



Counter Based Electrode Cleaning to Avoid Sparking Issue that Causes Delay (Speed Loss)

Final Project

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2025**

Statement of Authenticity of Final Project

I, the undersigned, certify that the contents of part or all of my Final Project entitled: "Counter Based Electrode Cleaning to Avoid Sparking Issue that Causes Delay (Speed Loss)" is my **own work, completed without the use of materials that are not permitted**, and is **not the work of other parties which I acknowledge as my own work**. All references cited or referred to have been written in full in the bibliography. If it turns out that my statement is not true, I am willing to accept sanctions in accordance with applicable regulations.

Batam, 04 July 2025



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Approval sheet

The Final Project is structured to fulfill one of the requirements for
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Counter Based Electrode Cleaning to Avoid Sparking Issue that Causes Delay (Speed Loss)

Abstract

Wire Bond is one of the most important processes in the IC manufacturing stage, this process aims to create an electrical connection between the die and the lead frame using a thin wire, one of the critical steps in this process is the Electronic Flame Off (EFO). Electrode Flame-Off (EFO) is a controlled process where the thin wire on the capillary (Tail) is heated using high current pulses that generate intense heat through the Torch Electrode. These pulses generate intense heat through the Torch Electrode, which melts the tip of the Tail. This melt form a small ball of molten metal called the Free Air Ball (FAB). The high current pulse applied to the wire causes the wire tip to melt and then solidify, creating a buildup. This buildup leads to spark faults/failures, which results in decreased UPH (units per hour) and reduced OEE (overall equipment effectiveness) due to high speed loss, the current cleaning method requires removing the Torch Electrode from the Nozzle, the Torch Electrode is only cleaned when there are severe sparking problems. When that happens, there's a lot of buildup on the Torch Electrode, which makes cleaning take longer. Sometimes, the buildup hardens so much that it can damage the Torch Electrode when it is removed. In such cases, the Torch Electrode needs to be replaced. The author used the PDCA approach method to test a cleaning method that was expected to be efficient. The author also monitored the methods to determine the best frequency. This led to the decision to clean without removing the Troch Electrode from the Nozzle follow the set time. By implementing this project, it is hoped that an efficient Torch Electrode cleaning method and proper frequency definition can prevent Spark problems.

Keywords: Electrode, OEE, PDCA, Spark, UPH, Wire Bond

Foreword

Alhamdulillah, all praise and gratitude be to Allah SWT, the Most Merciful and Most Gracious, for His endless blessings which have enabled the completion of this final project entitled "Counter-Based Electrode Cleaning to Avoid Sparking Issue That Causes Delay (Speed Loss)" as partial fulfillment of the requirements for the Manufacturing Electronics Engineering program at Politeknik Negeri Batam.

This project addresses electrode sparking issues that lead to speed loss in manufacturing processes. The execution proved particularly challenging due to the extensive validation period required to verify the proposed solution. These obstacles provided valuable lessons in perseverance, problem-solving, and engineering precision. The author expresses deepest gratitude to:

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The author acknowledges this work has room for improvement. Constructive feedback is sincerely welcomed. May this research contribute to manufacturing electronics and inspire future innovations.

Batam, 04 July 2025



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Counter Based Electrode Cleaning to Avoid Sparking Issue Causes Delay (Speed Loss)

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Abstract— Wire Bonding is a critical step in IC manufacturing, creating an electrical connection between the die and lead frame using a thin wire. A key phase in this process is the Electronic Flame-Off (EFO), where high current pulses generate heat through the Torch Electrode to form a Free Air Ball (FAB). However, repeated high current pulses can cause metal buildup on the Torch Electrode, leading to sparking problems, decreased Units Per Hour (UPH), and decreased Overall Equipment Effectiveness (OEE). The current cleaning method is reactive and involves removing the Torch Electrode, which risks damage and longer downtime. This project applied the Plan-Do-Check-Act (PDCA) method to develop a preventive cleaning process without removing the Torch Electrode. By determining the optimal cleaning frequency, this project aims to minimize sparking errors and improve production efficiency.

Keywords: Electrode, OEE, PDCA, Sparks, UPH, Wire Bonding

I. INTRODUCTION

Infineon Technologies is a German semiconductor company. It was founded on April 1, 1999. Infineon is a global leader in the semiconductor industry. It has four main divisions: automotive, power management, energy-saving technologies, and the Internet of Things (IoT). Infineon has manufacturing facilities for making wafers and testing and assembling integrated circuits (IC) [1]. These facilities are located at 15 different places in various countries. One of these backend facilities is PT Infineon Batam Technologies (IFBT) in Batam, Indonesia. There, IC are made through Front of Line (FOL) stages such as wafer mount, wafer saw, die attach, wire bond, and A2 coating. Then, the IC go through End of Line (EOL) testing and MSP [2].

Wire Bond is one of the most important processes in the FOL Backend process stages, where its quality and efficiency greatly affect productivity, this process aims to create an electrical connection between the die and the lead frame using thin wires [2]. This process is crucial in microelectronics and semiconductor manufacturing. There are three common types of binding wire materials used in wire bonding: Aluminum (Al), Copper (Cu), and Gold (Au). Each material has its own advantages and disadvantages, such as conductivity, strength, and cost. For instance, gold wires are commonly used due to their high conductivity and resistance to corrosion, while aluminum wires are often used for their lower cost and lighter

weight. There are two main types of wire bonding techniques: Ball Bonding and Wedge Bonding. Ball bonding involves creating a small ball at the end of the wire, which is then bonded to the die and the main frame. Wedge bonding, on the other hand, involves using a wedge-shaped tool to bond the wire to the die and the lead frame. It requires precise control over the wire bonding process to ensure reliable and consistent connections. Some of the key factors that affect wire bonding include wire material properties, bonding temperature, bonding pressure, and ultrasonic energy [3].

One of the crucial steps of Wire Bonding process is the Electronic Flame- Off (EFO), EFO is a controlled process where a thin wire on capillary (Tail) is carefully heated using a high-current pulse that generates intense heat thru Torch Electrode. This heat melts the end of Tail forming a small molten ball. Once the current pulse is removed from Torch Electrode, the molten metal rapidly cools and solidifies shaping it into a spherical form known as the Free Air Ball (FAB). This high-current pulses applied to the wire caused localized melting and solidification which allows material from the wire to transfer onto Torch e Electrode tip creating a buildup [4].

The UTC5000NeoCu machine is a type of wire bonding machine specifically designed to cater to the needs of the semiconductor and microelectronic industries. This machine is utilized to perform wire bonding with a high level of precision, which is a crucial step in the manufacture of electronic devices such as chips and power modules. One of the key advantages of NeoCu's UTC5000 machine is its multi- material capabilities, which support the use of gold (Au), copper (Cu), and other metals, providing great flexibility in various applications. With advanced technology, the machine is capable of achieving high levels of precision in every wire bond, making it an excellent choice for production needs that demand high accuracy. Additionally, the machine is designed for operational efficiency, featuring low energy consumption, making it suitable for continuous mass production. Equipped with a modern control system based on algorithmic software, the UTC5000 NeoCu enables flexible and adaptive parameter settings as required [5].

However, this process is not without its problems. One of the main issues is the accumulation of oxidation on the electrodes due to constant sparking during machine operation, this build-up often leads to spark failure, resulting

in a decrease in hourly output and overall equipment efficiency (OEE) as productivity drops significantly. Current cleaning methods require removing the electrode from the nozzle, which is time consuming and risks damage - especially if the deposits have hardened, this leads to increased maintenance costs due to frequent electrode replacement, this contamination disrupts the bonding process and requires immediate cleaning. If the electrodes are not too dirty, they can be cleaned on the spot with cotton wool and alcohol. However, if the electrodes are heavily contaminated, they must be removed from the machine for more thorough cleaning.

This project aims to solve the problem of speed loss in the wire joining process caused by material buildup on the Torch Electrode due to repeated burning during Electronic Flame Off (EFO) by using the Plan-Do-Check-Act (PDCA) method. The solution is to develop an effective cleaning method without the need to remove the Torch Electrode from the nozzle and determine the optimal cleaning frequency based on monitoring the number of sparks and electrode condition. This method is expected to reduce production downtime, maintain Torch Electrode performance, minimize damage and replacement, and be easily implemented without special tools. The scope of this project is limited to the EFO process on the UTC5K platform, without major modifications to the equipment, so the results may not be representative of other wire bonding systems.

II. METHOD

A. Designs

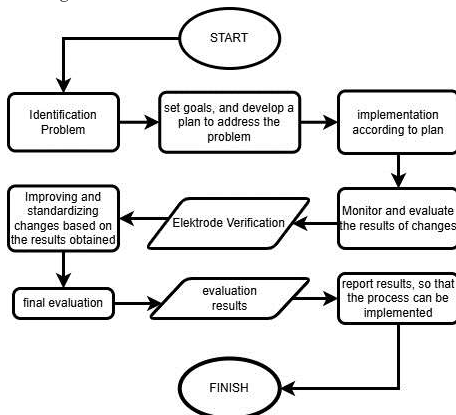


Figure 1. Flowchart Project

Figure 1 shows the workflow of the PDCA method, which has been broken down into several stages. The PDCA cycle is a structured method for implementing and evaluating changes in a process. This method is particularly useful in this project because it provides a systematic framework for testing and refining cleaning methods and frequencies. This flowchart shows the systematic steps to solving a problem, starting with

problem identification. Then, goals are defined, a plan to address the problem is developed, and the plan is implemented. Next, the results of the changes are monitored and evaluated. A results report is generated to ensure the process is applicable, then an evaluation of the results is performed. If necessary, the electrodes are verified and the changes are improved or standardized based on the results. The process concludes with a final evaluation to thoroughly resolve the issue.

The PDCA cycle, also known as Deming cycle or Shewhart cycle, is a lean manufacturing methodology that was developed in 1930, when there was no more exclusive products and a more quality management focusing on competitiveness raised in the global market. today, is one of the most worldwide known and applied. In its beginnings, the PDCA cycle was used as a tool for the quality control of products. However, rapidly, it was highlighted as a method that allowed developing improvements in process at organizational level. Currently, the PDCA cycle is characterized by its continuous improvement approach and it is recognized as a logic program that allows improving the activities [6].

Several authors state that the PDCA cycle is much more than a simple lean manufacturing tool. Instead, they mention that the PDCA cycle is a philosophy of continuous processes improvement introduced in the organizational culture of companies that is focused in the continuous learning and the knowledge creation. The following rows describe the four stages of the PDCA cycle:

- a. Plan: In this phase improvements opportunities are identified, and later priorities are assigned to them. Likewise, the current situation of the process to be analyzed is defined by means of consistent data, the problem causes are determined, and possible solutions are proposed to solve it.
- b. Do: In this phase, it is intended to implement the action plan, select and document the information. Also, unexpected events, learned lessons and the acquired knowledge must be considered.
- c. Check: In this step, the results of the actions implemented in the before step are analyzed. A before-and-after comparison is performed verifying whether there were improvements and if the established objectives were achieved. To this, several graphic support tools, such as Pareto chart or Ishikawa diagram, can be used.
- d. Act: This phase consists in developing methods aimed to standardize the improvements (in the case objectives had been reached). In addition, the proof is repeated to obtain new data and re-test the improvement (only if data are insufficient or circumstances had changed), or the project is abandoned and a new one is begun from the first stage (in the case the implemented actions did not yield effective improvements) [6][7].

figure 2 shows an overview of the PDCA method workflow



Figure 2. PDCA Cycle

Using the PDCA method, this project aims to systematically develop and evaluate efficient cleaning methods and frequencies to eliminate splash errors and improve the OEE of the wire bonding process.

B. Indicator

Overall Equipment Effectiveness (OEE) is a method for measuring effectiveness and efficiency in processes that helps to see and measure problems so that a standardized method can be set up to measure progress and to improve. Overall equipment effectiveness (OEE) is one of the best metrics to identify losses, measure progress, and improve productivity of manufacturing equipment by eliminating waste. In essence OEE is a measure that identifies equipment potential, OEE identifies and tracks losses, OEE identifies opportunities. The main objectives of OEE are to increase productivity, lower costs, increase awareness of equipment productivity needs, increase equipment life [8]. figure 3 shows an overview of how OEE calculates.

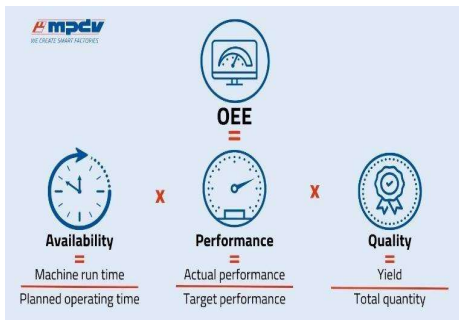


Figure 3. OEE (Overall Equipment Effectiveness)

In this project, OEE is a critical indicator as it directly affects the production efficiency and quality of the wire bonding process. By optimizing the cleaning method and

frequency, we can significantly improve the Overall Equipment Efficiency (OEE). This can be achieved by reducing downtime, increasing production speed and minimizing defects. Thus, the production process can become more efficient and effective.

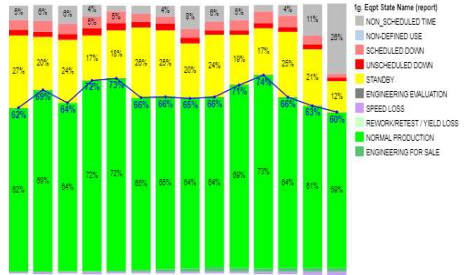


Figure 4. OEE All Machine Utc5000

Figure 4 is an example of the OEE data to be used. The above is an example of OEE whose data has been processed and displayed directly through a web interface, allowing us to monitor equipment performance better and faster.

C. Data verification

The data below will support the project process, both in monitoring and implementation, allowing us to achieve project goals more effectively.

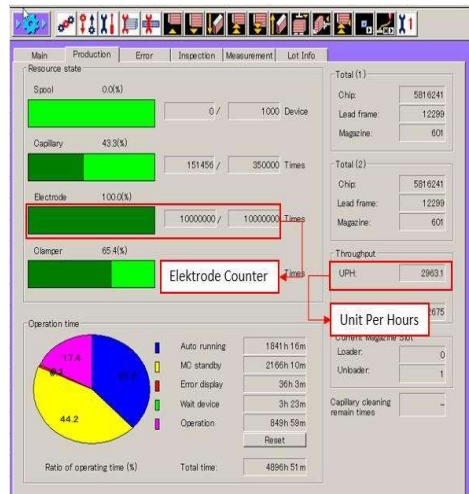


Figure 5. Production Menu Application Wbs UTC-5000

Figure 5 is a view of the machine that can be used to monitor sparking numbers and units per hour. To control or monitor how much sparking and how many units are produced in an hour, can use 2 indication features namely electrode counter and Unit Per Hour (UPH).

a. Electrode counter

The counter electrode in the Wire Bond Sinkawa (WBS) application functions as a counter to calculate the amount of sparking that has been done by the machine, thus allowing us to monitor the performance of the machine and perform the necessary maintenance.

b. Unit Per Hour (UPH)

UPH in the production menu of the WBS application displays the number of units of products that can be produced by the machine in one hour, based on the production speed at that time, allowing us to identify speed loss and monitor whether the machine has reached the set production target.

D. Speed Loss Trend

Below is the average OEE data of the 4 engines to be monitored, namely WBS251, WBS252, WBS253, WBS254. This data shows the OEE trend for the 4 engines, starting from the last 3 months, the last 5 weeks, and the last 14 days. This data was taken on December 23, 2024.

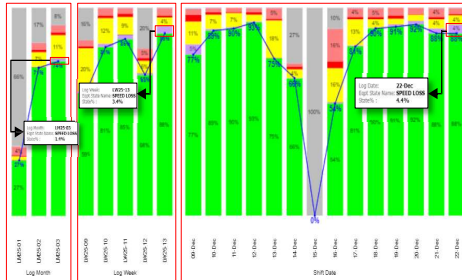


Figure 6. OEE Trend for Machine Monitoring

Figure 6, is the pre-implementation data, which has been taken as an indicator of the success of this project. The data above shows that the Speed Loss experienced by the 4 engines has increased, starting from a monthly trend that increased by 1.4%, a weekly trend that increased by 3.4%, and a daily trend that increased by 4.4%.

E. Tool and material

During the implementation of this project, various tools and materials will be used to ensure the success of each stage, especially in the process of cleaning dirty electrodes. This process is carefully carried out using the right materials and techniques to maintain the cleanliness, durability and performance of the electrodes, thus supporting the optimization of overall project outcomes. Table 1. below are the tools that will be used in this project.

TABLE 1.
TOOLS AND MATERIALS TO BE USED IN THE PROJECT

No	Name	Quantity	function
1	sefly clothes cotton buds/ESD clothes	1 set	Protect the body from chemicals, and protect the unit from ESD interference
2	hand glove	1 set	Protect hands from chemicals
1	cotton buds	2 pcs	Serves to reach the electrode area that is dirty due to oxidation
2	IPA	1 btl	Serves as a cleaning fluid to reduce oxidation on electrodes
3	Tweezers	1 pcs	Serves as a tool to lift the cavilery to perform electrode cleaning
4	cloth soaked	1 pcs	Serves to clean cutton buds to ensure areas that still need cleaning
5	Tool remove cavilery	1 pcs	Special tool for cavilery removal
6	Jig cavilery	1 pcs	Serves as an alignment for cavilery reattachment
7	Laptop	1 pcs	Making to report

F. Cleaning Methode

Electrodes are critical components in projects that require regular maintenance to maintain optimal performance. Two methods of electrode cleaning will be described: the previous cleaning method and the new cleaning method.

1. Previous Cleaning Method

Precleaning is done when a sparking issue has occurred, usually because of too much buildup on the electrodes. Cleaning them directly under these conditions often does not get the best results, so a more in-depth process is needed.

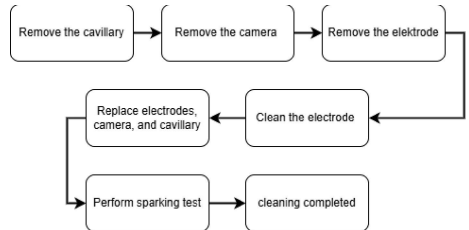


Figure 7. Flow Previous Cleaning Method

The first step is to remove the cavilery using a cavilery removal tool so that it does not block the electrode removal. After that, the camera is removed by loosening the locking bolts and manually removing it to provide more working space. Next, the electrodes are removed by loosening the locking bolts and carefully removing them. The removed electrodes are cleaned using a cloth soaked in alcohol until all dirt is completely removed. Then, the electrodes are reinstalled, followed by the camera and cavilery installation

in sequence. Finally, sparking tests are conducted on the dummy unit to ensure that the electrodes are functioning properly. After several tests, the machine is ready for production.

2. New Cleaning Method

After the project was implemented, cleaning was done when the sparks had reached a predetermined number. This was because the build-up on the electrodes was not yet too severe.

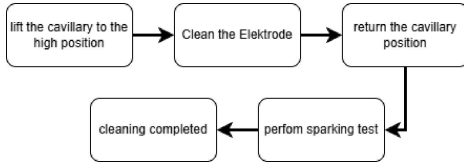


Figure 8. Flow New Cleaning Method

So the cleaning steps were simpler: first, the cavillary was moved to the highest position of the bond so that it could be cleaned. Then, the electrodes are cleaned using a cotton swab soaked in alcohol, which works better, as the build-up is minimal. Then, the cavillary is returned to its original position, and finally, a spark test is performed to heat the electrode. Since the position of the electrodes and cavilers do not change during this process, this cleaning method does not require a dummy unit for testing and can be directly applied to a good unit.

III. RESULT AND DISCUSSION

Table 2 shows the list of machines that have been monitored as well as the implementation of the improvement cleaning method. There are a total of 11 machines with WBS codes, all of which have completed the process on the same date, December 27, 2024. The “done” status indicates that the implementation has been completed and the data from each machine is ready for further analysis.

TABLE 2.
SOME MACHINES TO BE MONITORED

Machine	Status	Date
WBS137	done	27/12/2024
WBS155	done	27/12/2024
WBS156	done	27/12/2024
WBS157	done	27/12/2024
WBS164	done	27/12/2024
WBS176	done	27/12/2024
WBS196	done	27/12/2024
WBS200	done	27/12/2024
WBS201	done	27/12/2024
WBS202	done	27/12/2024

Figure 9. shows the speedloss data before and after implementation, starting from the end of August 2024 to the end of April 2025. This figure can be a reference to validate the clearance method, whether the clearance method is effective or needs better improvisation, in this graph the lower the value, the better the results.

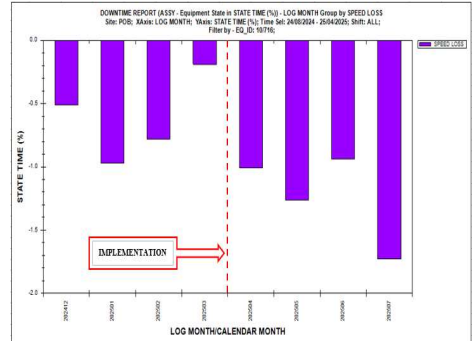


Figure 9. Machine Data Monitored From (24/08/2024-25/04/2025)

The graph above shows a trend of reducing the state time (%) that is related to the speed loss of the equipment after the implementation of the improvement project. During the pre-implementation period, which lasted from the end of August to the end of December, the equipment performance still showed instability. During this period, the highest state time value was recorded at -0.97%, while the lowest value reached -0.19%. The range of values reflects the significant variation in performance, which could be due to a variety of factors, including variations in device type or production process conditions. However, after the implementation of the project, which started in early January until the end of April, there was a notable positive change. The highest state time value after implementation was recorded to decrease further to -1.73%, while the lowest value increased to 0.94%. This further decrease in state time indicates that speed loss was successfully suppressed, and the equipment can operate with higher and more stable efficiency. The comparing of pre- and post-implementation data provides a strong validation that the project had a significant impact on improving production performance. In other words, the success of the project is not only reflected in the reduction of time losses, but also in the greater stability of performance in the post-implementation period. This result reinforces the belief that the improvement approach is well-targeted and capable of adding value to the overall operational process.

IV. CONCLUSION

This study has successfully demonstrated the implementation of an optimized torch electrode cleaning method for wire bonding processes, utilizing the PDCA (Plan-Do-Check-Act) approach to minimize speed loss caused by electrode buildup. The proposed solution, which introduces a scheduled, non-invasive cleaning process, effectively reduces equipment downtime and enhances Overall Equipment Effectiveness (OEE) without requiring structural modifications or additional tools. The improvement was validated across multiple machines, with data indicating a significant recovery in performance and a consistent reduction in sparking-related delays. This research contributes to the field of semiconductor manufacturing by offering a practical yet impactful method for maintenance optimization. However, the scope of implementation is currently limited to the UTC5000 platform. Future work may explore the integration of predictive maintenance technologies or evaluate the applicability of this method across diverse wire bonding systems.

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