer's reflow process and subsequently cause short circuit as reported by Brusse et al., (2002). Not all the sliver units can cause short circuits, but only the gross ones. According to Janiuk, (2015), this defect has long time been a issue for chip manufacturers, assemblers and Burn-in test industries and its criticality and occurrence has become more severe since the restriction of the use of certain hazardous substances in electrical and electronic equipment specifically Lead (Pb) through the directive for semiconductor taking effect starting year 2006.

### 2.4 Background of 40x Inspection Process

The completed lot will undergo 100% 40X inspection to screen out the sliver defects before shipping out the lot to customer. Study conducted by Sim, (2008) explains that an inspection does not add any value to the product quality and the customers will still complaint about the defects although the company has checked the product before it is shipped out to their customers. It will lead to extra cost if 100% inspection to be installed at outgoing quality assurance (OQA) gate which will decrease the productivity and does not guarantee that 100% screening will be effective since the error in inspection will still exist due to inspection is being done by operators.

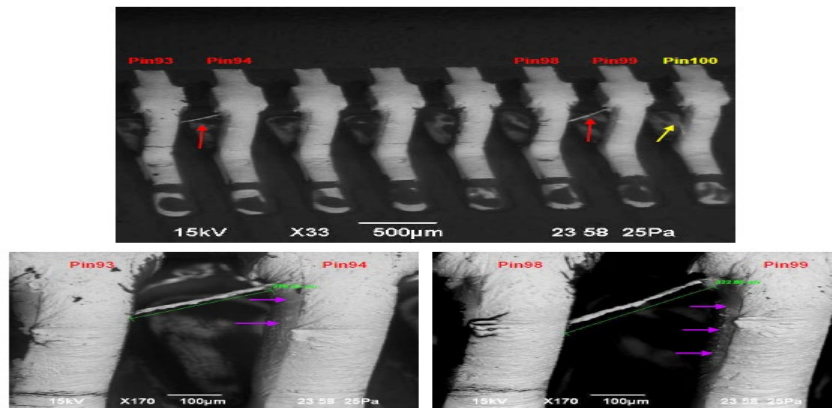


Figure 2.3 : Image from lead front showing the length of metallic sliver. Scratch marks we noted at side of lead risers as indicated by purple arrows.

## 2.5 Definitions of quality

Quality is defined as non-physical or physical characteristic. Sarvin, (2008) mentions that all the issues involve the quality of manufactured product is convenient to think of in term of the three functions of specification, production and inspection which will be perform for every manufactured product. The product or service performance its intended function which brings out the quality performance identified by the customer.

## 2.6 Lean Manufacturing

Lean manufacturing is known as a tool use in eliminating waste which is a non value-added components in any process and to satisfy the customers. Rahman et al., (2013) also mention that lean manufacturing is mainly use to reduce waste in human effort and inventory, managing manufacturing stocks and reaching the market on time that are highly responsive to customer demand while producing high quality products in the most efficient and economical way. By implementing lean, manufacturing output can be achieved to produce the similar product by using less man power in the factory, save space, low financial resources and less material (Alefari et al., 2017).

## 2.7 Total Quality Management (TQM)

TQM literature is constructed greatly on contextual investigations studies, narrative confirmation and the individual prescriptions of the known gurus of the discipline, including Deming, Juran, Crosby and Ishikawa (Black et al., 1996). TQM is integrated management philosophy focus on consistently improving the quality of product and process to accomplish better customer satisfaction. TQM has been very much acknowledged by managers and quality professionals as a change management quality approach (Arumugam et al., 2014). Terziovski in 2006 found out that continuous improvement was the most important predictor for the productivity improvement.

## 2.8 Six-Sigma Quality Approach and Strategies, Tools, Techniques, and Principles

Six Sigma was developed in 1986 by Motorola as a response to the need for quality improvement and defects reduction in their products. Motorola has reduced defects in their semiconductor devices by 94 percent from 1987 to 1993 (Arumugam et al, 2008). The six sigma normally applies to problems common to production and its' fundamental principle is to lead an organization to an improved stage of sigma capability through the rigorous application of statistical tools and techniques. The Define, Measure, Analyze, Improve and Control processes is five phase of problem solving algorithm used in Six Sigma which is called DMAIC cycle. Organizational process improvement and problems can be resolve using DMAIC model which helps to identify an issue, determines the key measurements, implement the identified solutions, set the procedures and finally control the implemented process and allows for continuous improvement. The analytical tools of Six-Sigma has been utilized for years in traditional quality improvement activities. What differentiate their application to Six-

Sigma is the integration of the tools in a wide management system. The tools is similar to all quality incidents, and also Six-Sigma which contains flowcharts, Pareto charts, histograms, cause-and-effect diagrams, check sheets, and control charts.

## **2.9 Kaizen**

Kaizen is an important tool use in Lean for continuous improvement. Kaizen is a Japanese word which means Improvement. Suárez-Barraza et al., (2008) mentions that, Kaizen basically is known as continuous improvement in quality, processes, technology and others. In continuous improvement, Kaizen principle is one of the key successes. Kaizen means small and incremental changes but constant throughout long-term improvement processes and for process interactions (Deshpande et al., 2009). Besides that, “kaizen” which is known as the Japanese philosophy for process is aimed at continuous, step-by-step improvement of a process which involves everyone in the organization to participate.

## **2.10 Literature Summary**

In summary, this literature review gives a brief picture regarding the quality approaches. Six Sigma uses DMAIC methodology to reduce defects issues, while Kaizen concept is similar to Lean principle. This chapter briefly explain on the burn-in industry, process flow of the company and describe the topics which related to quality such as the similarities and differences among concepts of TQM, Lean, Six Sigma and Kaizen. The focus is more on six sigma and kaizen methodology since the study conducted in a combination of Six Sigma and Kaizen manner.

## **3. Methodology**

### **3.1 DMAIC Approach**

The methodology used for this project is by applying the DMAIC (Define, Measure, Analyse, Improvement and Control) method. It is one of the DMAIC problem solving tool used in Six Sigma approach which has similar function as plan-do-act-check (PDCA) to solve problems. The DMAIC methodology is frequently used for improvement and problem solving purpose (De Mast et al., 2012). It is designed to take a breakthrough using DMAIC approach via establishing a group of members to improve the quality and process via step by step approach.

### **3.2 Design of Experiment Proposal**

#### **DOE 1:**

- 1) The misload data to be collected for 4 loading machines since the four machines which is located at the loading area used to load the same product (144LDS).
- 2) Misload data to be collected for continuously 3 months from Mar to May 2017 using the control chart which will be available at each loading machines that focused only on the production part named 144LDS.
- 3) The collected data from 4 machines to be use to construct the misload trend chart by machine and to analyze which machine having highest misload fallout.
- 4) Sliver fallout data by lot to be collected from 40X inspection for 3 month from Mar to May 17 for all the 4 machines which is mention in DOE 2.
- 5) The data to be plotted in chart for comparison and machine with highest misload and sliver fallout will be selected for further study and improvement.

#### **DOE 2 :**

- 1) All misload units from DOE 1 to be remove from the burn-in board and send for 40X inspection before proceeding to oven process.
- 2) Misload units to be inspected at 40X process to collect sliver data from the misload units to determine total sliver units cause by misload.
- 3) These data then to be used to construct the Sliver versus misload trend chart by machines.

### DOE 3 :

- 1) The misload root cause to be identify using fish bone analysis and through kaizen activity based on the selected machine from DOE 1.
- 2) Using the fish bone analysis, team to identify the best solution method to prevent or eliminate the sliver creation
- 3) Identified solution to be fan out to all the remaining loader machines.
- 4) 40X inspection to be gradually remove based on the 6 month of lot monitoring data after the implementation of solution confirming no sliver detected during 40x inspection and no unit misloaded during loading process. Also after confirming zero customer complaint (CQI).

## 4. Results and Discussion

### 4.1 Results of All Design of Experiment

Data was collected for 3 months continuously from Mar to May 2017 for misload and sliver reject that occurred in the loading process. Based on the collected data as per the Figure 4.1 on sliver versus misload trend by loader machines, Falcon 3 recorded the most misload unit and sliver fallout in total from Mar to May 2017. The other 3 machine recorded misload units less than falcon 3. It is an unhealthy trend for Falcon3 when it is compared with the other 3 machines of the same models. These data were use for further study and improvement of Falcon3 loader machine.

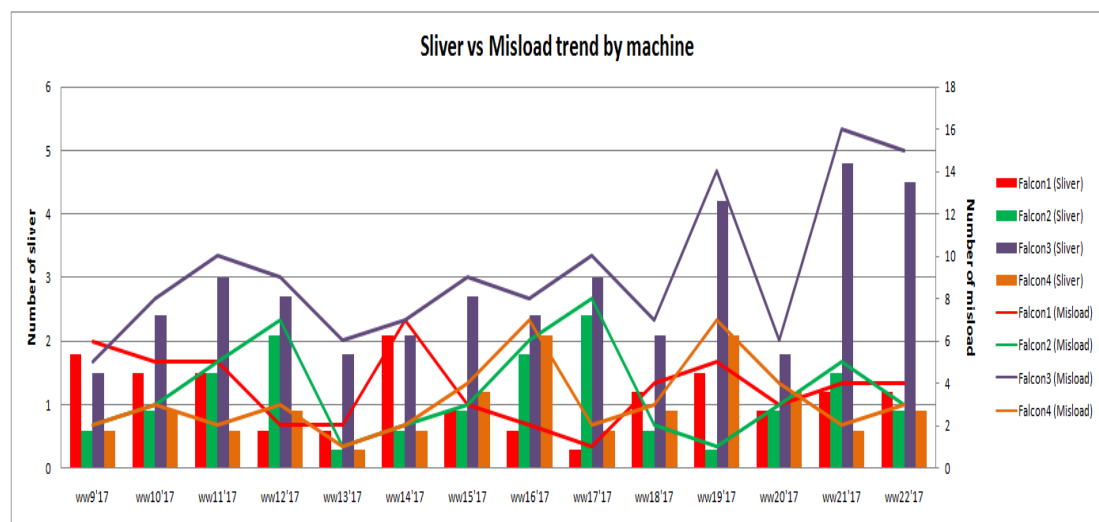


Figure 4.1: Sliver versus misload trend by loader machines

### 4.2 Root cause Analysis

Several problems were identified as the main root causes to misload which generates sliver defects in production line. The problem identified from the analyze section is pointing to the machine. This is due to the data which was collected indicates that the root cause of misload is majority due to machine part offset or worn out which happens on long run. Besides that, method of aligning the pick and place head also can cause misload if wrongly align by the technicians. Although there are also other factors affecting the misload problems, the main focus has given to the machine and method factors.

### 4.3 Implementation and Monitoring

As per management decision, misload sensor and a single press plate were implemented at all loader machine at production floor after 1 month of monitoring to detect and trigger misload units for reseating and in the same time keeping the single press plate actuating the socket to prevent misloaded units from clamping and creating sliver defect. Based on the run chart as in Figure 4.2, there was still some misload fallout reported for falcon 3 before the misload sensor module and single press place was implemented. The result after and before the implementation can be seen in the run chart below. The misload rate decreases to zero after the implementation of the mentioned misload sensor module and single press plate and at the same time it proved that when there is

zero misload, there will be zero sliver fallout induce based on the sliver versus misload trend as shown in Figure 4.3. It is also proven that the main factor of the sliver defect is due to misload.

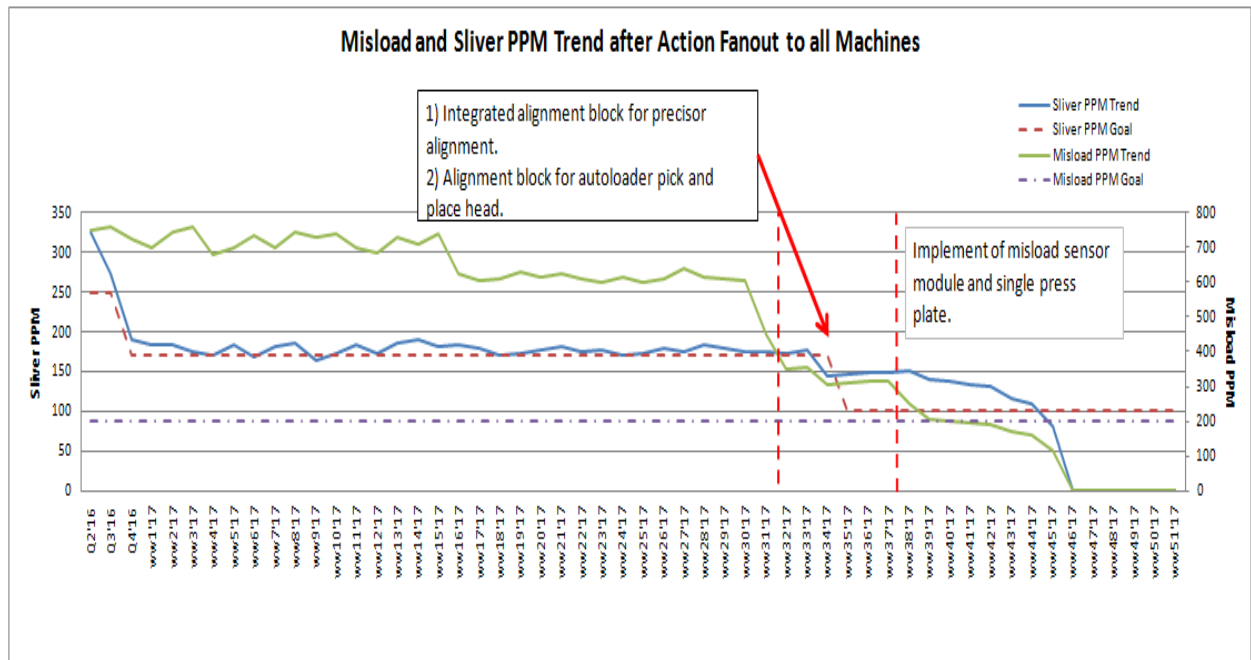


Figure 4.2 : Misload trend before and after the implementation of misload sensor module and single press plate

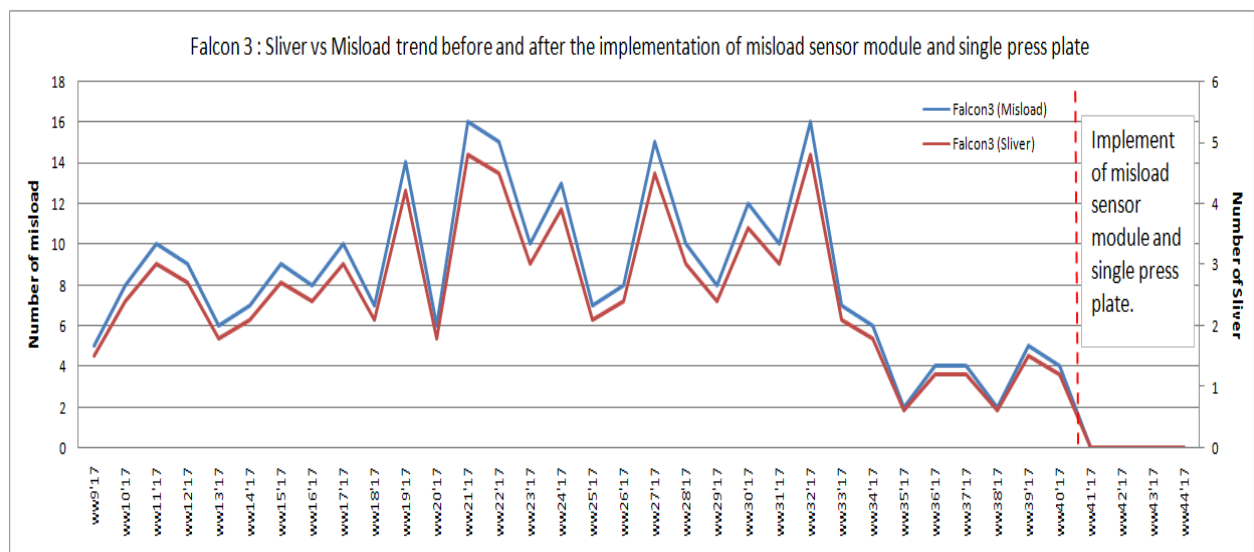


Figure 4.3 : Sliver versus misload trend before and after the implementation.

## 4.5 Summary on Implementation

With all the improvement done, the 40x inspection process and the man power can be totally removed to make profit for the company after confirming on the effectiveness of the misload sensor in preventing the escapee of misload out of autoloader and ensuring zero sliver by monitoring few more lots under 100% 40X inspection.

## 5. Conclusion

The DMAIC methodology as the Six-Sigma approach was used in this burn-in test company to solve the sliver escapee to the customer by identifying the root cause using analysis tools such as fish bone and kaizen and

the implementation of misload sensor and single press plate implementation at auto loader was successfully implemented. The improvement was done on all the loading machine at production floor. The root cause of the sliver defect had successfully determined. 40X inspection removal will be done after confirming no sliver from all the 50 lots loaded in the loaders equipped with misload sensor module which will definitely help to improve the overall cycle time by 9 hours of reduction. Corrective actions to solve this quality problem has been suggested and implemented. The solution has gained huge customer trust during Continuous Improvement Plan activity sharing with them.

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## Biography / Biographies

**Assoc. Prof. Dr. Norzima Zulkifli** is currently attached with Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia. She is in charge of the Master Program in Engineering Management in the university. Previously, she has worked with Standards and Research Institute of Malaysia (SIRIM) during which she dealt with many small and medium industries. Her areas of interest include small and medium industries, industrial engineering, quality and manufacturing management.

Haresh Kumar Shanmugam completed his Bachelor's of Degree in Mechatronics Engineering from University of Selangor in year 2012 and completed his masters degree from UPM in 2017. Haresh has been attached to Burn-in service industry for past 5 years in process field. He was given a role to manage 80% of the process in the factory from front end to backend process. He has done many projects and all the projects was documented in Quality System.