Defective Reduction in Automotive Headlining Manufacturing Process

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Abstract. In an automobile parts manufacturing company, currently the headlining process has a lot of wastes resulting in a high cost of quality per year. In this paper, the Six Sigma method is used to reduce the defects in the headlining process. Cause-and-effect matrix and failure mode and effect analysis (FMEA) were adopted to screen the factors that affect the quality of headlining. The $2^{k-1}$ fractional factorials design was also used to determine the potential preliminary root causes. The full factorial experiments were conducted to identify appropriate settings of the significant factors. The result showed that the process can reduce the defects of headlining from 12.21% to 6.95%.

1. Introduction
Six Sigma is a method with highly disciplined for reducing the variability of the process to ensure customer satisfaction and cost reduction of the organization. It is one of the most effective improvement strategies for overall operation excellences [1]. Six Sigma is the statistical term of a process that produces defects fewer than 3.4 defects per million opportunities [2]. Six Sigma provides a systematic steps known as DMAIC (i.e. Define, Measure, Analyze, Improve, and Control) in a formalized problem solving process [3]. The DMAIC process can improve any type of process in any organization to improve its efficiency and effectiveness [4].

The case study company was established in the early 2013s to manufacture various automotive parts to domestic and international customers. The automotive headlining process is focused in this study since it produces most defects (12.21% or 122,082 DPPM) when comparing with another process. Its value is estimated around 3 million baht per year. Currently, the main production problem is the dimension of the part which do not meet the customer specifications. Hence, this research aims to reduce the defective parts in the automotive headlining process by using the Six Sigma approach.

2. Define Phase
The Define phase is the starting point of the DMAIC Six Sigma approach. This phase help define the problem of interest in detail and thus making the way ahead clearer in terms of actions required to be taken. The prolong analysis and discussion are carried out with the project charter team members to identify the main problem which impacts significantly on the defective rate. The historical manufacturing defect data from January 2015 to May 2015 showed that the proportion of wastes were classified as follows: part dimension out-off standard 45.30%, feeble parts 12.90%, peeling parts...

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9.30%, creasing parts 9.10%, bulging parts 6.80%, bloated parts 6.20%, wrinkle parts 5.70% and other 4.50% (Fig. 1). It is clear that the part dimension out-of-standard is the highest proportion; therefore this problem is subject to be improved in this research.

![Pareto Chart of Type of defects](image.png)

**Figure 1.** Pareto chart of defect (source: Production data of headlining from 1 January – 31 May 2015)

3. **Measure Phase**

This phase involves two main steps, i.e. measurement system analysis (MSA) and root-cause analysis.

3.1. **Measurement System Analysis**

The analysis of gauge R&R with attribute data was used to measure the goodness of current measurement system [5]. This approach was used to analyze the repeatability and accuracy of operators who perform self-inspection on the finished parts. The test results showed that three operators have the percentage of repeatability equal to 95%, 97% and 97%; whereas the accuracy in measuring is 95%, 97% and 97%, respectively (Fig. 2). As a result, the overall effective repeatability and accuracy are equal to 92.5% and 92.5%, respectively. It was clear that all operators were failed by the testing criteria of the MSA which were set as 100%. Therefore, the company had to sent all operators to the retraining course (i.e. QC parts inspection course). The training program was conducted into two parts, i.e. theoretical and practical. In the theoretical part, operators were trained to understand about the basic background and limitation of parts. For practical training, a QC expert provided insight knowledge of how to check parts properly and effectively. After completing the course, the attribute MSA was reconducted to these operators again and the testing results showed that all of them passed the given standard (Fig. 3).

![Attribute test performance chart](image.png)

**Figure 2.** Attribute test performance chart (Before-training)

![Attribute test performance chart](image.png)

**Figure 3.** Attribute test performance chart (After-retraining)
3.2. Root-Cause Analysis

The brainstorming meetings by a knowledgeable team who specializes in the production process of the headlining process were conducted to articulate the relevant potential factors that can affect quality of headlining. The cause-and-effect diagram with 4M (i.e. Man, Machine, Material and Method) was applied to this process to indicate the root-causes of the problems. For the part dimension out-of-standard problem, 12 potential factors were concluded (Fig. 4). The causes of the problem can be summarized as follows: First, operators do not have enough skill to place part correctly on the platform. This makes parts shaken while cutting their edges by the water jet cutting machine. In addition, it also causes operator fatigue. Second, there is no method to specify the proper air pressure level and the cycle time of cleaning platform which cause parts located not tightly adhere to the platform. Third, the machine’s components are damaged and the type of the holder on the machine platform is not appropriate which causes misalignment of parts. Forth, material deformation and inappropriate type of cleaning tools cause scraps remaining on the platform.

These factors were then used to analyse the relationship between the cause and its associate effects using the cause-and-effect matrix. A priority rate of 10 point was given for each problem that causes part dimension out-of-standard problem and the score ranges between 1-10 points. These scores were sorted from large to small by the Pareto chart and the factors with significant impacts (score > 50 point) were selected for further analysis. As a result, the relevance factors were reduced to 8 (Fig. 5). These factors are further screened by using the Failure Mode and Effects Analysis (FMEA). The results showed that 4 factors with the highest scores were identified (Fig. 6). These factors were chosen for the next experiments.

![Cause-and-effect Diagram](image)

**Figure 4.** Cause-and-effect diagram of the part dimension out-off standard
4. Analysis Phase

In this phase, the experimental design method was adopted to find the factors that show statistically significant effects to the part dimension out-of-standard defect. Four factors obtained from the previous phase were experimented including air pressure, types of the holder on the platform, types of cleaning tools and cycle time of cleaning. The $2^{k-1}$ fractional factorial design [6] with 4 factors and 2 levels of each factor were adopted to test whether or not the main effects and their interactions were significant (Table 1).
Table 1. Factors and levels in the $2^{k-1}$ fractional factorial design

| No. | Factors                        | Units      | Symbols | Levels of factor          |
|-----|--------------------------------|------------|---------|---------------------------|
|     |                                |            |         | Low (-1) | Medium (0) | High (1) |
| 1   | Air pressure                   | Bar        | A       | 5         | 8          | 10       |
| 2   | Type of holder                 |            | B       | Old       | New       |
| 3   | Type of cleaning tools         |            | C       | Old       | New       |
| 4   | Cycle time of cleaning         | Time/Day   | D       | 1         | 4         |

The experimental data were analyzed by using the Minitab software [7]. From the Pareto chart of effects (Fig. 7), the factor effect with its value greater than 0.02053 is a significant factor at 95% confident interval equal. The Pareto chart of effects showed that the main effects A and B have P-values less than 0.05 (significant level $\alpha$), whereas factors C and D and interactions (AD, AB and AC) were not significant. Therefore, it can be concluded that the main effects A and B are significant at 95% confident interval. As a result, all significant factors need further investigation to find their appropriate level settings.

5. Improvement Phase
In this phase, more levels of the significant factors derived from the $2^{k-1}$ factional factorial experiments were tested to find their appropriate levels that can reduce defects in the headlining process. The general full factorial design was used in this experiment. Three levels of air pressure and two levels of holder on the platform were randomly run with 2 replicates (Table 2).

Table 2. Factors and level in full factorial design

| Factors                        | Units      | Symbols | Levels of factor          |
|--------------------------------|------------|---------|---------------------------|
|                                |            |         | Low (-1) | Medium (0) | High (1) |
| Air pressure                   | Bar        | A       | 5         | 8          | 10       |
| Type of holder on platform     |            | B       | Old       | -          | New      |

The statistical analysis showed that both main effects obtained the P-values less than 0.05 (Fig. 8). Therefore, it can be concluded that the main effects affected the defective at 95% confident interval. Since the main effects were used as a mean to select the proper setting for factors, the factors A was set at 10 Bar (high level of factor A) and B was set with the new type holder on platform (high level of factor B) (Fig.9).
General Linear Model: F&T versus A, B

Factor Type | Levels | Values
--- | --- | ---
A | fixed | 3 | 5, 8, 10
B | fixed | 2 | Old, New

Analysis of Variance for F&T, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| A | 2 | 0.0097543 | 0.0097543 | 0.0048771 | 72.84 | 0.000 |
| B | 1 | 0.0012569 | 0.0012569 | 0.0012569 | 18.77 | 0.005 |
| A*B | 2 | 0.0001175 | 0.0001175 | 0.0000588 | 0.88 | 0.463 |
| Error | 6 | 0.0004018 | 0.0004018 | 0.0000670 | | |
| Total | 11 | | | | | |

S = 0.00818293  R-Sq = 96.52%  R-Sq(adj) = 93.61%

Figure 8. Results of ANOVA

Figure 9. Main effects plot

6. Control Phase

In this phase, all settings of the significant factors derived from the previous phase were implemented in the process and the data relating to the defect occurred in the automotive headlining process were collected for 30 days. It was found that the quantity of defects was reduced substantially (Fig.10).

Figure 10. Comparison of defects
To maintain the quality of the headlining process after the improvement, the work instruction for operational control in the headlining process was written. In addition, the operators were trained to understand the importance of controlling these parameters to ensure that the performance improvements were maintained.

7. Conclusion
The objective of this research was to apply the Six Sigma method to reduce wastes that occurred in the automotive headlining manufacturing process. Five steps of the Six Sigma were systematically utilized so as to find the proper parameter settings of the significant factors. The experimentation results indicated that the defect was decreased when the air pressure of the water jet cutting machine is increased and when the new part holder type was used. Therefore, it can be concluded that the air pressure and holder on the platform factors had significant effects on the problem of interest. After applying all new settings to the process, the defect rate was reduced to 69,489 DPPM.

References
[1] D.A. Desai, P. Kotadiya, N. Makwana and S. Patel, 2015 Curbing variations in packaging process through Six Sigma way in a large-scale food-processing industry, Journal of industrial engineer international, 11(1), 119-129
[2] C. Gygi, N.D. Carlo and B. Williams 2005 Six Sigma for dummies (New Jersey: Wiley Publishing, Inc)
[3] T. Bertels 2003 Rath & Strong's six sigma leadership handbook (New Jersey: Wiley Publishing, Inc)
[4] H.C. Hung and M.H. Sung 2011 Applying six sigma to manufacturing processes in the food industry to reduce quality cost, Scientific Research and Essays, 6(3), 580-591
[5] C.T. Carroll 2013 Six Sigma for powerful improvement (New York: Taylor & Francis Group)
[6] D.C. Montgomery 2008 Design and analysis experiments (America: John Wiley & Sons, Inc)
[7] D.C. Montgomery and G.C. Runger 2010 Applied statistics and probability engineers (America: John Wiley & Sons, Inc)