Silver Line Defect Reduction of Rear Lens Combination Lamp Process

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Abstract. The company in this research supplies the automotive lamps to many automotive manufacturing companies. The research focuses on the Rear Lens Combination Lamp Injection Process which causes a lot of silver line defectives and has the most impact on customer viewpoint. The DMAIC phases of the Six Sigma methodology are applied to solve the problem. New parameters are set at the optimal values as the result of the experimental design and analysis. After the improvement is implemented, the silver line defects are reduced from 10.21\% to 2.41\% (7.8\% defect reduction)

1. Introduction
In order to improve customer satisfaction on the vehicle, the automotive manufacturing company has focused on part appearance quality improvement. The latest model is going to launch. After collecting of previous model defective ratio from suppliers [1,2], the rear combination lamp is the first rank defective. Rear combination lamp is consisted of 4 main components. There are 1. Lens, 2. Extension, 3. Reflector and 4. Housing. Almost of defectives are occurred on the lens component. Therefore, the rear lens combination lamp process is selected to study for quality improvement. There are 2 sub-processes which are lens injection process and surfacing process. Defects are mainly presented at lens injection process due to any defective is 100\% to be scrapped and cannot be passed to surfacing process. From the historical data, the Silver line defective is the highest ratio from the rear lens combination lamp process.

The Six Sigma methodology is applied for this research to improve the process. DMAIC consists of 5 phases, i.e. Defining – identify the problem to be improved, Measurement – ensure the accuracy and precision of measurement system and identify causes of problem, Analysis – identify the significant factor that directly affect by causes of problem, Improvement – utilize design of experiment method to get the optimal value, Controlling – apply the optimal value from improvement phase and standardize to control the quality in the process [3].

2. Define phase
The process of the rear combination lamp is consisted of 2 sub-processes. The defect is mainly from Lens injection process [4]. The historical defect data from the previous model (recorded during April 2018 – March 2019) has shown in figure 1 that the highest defect came from Silver line.
3. Measurement phase

In this phase, 2 main methods are conducted those are \textit{GR&R} (Gage Repeatability & Reproducibility) and \textit{Problem Identification Analysis}. \textit{GR&R} is applied to be ensured the accuracy and precision of the measurement system. Measurement variation consists of 2 factors, repeatability – variation from equipment and reproducibility – variation from the inspector. Two inspectors have been provided with the training and assigned to be performed repeatedly 2 times with random inspection on 20 different critical of Silver line defect lens components. The result of this method, as shown in ‘table 1’, can be summarized that the accuracy and precision of the measurement system are acceptable.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{Index} & \textbf{Inspector 1} & \textbf{Inspector 2} & \textbf{Both Inspectors} \\
\hline
\%Repeatability & 100\% & 100\% & - \\
\%Reproducibility & 100\% & 100\% & - \\
\%Repeatability Effectiveness & - & - & 100\% \\
\%Reproducibility Effectiveness & - & - & 100\% \\
\hline
\end{tabular}
\caption{Result of Gage Repeatability & Reproducibility.}
\end{table}

\textit{Problem Identification Analysis} consists of 2 steps to identify the factors affecting the silver line defect in the lens injection process. \textit{Cause-and-Effect Matrix} is the first step to find out the root causes by working team. After listing up all possible factors, the working team has scored the relation of the cause-and-effect matrix. From descending sorted of relation scoring in figure 2, 10 from 17 factors are significantly highlighted by 80/20 rule from the Pareto chart.
3. Analysis phase

The three factors from Cause-and-Effect Matrix and FMEA, i.e. Cavity Temperature, Core Temperature and Barrel Temperature of the lens injection process, are analyzed to be ensured that they are the significant factors of Silver line defect by Hypothesis testing. Two-Proportion Testing is applied to this phase. Defect ratio of 2 Difference values parameters is collected to find the appropriate sample size from Minitab software. Then hypothesis testing at 95% confident interval is conducted as
the result shown in ‘Table 2’. All three factors’ P-Value is less than 0.05. The null hypothesis is rejected. Mean that all three factors are affected by the Silver line defect in the lens injection process.

**Table 2.** Two-Proportion Testing of Three factors of the Silver line defect.

| Cavity Temp | Core Temp | Barrel Temp |
|-------------|-----------|-------------|
| 88°C        | 90°C      | 92°C        |
| Sample size | 66        | 36          | 53          |
| No. of Defect | 3        | 15          | 2           |
| % of Defect | 0.05      | 0.23        | 0.06        |
| P-Value     | 0.002     | 0.004       | 0.000       |
| 94°C        | 250°C     | 260°C       |
| 16          | 2         |

5. Improvement phase
From all three significant factors, the design of the experiment is conducted as full factorial design by 3 factors and 2 levels with 2 replicates as shown in ‘Table 3’. The experiments resulted in Minitab software as shown in figure 4, the main effect Cavity, Core and Barrel temperature are significant at 95% confident interval.

**Table 3.** Lens injection process parameters and level.

| No. | Input factor       | Symbol | Low | High |
|-----|--------------------|--------|-----|------|
| 1   | Cavity Temperature | Cavity Temp | 88  | 90   |
| 2   | Core Temperature  | Core Temp | 92  | 94   |
| 3   | Barrel Temperature | Barrel Temp | 250 | 260  |

**Analysis of Variance**

| Source                      | DF | Adj SS | Adj MS | F-Value | P-Value |
|-----------------------------|----|--------|--------|---------|---------|
| Model                       | 7  | 0.068282 | 0.009755 | 169.75  | 0.000   |
| Linear                      | 3  | 0.046113 | 0.015371 | 267.48  | 0.000   |
| Cavity Temp                 | 1  | 0.019924 | 0.019924 | 346.71  | 0.000   |
| Core Temp                   | 1  | 0.007114 | 0.007114 | 123.60  | 0.000   |
| Barrel Temp                 | 1  | 0.019074 | 0.019074 | 231.02  | 0.000   |
| 2-Way Interactions          | 3  | 0.020438 | 0.006813 | 118.55  | 0.000   |
| Cavity Temp/Core Temp       | 1  | 0.002439 | 0.002439 | 42.45   | 0.000   |
| Cavity Temp/Barrel Temp     | 1  | 0.015915 | 0.015915 | 276.94  | 0.000   |
| Core Temp/Barrel Temp       | 1  | 0.002084 | 0.002084 | 56.27   | 0.000   |
| 3-Way Interactions          | 1  | 0.001731 | 0.001731 | 50.15   | 0.001   |
| Cavity Temp/Core Temp/Barrel Temp | 1 | 0.001731 | 0.001731 | 30.13   | 0.001   |
| Error                       | 8  | 0.000450 | 0.000057 |
| Total                       | 15 | 0.069742 |        |

**Figure 4.** ANOVA result of Lens injection process.

The normal probability plot of the residual for defects represented the errors are normal distribution as the straight line. The residual versus fit represented the variance stability. The residual versus order represented the independent. All are shown as figure 5, that means the experiment has followed the condition of the experiment design NID (0, σ²). Therefore, the optimum value of each factor should be 88°C of Cavity Temperature, 92°C of Core Temperature and 260°C of Barrel Temperature.
6. Control phase

The result of the Improvement phase is implemented in the lens injection process. The defective data comparing before and after improvement shown as figure 6 Running the operation for 8 days. Silver line defect ratio has been reduced for 7.8 %

![Figure 5. Residual Plot for Defects.](image)

**Figure 6.** Defect Ratio Comparison between before and after improvement.

After the improvement, Standard Operation must be updated and revised to maintain the quality of lens injection process, i.e. 1. The appropriate value of cavity, core, and barrel temperature for this product (specific to the type of resin) 2. Add the working step of temperature control checking by the operator [6]. In addition, both operation and inspection training have to be given to operators and inspectors. Post-test is recommended to conduct after training and periodically re-training every 6 months to be maintained their skill.

7. Summary

The objective of the research is to reduce the silver line defects in the lens injection process by applying the Six Sigma methodology. The DMAIC is applied step-by-step to analyse the root causes and to indicate the new optimal parameters. The result reveals that after implementing the new parameter settings to the process, the silver line defects are reduced by 7.8%.

8. References

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