Seed defective reduction in automotive Electro-Deposition Coating Process of truck cabin

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Abstract. The case study company is one of players in Thailand’s Automotive Industry who manufacturing truck and bus for both domestic and international market. This research focuses on a product quality problem about seed defects occurred in the Electro-Deposition Coating Process of truck cabin. The 5-phase of Six Sigma methodology including D-Define, M-Measure, A-Analyze, I-Improve, and C-Control is applied to this research to identify root causes of problem for setting new parameters of each significant factor. After the improvement, seed defects in this process is reduced from 9,178 defects per unit to 876 defects per unit (90% improvement)

1. Introduction
The Electro-Deposition Coating (ED) is one of the most important processes which widely used in painting process in automotive industry in order to protect corrosion and rust. This process is used for preparing truck or car surface being smooth before delivery to topcoat process. ED coating process can be divided into 2 sub-processes, namely Pre-treatment process and Electro-Deposition Process. The historical data from October 2016 – March 2017 of the case study company showed that seed defective was found as the highest defect in the ED coating process (84.1% of all defects) which directly impact to the quality of products.

This research applies the Six Sigma methodology for process improvement in order to reduce seed defects. There are 5 phases in the Six Sigma DMAIC process, i.e. 1. Defining Phase – to investigate for getting basic understanding of the process and then specify a problem to solve, 2. Measure Phase – focusing on measurement system analysis to determine the current performance and quantify the problem, 3. Analyze Phase – analyzing by brainstorming and statistic methodology to identify significant factors affecting the problem, 4. Improve Phase – to identify a solution to the problem by designing experiment to find out the optimal key factors, and 5. Control Phase – ensuring that the result from improve phase are well-maintained by creating document procedure in order to control the process and for reacting to any problem in time.

2. Define phase
Define phase is an important first step to identify the problem, target, and scope of the project. In this case study, ED Coating Process of Truck Cabin is selected to study because many of seed defects were found as a major problem in product’s quality. Regarding the data of case study company in October 2016 to March 2017 in Figure 1 show that 84.1% of all quality issues comes from seed defect.
3. Measure phase
Measure Phase consists of 2 main steps, i.e. Measurement System Analysis (MSA) and Problem Identification Analysis.

3.1 Measurement system analysis (MSA)
In this case study, the quantity of seed defects occurred in ED Coating process of truck cabin is measured for determining quality of the product. Measurement System Analysis (MSA) is used by experimenting 2 operators who perform self-inspection on truck cabin after finished ED coating process. To ensure accuracy and precision of measuring instrument, this approach is repeatedly performed by randomly inspection on 20 truck cabins. The result from the experiment is shown in Table 1 which can be stated that the measurement system is acceptable in term of accuracy and precision.

Table 1. Attribute data test performance operator.

| Index               | Operator A | Operator B | Both operators |
|---------------------|------------|------------|----------------|
| %Repeatability      | 100%       | 100%       | -              |
| %Attribute Score    | 100%       | 100%       | -              |
| %Reproducibility    | -          | -          | 100%           |
| %Attribute Screen   | -          | -          | 100%           |
| Effective Score     |            |            |                |

3.2 Problem identification analysis
The expert team brainstorm to list up all potential factors affecting the seed defect in ED Coating process of truck cabin. Next, a Fishbone diagram or Cause-and-Effect matrix is applied in this study as a tool for analyzing and finding out root causes of the problem by categorized relevant factors with 5M1E methodology. It was found that the number of tentative causes is 21 factors. These 21 factors are analyzed the cause relation by scoring these relationships on cause-and-effect matrix. After that, the relevant factors are descending sorted according to Pareto principle (The 80/20 rule). There are 12 factors shown in Figure 2 significantly impacts on seed defects in ED coating process of truck cabin. These factors are further analyzed in the next step by scoring (RPN) each factor by Failure Mode and Effect Analysis (FMEA). The result in Figure 3 show that three highest scored factors, including 1. The proportion of chemicals, 2. Dipping time of degreasing process, and 3. Temperature of chemicals in the degreasing tank, which is 64.7% of the total score are selecting for designing of experiment (DOE) in the next analyze phase.
Figure 2. Pareto chart of cause and effect Matrix.

Figure 3. Pareto chart of failure mode and effect analysis (FMEA).

4. Analyze phase
In analyze phase, the significant factors, which are screened by Pareto diagram and Failure Mode and Effect Analysis (FMEA), including the proportion of chemicals, dipping time of degreasing process, and temperature of chemicals in the degreasing tank are selected to conduct the experimental design method by adopting the Box-Behnken to analyze the root cause of the defect. The experiment design conducts 3 factors and 3 levels each as shown in Table 2. The response variable of this experimental is coating weight which measuring the result by x-ray fluorescence (XRF) Model RIGAKU, RIX-2000. Regarding the standard of case study company, the coating weight required to equal 3-5 g/m².

Table 2. Factors level in Box-Behnken design in degreasing process.

| No. | Input factors      | Symbols | Unit       | Factors Level |
|-----|--------------------|---------|------------|---------------|
| 1   | Chemical proportion| Chemical| %          | 25 62.5 100   |
| 2   | Dipping time       | Time    | Seconds    | 180 210 240   |
| 3   | Temperature        | Temp    | Degrees Celsius | 45 50 55     |
The result from the experiments are statistically analyzed by Minitab software as Figure 4 shows that the main effect Proportion, Time, and Temperature are significant at 95% confident interval. In addition, two-way interaction of Chemical proportion*Temperature and Temperature*Time are also significant.

Figure 4. The result of ANOVA Box-Behnken design in degreasing process.

5. Improvement phase
All of 3 significant factors derived from previous phase including proportion, dipping time, and temperature need further analysis in improvement phase to find the optimum conditions in order to reduce seed defect in Electro-Deposition Coating Process of Truck Cabin by using full factorial design in the experiment. The experiments were randomly run with 2 replicates. The result of the experiments analyzed by the Minitab software as shown in Figure 5 demonstrates that the optimum condition of each factor should be the proportion of new chemical is 100%, temperature is 45 degrees Celsius, and dipping time is 180 seconds.

Figure 5. New Parameter Setting for degreasing process.
6. Control phase
According to the result from improvement phase, the new parameters setting of the significant factors are implemented in the current process and the defect data in the Electro-Deposition Coating Process of Truck Cabin are collected for 30 days. It proves that the quantity of seed defects is significantly reduced as shown in Figure 6.

![Comparison number of defects per unit in production line.](image)

To maintain the quality of the process after the improvement, Work instruction and control plan of this process are created. Moreover, an operator training is essential for clear understanding the importance of parameter controlling to ensure that the performance is maintained at this good level.

7. Conclusion
The objective of this research is for reducing seed defects of truck cabin in the Electro-Deposition Coating Process by applying the Six Sigma methodology to improve the process. This research study follows the DMAIC steps of the Six Sigma methodology to find the root causes that affect to seed defects on truck cabin and determine the optimum conditions for setting set as new parameters. The result of the experiment shows that the quantity of seed defects of truck cabin in the Electro-Deposition Coating Process is reduced from 9,178 defects per unit to 876 defects per unit (90% improvement). Work instruction and training are created to maintain this good performance.

8. References
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