ELIMINATION OF LOW INSULATION DEFECT ON WIRING HARNESS IN NISSAN 1–ALTIMA USING SIX SIGMA METHODOLOGY AT YAZAKI-TORRES MANUFACTURING INC.

[1]R. Malabuyoc, [1]K.A. Salle, [1]D.R. San Jose, and [1]D.R. Sancebuche, [2]Engr. R.J. Curbano
[1]Undergraduate Student, Industrial Engineering Department
[2]Industrial Engineering Faculty, Lyceum of the Philippines – Laguna

ABSTRACT

Yazaki-Torres Manufacturing Inc. is one of the Philippines' prime automotive wiring harness manufacturer and supplier catering to well-known foreign brands such as Nissan, Ford and Mitsubishi. An automotive wiring harness goes through various processes from cutting to final inspection. Recently, the researchers found out that the processes produced defects that has a relevant effect in the quality, cost, customer satisfaction and consumers. Six Sigma is an effective approach for defect reduction and elimination. Moreover, Six Sigma aims to ensure process improvement and consistent output in manufacturing through the use of its known approach such as Define, Measure, Analyze, Improve and Control, well-known as the DMAIC Methodology. To ensure validity and reliability of the study, the researchers collaborated with a team designated by the company. The researchers focused on the Low Insulation defect in the crimping process of Nissan-1 Altima. It was found out that the current low insulation defect has 7 defects per million opportunities (DPMO). The researchers found out that such defect occurs when the strip is out of standard. Joint efforts with the team, the researchers were able to come up with corrective and preventive action plans on how to eliminate Low Insulation defect. The improvement done by the team was successfully implemented and resulted to 100% decrease in the defect rate, totally eliminating the Low Insulation defect in the crimping process. From the Cp of 1.75 to 2.63, the overall capability was also improved from Pp 1.50 to 2.24. A maintenance procedure and schedule was carefully constructed which contains the preventive actions and following observation for continuous improvement. More so, work procedure was strictly disseminated all throughout the production line so that the workers are well-informed about the recent changes made.

Key words: *Crimping, Low Insulation Defect, Six Sigma, DMAIC, DPMO, Capability*

I. INTRODUCTION

In recent years, companies have begun using Six Sigma Methodology to reduce errors, excessive cycle times, inefficient processes, and cost overruns related to financial reporting systems. To achieve Six Sigma quality in terms of internal defects, a process must produce no more than 3.4 defects per million opportunities (DPMO).

Six Sigma is a set of techniques developed and used to ensure process improvement and consistent output in manufacturing. It is a data-driven approach designed to eliminate defects in any process. Process improvement and variation reduction can be achieved with the implementation of Six Sigma, its main objective is to implement a measurement-based strategy that will give emphasis to process improvement [1].

Six Sigma is a highly disciplined process that helps us focus on developing and delivering near-perfect products and services. It is a statistical term that measures how far a given process deviates from perfection. The central idea behind Six Sigma is that if you can measure how many "defects" you have in a process, you can systematically figure out how to eliminate them and get as close to "zero defects" as possible [1].

The Six-Sigma methodology is designed to provide a systematic way of applying statistical tools in the context of process improvements in any organization. This is done by the application of the DMAIC methodology. The five stages of the present Six Sigma comprise the Define, Measure, Analyze, Improve and Control (DMAIC) [8].

DMAIC methodology is mainly used to identify, analyze and formulate solutions to problems in the processes [5]. It is usually applicable to a problem which has a current, steady-state process, product or services. It provides solutions to different problems such as nonconformity, defects or flaws, high cost or time, and deterioration [4].

Defects are imperfections that can decrease a product's value or worth. Eliminating defects can also provide satisfaction to the customers as their expectations and requirements can be easily met by producing the best quality products.
Yazaki-Torres Manufacturing Incorporated is the largest wiring harness manufacturer in the Philippines, and likewise the Top Exporter of Automotive Parts. With their continuing success in the industry and in expectation of more domestic demand for automobiles, Yazaki-Torres is looking forward to continuing and enhancing their operations in the Philippines.

There was an attempt to implement Six Sigma but due to its difficulty, YTMI Inc. was not able to finish it. As a counter measure, its tools alone are being used. This was supposedly used to eliminate waste in all of the work processes. As a result, this gives an improvement in quality, enhances customer satisfaction, a reduction in operation cost, increase in output and an increase in productivity. But there are still existing unavoidable factors that need improvement. Internal defect is one of the common problems in the

CONCEPTUAL FRAMEWORK

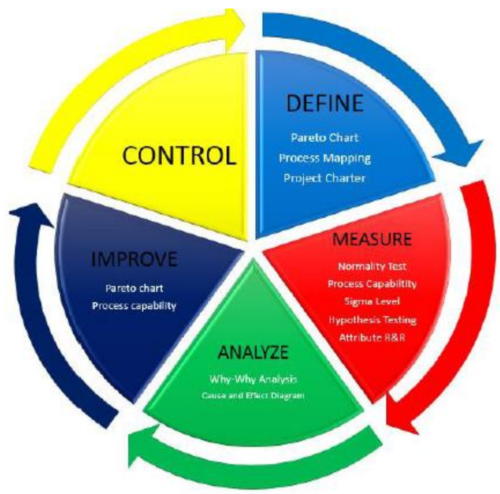


Figure 1. Research Paradigm

The Six Sigma DMAIC Methodology is a helpful tool in reducing internal defects since the main focus of the study is product quality improvement.

Define, measure, analyze, improve and control (DMAIC) helps the researchers come up with solution of problems, future plan, and also maintain the standing operating procedure with improvements in quality and reduced internal defects rate. With the help of this tool, the researchers will be able to identify, differentiate, evaluate and improve internal defects to attain product quality improvement.

OBJECTIVES OF THE STUDY

The main objective of this study is to eliminate low insulation defects in the crimping process of Nissan 1 – Altima at Yazaki-Torres Manufacturing Incorporated.

Specifically, the study wants to achieve the following objectives:

1. To define the wiring harness defect condition for the months July-December of the year 2015.
2. To measure the crimp height of the strip based on the standard requirement.
3. To analyze the root causes of low insulation defect.
4. To eliminate the number of low insulation defect.
5. To propose an action plan to sustain the improvement done.

II. RESEARCH METHODOLOGY

A. Research Design

This study used an applied research design where a specific question is answered with direct applications. Specifically, an experimental method type of study was used in which a treatment, method or project is deliberately presented and an outcome or result is seen. The researchers eliminated the low insulation defects on wiring harness by implementing DMAIC Methodology based on the different process being performed.

The researchers gathered data through keen observation and the analysis of process internal defects report of the company from July-December 2015. The process report showed that there are a lot of internal defects in different processes that the company encounters. The study also used figures to aid the readers in understanding the data.

B. Research Locale

The study was conducted at Yazaki-Torres Manufacturing Inc. located at Km. 54 Makiling Calamba City, Laguna.

C. Participants of the Study

The participants of the study was a team from the company which consisted of the Asst. Department head, Fajie Fajilan, Arturo Marfa, Section Head, and Renato Apdohan; Redentor Ortiz, a Quality Management Manager; Sub-section Heads, Area leaders and operators. It also includes the researchers of the study.

Interviews with operators, area leaders, sub-section heads and managers were one of the effective ways in collecting relevant data that helped the researchers in process familiarity. In the application of the DMAIC methodology, the define phase and measure phase were completed by the researchers. Meanwhile, the analyze phase and improve phase were accomplished by both the team and the researchers. Lastly, the
control phase was conducted by the team alone.

D. Data Gathering Procedure

The researchers submitted a letter to conduct a study to Yazaki-Torres. Once approved, the heads orient the researchers about the policy, safety and overall procedures in the company. The researchers were also introduced to the sub-section heads, and area leaders. The data gathering started last January 28, 2016. All the data were provided to the researchers by Mr. Fajie Fajilan, the Asst. Department head, and Mr. Redentor Ortiz, a Quality Management Manager. The researchers used Minitab software version 15 to help in analyzing the data collected.

The Define phase started last February 3, 2016. The researchers observed the production line and gathered data from the wiring harness office and from the Quality Management Department. The data presented different kinds of defects in different processes that occurred in Nissan-1 Altima, specifically in the crimping process from July-December 2015. The data was stratified using Pareto Chart, and Process Mapping. A Project Charter was also developed to summarize the focus points in the study.

The Measure phase was conducted last February 8, 2016 since all the data was provided to the researchers by Mr. Redentor Ortiz, a Quality Management Manager. The researchers run the data and start to verify the measurement in the crimping process to determine which factor is not capable of meeting the customer requirements. Normality test, Process Capability, Sigma level, Hypothesis testing, and Attribute R&R were determined.

The Analyze phase was conducted last February 15, 2016. The team and the researchers analyzed the causes of low insulation defects. This helped the team in determining the root cause of the problem. A 5 Why Analysis and Cause and Effect Diagram were used.

In the Improve phase, planning of improvement was discussed last February 22, 2016. Once approved, the implementation of the improvement started from March 1 to March 31, 2016. A Pareto Chart was used to identify the current position or condition of the crimping process after the improvement; and Process Capability was used by the researchers to compare its current performance in meeting the standard and the Sigma level was also determined.

For the Control phase, the team was the one responsible in sustaining the improvement done created in the improve phase of the study.

E. Data Analysis

The researchers used different tools in order to identify the problems and analyze the data given by the Quality Management Department. DMAIC Methodology was used as the main instrument of the study.

1. Define Phase

1.1. Pareto Chart was used in stratifying the internal defects in order to determine the defect to be prioritized. The focus was on low insulation defect.

1.2. Process Mapping was used to illustrate the flow of the process in order to understand it clearly and to identify opportunities for improvement.

1.3. Stratification was constructed to breakdown the problem into smaller details.

1.4. Project Charter was used to define the main problem and the objectives of the study.

2. Measure phase

2.1. Attribute R&R was conducted to verify if the measurement of the wire in the crimping process meet the 3standard. It was also used to validate the reliability of the data collected.

2.2 Normality test was conducted to determine if the data has a pass or fail mark from a normally distributed population.

2.3 Process capability was used to analyze how capable a process is in meeting its customer requirements.

2.4. Hypothesis testing was conducted to determine the significant difference of the process and the probability that a given hypothesis is true.

2.5. Sigma level was used to determine the current condition of the process in terms of low insulation defect. It was also to measure how much a process varies from perfection, based on the number of defects per million units.

3. Analyze phase

3.1. Why Analysis helped the team in determining the root cause of its occurrence.

3.2. Cause and Effect Diagram was used to identify the many possible causes for the low insulation defect, specifically, the causes brought by man and machine.

4. Improve phase

4.1. Pareto chart was constructed to determine the current standing of the process in terms of the low insulation defect and to compare the performance on a before-and-after improvement type of basis.

4.2. Process capability was determined to analyze how capable a process is in meeting its customer requirements after the improvement.

III. RESULTS AND DISCUSSION

1. Define Phase

The study started by determining the problem which will be the focus of the study. It was found out that internal defect is the common problem of Yazaki-Torres, particularly in the crimping process. The company provided the researchers a copy of the data on defects from July to December 2015. From the data, the researchers constructed a Pareto Chart to determine which process has the highest percentage of defect. The figure below shows the data on different processes:

Figure 2. Pareto Chart of Defects in Different Processes

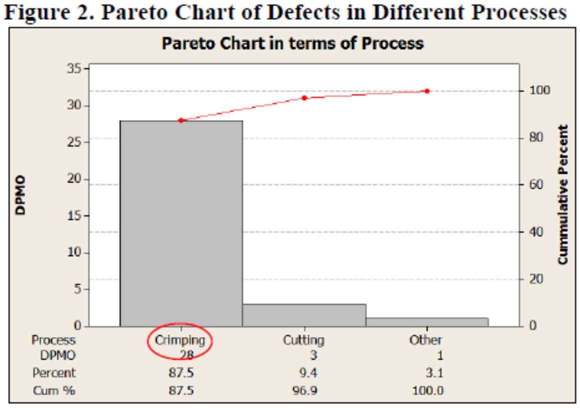


Figure 2 shows that the crimping process has the highest occurrence of defects among all the processes. The researchers found out that the crimping process has 87.5%, cutting has 9.4% and others have 3.1%.

Table 1. Defect data

Defects	DPMO	Relative Frequency	Cumulative Frequency
Low Insulation	7	25	25
High Insulation	5	17.9	42.9
Low Conduction	5	17.9	60.8
No Good Appearance	4	14.3	75.1
Excess Soldier	2	7.1	82.2
Big arc	1	3.6	85.8
High Conductor	1	3.6	89.4
igh Connector	1	3.6	93
Low Conductor	1	3.6	96.6
Others	1	3.6	100
Total	**28**		

Table 1 shows the tabulation of all the defects that occurred in the crimping process from July to December of the year 2015. A total of 28 DPMO in the crimping process was computed. These data were used in making a Pareto Chart in order to determine the defect that needs to be prioritized.

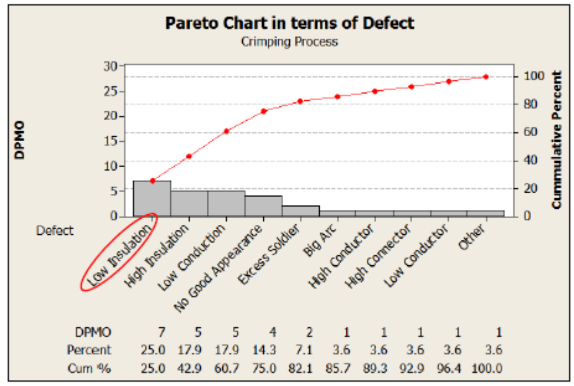


Figure 3. Pareto Chart of Defects in the Crimping Process

A Pareto Chart was constructed by the researchers using the Minitab software version 15 as shown in Figure 3. Since it is known for its "80/20" rule, the defects Low Insulation, High Insulation, Low Conduction and No Good Appearance belong to the 80% or the vital few of the problem. Meanwhile, the remaining 20% or the useful many came from the defects Big Arc, High Conductor, High Connector, Low Conductor, and others.

The researchers determine the main problem of the crimping process. Based on the Pareto Chart, the low insulation defect has the highest percentage from all the defects which is equivalent to 25% making it the priority of the study.

A process map was developed by the researchers to have a better understanding about the overall process. Figure 4 shows the step-by-step process in making a wiring harness. It also shows what is done in every process including decision making, storage, inspection, waiting and reworks by using different shapes.

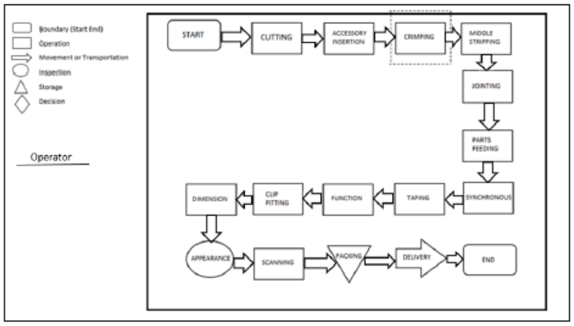


Figure 4. Process Mapping

The crimping process was the focus of the researchers since the majority of defects happened here. A machine called Pull test "CJ20" was used to measure the crimp height of the wires in the said process.

After the validation of data, the researchers stratified the data in order to breakdown the major problem into details. This helps the researchers identify the defect problem that needs to be prioritized.

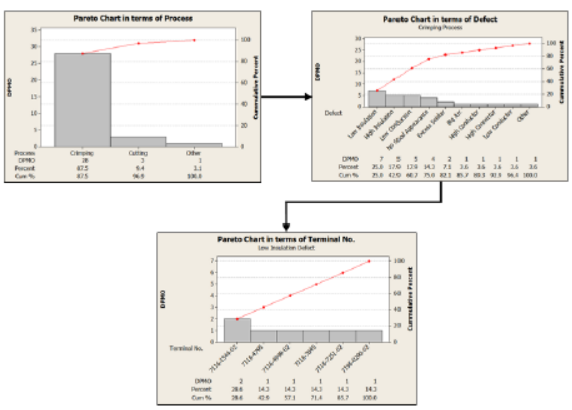


Figure 5. Stratification Process

The stratification started by determining the process that has the highest occurrence of defects. There are six main processes in the initial inspection and the Crimping process was chosen with a percentage equivalent to 87.5%. This was stratified in terms of the internal defects in the said process.

From all the defects in the crimping process, the researchers found out that the low insulation defect has the highest percentage equivalent to 25%.

This was then stratified in terms of its terminal number. With this, the researchers came upon the machine that produces the highest terminal number which was 7116-1544-02 with a percentage equivalent of 28.6%. This was used in analyzing the main reasons why the low insulation defect gained the top spot. Also, the specific machine was the basis in making the improvement for all the crimping process machines.

The researchers developed a Project Charter to classify the focus points in this study. The primary purpose of the said project charter is to identify the reasons for undertaking the project, outline the objectives and the constraints faced by the project, and provide solutions to the problem in hand.

Table 2. Project Charter

Project Title: Elimination of Low Insulation Defect		
Problem/Opportunity Statement:		
Low Insulation is the top defect in the crimping process on the production of wiring harness in Nissan 1-Altima, with a DPMO of 7 and a percentage of 25%. Low Insulation occurs when the strip is too long or when there is overfeeding.	Standard: 0.97 Good Crimp Ex. 0.94 No Good Crimp	
Goal Statement:	**Project Scope:**	
To reduce the number of low insulation defects using DMAIC, a Six Sigma Methodology	This study will be completed by process improvement with the aid of Six Sigma Methodology specifically the DMAIC principle focusing on the crimping process of Nissan 1 – Altima.	
Project Team		
Team Leader:	**Researchers:**	
Fajie Fajilan (Assistant Department Head)	Malabuyoc, Randel S.	
Arthur Marfa (Section Chief)	Salle, Kimberly Anne D.	
Rene Apduhan (Associate Section Chief)	San Jose, Dustine Roland R.	
Internal Members:	Sancebuche, Donita Rose N.	
Redentor Ortiz (Quality Management Manager)	**Timeline:**	
External Members:		
Malabuyoc, Randel S.	Define	February 3-5
	Measure	February 8-12
Salle, Kimberly Anne D.	Analyze	February 15-19
San Jose, Dustine Roland R.	Improve	February 22-29 March 1-31
Sancebuche, Donita Rose N.	Control	April

As illustrated in Table 2, the Project Charter briefly defines the main problem and also the main objective of the study. As shown, the project scope focused on the crimping process of Nissan 1-Altima in collaboration with the project team.

2. Measure Phase

The researchers used Normality Test, Sigma Level, Attribute R&R, Hypothesis Test, and Process Capability.

In this phase, the researchers conducted a measurement analysis to verify if the data is accurate. The different tests were applied in the crimping process of Nissan 1 – Altima and these were administered using the crimp height of the wire. This was to determine if the standard measurements are followed.

Table 3. Operational Definition in conducting Attribute Agreement Analysis

Operational Definition
1. Collect 15 pieces of wire with a terminal no. of 7116-1544-02.
2. Assign designated no. for each wire (in random order).
3. Conduct crimping on each wire. This was done in 4-5 minutes.
4. Measure the crimp height of each wire and record it based on its actual measurement. This was done in 8-10 minutes.
5. Determine which passed and which failed based on the standard measurement. This was done in 2-3 minutes.
6. Compare the results of the measurements.
7. Analyze the results on Minitab and interpret.

The researchers created an operational definition in order to show the step-by-step process in conducting the experiment for the Attribute Agreement Analysis, as shown in Table 3.

Attribute Agreement Analysis was used to test the reliability of the data. The researchers conducted fifteen (15) samples in the experiment since one bundle consists of fifteen strips of wire.

Table 4. Attribute for Agreement Analysis

Item No.	Reference Crimp Height	Actual Crimp Height	Reference	Actual
1	0.97	0.97	PASS	PASS
2	0.97	0.97	PASS	PASS
3	0.97	0.97	PASS	PASS
4	0.97	0.96	PASS	FAIL
5	0.97	0.97	PASS	PASS
6	0.97	0.97	PASS	PASS
7	0.97	0.96	PASS	FAIL
8	0.97	0.96	PASS	FAIL
9	0.97	0.97	PASS	PASS
10	0.97	0.97	PASS	PASS
11	0.97	0.98	PASS	FAIL
12	0.97	0.97	PASS	PASS
13	0.97	0.97	PASS	PASS
14	0.97	0.97	PASS	PASS
15	0.97	0.97	PASS	PASS

Table 4 shows the data gathered for the Attribute Agreement Analysis. The standard measurements in the process were used as the reference while the measurements obtained from the pull test "CJ20" were used as the actual measurements. Each measurement was rated whether Pass (P) or Fail (F). If the measurement did not exceed the standard, it is considered "Pass" otherwise, it is considered "Fail".

Table 5. Attribute Agreement Analysis Result - Assessment Agreement

Appraiser	# Inspected	# Matched	%	95 % CI
Crimp Height	15	15	100.00	(81.90, 100.00)
# Matched:	Appraiser agrees with the known standard across trials.			

Fleiss' Kappa Statistics

App-raiser	Res-ponse	Kappa	SE Kappa	Z	P (vs >0)
Crimp Height	F	1	0.258199	3.87298	0.0001
	P	1	0.258199	3.87298	0.0001

The researchers investigated the percentage and the kappa value, as shown in Table 5. The kappa value of 1 indicates that a Perfect Agreement exists in the measurement system. A 100% percentage result signifies reliability and highly acceptance of the data.

Table 6. Interpretation of Kappa Value

Kappa Value	Interpretation
0	Equal to chance Agreement
≤ 0.20	Poor Agreement
≤ 0.40	Fair Agreement
≤ 0.60	Moderate Agreement
≤ 0.80	Substantial Agreement
≤ 0.99	Excellent Agreement
1	Perfect Agreement

Source: Adapted from "The Kappa Statistic". Anthony J. Viera, MD; Joanne M. Garrett, PhD, 2005.

The Kappa value can range from -1 to +1. If there is a stronger agreement between the rating and standard, there is a higher kappa value.

The researchers used Normality Test to determine if the data is normally distributed and if there are measurements which are much smaller or much greater than most of the other values in the set of data that were given.

Table 7. Data for Crimp Height

Item No.	Crimp Height
1	0.97
2	0.97
3	0.97
4	0.97
5	0.97
6	0.97
7	0.97
8	0.94
9	0.95
10	0.96
11	0.98
12	0.96
13	0.98
14	0.96
15	0.98

Table 7 shows the July-December 2015 data of the company for the crimp height. There were 15 samples conducted and the researchers used this to test the normality of the data.

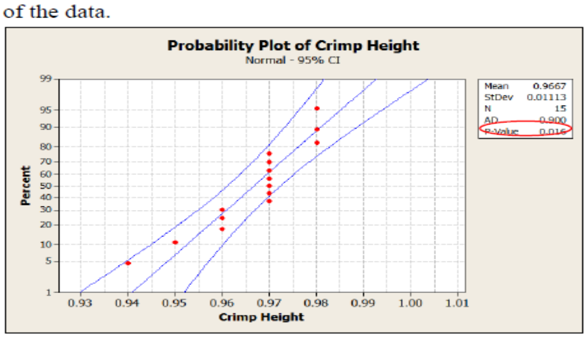


Figure 6. Normality Test for Crimp Height

The test rejects the hypothesis of normality when the P-value is less than or equal to 0.05. Failing the normality test means that there is a 95% confidence that the data does not fit the normal distribution. Passing the normality test only allows you to state that there is no significant departure from normality. The following are the hypotheses for the normality test:

Ho: The data follows a normal distribution.

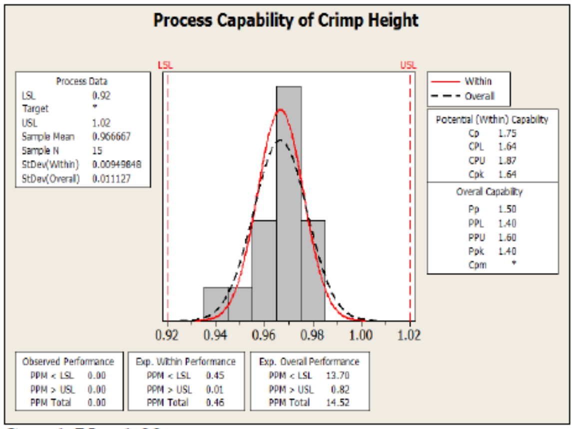
Ha: The data does not follow a normal distribution.

Figure 6 shows that the P-value < 0.016 for the crimp height of the strip is less than $\alpha = 0.05$. Hence, the data does not follow a normal distribution. Also, there are no outliers that could affect the process.

The standard crimp height output in Nissan 1 – Altima is 0.97 and the majority of the results point to this. The test that the researchers run was not sensitive to normality. Therefore, it does not require a normally distributed data and in conclusion, its non-normality is still acceptable.

The researchers conducted a Process Capability to provide an answer as to whether the process is capable of meeting the requirements of the customers or not. It also indicates whether your process is centered and on target.

There were 15 samples and reaching a minimum value of 1.33 for the Cpk will consider the process capable of meeting the customers' requirements.



Cp = 1.75 > 1.33

Figure 7. Process Capability for Crimp Height

Figure 7 shows the capability analysis of the crimp height. The results indicate an overall capability of Pp = 1.50 and a potential capability of Cp = 1.75. The results show that the process is capable since the capability indices are higher than the de facto standard of 1.33.

Hypothesis Testing using one sample t-confidence interval and test procedures are conducted by the researchers. This are used to know whether the sample comes from a particular population and to examine the mean difference between the sample and the known value of the population mean.

Table 8. One-Sample t-Test and CI: Crimp Height

Varia-ble	N	Mean	St. Dev.	SE Mean	95% CI	T	P
Crimp Height	15	0.96667	0.01113	0.00287	(0.96050 ,0.97283)	-1.16	0.265

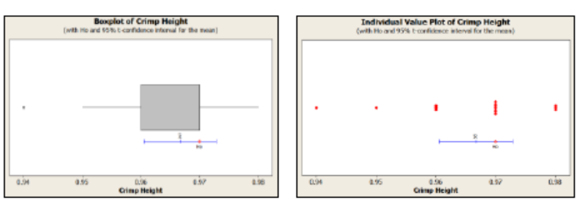


Figure 8. Hypothesis Test for Crimp Height

The hypothesis used for this test is as follows:

ACCEPT $H_0: \mu = 0.97$

$H_a: \mu \neq 0.97$

Table 7 and Figure 8 shows the hypothesis test for the Crimp Height. Having an indication of a P-value greater than the predetermined level of significance, 0.265, the null hypothesis is accepted and the alternative hypothesis is rejected. Therefore, there is no significant difference between the sample mean and the population mean.

The researchers determined the sigma level of the crimping process to know its current condition.

Table 9. Process Sigma Level

Sigma (σ) Levels	DPMO
1	697, 700
2	308, 537
3	66, 807
4	6210
5	233
6	3.4

Source: Adapted from "Total Quality Management". Ramasamy Subburaj. 2008.

Table 9 shows the sigma level in relation to its equivalent defect per million opportunities. From the resulting DPMO of the low insulation defect shown in figure 3, it produced 7 defects per million opportunities. The sigma level of the low insulation defect's current condition is 3 since the amount of DPMO falls in this category.

3. Analyze phase

This phase is where the researchers gather data on the root causes of the problem. This is to determine a cause and effect relationship. The researchers analyze the process using why-why analysis and cause and effect diagram.

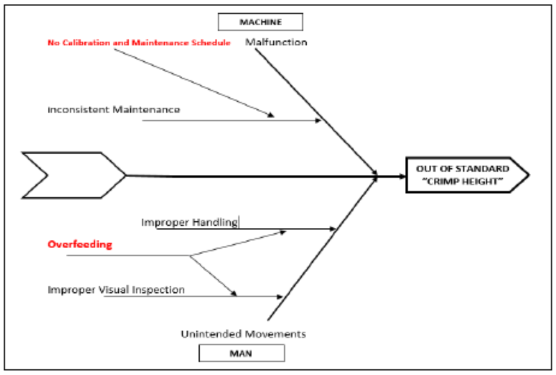


Figure 9. Cause and Effect Diagram

Out of Standard – Crimp Height is the main problem of the process. As illustrated in Figure 9, the root causes of having this problem in relation to crimping is brought about by man and machine.

A cause and effect diagram was made to help the researchers brainstorm in order to identify the possible causes of a problem and sorting this into useful categories

Table 10. Why-Why Analysis (Machine)

WHY-WHY ANALYSIS (Machine)	
WHY 1	Out of Standard Strip
WHY 2	Machine Malfunction
WHY 3	Machine is not consistently calibrated and maintained
WHY 4	No Maintenance and Calibration Schedule

Table 11. Why-Why Analysis (Man)

WHY-WHY ANALYSIS (Man)	
WHY 1	Out of Standard Strip
WHY 2	Unintended Movements
WHY 3	Improper Visual Inspection and Wire Handling
WHY 4	Overfeeding

Table 9 shows that the main reason for having an out of standard strip is due to the machine not having a maintenance and calibration schedule. Meanwhile, it is shown in Table 10 that it is due to overfeeding. A wire with an out of standard strip is the main aspect of the low insulation defect.

The Why-Why Analysis can be used whenever the real cause of a problem or situation is unclear.

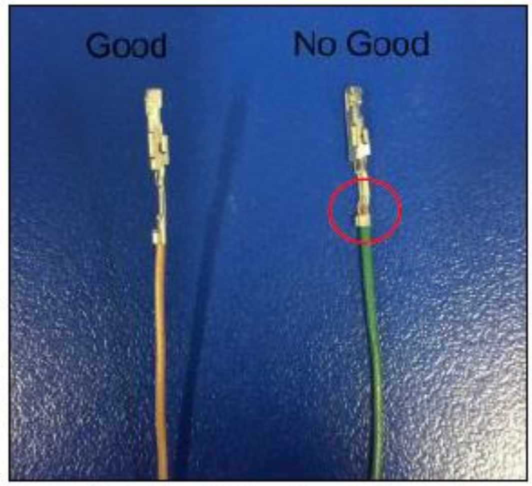


Figure 10. Good-No Good Appearance

Figure 10 shows the good and no good output of low insulation defect. The insulator of the strip wire is seen when it is a “no good” output, otherwise, it is a “good” output.

4. Improve Phase

This phase aims to provide solutions to the difficulties identified. This involves brainstorming for potential actions, tests and evaluation of the results. The team used a variety of techniques to find possible answers to counter the root causes identified in the Analyze phase.

Preventive actions to eliminate defects are prioritized since it was suggested by the team. The researchers along with the team gave their insights based on series of observations. Discussions and consultations were conducted in order to come up with preventive actions.

After the brainstorming, the team have implemented the solutions to eliminate the low insulation defects in the crimping process. Since one of the root cause in having such defect is inconsistent maintenance, the team required a regular maintenance of machine at least twice a week. Its purpose is to ensure that the equipment required for the process is operating at 100% efficiency.

Calibration of machine is very important as it ensures the ability to provide accurate and consistent readings of measurements. It also establishes the reliability of the instrument.

In the previous phase, it was found out that the strip of the wire being out of standard is one of the root cause of having a low insulation defect. The team required the operators to conduct inspection of strip before it proceeds to the crimping process. Providing a sample strip of wire is another implementation. This would serve as a visual basis or pattern for the operators.

When the company tried to apply Six Sigma methodology to reduce the defect in different processes, the company started to create a visual order and visual indicator standard. Through the visual order, work is visible along with blockers, bottlenecks and queues. On the other hand, the visual indicator standard will help the operator quickly recognize any deviation from the standard.

Figure 11. Pareto Chart of Defects after the improvement (March-April 2016)

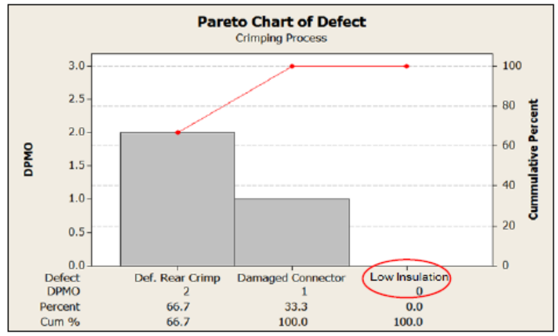
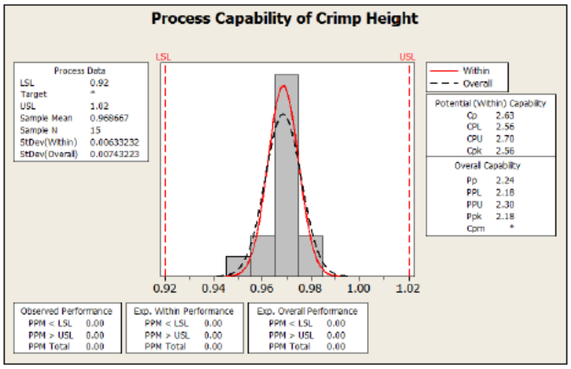


Figure 11 shows the Pareto chart after the improvement. From 7 DPMO to zero, low insulation defects were eliminated. This displays 100% improvement. It also shows that other defects in the crimping process were also eliminated. The team in Nissan-1 Altima also conducted countermeasures in every defect that occurred in the said process. The improvement done by the team was successful in meeting the zero defect target.

Since continuous improvement is one of the main goals of Six Sigma DMAIC methodology, the researchers further improved the current sigma level (Sigma level 3) to Sigma level 6 of the crimping process in order to practice the DMAIC principle. Having a sigma level of 3, the crimping process produced 7 DPMO which indicates a relevant additional cost for the company.

By further improving the current sigma level and eliminating defects for continuous improvement of processes through defects reduction, results such as massive impacts in cost, customer satisfaction and product quality are assured.



After: Cp = 2.63 > 1.33

Figure 12. Process Capability of Defects after the improvement

Figure 12 shows the process capability of the crimp height before-and-after the improvement. From the Cp of 4.39, it improved to 6.58. Since the process capability was already capable, being higher than the company's standard Cp of 1.33, the researchers wanted to maintain this result.

The researchers wanted to increase the capability of the process after the improvement. The overall capability was also improved from Pp 1.50 to 2.24. It was therefore, successfully maintained.

In collaboration with the team and the approval of the department head in Nissan 1-Altima, the researchers were able to implement the previous countermeasures that demonstrates how Low Insulation defect can be eliminated. As a result upon observation, the team along with the researchers were able to eliminate the Low Insulation defect in the Crimping process of Nissan 1-Altima, from 7 DPMO to 0 DPMO, the study was considered successful.

5. Control Phase

In the control phase, the team is responsible in sustaining the improvement done. It was ensured that the gains are maintained for long-term purposes. The team created a plan for ongoing monitoring of the process and for preparing countermeasures.

The plan clarifies how the process performance will be continuously monitored and the responses required. Regular check-ups of machines and pre-process inspection of strip helps the Nissan-1 Altima in eliminating the low insulation defect. This results to an increase in efficiency and productivity of employees. The team also maintains the process capability to meet the customer requirements.

Table 12. Machine Maintenance

Preventive Action	Time Frame
Maintenance Schedule	At least twice a week
Calibration Schedule & Status	At least twice a week
Check the Maintenance Attendance	At least once a week
Maintenance Requisition	At least once a week

Table 13. Crimping Process Procedure

Procedure
1. Get the pre-operation checklist and check the items.
2. Get the WOS with the wire from the input hanger and check the terminal number to be used.
3. Set the applicator and terminal in the YCM machine.
4. Open the CFM and set the program based on the crimp height adjuster plate reference setting.
5. Get the sample standard strip and conduct 5 pieces sample test.
6. Check if the strip properly meets the stopper.
7. Measure the crimping dimension of the front/rear of the terminal based on the crimping standard requirement.
8. Get one sample and conduct a pull test.
9. Proceed to mass production and get 2 pieces of the first output. Measure the crimping height and record it in the pre-control check sheet.
10. Visually check the appearance of the terminal after every 5 pieces of output.

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

In relation to the objectives of the study, the following conclusions are made based on the findings gathered:

1. The researchers were assigned to study the process of Nissan 1 – Altima. The data of defects from July to December of the year 2015 were provided and after careful stratification, it was found that the crimping process contributed the most number of defects. The defects that occurred in the crimping process were further stratified and the researchers found out that the low insulation defect has the highest number of defects with 7 DPMO. The low insulation defect became the priority of the study since it was the top defect in the crimping process.

2. After the focus of the study was determined, the team conducted brainstorming in order to find the main cause of low insulation defect. The team agreed that strips which are out of standard measurement may be a cause. The team used Attribute R&R to verify if the strips which are shorter or longer than the standard can cause low insulation defects. The test provided a proof that using out of standard strip measurement causes low insulation defect.

3. After identifying the main causes of the low insulation defect, the team analyzed the method in the crimping process. The team examined the process using why-why analysis and cause-and-effect diagram. Through brainstorming, it was found out that having low insulation defect is mainly caused by man and machine. The root cause of having such defect is due to inconsistent maintenance and overfeeding.

4. The DMAIC principle served as the team's roadmap for process improvement. The Define phase helped the team through the stratification process, in which they come up with the main scope, focus and goal of the study. Data were analyzed carefully and verified accurately in the Measure phase. The team shared their insights about the problem and come up with various countermeasures that eliminated the defects in the process. Countermeasures were further examined and tested to ensure effectiveness. Implementation of countermeasures is accomplished in the Improve phase. With further observations of the processes in the Control phase, decline of the defect rate is seen all throughout the process. As a result of improvement, the process capability was also improved from 1.75 to 2.63. Also, the previous number of low insulation defects with 7 DPMO was totally eliminated, therefore having 0

DPMO. In conclusion, these defects are eliminated in the crimping process after the DMAIC methodology took place.

5. Preventive actions were made in order to eliminate defects in a long-term basis. Since the suggested countermeasures were proven effective, work instructions must be revised with the proper preventive policies. The team is responsible for the dissemination of work instructions and ensuring that practical applications of the previous countermeasures will develop a continuously improving process all throughout the production.

B. *Recommendation*

After obtaining the results and conclusions, the following recommendations are made:

1. The study provided a great help in the elimination of the low insulation defect. The team should continue to have calibration schedules and machine check-ups at least 2 times a week in all machines terminal number.

2. It is recommended that the future researchers should conduct a study on reducing low insulation defects which are developed outside the crimping process. This is for the perfectly-crimped wires that gets damaged and becomes low insulated through the transportation to the other processes, improper handling and collision in the working area.

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