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Six Sigma Implementation in Connector and Terminals Manufacturing Company : A Case Study

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A B S T R A C T

This research was conducted at an electronic component company located in Bekasi, Indonesia. Quality is a characteristic of this company, with the company's mission, one of which is eliminating customer claims. The application of the Six Sigma DMAIC method is expected to be used as a guideline for making durable product quality and reducing the high variation in the manufacturing process for bullet type products. This study aims to determine the variables of the factors that can affect the retention force value of bullet type terminal products, using the Taguchi method experiment. The research results with the Taguchi method experiment found that three variables affect the product retention force value, namely the largest outer diameter dimension, the most significant input diameter size dimension, and the smallest length position size dimension. After monitoring and data collection on the retention force dimension, it was found that the overall Cp process capability was 3.38, and Cpk was 1.58, so it could be said that the machine performance was excellent and stable.

1. INTRODUCTION

Organizations must continue to improve the quality of products and business processes to survive in a business world with a very competitive climate. Quality is one aspect that determines the success of a company by increasing the added value of the product by minimizing the defect rate of a product during the production process (Darmawan et al., 2018). It is more challenging to apply a systematic methodology to monitor and prevent defects from occurring on the production floor as the complexity of the production system increases (Jacob et al., 2018). The Six Sigma concept is proven successful and adopted by the Motorola company so that the rate of product defects can be reduced, productivity increases, customer satisfaction increases, and operational costs are reduced, using practical and effective statistical engineering tools. (Antony, 2006). Researchers and practitioners provide an overview and also the concept of Six Sigma so that business processes can operate more effectively (Antony & Banuelas, 2002). Six Sigma is a comprehensive framework so that problems in the industrial sector can be resolved using quantitative research methods (Brun, 2011). Six Sigma is designed to reduce the variety of processes in five steps, namely defining, measuring, analyzing, improving, and controlling business processes (Sarkar et al., 2013).

Likewise, an electronic component company located in Bekasi, Indonesia, quality is the target of a business strategy to increase the competitiveness value of a product so that it can compete with other electronic component products. Organizations analyze, monitor, and make improvements to existing manufacturing systems so that the competitive value of products can also increase.

Figure 1. Terminal product

During the past two years, the demand for electronic component products has increased. So that quite a lot of products with new types or different types are produced in this place. Historical data shows that there are customer complaints about quality problems on bullet type products (Figure 1). The product defect found by the customer is that the terminal retention force is low so that when using the wire, it can be detached. Based on customers' information, there are many findings, which means that the production process capability at the time the product is produced is still not excellent. The process of measuring the compressive strength of the product uses a force gauge (Figure 2). After verification by the Engineering Center, the measurement of the compressive strength of the product does not match specifications, namely 10.2N or about 1 Kg. The machining process cannot detect this. The product recall must be made by the company and replace the products that have been sent to customers. Of course, this can result in huge losses, so it is necessary to immediately take corrective action by knowing the root cause of the problem that occurred so that the issue does not reoccurrence. Companies or organizations need to maintain the production process and always make continuous improvements so that product quality can be maintained and the resulting product becomes better (Nugroho et al., 2017).

Figure 2. Force gauge

From the description of the problem, it is known that the production process capability is still not good, resulting in unstable product quality. The production process capability procedure is carried out using a control diagram to detect the causes of problems that can cause variations so that the production process can be controlled using statistical process control (Chen et al., 2009). Among the various production processes, the process capability index *CP* and *CPk* are easy to understand and can be directly applied to the manufacturing industry (Chen et al., 2002).

2. LITERATURE REVIEW

General Electric and Motorola are two large and well-known companies, and the company has successfully implemented six Sigma. For the successful application of Six Sigma in an organization, it is necessary to understand the barriers and motivational factors in Six Sigma (Hekmatpanah et al., 2008). The Six Sigma process aims to achieve perfection in every company process (Narula et al., 2015). Six Sigma means having less than 3.4 defects per million opportunities (DPMO) or a success rate of 99.9997%. In Six Sigma the term sigma is used to represent process variation (Antony & Banuelas, 2002).

Table 1. Previous research

No	Journal Title	Result
1	Improvement of Magazine Production Quality Using Six Sigma, (Hernadewita et al., 2019)	The results of the research the current sigma value is 3.6, the type of defect blurred is 59%, unregistered is 29% and the paper cut is 12%.
2	Lean Six Sigma Approach to Improve the Production Process in the Mould Industry: a Case Study, (Pereira et al., 2019)	The dominant factors are the absence of operators (16.4%), machine programming (14.4%) and tool exchange (12.4%), the application of Lean Six Sigma tools can increase the global OEE value by 20%.
3	Improve Capability Process to Optimizing Productivity: Case Study Line Process Packing Assembly in Electronic Manufacturing Company, (Rofiudin & Santoso, 2018)	Reduce takt time from 9.2 sec to 8.5 sec.
4	Six-sigma application in tire-manufacturing company: a case study, (Gupta et al., 2018)	The capability index value was an increase from 1.5 to 2.95, and capability index increased from 0.94 to 2.66
5	Reducing the nonconforming products by using the Six Sigma method: A case study of a polyester short cut fiber manufacturing in Indonesia, (Syafwiratama et al., 2017)	Capability process value was increased from 2.2 to 3.1
6	Implementation of Six Sigma in a Manufacturing Process: A Case Study, (Valles et al., 2009)	Electricity target failure was decreased by around 50%.
7	Implementasi Six Sigma Dalam Peningkatan Kualitas dengan Mengurangi Product Cacat NG Drop di Mesin Final Test Produk HL 4.8 Di PT. SSi (Kholil, & Pambudi, 2014)	Production yield was increased from 92.17% to 99.88%, level sigma was increased from 1,4482 to 2,9730 and Defective production was reduced from 0.62% to 0.036%.

Six Sigma is a methodology that allows the company or organization to review existing processes and guide employees to make improvements by analyzing those processes with statistical approach methods (Erbiyik & Saru, 2015). Six Sigma defines-measures-analysis-improve-control (DMAIC) is an approach that can guide the industrial world to focus on developing the right products, processes, and services. Six Sigma identifies and then eliminates product defects or product feature failures that do not meet customer demand, affecting system performance (Gupta et al., 2018) (Table 1).

3. RESEARCH METHOD

Subjects and Objects The research was carried out in an electronics component company located in the east of the capital city of Jakarta. The focus of research is carried out in the assembly department, where many transfer products from Japan will be produced in Indonesia, with terminals type bullets. The steps of this research use five phases of DMAIC which are applied to overcome problems to achieve Six Sigma performance goals (Thomas et al., 2009). The main activities carried out at different phases through the DMAIC method in the case study are as follows:

3.1 Define

Creating a team to identify problems that arise in the company which is taken from monthly reports from companies with the theme of quality targets, namely zero customer claims that have not been achieved, and have an impact on quality costs, which will become the focus of the team to carry out improvement projects (Table 2).

Table 2. Project charter

Project Theme	**Design of robust quality bullet type terminal products**
Loss Business	Customer Claim, so the product must be returned and must be replaced.
Main Problem	Terminal loose
Objective target	Determine the variable factors that affect the occurrence of claims, and design parameter values so that the maximum retention force value is obtained.
Project team	Production head (Project leader), Process Chief, 2 Inspection Staff, and Director
Project boundary	Terminal machines, bullet type terminal products
Advantage	Reduction claim, Reduction selection, and customer satisfaction

3.2 Measure

The product claim for bullet type returned by the customer has been verified by the engineering center in Japan and then made into a master measurement. The next step is to be re-measured by the assembly department to ensure that the product size, measuring instruments used, and the measuring operator is valid using Gage R&R. Measurement system analysis or also known as gage repeatability and reproducibility study or Gage R&R is used to ensure the reliability of the measurement system (Mast & Trip, 2005).

$$\sigma^2_{Total} = \sigma^2_{Part} + \sigma^2_{ms} \quad (1)$$
$$\sigma^2_{ms} = \sigma^2_{rpt} + \sigma^2_{rpd} \quad (2)$$
$$\sigma^2_{rpd} = \sigma^2_{op} + \sigma^2_{opXpart} \quad (3)$$

Then proceed to conclude the hypothesis from the measurement results by performing the t-test for the non-homogeneous variance, that:
Ho: sample measurement (JPN) = sample measurement (IND)
H1: sample measurement (JPN) ≠ sample measurement (IND)

3.3 Analyze

Conduct a more in-depth examination of samples that do not meet specifications (sample 2), by examining supporting materials to produce bullet type products and compare products that meet specifications (sample 1) and those that do not meet specifications (sample 2). The supporting material data taken for further analysis are (units in millimeters):

1. Input diameter (A).
2. Center diameter (B).
3. Output diameter (C).
4. Length position (D).
5. Inside diameter tube (F)

The data is taken to find out from the five variables above whether there is a difference between sample 1 and sample 2 with the assumption that:
H1: There is a difference in Input diameter (A) between sample 1 and sample 2.
H2: There is a difference in Center diameter (B) between sample 1 and sample 2.
H3: There is a difference in Output diameter (C) between sample 1 and sample 2.
H4: There is a difference in Length position (D) between sample 1 and sample 2.
H5: There is a difference in Inside diameter tube (F) between sample 1 and sample 2.
Make conclusions for the factors that most influence the retention force size of bullet type products by performing a t-test for the non-homogeneous variety.

3.4 Improvement

Creating a machine process flow for bullet type products from the initial material to the finished product, to know the formation process of each variable. Because there is no standard size of the supporting material, an experiment was carried out using the Taguchi method on a bullet type terminal machine. The Taguchi method is a new methodology in the engineering field that aims to improve product quality so that it is robust by reducing costs and resources to a minimum (Soejanto, 2009). This study seeks to evaluate the maximum results on the size of the retention force, by selecting the supporting variables, namely input diameter (mm), output diameter (mm) and length position (mm) during the production process of bullet type products. The parameters used in this study are divided into three different levels of variation.

Select the experimental array data formulation with the required degrees of freedom. The factor of degrees of freedom can be calculated with the equation (4), where N_f is the number of factors, and N_n is the number of levels for each factor. The degree of freedom of interaction can be calculated with the equation (5), where N_i is the number of interactions. The total number of degrees of freedom can be calculated with the equation (6).

$$GL_f = N_f.(N_n - 1) = 3.(3 - 1) = 6 \quad (4)$$
$$GL_i = N_i.(N_n - 1) = 3.(3 - 1) = 6 \quad (5)$$
$$GL_t = GL_f + GL_i = 6 + 6 = 12 \quad (6)$$

The number of degrees of freedom of the matrix array is at least 12 experiments. According to Taguchi, the method approach used for the experimental design is the L9 matrix with array design (Figure 3).

$$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & 2 \\ 1 & 3 & 3 \\ 2 & 1 & 2 \\ 2 & 2 & 3 \\ 2 & 3 & 1 \\ 3 & 1 & 3 \\ 3 & 2 & 1 \\ 3 & 3 & 2 \end{pmatrix}$$

Figure 3. Orthogonal arrays L9(3^3)

3.5 Control

To maintain the process performance that has been achieved in the application of the Six Sigma method, the Define-Measure-Analyze and improves steps must be monitored regularly so that when a deviation occurs the data can be immediately checked and corrected.

4. RESULT AND DISCUSSION

4.1 Define

A team to carry out a repair project has been created with the Terminal loose problems found by the customer when it will be used, then determines the cause of the problem and continues to determine corrective actions to eliminate the cause of the problem.

4.2 Measure

At the measuring stage, an evaluation of the measuring instrument is carried out, the operator who takes the measurement, using the Gage R&R. After the evaluation, it was found that the measurement system varied by 13.2% so it was feasible to carry out further examinations (Figure 4). Furthermore, the team took data on product measurements that had been returned by the customer, to determine the process capability of the machine, by taking 35 samples, with the allowed size specifications of 39.4N (Figure 5).

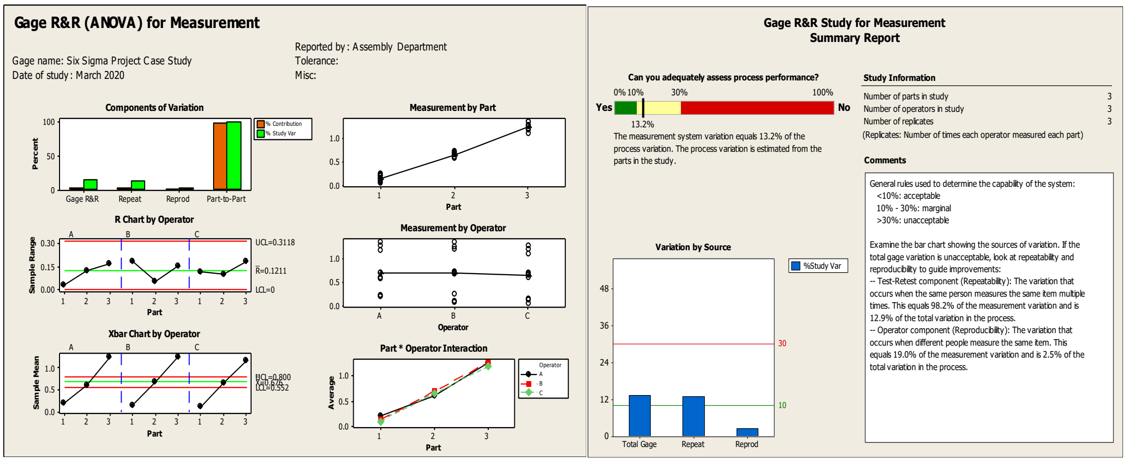

Figure 4. Measuring system analysis.

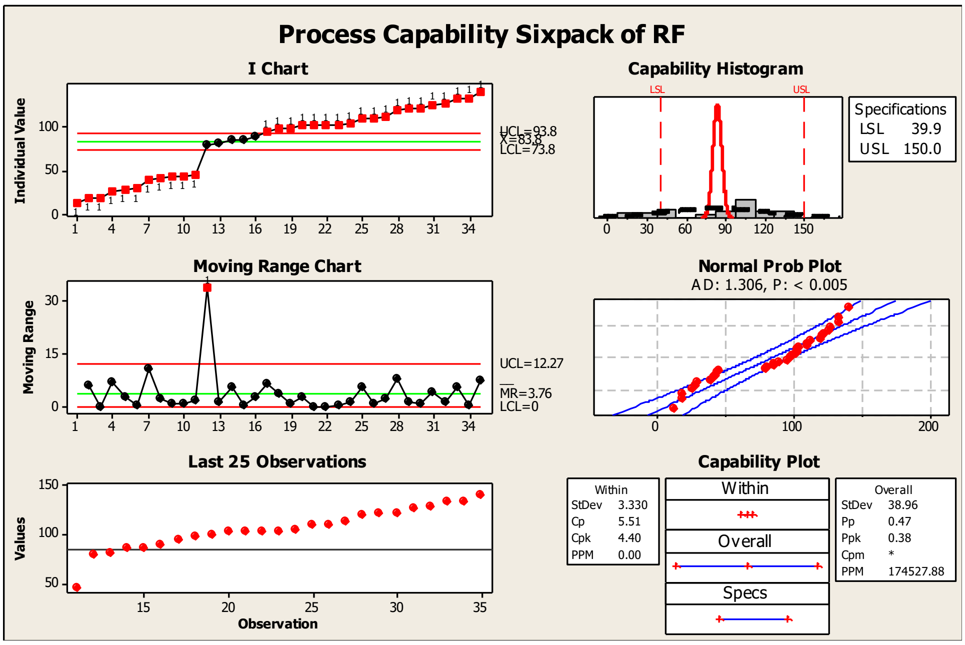

Figure 5. Process capability sixpack graph.

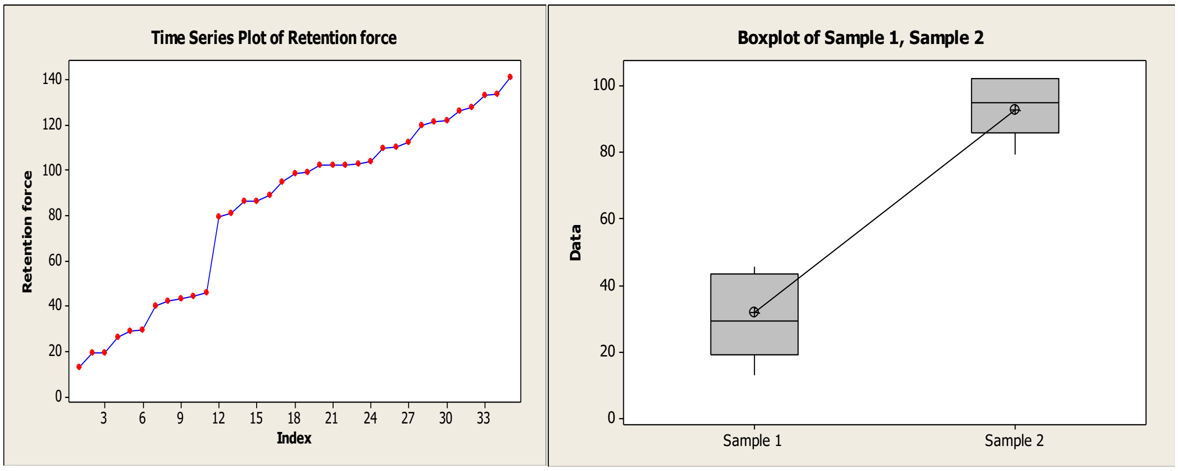

Figure 6. Graph plots and sample box plots.

From the data processing, it seems that the population value of Pp performance is 0.47 and Ppk is 0.38, which means that the processing capability is still not good and unstable. In the graphic plot and the box plot, it is clear that there is a difference in the change of retention force dimension in the twelfth sample (Figure 6). From this situation, hypothesis testing is performed concerning the retention force dimensions of sample 1 and sample 2, namely:

Ho: $Sample\ 1 = Sample\ 2$

H1: $Sample\ 2 \neq Sample\ 2$

Two-Sample T-Test and CI: Sample 1, Sample 2

```
Two-sample T for Sample 1 vs Sample 2

            N   Mean  StDev  SE Mean
Sample 1   11   31.9   11.7      3.5
Sample 2   11  92.70   8.80      2.7


Difference = mu (Sample 1) - mu
(Sample 2)
Estimate for difference:  -60.79
95% CI for difference:  (-70.06, -
51.52)
```

```
T-Test of difference = 0 (vs not =):
T-Value = -13.77  P-Value = 0.000  DF
= 18
```

Testing the hypotheses of sample 1 and sample 2 using the Minitab software found that a p-value of fewer than 0.05 means Ho rejects or it can be said that the average values of sample 1 and sample 2 are different. As seen in Figure 6, there are 2 different data populations during the production process, to find out the cause of the data population differences, a more in-depth inspection is done by taking product samples and then measuring and comparing the composition of supporting materials, between products according to specifications and products not according to specifications.

4.3 Analyze

After measuring and processing the data, it was found that the hypotheses H1, H2, and H5 have a p-value above 0.05 which means that there is no difference between sample 1 and sample 2 (Figure7). But hypotheses H3 output diameter (C) and H4 position length (D) has a p-value below 0.05, so it can be said that there is a difference between sample 1 and sample 2, the following are the results of data processing for hypotheses H3 and H4.

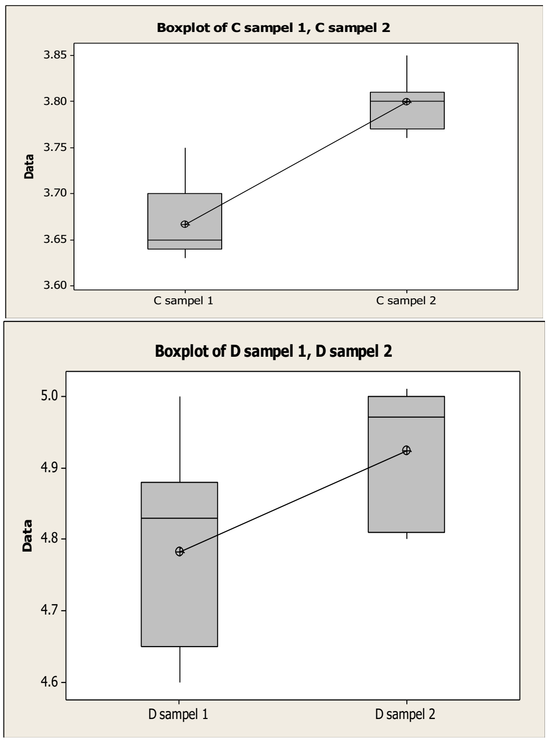

Figure 7. Box plot sample

Two-Sample T-Test and CI: C sampel 1, C sampel 2

```
Two-sample T for C sampel 1 vs C
sampel 2

Difference = mu (C sampel 1) - mu (C
sampel 2)
Estimate for difference:  -0.1327
95% CI for difference:  (-0.1636, -
0.1019)
T-Test of difference = 0 (vs not =):
T-Value = -9.03  P-Value = 0.000  DF =
18
```

Two-Sample T-Test and CI: D sampel 1, D sampel 2

```
Two-sample T for D sampel 1 vs D
sampel 2

Difference = mu (D sampel 1) - mu (D
sampel 2)
Estimate for difference:  -0.1409
95% CI for difference:  (-0.2517, -
0.0301)
T-Test of difference = 0 (vs not =):
T-Value = -2.70  P-Value = 0.016  DF =
16
```

From the data analysis, it can be concluded that the reason why the holding force measurement is outside the specification and unstable is due to the change in measurement in variables C (output diameter) and variable D (length position).

4.4 Improve

The process of forming a bullet type product starts from the arrival of the tube material for the first forming process, then continues with the second forming process by controlling the results of the first forming process. The second forming process consists of:

1. Forming the Input Diameter
2. Forming of Output Diameter and
3. Length position alignment.

The last is the third forming process by ensuring that the second forming process is following the specifications (Figure 8). Each process affects the size dimensions of the formed product by controlling forward and backward. Because there is no standard for the size of the supporting material for product formation, an experiment was carried out with the Taguchi method to get the best (maximum) retention force value, in the second forming proce

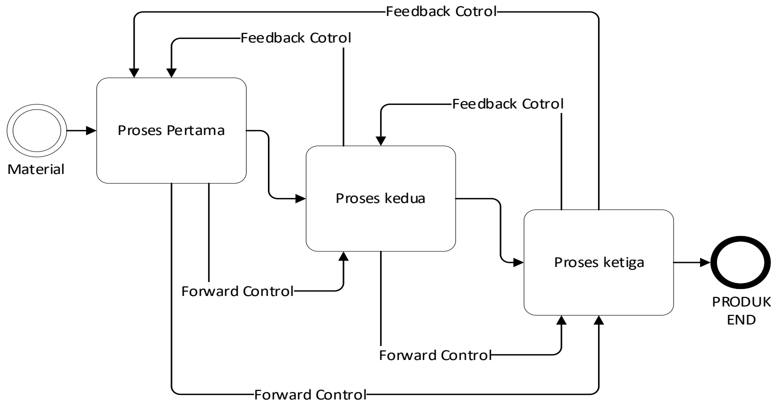

Figure 8. Bullet type of product production process.

Based on the Taguchi experimental plan (Table 3), it shows the value of the parameters of the L9 orthogonal matrix arrangement with four retention force values in each experimental data. Determination of the influence of each factor and their interactions (input diameter, output diameter, and length position) are processed using Minitab. The Taguchi method is better than the classical experimental method, with the next step, namely determining the value of the Signal/Noise ratio ability (Pop et al., 2018). In Figure 9, it can be seen that the parameters that produce the greatest retention force are the input diameter at the value level of 3.66 mm, the output diameter at the value level of 3.90 mm and the Length position at the value level of 4.6 mm. or it can be concluded that to get the highest retention force value, the input diameter uses the largest value level, the output diameter uses the largest value level and the Length position uses the smallest value level. The purpose of this graphic analysis is to make it easier for researchers to compare the two types of average and signal/noise retention force measurements in mm.

Table 3. Process parameters and the value level of the taguchi method

Experiment	Parameters (mm)			Value (N)			
to	Diameter input	Diameter output	Length Position	RF 1	RF 2	RF 3	RF4
1	3.50	3.63	4.60	28.8	27.6	29.0	29.3
2	3.50	3.80	4.80	39.0	40.3	37.8	44.1
3	3.50	3.90	5.00	55.6	60.2	63.8	61.4
4	3.58	3.63	4.60	44.1	45.7	43.3	42.3
5	3.58	3.80	4.80	39.9	40.3	37.4	33.3
6	3.58	3.90	5.00	102.1	121.3	112.2	90.2
7	3.66	3.63	4.60	43.3	49.8	51.1	37.4
8	3.66	3.80	4.80	90.6	98.4	99.2	86.2
9	3.66	3.90	5.00	127.6	103.2	107.6	112.2

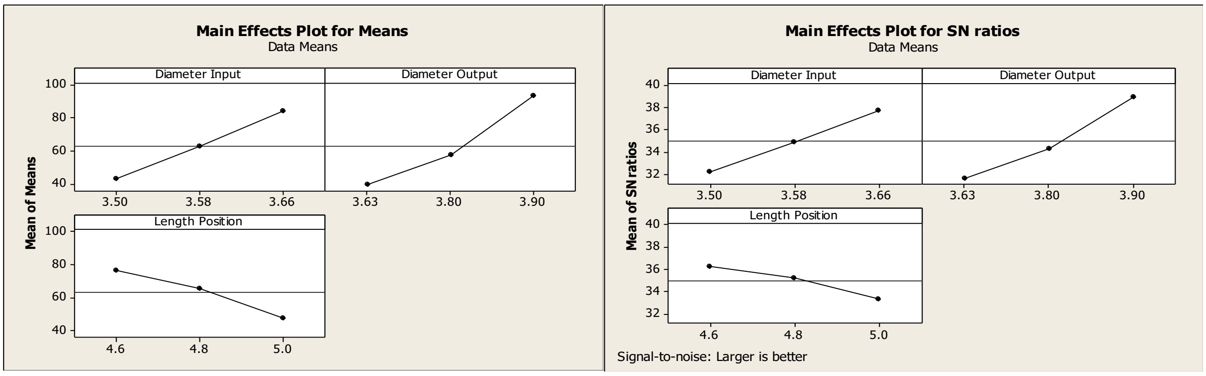

Figure 9. Main effects plot graph

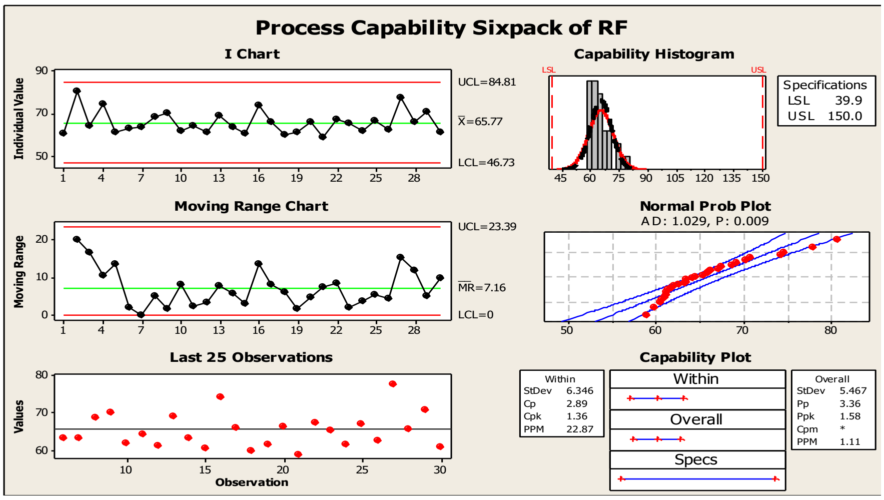

Figure 10. Process capability sixpack retention force after improvement

4.5 *Control*

After experimenting, the optimum value for each product forming factor is obtained, so that the greatest retention force value is obtained by setting the input diameter at the level of 3.66 mm, the output diameter at the level of value of 3.90 mm and the Length position at the level of value of 4.6 mm. The control is performed by setting the previously verified level parameters, then taking 30 data, the result shows that the population value of Pp performance is 3.36 and Ppk is 1.58 (Figure 10). While the minimum retention force value is 58.9N and the specs set a minimum of 39.9N, so the processing ability is good. To maintain the process performance that has been achieved in the application of the Six Sigma method, the Define-Measure-Analyze and Improve steps must be monitored regularly so that when a deviation occurs the data can be immediately checked and corrected.

5. CONCLUSION

Based on data collection and analysis, it can be concluded that customer claim terminal loose found by the customer is caused by unstable machine processing capability, with a population performance value of Pp of 0.47 and Ppk of 0.38. The application of the DMAIC Six Sigma method and robust design through the Taguchi experiment method found the factors that influence the maximum retention force value are the input diameter at the level of 3.66 mm, the output diameter at the value level of 3.90 mm and the long position at the value level of 4.6 mm. Application of the DMAIC Six Sigma method, there is an increase in the population value of performance Pp by 3.36 and Ppk by 1.58, which means that the ability of the production process for bullet type products is excellent and stable. This research can be continued by using Lean Six Sigma to get better results.

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