Six Sigma Approach to Improve Stripping Quality of Automotive Electronics Component – a case study

Noraini Mohd Razali, Siti Murni Mohamad Kadri and Toh Con Ee
Faculty of Manufacturing Engineering, Universiti Malaysia Pahang, Malaysia

noraininmr@gmail.com, sitimurnikadri0@gmail.com, coneetoh@gmail.com

Abstract. Lacking of problem solving skill techniques and cooperation between support groups are the two obstacles that always been faced in actual production line. Inadequate detail analysis and inappropriate technique in solving the problem may cause the repeating issues which may give impact to the organization performance. This study utilizes a well-structured six sigma DMAIC with combination of other problem solving tools to solve product quality problem in manufacturing of automotive electronics component. The study is concentrated at the stripping process, a critical process steps with highest rejection rate that contribute to the scrap and rework performance. The detail analysis is conducted in the analysis phase to identify the actual root cause of the problem. Then several improvement activities are implemented and the results show that the rejection rate due to stripping defect decrease tremendously and the process capability index improved from 0.75 to 1.67. This results prove that the six sigma approach used to tackle the quality problem is substantially effective.

1. Introduction
Six Sigma is an organized methodology that concentrate continuous improvement to minimize the variation and defects of the product. Six Sigma was first developed by Motorola in 1987 and later effectively tested by GE Corp. in 1990. It targeted an invasive goal of 3.4 parts per million (ppm) defects, means that the process is near to “zero defects” or 99.9997% perfect [1]. In other words Six Sigma is a data driven, disciplined approach and methodology. It is based on eliminating the defects in any process. Lo et.al [2] define Six Sigma approach as a method that follow the theories and steps to determine the shifting of standard deviation in between the mean and specification limit and then reduce the defects quantity for a specific process. It is an effective method to determine which part of the process is the most important and determine the weakness of the process [3]. The method offer computable indicators and sufficient data for analysis and became the most outstanding management method for quality improvement [2].

Several studies have been done by the previous researchers on Six Sigma approach applied to manufacturing industries. Valles et al. [4] for instance conducted six sigma project at a semiconductor company, which eliminate 1.88% of nonconforming units. They claimed that the organization management was very supportive and encouraging with the project team and conclude that Six Sigma implementation can be helpful in reducing the nonconforming units or improving the organization quality and personal development. The improvement was a reduction in the electrical failures of around 50%. Gijoa et al. [5] explored how a manufacturing process can use a systematic methodology to move towards world-class quality level. The application of the Six Sigma methodology resulted in reduction of defects in the fine grinding process from 16.6 to 1.19%. The DMAIC methodology had a significant financial impact on the profitability of the company in terms of reduction in scrap cost, man-hour saving.
on rework and increased output. A saving of approximately US$2.4 million per annum was reported from their project. Jirasukprasert et al. [6] demonstrated the empirical application of Six Sigma and DMAIC to reduce product defects within a rubber gloves manufacturing organization. The study followed the DMAIC methodology to investigate defects, root causes and provide a solution to reduce these defects. A reduction of about 50% in the “leaking” gloves defect was achieved, which helped the organization studied to reduce its defects per million opportunities (DPMO) from 195,095 to 83,750 and thus improve its Sigma level from 2.4 to 2.9. On the other hand Rohit Chandel and Santosh Kumar [7] focused on analysing and elimination of in-process variations causing rejection and rework at different stages of production by using DMAIC approach. By implementing DMAIC technique the rejection rate and rework rate was reduced from 8.79 % to 5.30 % and 12.8 % to 8.2 %, respectively. Also, a significant enhancement in sigma level was obtained from 2.85 to 3.13.

2. Background of the study
This paper presents a case study conducted at one of electronics manufacturing company located in the east coast of Malaysia. The company produce various electronics component for automotive application such as inductor, common mode chock, transformer and others. The manufacturing of components consist of many process steps. The main focus of this study is to produce a good quality at manual mechanical stripping process. The purpose of this stripping process is to remove insulation around wire. Insulation must be removed properly and must not damage the wire to ensure the better connection of wire with terminal. The stripping of the insulation from copper wire is similar to a milling process, but the stripping of insulation is done by rotational tools. The materials needed to undergo stripping process are stripping machine, rotating tool with appropriate wire size and copper wire. The manual stripping process requires experience operators to proceed the operation. All the operators have to be trained before enter the operation in production. The rotating bullet is initially covers with the wires until the whole length of wire is stripped inside the rotating bullet. The operator have to make sure that the wire is always straight when feeding into the bullet, and hitting the centre to feed wire tip to the bullet. At this time, the stripping process created a significant force and the wire is pushed into the bullet. The rest of the wire is usually stay at the end of the stripping part. For the thinner or longer wire, it is required to maintain at the middle of the stripping wire to prevent the deformation of the inserting force.

Based from the process performance history, defects in stripping process accounted for 58.2% of the whole manufacturing process. The defects include bent wire, twist wire, line mark on wire, broken wire, reduced diameter on wire, improper strip and corkscrew on wire. Because of manual operation of stripping process, the defects occur might be due to skills of the operators, tools problem or improper cleaning method at the stripping machine. Figure 1 shows the acceptable wire where it should be as straight as possible and does not peel off, while Figure 2 shows examples of rejected wire in which the wire is ripped off or turned off.

![Figure 1. Acceptable wire](image1.png)  ![Figure 2. Rejected wire](image2.png)

3. Methodology
The improvement of the stripping process is conducted according to Six Sigma DMAIC steps. DMAIC provides a schedule for project members to identify the problems, solve the problems and make improvement to the process. The objective of the DMAIC method is to ensure the project team follow the steps given to prevent the project straight to the conclusions without searching for more adequate alternative solutions to the related problem. In every phase of the method, several quality tools are used
to obtain particular result for each phase [8]. This section discussed in details about the method used to reduce the defects in stripping process of electronic components. It include five steps which is Define, Measure, Analyse, Improve and Control.

3.1. Define Phase
In define phase, the project team start with problem identification. Understanding on the present situation is the important factor for setting the appropriate improvement target. In addition, boundary of the project and team members’ responsibility need to be defined clearly. Any related information or data collection such as customer complaint, machine downtime, scrap and rework or process inefficiency can be used to identify the problem statement. There are several common quality tools can be used in this Define Phase such as:

- SIPOC
- Pareto chart
- Process mapping
- CTQ characteristics
- 5W and 1H

In this study, Pareto chart as depicted in Figure 3 was used to prioritize and to identify the major contribution to the problem. By applying Pareto principle also known as the 80/20 rule, it will help to show the most important problem to be solved.

![Figure 3. Pareto chart of scrap & rework](image)

3.2. Measure Phase
In the Measure Phase, related data collection was evaluated in order to understand the existing process performance. Understanding the process variation of existing system is the important step for the improvement project in order to achieve the desired outputs. There are several common tools can be used in Measure phase such as:

- Failure analysis
- Process capability study
- Measurement system analysis
- Control chart
- Process analysis

This step will be done by first mapping the overall process and all related parameters. In order to evaluate the present process capability a set of data collection must be done accordingly. The performance of measurement system analysis need to be evaluated to ensure the data is valid and accurate. The important step for improvement project of stripping process is evaluation on present situation. Result from this
step will be a guideline to identify process variation and to support the understanding of existing system. This will be an important input to the project team to setup a goal of improvement to achieve the desired outputs. Figure 4a shows measurement system analysis while Figure 4b shows a cause and effect diagram for mechanical defect.

Based from the measurement system analysis study it can be conclude that the existing measurement system for checking wire diameter after stripping process is valid and accurate, in which the variability from repeatability and reproducibility is very small. Brainstorming with involvement of multidisciplinary unit has been done to collect all potential root causes. The cause and effect diagram was used in order to identify the real root causes of the defect by mechanical treatment during stripping process. All four elements which is man, machine, material and method were evaluated comprehensively by the team.

3.3. Analysis Phase
In this phase all related analysis or experiment is conducted in order to validate the potential root causes. Result of the analysis will be used to identify the actual root cause of the problem statement. Besides that, this phase can also be used to determine the best setting parameters on the required improvement plan where it is able to determine which inputs parameters are the most important factor for the overall performance. There are several common tools can be used in the Analysis phase:

- Hypothesis Testing.
- Multi-Variance Analysis.
- Cycle-Time Analysis.
- Regression Analysis
- Brainstorming
- Analysis of variance (ANOVA)

In Analysis phase, the current existing system has been analysed to understand the process performance. Data for wire diameter measurement after stripping process were collected and analysed using Minitab Software. The focus in this phase is on the root cause that can be controlled with a reasonable effort. The test results show that a very short insertion speed increases the risk of poor stripping results. It can be conclude that setting the insertion speed slightly slower than the maximum possible speed will give a balance production quality. As a conclusion, bent wire with a diameter greater than 4 mm cannot be removed by manual straightening in a way that they will not influence the stripping process. The straightening of bent wire with diameter greater than 4 mm has a positive effect in stripping process. Therefore, the target is to keep the wires as straight as possible during production process.
3.4. Improve Phase

Implementation of corrective action is done by selecting the actual root cause of the problem. The validation is done through design of experiment (DOE). After the solution has been validated, the critical factor will be controlled in a way to ensure the effectiveness of corrective action. There are several common tools can be used in this Improve phase:

- Taguchi Method.
- Simulation Method.
- Design of Experiments (DOE).

As an improvement strategy, the team established a prototype for a new stripping machine. A prototype of new stripping machine has been designed with function that is able to strip the bent wire. The machine also has a platform to support the handling of unit during feeding the wire lead-out into bullet stripping. Factors such as insertion angle and feeding speed can be eliminated by this element. Stripping bullet is the main element on this stripping machine. In order, to produce a high quality of mechanical treatment by stripping process a special stripping bullet with rotary spindle blade to grip and remove wire insulation is implemented. The current machine requires the operator to put the jigs on the stripping platform and insert the wire to the stripping point where as for a new design machine, the operator does not need to push the wire to the bullet during wire insertion, the rotation bullet will gently pull the wire inside. This can avoid the wire being twisted and stuck in the bullet of the machine. The advantage of the new machine is that no force needed to push the wire into the stripping blade, thus eliminate ‘reduced diameter’ and ‘improper strip’ defects that caused by excess materials and wear blades. Figure 5 shows the design of a new and old stripping machine.

![New stripping machine vs Old stripping machine](image)

**Figure 5.** Comparison between new stripping machine and old stripping machine

Validation process is conducted to ensure the best parameter setting for a new machine. In this validation process the 300 pieces sample was run at the new machine using 500 rpm and 3.0 feeding speed. Figure 6a shows the process capability study of wire diameter using current machine, which is before improvement made while Figure 6b shows the process capability study of wire diameter using a new machine. It can be seen that the variability of the process has reduced and the Cpk value has increased from 0.75 to 1.67. Thus, the process with new machine is more capable than the old machine.
3.5. Control Phase

The main objective of this Control phase is to ensure the important aspect is practiced in place. All the improvement plans with introduction of the new setup for man, machine, method and material become part of the normal task and must be maintained all the time. There are several common tools that can be used in Control phase such as:

- Mistake proofing.
- Lean manufacturing.
- Work standardization.
- Preventive maintenance.
- Statistical Process Control (SPC)

In this phase performance of new stripping machine need to be reviewed and monitored. The purpose of monitoring is to understand the positive and negative effect of the improvement project to the manufacturing system. Observation of process performance after implementation of improvement is under process owner responsibility. The data collection was plotted into control chart. In order to maintain the performance of the process, the process should be supervised by control charts over time so that the wire diameter variation can be controlled and meets customer requirements. Figure 7 shows the Xbar and R chart of wire diameter after improvement. Based on both charts, it can be seen that the process are falling within the specification limits. It can be conclude that the process is stable and in control. All the points are within the control limit, and the variation has been reduced. Finally, this project is documented, continuously update and kept into the company directory.
4. Conclusion and Recommendation
Six sigma approach is a method which aim for continuous improvement to reduce defects in manufacturing process. In this study, implementation of Six Sigma approach with DMAIC steps is carried out to improve the quality of the product and the performance of stripping process. The critical process parameter for this stripping process has been determined. The team agreed to select the wire diameter as a critical control parameters. After implementing the new stripping machine to the stripping process, the process capability index for wire diameter is improved from 0.95 to 1.67. Implementation of control chart to illustrate the sampling result from in-process quality control gives good result for real time feedback. The project involved multidisciplinary approach and the ideas are generated by the team members from various section. There are several improvement opportunities were identified. However selection on the best idea was based on the time limitation of these project. At the end of this project, the team had gain knowledge and better understanding on problem solving technique. As a moving forward, all project team members will be a team leader to establish and setup their own project team to solve another quality problem in future. After implementation of this project, other improvement opportunities can be considered for better performance. This include optimization on winding until cutting process, and optimization of the new stripping machine with fixture to automatically measure the wire diameter after stripping process. All this potential ideas could contribute to better process capability performance.

Acknowledgments
This research is fully funded by the Faculty of Manufacturing Engineering, Universiti Malaysia Pahang under the Grant number RDU170390.

References
[1] Schroeder, R. G., Linderman, K., Liedtke, C., & Choo, A. S. Six Sigma: Definition and underlying theory. Journal of Operations Management, 26(4), 536–554, 2008
[2] Lo, W. C., Tsai, K. M., & Hsieh, C. Y., Six Sigma approach to improve surface precision of optical lenses in the injection-molding process. International Journal of Advanced Manufacturing Technology, 41(9–10), 885–896, 2009
[3] Sokovic, M., Six Sigma process improvements in automotive parts production. Journal of Achievements in Materials and Manufacturing Engineering, 19(1), 96–102, 2006
[4] Adan Valles, Jaime Sanchez, Salvador Noriega, and Berenice Gómez Nuñez, Implementation of Six Sigma in a Manufacturing Process: A Case Study, International Journal of Industrial Engineering, 16(3), 171-181, 2009
[5] E. V.Gijoa, Johny Scaria and Jiju Antony, Application of Six Sigma Methodology to Reduce Defects of a Grinding Process, Quality and Reliability Engineering International, John Wiley & Sons, Ltd., 2011
[6] Ploytip Jirasukprasert, Jose Arturo Garza-Reyes, Horacio Soriano-Meier, Luis Rocha-Lona, A Case Study of Defects Reduction in a Rubber Gloves Manufacturing Process by Applying Six Sigma Principles and DMAIC Problem Solving Methodology, Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management Istanbul, Turkey, July 3 − 6, 2012
[7] Rohit Chandel, Santosh Kumar, Productivity Enhancement Using DMAIC Approach: A Case Study, International Journal of Enhanced Research in Science, Technology & Engineering ISSN: 2319-7463, Vol. 5 Issue 1, January-2016
[8] Johannsen, F., Leist, S., Johannsen, F., & Leist, S., A Six Sigma approach for integrated solutions, 2009